DOI: 10.2428/ecea.2017.24(1)5 ECOL CHEM ENG A. 2017;24(1):65-74

Beata BIEŃ[1]

THE QUALITY OF SLUDGE LIQUIDS PRODUCED IN THE PROCESS OF MECHANICAL DEWATERING OF DIGESTED SLUDGE

JAKOŚĆ CIECZY OSADOWYCH POWSTAJĄCYCH W PROCESIE MECHANICZNEGO ODWADNIANIA OSADÓW PRZEFERMENTOWANYCH

Abstract: The quality of sludge liquids produced in the processes of mechanical dewatering of sludge depends on the stabilization technology and the kind of device, its proper operation, and an appropriate choice of conditioning chemicals. The article presents the impact of selected conditioning chemicals and methods, such as: PIX 113, PIX 123, Zetag 8160 polyelectrolyte, ultrasonic field, and their combined effect on the properties of sludge liquids. crude sludge liquids were characterized by high concentrations of ammonium nitrogen (931–1,508.9 mg $N\text{-}NH_4^+/dm^3$), phosphates (24.3–89.4 mg PO_4^{3-}/dm^3) and organic compounds referred to as COD (784–1,856 mg O_2/dm^3). It was found that the combined effect of inorganic coagulant PIX 123 and polyelectrolyte allowed the reduction of suspended solids and COD in sludge liquids. In the case of suspension, the highest reduction (53.8%) was obtained when using PIX 123. With regard to the changes of COD, similar effects were obtained for PIX 123 (43%) and the combined method (41.6%). The use of the PIX 113 coagulant and Zetag 8160 polyelectrolyte increased the ratio of total suspended solids in the sludge liquids in relation to crude sludge liquids. The PIX 113 coagulant led to reducing the values of COD (90%), ammonium nitrogen (14.9%) and phosphates (93.8%) with relation to crude sludge liquids. Zetag 8160 alone proved to be the least effective.

Keywords: sludge liquids, coagulants, polyelectrolytes, ultrasonic field, mechanical dewatering

Introduction

Improving the efficiency of sewage treatment by means of using integrated systems to remove nitrogen and phosphorus compounds from sewage results in greater sludge volume and changes in the qualitative parameters of sludge, caused *ie*, by substantial accumulation of phosphorus in bacteria cells. During sewage treatment in anaerobic conditions (methane fermentation), even 60% phosphorus removed from the sewage may be discharged again during the hydrolysis of polyphosphates to sludge liquid [1, 2]. It

[1] Department of Chemistry, Water and Wastewater Technology, Faculty of Infrastructure and Environment, Czestochowa University of Technology, ul. Dąbrowskiego 69, 42–200 Częstochowa, Poland, phone: +48 34 325 09 11, email: bmat@is.pcz.czest.pl

was also found that 70% of total nitrogen introduced together with crude sludge to the digestion chamber got to sludge liquid in the form of ammonium nitrogen [3]. Besides, sludge liquid has high contents of organic compounds, total, non-settling and colloidal suspensions, dissolved gases (methane, ammonia, CO_2, H_2S), heavy metals, fats, and ammonia. In liquid digestate there are also high concentrations of volatile fatty acids (VFAs), carbonates, and potassium and magnesium cations [4, 5]. The intensification of sewage sludge processing, motivated by the pursuit of easy management of the end product, results in increased influence of the sludge processing line on the operation of sewage treatment technological line [6]. Including all untreated reject water in the stream of crude sewage, which is still the standard method, has a definitely detrimental effect on the conditions of operation of biological reactors through reducing the ratio of the content of biologically decomposing organic compounds and the content of nutrients, especially nitrogen. The total nitrogen concentration in crude sewage, caused by mixing sewage with untreated sludge waters, in typical technological systems, increases approximately by 20% [7, 8]. The problem of sewage management return loads is more and more often the object of research [9–13]. The amount and quality of sludge liquids mainly depend on the adopted technological system of sewage treatment and sewage sludge processing (especially the way of stabilization and dewatering) as well as the performance of devices in the sewage process line [14, 15]. The proper choice of polyelectrolyte or filter fabric is often decisive, not only for thickening or dewatering of sludge but also for the quality of liquids discharged from the devices [16]. Taking into account the importance of sludge liquid quality, the article presents the influence of selected conditioning chemicals and methods, such as: PIX 113, PIX 123, Zetag 8160 polyelectrolyte, ultrasonic field, and their combined effect on the properties of sludge liquids.

Material and methods

Sewage sludge after the process of methane fermentation was used in the experiment. The experiment included two parts. Digested sludge samples used in each part were collected on two different days and marked digested sludge A and B. In the first part, non-sonicated and sonicated digested sludge A was studied. Sludge A was conditioned with PIX 123, Zetag 8160, and the method combining 1.0 mg/g d.m. (d.m. – dry matter) of PIX 123 and different doses of Zetag 8160: 0.5; 1.5; 2.5; 3.5 mg/g d.m. In the second part, non-sonicated and sonicated digested sludge B was studied. It was treated with PIX 113 and the method combining 4.5 mg/g d.m. of PIX 113 and different doses of Zetag 8160: 1.5; 2.5; 3.5 mg/g d.m. Samples of sludge liquid were obtained after the process of centrifugation of properly treated sewage sludge. The time of centrifugation was 5 min, and the speed, 5,000 rot/min. The characteristics of the coagulants are shown in Table 1.

In order to obtain a solution of Zetag 8160 polyelectrolyte, it was thoroughly mixed with water. After 120 minutes of mixing, the solution was mature and ready to use.

In the method combining the chemicals, PIX 123 (or PIX 113) coagulant was administered first, followed by Zetag 8160 polyelectrolyte. This way both reagents are used to the full and can influence each other.

Table 1

Characterization of chemicals used in the research

Coagulant	Coagulant properties
PIX 123	A dark brown solution of ferric sulfate, with total iron (Fe) content of 12.6 ± 0.3%, and iron ions Fe^{+2} content of max 0.7%.
PIX 113	A ferric coagulant, a dark brown water solution of ferric sulfate, with total iron (Fe) content of 11.4 ± 12.2%, and iron ions Fe^{+2} content of 0.4 ± 0.3%.
Zetag 8160	A synthetic polyacrylamide with a high molecular mass, provided as loose white powder. Zetag 8160 is a cation polyelectrolyte.

In order to obtain a solution of Zetag 8160 polyelectrolyte, it was thoroughly mixed with water. After 120 minutes of mixing, the solution was mature and ready to use.

In the method combining the chemicals, PIX 123 (or PIX 113) coagulant was administered first, followed by Zetag 8160 polyelectrolyte. This way both reagents are used to the full and can influence each other.

The sewage sludge was sonicated in static conditions, with a constant sample volume of 0.3 dm^3. An high power, microprocessor-based ultrasonic processor Sonics VC750 with automatic tuning, the frequency of 20 kHz and amplitude of 30.5 μm (corresponding to the 50% amplitude) was used to sonicate the samples. The variable of the sonication process was the disintegration time t = 60 s.

The following parameters were determined in the sludge liquid: pH with the potentiometric method (pH-meter CP401 from Elmetron), total suspended solids with the weighing method, COD with the short dichromate method (PN-ISO 6060:2006), ammonium nitrogen and phosphates PO_4^{-3} as well as total phosphorus (P_{og}) with the spectrophotometric method (Spectrophotometer JENWAY 6300). The following conditioners were used in the research: 10% solution of PIX 123 and PIX 113 coagulant, 0.1% solution of Zetag 8160 polyelectrolyte, ultrasonic field.

Results and discussion

Crude sludge liquids had very high concentrations of ammonium nitrogen (931–1,509 mg $N\text{-}NH_4^+/dm^3$), phosphates (24.3–89.4 mg PO_4^{3-}/dm^3) and organic compounds referred to as COD (784–1,856 mg O_2/dm^3). The characterization of the sludge liquids is shown in Table 2.

In samples of sludge liquid (Table 3) obtained from non-sonicated and sonicated sludge A treated with PIX 123 the pH value dropped. The pH value decreased with the increasing dose of the coagulant. For 3.5 mg/g d.m. it was 6.04 (reduced by 12.7%). In the liquid separated from non-sonicated and sonicated sludge A treated with Zetag 8160 and liquid treated with 1.0 mg/g d.m. of PIX 123 and different doses of Zetag 8160, the pH value grew with the growing dose of the chemicals used (Table 3). In the case of all the analyzed methods of conditioning, the amount of suspended solids in sludge liquids decreased as the dose of reagents increased. The greatest reduction was 53.8% (for 3.5 mg/g d.m. of PIX 123).

Table 2

Characteristics of sludge liquids

Determination	Unit	Crude liquids separated from digested sludge	
		A	B
pH	—	6.92	6.76
Suspension	mg/dm^3	1,300	280
COD	mgO_2/dm^3	1,856	784
Ammonium nitrogen	$mgN\text{-}NH_4^+/dm^3$	1,509	931.5
Phosphates	$mgPO_4^{-3}/dm^3$	89.4	24.3
Phosphorus	$mgP\text{-}PO_4^{-3}/dm^3$	29.2	7.94

In samples of sludge liquid (Table 3) obtained from non-sonicated and sonicated sludge A treated with PIX 123 the pH value dropped. The pH value decreased with the increasing dose of the coagulant. For 3.5 mg/g d.m. it was 6.04 (reduced by 12.7%). In the liquid separated from non-sonicated and sonicated sludge A treated with Zetag 8160 and liquid treated with 1.0 mg/g d.m. of PIX 123 and different doses of Zetag 8160, the pH value grew with the growing dose of the chemicals used (Table 3). In the case of all the analyzed methods of conditioning, the amount of suspended solids in sludge liquids decreased as the dose of reagents increased. The greatest reduction was 53.8% (for 3.5 mg/g d.m. of PIX 123).

Table 3

Changes of selected parameters of sludge liquids from sludge A

Parameters of sludge liquids	Dose [mg/g d.m.]	pH [-]	COD [mg O_2/dm^3]	Suspension [mg/dm^3]
Sludge liquids separated from non-sonicated, digested sludge treated with different coagulants				
Crude sludge liquids	—	6.92	1,856	1,300
PIX 123	0.5	6.86	1,522	1,140
	1.5	6.59	1,465	850
	2.5	6.20	1,171	720
	3.5	6.04	1,057	600
Zetag 8160	0.5	7.21	1,729	1,220
	1.5	7.24	1,653	1,080
	2.5	7.34	1,622	930
	3.5	7.38	1,503	880
PIX 123 (1.0) + Zetag 8160*	0.5	6.97	1,240	1,260
	1.5	7.00	1,206	1,110
	2.5	7.23	1,156	1,020
	3.5	7.36	1,083	920

Table 3 contd.

Parameters of sludge liquids	Dose [mg/g d.m.]	pH [-]	COD [mg O_2/dm^3]	Suspension [mg/dm^3]
Sludge liquids separated from sonicated, digested sludge treated with different coagulants – the sonication time was 60 s, and the amplitude 30.5 μm				
Crude sludge liquids PIX 123	—	7.49	2,894	1,620
	0.5	7.30	2,122	1,250
	1.5	6.89	1,578	960
	2.5	6.61	1,135	820
	3.5	6.47	674	710
Zetag 8160	0.5	7.57	2,689	1,480
	1.5	7.67	2,558	1,190
	2.5	7.83	2,479	1,070
	3.5	7.87	2,128	930
PIX 123 (1.0) + Zetag 8160*	0.5	7.14	1,488	1,490
	1.5	7.22	1,422	1,220
	2.5	7.28	1,406	1,140
	3.5	7.32	1,386	1,010

* Sludge liquid obtained from sewage non-sonicated or sonicated sludge A, first treated with 1.0 mg/g d.m. of PIX 123 and then with different doses of Zetag 8160: 0.5; 1.5; 2.5; 3.5 mg/g d.m.

The amount of organic compounds (COD) in sludge liquids decreased during the process of sewage sludge conditioning. The efficiency of their removal grew with the growing dose in the case of each coagulant and the method combining PIX 123 and Zetag 8160 (Fig. 1). The best effect of organic compounds removal was observed for the liquid separated from sonicated sludge treated with PIX 123: between 26.7% and 76.7%. In the other methods the reduction in the amount of organic compounds was between 6.8% and 26.5% (for Zetag 8160) and between 33.2% and 52.1% (for the method combining PIX 123 and Zetag 8160).

In samples of sludge liquid (Table 4) obtained from non-sonicated sludge B treated with PIX 113 the pH value dropped. The pH value decreased with the increasing dose of the coagulant. For 5.5 mg/g d.m. of PIX 113 it was 5.57 (reduced by 17.6%). In the liquid samples treated together with 4.5 mg/g d.m. of PIX 123 and different doses of Zetag 8160, pH dropped to 5.70 (15.67%). The addition of the PIX 113 coagulant and Zetag 8160 polyelectrolyte increased the ratio of total suspended solids in relation to crude sludge liquids, and then the amount of suspended solids decreased as the doses of the reagents increased.

The content of phosphates and nitrogen decreased in all samples (Fig. 2). The lowest values of phosphates and ammonium nitrogen were observed for samples treated with PIX 113 (93.8% for phosphates and 14.9% for ammonium nitrogen, respectively). When

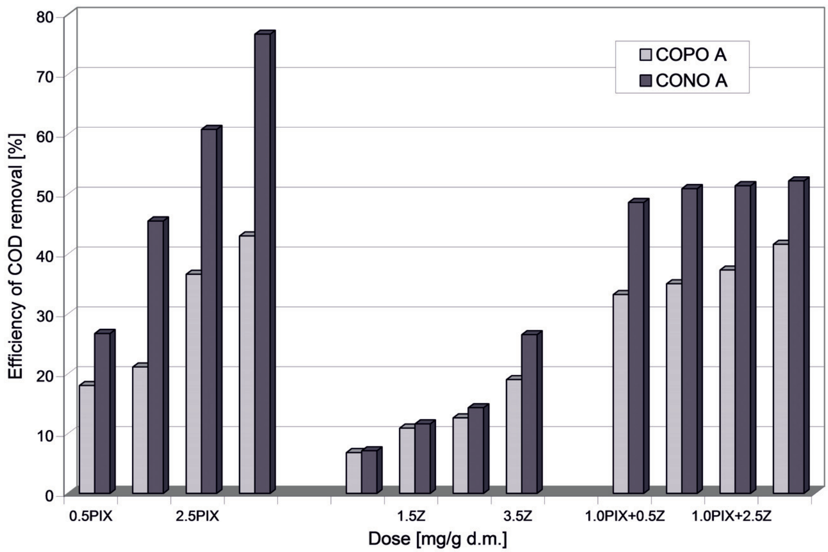

Fig. 1. Efficiency of COD removal in relation to dose and type of coagulant (COPO A – sludge liquid from digested sludge A, CONO A – sludge liquid from digested and sonicated sludge A)

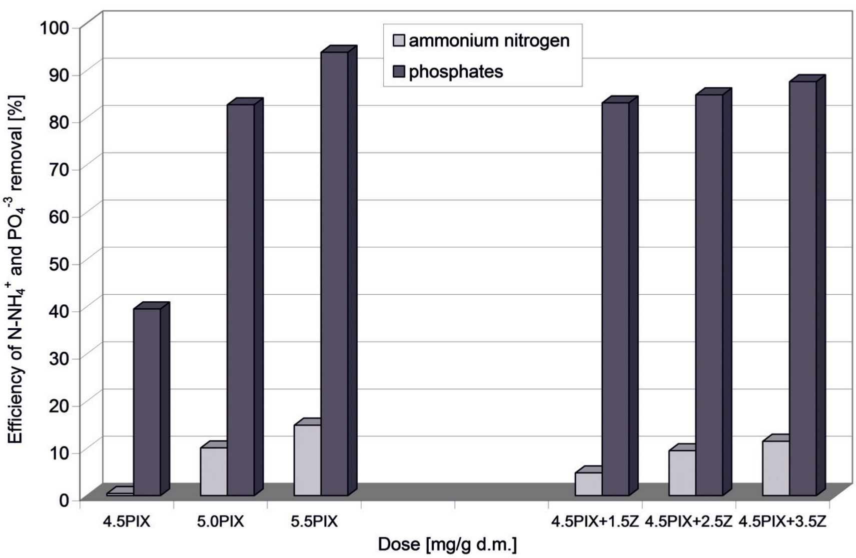

Fig. 2. Efficiency of ammonium nitrogen and phosphates removal depending on the dose and type of coagulant

using PIX 113, the phosphates content in the liquid dropped. This coagulant bound and retained the compounds in the sludge proportionally to the administered dose.

Table 4

Changes of selected parameters of sludge liquid from sludge B

Parameters of sludge liquids	Dose [mg/g d.m.]	pH [-]	Phosphates [mg PO_4^{-3}/dm^3]	Phosphorus [mg P-PO_4^{-3}/dm^3]	Ammonium nitrogen [mg N-NH_4^+/dm^3]	COD [mg O_2/dm^3]	Suspension [mg/dm^3]
Sludge liquids separated from non-sonicated, digested sludge treated with different coagulants							
Crude sludge liquids	—	6.76	24.3	7.94	931.5	784	280
PIX 113	4.5	5.97	14.7	4.81	927.3	387	620
	5.0	5.76	4.2	1.38	836.9	134.4	600
	5.5	5.57	1.5	0.49	792.7	78.4	500
PIX 113 (4.5) + Zetag 8160*	1.5	6.20	4.1	1.35	887	580	580
	2.5	5.94	3.7	1.21	843	545	520
	3.5	5.70	3.0	1.00	824	510	460

* Sludge liquid obtained from non-sonicated, digested sewage sludge first treated with 4.5 mg/g d.m. of PIX 113, and then with different doses of Zetag 8160: 1.5; 2.5; 3.5 mg/g d.m.

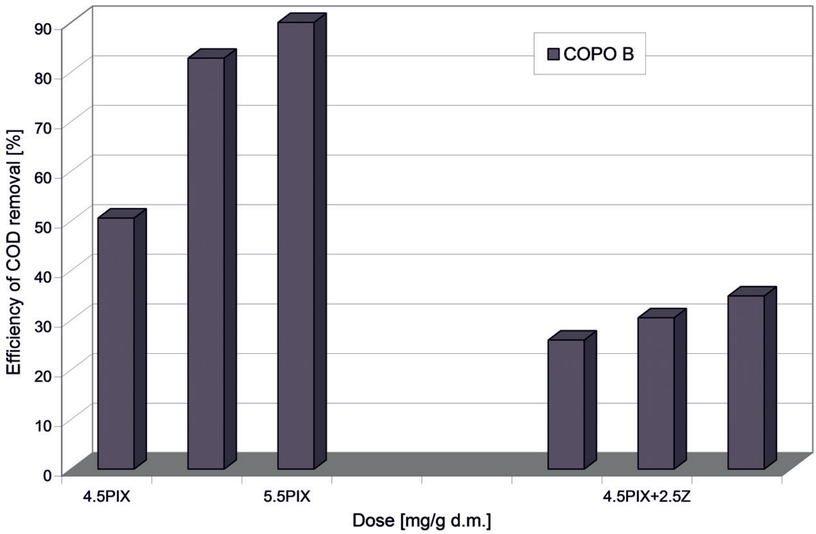

Fig. 3. Efficiency of COD removal in relation to dose and type of coagulant (COPO B – sludge liquid from digested sludge B)

The amount of organic compounds (COD) in sludge liquids decreased during the process of sewage sludge conditioning. The efficiency of their removal grew with the growing dose in the case of PIX 113 and the method combining 4.5 mg/g d.m. of PIX 113 and different doses of Zetag 8160 (Fig. 3). The best effect of organic compounds removal was observed for the liquid separated from sludge B treated with PIX 113: between 50.6% and 90%. In the combined method the reduction of organic compounds amount was between 26% and 34.9%.

Conclusions

1. After mechanical dewatering, sludge liquid was highly contaminated.

2. The reagents and ultrasonic field used to condition the sludge before mechanical dewatering caused the reduction of contamination in the lechates in relation to crude sludge liquids.

3. The combined effect of inorganic coagulant PIX 123 and Zetag 8160 polyelectrolyte allowed the reduction of total suspended solids amount in sludge liquids. The best effect was achieved when using PIX 123. It was 53.8%. The use of the PIX 113 coagulant and Zetag 8160 polyelectrolyte initially increased the ratio of total suspended solids in relation to crude sludge liquids, and then the amount of suspended solids decreased with the increasing dose of conditioning chemicals.

4. The best effect of organic compounds removal was observed for the liquid from sonicated sludge treated with PIX 123 (76.7%) and the combined method (52.1%). In the liquid from non-sonicated sludge the use of PIX 113 coagulant led to reducing the COD value to 90%, and in the combined method, to 26%.

5. In lechates from the dewatering of non-sonicated sludge treated with PIX 113 the amount of ammonium nitrogen was reduced to 14.5%, and phosphates to 93.8%, in relation to crude sludge liquids.

6. Zetag 8160 polyelectrolyte proved to be the least effective in reducing contamination in sludge liquids.

Acknowledgements

The study was carried out as part of the project BS-PB-402-301/11, realized in Department of Chemistry, Water and Wastewater Technology in 2016.

References

[1] Egle L, Rechberger H, Krampe J, Zessner M. Phosphorus recovery from municipal wastewater: An integrated comparative technological, environmental and economic assessment of P recovery technologies. Sci Total Environ. 2016;571(15):522-542. DOI: 10.1016/j.scitotenv.2016.07.019.

[2] Zhang X(J). Factors Influencing Iron Reduction – Induced Phosphorus Precipitation. Envir Eng Sci. 2012;29(6):511-519. DOI: 10.1089/ees.2011.0114.

[3] Guo ChH, Stabnikov V, Ivanov V. The removal of nitrogen and phosphorus from reject water of municipal wastewater treatment plant using ferric and nitrate bioreductions. Bior Techn. 2010;101(11):3992-3999. DOI: 10.1016/j.biortech.2010.01.039.

[4] Pitman AR. Management of biological nutrient removal plant sludges – change the paradigms? Water Res. 1999;33(5):1141-1146. DOI: 10.1016/S0043-1354(98)00316-9.

[5] Poepel HJ, Jardin N. Influence of enhanced biological phosphorus removal on sludge treatment, Wat Sci Technol. 1993;28(1):263-271. http://wst.iwaponline.com/content/28/1/263.

[6] Styka W, Beńko P. Wdrażanie dobrych praktyk w gospodarce osadami ściekowymi [Implementation of good practices in the management of sewage sludge]. Inż Ochr Środ. 2014;17(2):165-184. https://ios.is.pcz.pl/index.php/tom-17/numer-2-2014.

[7] Piaskowski K, Ocena jakości wód osadowych wybranymi parametrami [Analysis of sludge liquor quality using selected parameters]. Gaz, Woda Techn Sanit. 2015;2:56-61. DOI: 10.15199/17.2015.2.4.

[8] Fux C, Velten S, Carozzi V, Solley D, Keller J. Efficient and stable nitritation and denitritation of ammonium-rich sludge dewatering liquor using an SBR with continuous loading. Water Res. 2006;40(14):2765-75. DOI: 10.1016/j.watres.2006.05.003.

[9] Battistoni P, Paci B, Fatone F, Pavan P. Phosphorus Removal from Anaerobic Supernatants:? Start-Up and Steady-State Conditions of a Fluidized Bed Reactor Full-Scale Plant. Ind Eng Chem Res. 2006;45(2):663-669. DOI: 10.1021/ie050796g.

[10] Sperczyńska E. Wykorzystanie zeolitu do usuwania jonów azotu amonowego z cieczy osadowej [Use of zeolite to remove ammonium nitrogen from sludge liquids]. Inż Ochr Środ. 2016;19(3):391-399. DOI: 10.17512/ios.2016.3.9.

[11] Ren W, Zhou Z, Wan L, Hu D, Jiang LM, Wang L. Optimization of phosphorus removal from reject water of sludge thickening and dewatering process through struvite precipitation. Desal Water Treat. 2016;57(33):15515-15523. DOI: 10.1080/19443994.2015.1072059.

[12] Yang Y, Zhao YQ, Babatunde AO, Kearney P. Two strategies for phosphorus removal from reject water of municipal wastewater treatment plant using alum sludge. Water Sci Technol. 2009;60(12):3181-3188. DOI: 10.2166/wst.2009.609.

[13] Hu D, Zhou Z, Niu T, Wei H, Dou W, Jiang LM, et al. Co-treatment of reject water from sludge dewatering and supernatant from sludge lime stabilization process for nutrient removal: A cost-effective approach. Sep Pur Technol. 2017;172:357-365. DOI: 10.1016/j.seppur.2016.08.032.

[14] Myszograj S. Ilość i skład cieczy osadowych powstających w mechaniczno-biologicznej oczyszczalni ścieków [Quantity and characteristics of sludge liquids formed in wastewater treatment plants]. Inż Ochr Środ. 2008;11(2):219-227. https://ios.is.pcz.pl/index.php/tom-11/numer-2-2008.

[15] Ren WC, Zhou Z, Jiang LM, Hu DL, Qiu Z, Wei HJ, et al. A cost-effective method for the treatment of reject water from sludge dewatering process using supernatant from sludge lime stabilization. Sep Pur Technol. 2015;142:123-128. DOI: 10.1016/j.seppur.2014.12.037.
[16] Borowski S. Jakość cieczy osadowych powstających w procesach przeróbki osadów ściekowych [Quality of sludge liquids created in sludge treatment processes]. Forum Ekspl. 2004;16:10-12.

JAKOŚĆ CIECZY OSADOWYCH POWSTAJĄCYCH W PROCESIE MECHANICZNEGO ODWADNIANIA OSADÓW PRZEFERMENTOWANYCH

Katedra Chemii, Technologii Wody i Ścieków, Wydział Infrastruktury i Środowiska
Politechnika Częstochowska, Częstochowa

Abstrakt: Jakość cieczy osadowych powstających w procesach mechanicznego odwadniania osadów zależy od technologii stabilizacji oraz rodzaju urządzenia, prawidłowej jego pracy oraz właściwego doboru środków chemicznych do kondycjonowania. W artykule przedstawiono wpływ wybranych środków i metod kondycjonowania, takich jak: PIX 113, PIX 123, polielektrolit Zetag 8160, pole ultradźwiękowe oraz łączne ich działanie na właściwości cieczy osadowych. Surowe ciecze osadowe charakteryzowały się wysokimi stężeniami azotu amonowego (931,5–1508,9 mg $N\text{-}NH_4^+/dm^3$), fosforanów (24,3–89,4 mg PO_4^{3-}/dm^3) oraz związków organicznych oznaczonych jako ChZT (784,0–1856 mg O_2/dm^3). Stwierdzono, że połączone działanie nieorganicznego koagulantu PIX 123 i polielektrolitu pozwoliło na zmniejszenie ilości zawiesin oraz ChZT w cieczach osadowych. W przypadku zawiesiny najlepszy stopień jej zmniejszenia uzyskano przy stosowaniu PIX-u 123. Wynosił on 53,8%. Analizując zmiany ChZT, podobne efekty uzyskano dla PIX-u 123 (43%) oraz metody łączonej (41,6%). Natomiast użycie koagulantu PIX 113 i polielektrolitu Zetag 8160 spowodowało w cieczy osadowej zwiększenie zawiesin ogólnych w odniesieniu do surowych cieczy osadowych. Działanie koagulantu PIX 113 wpłynęło na zmniejszenie wartości ChZT (90%), azotu amonowego (14,9%) i fosforanów (93,8%) w odniesieniu do surowych cieczy osadowych. Najmniej skuteczny okazał się polielektrolit Zetag 8160.

Słowa kluczowe: ciecze osadowe, koagulanty, polielektrolity, pole ultradźwiękowe, mechaniczne odwadnianie