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ACTIVITY OF ACTIVATED SLUDGE MICROORGANISMS IN THE CO-TREATMENT OF THE LEACHATES IN THE SBR BIOREACTOR

AKTYWNOŚĆ MIKROORGANIZMÓW OSADU CZYNNEGO W PROCESIE WSPÓŁOCZYSZCZANIA ODCIEKÓW W BIOREAKTORZE SBR

Abstract: The aim of the study was to determine the optimum percentage share of leachates co-treated with synthetic wastewaters in biological SBR. The degree of impurities removal and the influence of leachates concentration on activated sludge microorganisms were investigated. Biologically treated wastewaters were cleaned via high-pressure filtration**.** The percentage share of leachates was changed in the range from 5 vol. % to 30 vol. %. The system was operated in the system of two cycles per day. The main criterion for the estimation of the effectiveness of the treatment process was the change of parameters indicating impurities content in crude and treated wastewaters. All analysis were made according to the Polish standards. Following parameters were analysed: pH, COD, BOD_5, contents of TOC, TC and concentrations of total phosphorus, total nitrogen, nitrate nitrogen and ammonium nitrogen. Additionally, the microscopic analysis of activated sludge was performed, that allowed to determine the influence of the leachates concentration on the amount and diversity of microorganisms present in the aeration chamber and biological activity.

The results revealed that the volume of leachate in the treated mixture should not exceed 5 vol. %. The decrease of values of COD and BOD_5 equal to 92.2 % and 99 %, respectively was observed for such conditions. The increase of leachates share in the treated mixture had a negative influence on the structure and composition of activated sludge flocks what resulted in the decrease of content and diversity of microorganisms.

Keywords: biological SBR, landfill leachates, activated sludge, microorganisms

The deposition of wastes on municipal landfills is the most popular method of their utilization. One of the crucial problems resulting from such a solution is the production of leachates, which are formed during drainage of fall waters through the waste dump [1]. The leachates characterize with the higher concentration of organic and inorganic

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substances in comparison with municipal wastewaters. Additionally, the variation of their amount and qualitative composition as well as low biodegradability causes leachates to be hardly treatable via biological processes. The leachates treatment usually comprises of integrated physico-chemical and biological methods. The choice between various methods needs to be ecologically and economically justified [2, 3]. The biochemical activity of microorganisms is one of the most important elements determining the efficiency of the biological process in the leachates treatment. The introduction of leachates containing toxic substance to municipal wastewaters can cause the atrophy of activated sludge microorganisms and, as a result, prelude the proceeding of biochemical processes. The monitoring of wastewater treatment is usually based on physico-chemical analyses, which do not allow to indicate the reason of process disturbances. The systematic microscopic study of the activated sludge allow to monitor its composition and the structure of flocks, what results in the improvement of treated wastewaters quality [4, 5].

Recently, the application of *Sequential Biological Reactors* (SBRs) in municipal landfill leachates treatment is more often considered. In this technology the cyclic changes of organic compounds and nitrogen concentrations as well as of hydrodynamic conditions (mixing, aeration and release phases) stimulate the growth of micro-organisms, which are resistant to environmental conditions. It results in the stabilization of the process, which additionally is more effective in comparison with constant flow treatment. Moreover, the SBR technology can be easily modified already during exploitation eg the length of phases, the method of the feed supply or the total length of the cycle can be changed. It is very important considering the treatment of the leachates, which vary in the amount and composition depending on the season and the waste dump age [2, 3, 6–9].

Materials and methods

The leachate collected at the municipal landfill in Tychy–Urbanowice constituted the substrate of the study. The leachates biological treatment process was carried out in the laboratory conditions with use of the activated sludge taken from the Municipal Sewage Treatment Plant in Gliwice. The experiments were performed in SBR of 3 dm^3 in volume and the activated sludge set in the synthetic sewage treatment was used. The operational cycle of the bioreactor took 12 h including: filling and mixing – 4 h, aeration – 7 h, sedimentation and removal of clarified sewage – 1 h. The percentage share of the leachates in the mixture with the synthetic sewage was changed from 5 vol. % to 30 vol. % The effectiveness of the treatment of the sewage and leachates mixtures was compared with the effectiveness of synthetic sewage treatment. The attempt of the treatment of crude leachates was also made. The synthetic sewage were prepared from a broth according to PN-72/C-04550 standard. The characteristic of the leachates and the synthetic sewage is showed in Table 1.

The concentration of the activated sludge was kept at the level of 4 g/dm^3, the concentration of oxygen was varied from 3 mg/dm^3 to 4 mg/dm^3, and the activated

Table 1

The characteristics of the municipall landfill leachates and the synthetic sewage

Parameter	Unit	Leachates	Synthetic sewage	Permissible values*
COD	g O_2/m^3	3855	900	125
BOD_5	g O_2/m^3	300	440	25
TOC	g C/m^3	602	198	30
TC	g C/m^3	1580	260	—
Ammonium nitrogen	g $N\text{-}NH_4/m^3$	1240	16	10
Nitrate nitrogen	g $N\text{-}NO_3/m^3$	9	7	30
Total nitrogen	g N/m^3	1500	120	30
Total phosphorus	g P/m^3	30	15	2
pH	—	8	6.8–7.5	6.5–9.0

* The permissible values of impurities content of sewage disposed to natural reservoirs according to The Regulation of The Minister of Environment, 28.01.2009.

sludge load was equal to 0.1 g COD/g_{dm} d. All analysis were made according to the Polish standards. Following parameters were determined: pH, COD, BOD_5, contents of TOC, TC and concentrations of total phosphorus, total nitrogen, nitrate nitrogen and ammonium nitrogen. The microscopic observation of the activated sludge was made using Opta-Tech N-180 M microscope equipped with the camera. It allowed to determine the amount and kind of microorganisms present in the activated sludge as well to evaluate flocks quality according to their size and structure. The respiratory activity of the activated sludge was also performed.

Results and discussion

The results showing the dependence of the effectiveness of the leachates co-treatment on their volumetric share in the mixture with the synthetic sewage are shown in Table 2.

Table 2

The effectiveness of the leachates co-treatment in the SBR bioreactor depending on their the volumetric share

Share of leaches [vol. %]	Denotation							
	COD [mg/dm^3]	R* [%]	BOD_5 [mg/dm^3]	R* [%]	TOC [mg/dm^3]	R* [%]	TC [mg/dm^3]	R* [%]
0	35	96.1	2	99.5	19.9	90.0	49	81.2
5	90	92.2	2	99.5	24.8	88.7	54	84.6
10	150	88.0	5	98.3	42.5	81.9	70.5	82.2
20	390	72.7	20	94.6	83.6	67.7	96.7	82.9
30	900	46.9	20	93.9	115.6	61.4	119	85.4

* R – the degree of the parameter decrease.

The degree of removal of impurities during the synthetic sewage treatment was high, and values of the sewage parameters did not exceed the permissible ones defined in the Regulation of The Minister of Environment on conditions to be met for the introduction of sewage into the water and soil from 28th January 2009. The dependence of the degree of removal of COD on the volumetric leachates share in the mixture with the synthetic sewage is shown in Fig. 1.

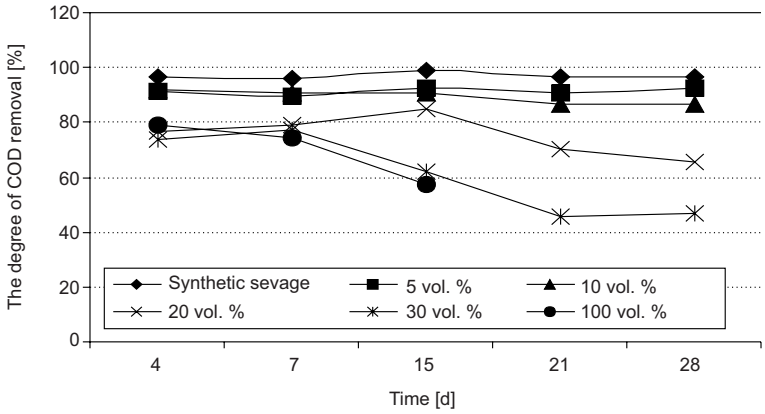

Fig. 1. The dependence of decrease of COD value of co-treated sewage on the co-treatment time and volumetric share

The highest degree of removal of COD during co-treatment of mixture of the leachates and the synthetic sewage was obtained for the leachates share equal to 5 vol. %. The value of the parameter in the treated mixture was 92.2 % lower (90 mg O_2/dm^3) in comparison with the crude mixture. For higher shares ie 10 vol. %, 20 vol. % and 30 vol. % the concentration of chemical oxygen demand of the treated mixture was at the level of 150 mg O_2/dm^3, 390 mg O_2/dm^3 and 900 mg O_2/dm^3, respectively, what precluded its direct deposition to the natural collector.

Nevertheless, it was observed that the increase of the volumetric leachates share in the mixture did not influence on the BOD_5 value of the treated mixture, that is shown in Fig. 2. Values of the parameter in bioreactors effluent were low and equal to 2 and 5 mg/dm^3 for shares 5 vol. % and 10 vol. %, respectively. It corresponded to the decrease of the parameter value by 98.3 % and 99.5 % in comparison with crude mixtures. BOD_5 of treated sewage of 20 vol. % and 30 vol. % leachates share was equal to ca 20 mg O_2/dm^3.

The similar dependence was observed for the higher concentrations of organic carbon in the crude mixture (Fig. 3).

The degree of removal of TOC was decreasing with the increase of the leachates share in the mixture with the synthetic sewage. After 28 days of the treatment of the mixture containing 5 vol. % of the leachates the concentration of TOC in the treated mixture was equal to 24.7 mg/dm^3. In case of higher leachates shares the concentration of total organic carbon exceeded the permissible level.

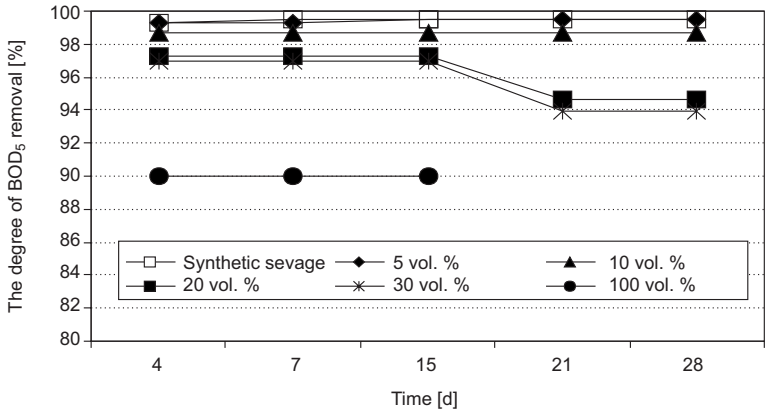

Fig. 2. The dependence of decrease of BOD_5 value of co-treated sewage on the co-treatment time and volumetric share

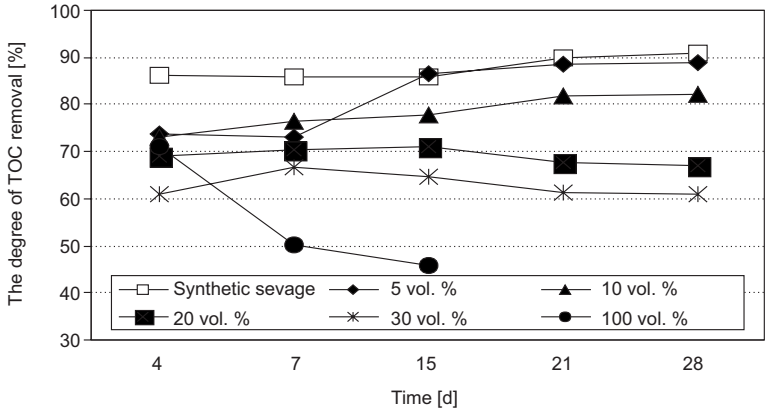

Fig. 3. The dependence of decrease of TOC value of co-treated sewage on the co-treatment time and volumetric share

The change of the concentration of biogenic substances during the co-treatment of the leachates in the SBR depending on their volumetric share is shown in Table 3.

It was revealed, that the degree of the decrease of ammonium nitrogen concentration was high for all mixtures of different leachates shares and exceeded 98%. The concentration of ammonium nitrogen exceeded the permissible level only in case of the treatment of just crude leachates and was equal to 25 mg/dm^3. In case of leachates mixtures the parameter values were below the permissible one. However, despite the fact, that the change of the leachates share in the mixture did not influence on the degree of removal of $N\text{-}NH_4^+$, it caused the significant increase of nitrate nitrogen concentration in the bioreactor effluent, which exceeded the permissible value. The increase of the leachates share in the mixture had also a disadvantageous influence on the effectiveness of removal of total phosphorus. The highest degree of the impurity removal

Table 3

The change of concentration of biogenic elements during leachates co-treatment in the SBR bioreactor depending on their the volumetric share

Share of leachates [vol. %]	Denotation				
	$N\text{-}NO_3^-$ [mg/dm^3]	$N\text{-}NH_4^+$ [mg/dm^3]	R* [%]	P_{tot} [mg/dm^3]	R* [%]
0	30	0.5	96.9	2	86.7
5	67	1.0	98.8	4.1	76.2
10	122	1.0	99.3	6.7	64.7
20	328	3.8	99.7	17	19.0
30	340	8.0	99.5	21	12.5

* R – the degree of the parameter decrease.

was obtained for the 5 vol. % share, similarly as in case of NH_4^+ ions. After 28 days treatment 76.2 % decrease (4.1 mg P_{tot}/dm^3) was observed. It was decided, that the biologically treated sewage mixture had to be improved via reverse osmosis (Table 4)

Table 4

The effectiveness of the reverse osmosis process

Parameter	Sewage after SBR [mg/dm^3]	Sewage after RO process	
		Concentration [mg/dm^3]	Retention [%]
COD	90	8.0	91.1
BOD_5	2	0.0	100
TOC	24.8	3.0	87.9
Ammonia nitrogen	1.0	0.0	100
Nitrate nitrogen	67	7.5	88.8
Total phosphorus	4.1	< 1.0	~99

The applied high-pressure membrane process improved the quality of the treated mixture that it could be disposed to the natural collector. Concentrations of nitrate nitrogen and total phosphorus in the final stream were equal to 7.5 mg/dm^3 and less than 0.1 mg/dm^3, respectively.

The microscopic observations of the change of activated sludge quality caused by the increase of the leachates share in the mixture were also performed in the study. The evaluation of the amount and the quality of microorganisms present in the crude activated sludge, as well as the analysis of its structure allowed to conclude that it characterized with flocks of medium size considerable cohesion, loose structure, regular shape and significant diversity of microorganisms. It indicated that the proper aerobic conditions were provided, while the presence of floating and creeping ciliates pointed the medium substrate load conditions. The age of the activated sludge was determined as the mature one according to the presence of many *Arcelli* and rotifers. For leachates shares in the range from 5 vol. % to 10 vol. % both, shape and size of flocks remained

unchanged. However, in case of these shares, in the fourth week of bioreactors operation the amount of ciliates, rotifers and *Arcelli* slightly decreased and filamentous bacteria appeared. For higher leachates share the significant decrease in microorganisms diversity was observed. Additionally, the presence of the considerable high amount of filamentous bacteria together with the decrease of the amount of ciliates and *Arcelli* were noted. It explained the decrease of the co-treatment effectiveness in these bioreactors showed by significantly exceeded permissible concentrations of impurities. It was also found, that the increase of the leachates in the mixture resulted in the change of shape and size of flocks, which became smaller and irregular.

In case of the treatment of crude leachates already in the second week of the process a white, rigid foam appeared on the surface of the bioreactor, that indicated on the overload of the activated sludge. The flocks were very fine and of small amount, and the bioreactor effluent was turbid, what confirmed the washing out of the activated sludge. The amount of microorganisms significantly decreased and the presence of filamentous bacteria was noted, what resulted in the ineffective treatment. In the next week of the study activated sludge microorganisms atrophied according to the substrate overload as well as toxicity of chemical compounds present in the leachates.

The obtained dependences of the change of the biochemical activity of activated sludge on the leachates share in the co-treated mixture confirmed microscopic observations. The respiratory activity of the activated sludge adapted for the synthetic sewage treatment was the highest and equal to 30 mg O_2/dm^3. It slightly decreased for the 5 vol. % leachate share to the level of 28.8 mg O_2/dm^3. For higher leachates share ie 10 vol. %, 20 vol. % and 30 vol. % values of the respiratory activity were equal to 25.5 mg O_2/dm^3, 24.2 mg O_2/dm^3 and 22.8 mg O_2/dm^3, respectively. In the bioreactor containing only the crude leachates after two weeks of the treatment the respiratory activity was undeterminable.

Conclusions

It was shown that the increase of the leachates in the mixture with synthetic sewage co-treated in the SBR caused the increase of the content of organic substances. The optimal leachates share in the mixture was established at the level of 5 vol. % what enabled the effective removal of organic impurities to the permissible level. However, the treated mixture still characterized with the exceeded concentrations of biogenic substances. It was decided to clean the bioreactor effluent via reverse osmosis.

The applied high-pressure membrane process improved the quality of the treated mixture that it could be disposed to the natural collector. Concentrations of nitrate nitrogen and total phosphorus in the final stream were equal to 7.5 mg/dm^3 and less than 0.1 mg/dm^3, respectively.

For the optimal leachates share (5 vol. %) both, shape and size of the activated sludge flocks remained unchanged during the treatment. The increase of the leachates share in the mixture significantly influenced on the flocks quality causing the decrease of both, the amount of flocks and microorganisms diversity.

The performance of the treatment of crude leachates was stopped after 15 days according to the activated sludge atrophy, which resulted in total inhibition of the treatment.

Literature

[1] Rosik-Dulewska Cz.: Basics of waste management, Scientific Publisher PWN, Warszawa 2002 (in Polish), pp. 148–160.
[2] Surmacz-Górska J.: *Removal of organic pollutants and nitrogen from leachate produced on municipal landfills*, Sci. Papers Silesian Univ. Technol., Environ. Eng., Gliwice 2000.
[3] Szyc J., Leachates from municipal landfill, Sci. Publisher Gabriel Borowski, Warszawa 2003, pp. 42–77.
[4] Buck H.: Microorganisms in activated sludge, "Seidel-Przywecki" Sp. z o.o. Publishers, Szczecin 1999, pp. 7–8.
[5] Eikelboom D.H.: The handbook of microscopic activated sludge sludies, "Seidel-Przywecki" Sp. z o.o. Publishers, Szczecin 1999, pp. 7–13.
[6] Laitinen N., Luonsi A. and Vilen J.: *Landfill leachate treatment with sequencing batch reactor and membrane bioreactor*, Desalination 2006, **191**, 86–91.
[7] Tsilogeorgis J., Zouboulis A., Samara P. and Zamboulis D.: *Applification of a membrane sequencing batch reactor for landfill leachate treatment*, Desalination 2008, **221**, 483–493.
[8] Surmacz-Górska J., Miksch K. and Kita T.: *Possibilities of biological treatment of leachate from municipal landfill*, Environ. Protect. Arch. Wrocław 2000, **26**, 42–54.
[9] Diamadopoulos E., Samaras P., Dabou X. and Sakellaropoulos G.P.: *Combined treatment of landfill leachate and domestic sewage in a sequencing batch reactor*. Water Sci. Technol. 1997, **36**(2–3), 61–68.

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Abstrakt: Celem pracy było wyznaczenie najkorzystniejszego udziału procentowego odcieków współoczyszczanych ze ściekami syntetycznymi w bioreaktorze SBR. Oceniano stopień usunięcia zanieczyszczeń oraz wpływ stężenia odcieków na metabolizm mikroorganizmów osadu czynnego. Współoczyszczone biologicznie odcieki dodatkowo doczyszczono w procesie odwróconej osmozy. Udziały procentowe odcieków zmieniano w zakresie wartości od 5 % obj. do 30 % obj. Układ pracował w systemie dwóch cykli na dobę. Kryterium oceny stopnia oczyszczenia ścieków była zmiana wartości wskaźników zanieczyszczeń charakteryzujących ścieki poddawane procesowi oczyszczania i odprowadzane z bioreaktora. Oznaczenia wykonano zgodnie z obowiązującymi polskimi normami. Wyznaczano: odczyn, ChZT, BZT_5, OWO, OW, stężenia fosforu ogólnego, azotu azotanowego oraz amonowego. Prowadzono również analizę mikroskopową osadu czynnego, oceniając wpływ stężenia odcieków na ilość i rodzaj aktywnych mikroorganizmów zasiedlających komorę napowietrzania. Określano aktywność oddechową biomasy w zależności od warunków prowadzenia procesu współoczyszczania odcieków.

Wykazano, że udział procentowy odcieków w mieszaninie ścieków nie powinien przekraczać 5 % obj. Stopień obniżenia wartości wskaźnika ChZT charakteryzującego ścieki oczyszczone w tych warunkach wynosił 92,2 %, natomiast stężenie BZT_5 kształtowało się na poziomie 99 %. Wzrost stężenia odcieków w mieszaninie ze ściekami syntetycznymi wpłynął negatywnie na strukturę i skład kłaczków osadu czynnego, wywołując obniżenie ilości i różnorodności mikroorganizmów oraz ich aktywności oddechowej.

Słowa kluczowe: bioreaktor SBR, odcieki składowiskowe, osad czynny, mikroorganizmy