J. Elementol. 2007, 12(4): 317–325

INFLUENCE OF FILLING IN AN SBR REACTOR ON THE TREATMENT OF LEACHATE FROM MUNICIPAL LANDFILLS*

Justyna Koc-Jurczyk, Łukasz Jurczyk

Chair of Natural Theories of Agriculture
University of Rrzeszow

Abstract

The aim of the present study was to determine the influence of solid filling on the effectiveness of removal of organic substances (as COD) and ammonium from leachate from municipal landfills in SBR and SBBR reactors. The reactors worked on a laboratory scale reactors working under aerobic conditions at constant hydraulic retention time (HRT) of 3 d.COD values in outflow were similar: on average 635 mg $O_2 \cdot dm^{-3}$ (SBR) and 646 mg $O_2 \cdot dm^{-3}$ (SBBR).

Regardless of the presence or absence of filling, nitrate dominated in the effluent. The average concentration was 693 mg $N_{NO3} \cdot dm^{-3} \cdot h^{-1}$ in SBR and 699 mg $N_{NO3} \cdot dm^{-3}$ in SBBR. The concentrations of ammonium and nitrite were low, less than 2.9 mg $N_{NH4} \cdot dm^{-3}$ and 0.5 mg $N_{NO2} \cdot dm^{-3}$ (SBR), and 3.2 mg $N_{NH4} \cdot dm^{-3}$ and 0.3 mg $N_{NO2} \cdot dm^{-3}$ (SBBR).

The results indicate that the presence of solid filling did not influence the effectiveness of nitrification in activated sludge.

Key words: leachate, SBR, SBBR, activated sludge, ChZT, ammonium.

dr inż. Justyna Koc-Jurczyk, Chair of Natural Theories of Agriculture, University of Rzeszow, ul. Ćwiklińskiej 2, 35-601 Rzeszów.

*The experimental part of this study was partially supported by the Univeristy of Warmia and Mazury (UWM project nr 0805-0214) and was carried out in a laboratory of the Department of Environmental Biotechnology.

WPŁYW OBECNOŚCI WYPEŁNIENIA W REAKTORACH SBR NA EFEKTYWNOŚĆ OCZYSZCZANIA ODCIEKÓW ZE SKŁADOWISK ODPADÓW KOMUNALNYCH

Abstrakt

W pracy badano wpływ obecności wypełnienia stałego w reaktorach SBR i SBBR na skuteczność usuwania substancji organicznych (ChZT) oraz azotu amonowego z odcieków ze składowisk odpadów komunalnych. Reaktory pracowały w skali laboratoryjnej, w warunkach tlenowych. Czas zatrzymania odcieków wynosił 3 d. Wartości ChZT w odpływie z reaktorów kształtowały się na podobnym poziomie, średnio 635 mg $O_2 \cdot dm^{-3}$ (SBR) i 646 mg $O_2 \cdot dm^{-3}$ (SBBR). Niezależnie od obecności wypełnienia, w odciekach oczyszczonych dominował azot azotanowy (V), średnio 693 mg $N_{NO3} \cdot dm^{-3}$ (SBR) oraz 699 mg $N_{NO3} \cdot dm^{-3}$ (SBBR). Stężenia azotu amonowego i azotu azotanowego (III) były niskie i nie przekroczyły: 2,9 mg $N_{NH4} \cdot dm^{-3}$ i 0,5 mg $N_{NO2} \cdot dm^{-3}$ (SBR) oraz 3,2 mg $N_{NH4} \cdot dm^{-3}$ i 0,3 mg $N_{NO2} \cdot dm^{-3}$ (SBBR). W badaniach stwierdzono, że obecność wypełnienia stałego w SBR nie ma wpływu na efektywność oczyszczania odcieków.

Słowa kluczowe: odcieki, SBR, SBBR, osad czynny, ChZT, azot amonowy.

INTRODUCTION

Leachate occurs as a result of rainwater migration through a landfill and the leaching of dissolved organic and inorganic compounds (KEMPA 1983). From the literature data it can be assumed that the dependence between the landfill operation time length and the amount of leachate has not been firmly stated. In contrast, the influence of waste disposal duration on the type, concentration and biodegradability of organic substances and nitrogen in leachate is well-known.

Depending on duration of landfill operation, KURNIAWAN et al. (2006), and earlier KANG et al. (2002) and AMOKRANE et al. (1997) divided landfills into young, in the maturation and stabilization phase (medium) or stabilized (old) ones.

During the first five years of waste disposal, COD in leachate varies within a wide range, from 204 up to 40 000 mg $O_2 \cdot dm^{-3}$, whereas BOD ranges from 18 to 25 000 mg $O_2 \cdot dm^{-3}$ (KANG et al. 2002, EL-FADEL et al. 2002, KURNIAWAN et al. 2006).

Leachate from landfills operating from 5 to 10 years is characterized by the COD value of 1 660–20 000 mg $O_2 \cdot dm^{-3}$, and BOD of 100-4 000 mg $O_2 \cdot dm^{-3}$ (EL-FADEL et al. 2002, KURNIAWAN et al. 2006).

In leachate from landfills operating over 10 years, concentration organic substances is the lowest: from 550 to 8 800 mg $O_2 \cdot dm^{-3}$ (as COD) and from 16.5 to 1 000 mg $O_2 \cdot dm^{-3}$ (as BOD) (EL-FADEL et al. 2002, BILA et al. 2005).

EL-FADEL et al. (2002) concluded from the literature data that the ammonia nitrogen concentration in leachate changes from values close to zero to about 1 250 mg $N_{NH4} \cdot dm^{-3}$, like that of organic nitrogen. In general, concentration of nitrate does not exceed 9.8 mg $N_{NO3}{\cdot}dm^{-3}$ and that of nitrite - 1.5 mg $N_{NO2}{\cdot}dm^{-3}$.

The investigations reported by KACZOREK and LEDAKOWICZ (2002) and SURMACZ-GÓRSKA et al. (2000) suggest that ammonium concentration in leachate from local landfills reaches value of 3 000 mg $N_{NH4}{\cdot}dm^{-3}$. OBRZUT (1997) reports that ammonium in leachate from ten Polish landfills ranged in concentration between 1.7 and 1 520 mg $N_{NH4}{\cdot}dm^{-3}$, with the mean value of 398 mg $N_{NH4}{\cdot}dm^{-3}$.

It is recommended that leachate should be treated by a variety of biological and physicochemical methods, different in the complexity of the process and advancement of technical solutions.

Initially, in the biological leachate treatment, anaerobic or aerated lagoons with long hydraulic retention time were used (SURMACZ-GÓRSKA et al. 1997). The necessity of nitrogen removal from leachate caused higher interest in more effective methods, such as activated sludge (LOUKIDOU, ZOUBOULIS 2001) or combined methods (WELANDER et al. 1997, ROSTRON et al. 2001, KIM et al. 2006).

One of the ways to enhance nitrification efficiency, in comparison with activated sludge alone, are mobile carriers introduced to sludge, which make it possible to lengthen sludge age and affect the increase of biomass concentration in a reactor.

High biomass concentration and long sludge age facilitate more effective removal of organic matter, with participation of slow growing heterotrophic bacteria and maintenance of suitable abundance of nitrifiers. The biomass in a reactor can be retained as a result of immobilization on a carrier, inclusion into a carrier or a combination of both methods. In practice, activated carbon, sand, plastic or sponges are used as carriers (KARAPINAR, KARGI 1996). For synthetic wastewater treatment by activated sludge, ARNZ (2000) used a reactor filled with a porous ceramic carrier (SBBR) and a SBR reactor working only with suspended biomass. The authors obtained higher biomass growth in the SBBR (90%) rather than in the SBR. KARAPINAR and KARGI (1996) applied sponges as a filling in an FBBR reactor. The biomass concentration in the reactor was 55 $g{\cdot}dm^{-3}$, thus being 90% higher in comparison with a reactor without the filling.

Research on enhancement of nitrification has also been conducted using activated sludge with biofilm on filling (mobile or immobile carriers).

The effectiveness of nitrification depends both on the carrier type and the structure of its surface. The investigations by WELANDER et al. (1997) dealt with these problems. The authors examined the influence of the filling type on nitrification in three reactors operated in parallel with different filling types. The leachate came from Hyllstofta, a twenty-year-old municipal and industrial landfill in Sweden, and were pretreated in anaerobic lagoons. The results demonstrated that in reactors with polyethylene pieces and polyethylene pieces with addition of 5% ammonium chloride as the filling, the nitrification rate was nearly identical, and depending on operational conditions changed within the range of about 5.6 to 11 mg $N_{NH4} \cdot dm^{-3} \cdot h^{-1}$. In a reactor with the filling of cellulose, the nitrification rate was evidently higher. Under optimal conditions it reached about 40 mg $N_{NH4} \cdot dm^{-3} \cdot h^{-1}$.

The aim of the present study was to determine the influence of filling in form of sponge of polyvinyl chloride (PVC) on the effectiveness of organics (as COD) and ammonium removal in SBR and SBBR reactors from leachate from municipal landfills.

MATERIAL AND METHODS

In the experiment, leachate collected from a municipal landfill located in Wysieka near Bartoszyce, Warmia and Mazury Province., was used. The landfill has been operated since January 1996. The investigations were conducted in 2004, when the landfill was in the stabilization phase. The characteristics of the landfill leachate are shown in Tables 1. The leachate was characterized by a low BOD_5/COD ratio equal 0.3, with ammonium as a dominating form of nitrogen.

The technological research on the leachate treatment by activated sludge was conducted in SBR reactors (Sequenting Batch Reactor) with volume of 5 dm^3, made of plexiglass and equipped with stirrers of adjustable rotation speed (36 r $min.^{-1}$) and aeration system (2.4 – 4.0 mg $O_2 \cdot dm^{-3}$).

The experiments were carried out in two reactors, at constant hydraulic retention time (HRT) of 3 d. The total operating time of the SBR was 24 h. The reactors worked under aerobic conditions and the operating cycle consisted of filling, aeration, settling and decantation.

Reactor 1 (SBR) worked with activated sludge, whereas reactor 2 (SBBR–Sequenting Batch Biofilm Reactor) contained additional stationary filling in the form of 42 strips of polyvinyl chloride sponge (2×11 cm).

The effectiveness of municipal landfill leachate treatment by activated sludge in SBR and SBBR under aerobic conditions was investigated. The efficiency of leachate treatment was estimated on the basis of organic matter concentration changes, expressed as COD and nitrogen forms (ammonium, nitrite and nitrate) in a reactor's cycle. The analyses were carried out according to HERMANOWICZ et al. (1999).

The differences between the effluent from the two reactors were determined using Statistica 7.1., non-parametric the Kurskal-Wallis test.

Table 1

Physicochemical composition of leachates from the municipal landfill in Wysieka (Warmia and Mazury Province, Poland)

Parameter	Unit	Value
pH	-	8.2
COD	mg $O_2 \cdot dm^{-3}$	805
BOD_5	mg $O_2 \cdot dm^{-3}$	242
Total N	mg $N \cdot dm^{-3}$	872.2
Organic N	mg $N \cdot dm^{-3}$	170.2
$N\text{-}NH_4$	mg $N_{NH4} \cdot dm^{-3}$	702
BOD_5/ COD	-	0.3
COD/total N	-	0.92

RESULTS AND DISCUSSION

The values of organic substances (COD) in treated leachate during the experiment are shown in Fig. 1. Initially, concentrations of organic substances fluctuated and then stabilized. This was probably associated with adaptation of activated sludge microorganisms to landfill leachate, which depended on operational conditions. The activated sludge adaptation in the SBR and SBBR was 6 and 11 days, respectively (Fig. 1).

For statistical analysis of the quality of treated leachate, the results obtained after adaptation of activated sludge were used. From the data it was concluded that the COD values were similar: on average 635 mg $O_2 \cdot dm^{-3}$ (SBR) and 646 mg $O_2 \cdot dm^{-3}$ (SBBR).

It can be inferred that the presence of stationary filling in a reactor did not influence the removal of organic matter from leachate.

It was demonstrated, however, that the efficiency of the removal of organic substances (COD) was low, which was caused by the fact that the leachate came from a landfill operated for 8 years, currently in the stabilization phase. The leachate composition from stabilized sites was characterized by relatively low concentration of organic substances (to 5000 mg $O_2 \cdot dm^{-3}$), hardly biodegradable (AMOKRANE et al. 1997).

LOUKIDOU and ZOUDOULIS (2001) treated leachate containing organic matter at concentration (COD) of 5000 mg $O_2 \cdot dm^{-3}$, BOD_5/COD ratio equal 0.2 and HRT = 1 d. Using an SBR reactor filled with polyurethane cubes, the authors achieved about 65% reduction of COD and 95% of BOD_5. The low efficiency of organic matter removal (as COD) was caused by partially

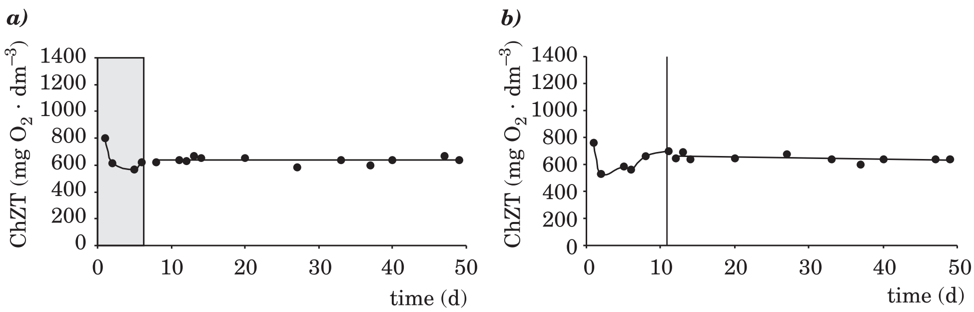

Fig. 1. Concentrations of organic compounds as a COD value in outflow from:
a) SBR; b) SBBR

stabilized leachate from a ten-year-old landfill, containing mainly nonbiodegradable organic compounds.

Rusten and Eliassen (1993) showed that by increasing the aeration phase in the SBR cycle from 61% to 67%, the efficiency of municipal wastewater was raised by about 5% (COD).

In our study, the effectiveness and course of ammonium removal from leachate in SBR and SBBR were also investigated.

Changes in removal of ammonium, nitrite and nitrate followed a similar course, regardless of the presence or absence of the filling in the reactor (Fig. 2). A distinctive feature of ammonium oxidation was that it consisted of two stages of nitrification (in phase II). It was assumed that the ammonium removal rate and increasing nitrate concentration (stage I) were linear in character, according to the zero-order reaction.

When in stage II, the nitrification rate was calculated according to the zero-order equation.

The values of the determined rate of ammonium removal and increasing nitrite and nitrate concentrations in leachate from SBR and SBBR can be found in Table 2. In stage I, the decrease in ammonium concentration was faster (28 mg $N_{NH4} \cdot dm^{-3} \cdot h^{-1}$ – SBR and 28.4 mg $N_{NH4} \cdot dm^{-3} \cdot h^{-1}$ – SBBR) than the increase in nitrite concentration (3.5 mg $N_{NO3} \cdot dm^{-3} \cdot h^{-1}$ for SBR and 1.22 mg $N_{NO3} \cdot dm^{-3} \cdot h^{-1}$ for SBBR). As a result, accumulation of nitrite in sediment water was observed. The maximum concentration of nitrite appeared at 7^{th} h of the cycle. Then the nitrogen concentration was 237 mg $N_{NO2} \cdot dm^{-3}$ in SBR and 158 mg $N_{NO2} \cdot dm^{-3}$ in SBBR. Afterwards, the nitrate concentration began to increase rather notably.

At stage II, the nitrification rate proceeded according to the first-order reaction in comparison with stage I. In SBR, it was 87.6 mg $N_{NO3} \cdot dm^{-3} \cdot h^{-1}$, whereas in SBBR – 80 mg $N_{NO3} \cdot dm^{-3} \cdot h^{-1}$.

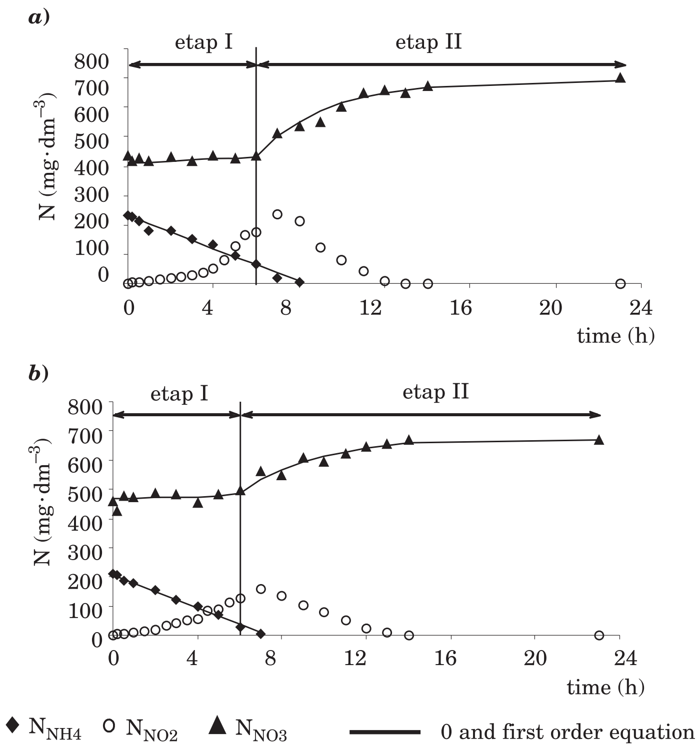

Fig. 2. Changes in concentration of nitrogen forms during an operating cycle of the reactor: a) SBR; b) SBBR

Regardless of the presence or absence of the filling, nitrate dominated in the effluent. Its average concentration was 693 mg N_{NO3}·dm^{-3}·h^{-1} in SBR and 699 mg N_{NO3}·dm^{-3} in SBBR. The ammonium and nitrite concentrations were low, less than 2.9 mg N_{NH4}·dm^{-3} and 0.5 mg N_{NO2}·dm^{-3} (SBR), and 3.2 mg N_{NH4}·dm^{-3} and 0.3 mg N_{NO2}·dm^{-3} (SBBR).

The results suggest that the presence filling did not influence the effectiveness of nitrification in activated sludge.

YALMAZ and ÖZTÜRK (2001) claimed that the rate of ammonium loss was kept at a level of 10.5 mg N_{NH4}·dm^{-3}·h^{-1} during the treatment of leachate in SBR reactors.

WELANDER et al. (1997) demonstrated the influence of the type of filling on the effectiveness of nitrification in leachate. In a reactor filled with cellulose moulders, the nitrification rate was definitely higher (about 40 mg N_{NH4}·dm^{-3}·h^{-1}), whereas when filled with polyethylene pieces and polyethylene pieces with an addition of 5% ammonium chloride, it varied from about 5.6 to 11 mg N_{NH4}·dm^{-3}·h^{-1}.

Table 2

The constant of ammonium nitrogen removal and nitrate increase rates in SBR and SBBR

Parameter	Unit	Value					
		nitrogen forms					
		ammonium		nitrate			
		SBR	SBBR	etap I		etap II	
				SBR	SBBR	SBR	SBBR
k_1	$mg \cdot dm^{-3} \cdot h^{-1}$	28	28.4	3.5	1.22	-	-
k_2	h-1	-	-	-	-	0.3	0.28
rv	$mg \cdot dm^{-3} \cdot h^{-1}$	28	28.4	3.5	1.22	87.6	80
Correlation coefficient	-	0.99	0.98	0.66	0.71	0.94	0.98
Conformity coefficient	-	0.01	0.02	0.58	0.1	0.11	0.1

ROSTRON et al. (2001) conducted investigations on synthetic wastewater in CSTR reactors. In a reactor working with suspended biomass, the nitrification rate was 8.64 kg $N \cdot m^{-3} \cdot h^{-1}$. However, when using Linpor moulders, the rate reached 13.68 kg $N \cdot m^{-3} \cdot h^{-1}$, and with Kaldnes moulders, it went up to 12.72 kg $N \cdot m^{-3} \cdot h^{-1}$. The highest nitrification rate (16.8 kg $N \cdot m^{-3} \cdot h^{-1}$) was obtained when biomass immobilized in capsules of polyvinyl chloride (PVC) was applied.

LOUKIDOU and ZOUDOULIS (2001) achieved 60% reduction of ammonium from leachate. Their experiments were carried out in a reactor filled with polyurethane cubes. The ammonium concentration in leachate was 1 800 mg $N_{NH4} \cdot dm^{-3}$. According to the authors, aeration time of 18 h turned out too short to obtain complete nitrification.

CONCLUSIONS

1. The effectiveness of organic matter removal from leachate was low and at HRT of 3 d, operating time of 24 h and under aerobic conditions, it reached about 20%, with or without filling in a reactor.

2. Ammonium oxidation to nitrate was parallel to the accumulation of nitrite. Nitrification in phase II occurs in two stages. Following ammonium oxidation and maximum nitrite concentration in leachate (stage I), nitrite decreases whereas the nitrate concentration goes up (stage II).

3. Presence of filling in a reactor did not influence the rate of ammonium oxidation in SBR and SBBR reactors.

REFERENCES

AMOKRANE A., COMEL C., VERON J. 1997. *Landfill leachates pretreatment by coagulation - flocculation*. Wat. Res., 31: 2775-2782.

ARNZ P., ESTERL S., NERGER C., DELGADO A., WILDERER P. A. 2000. *Simultaneous loading and draining as a means to enhance efficacy of sequencing biofilm batch reactors.* Wat. Res., 5/34: 1763-1766.

BILA D.M., MONTAVÃO A.F., SILVA A.C., DEZOTTI M. 2005. *Ozonation of a landfill leachate: evaluation of toxicity removal and biodegradability improvement.* J. Hazard. Mater., B117: 235-242.

EL-FADEL M., BOU-ZEID E., CHAHINE W., ALAYLI B. 2002. *Temporal variation of leachate quality from pre-sorted and baled municipal solid waste with high organic and moisture content.* Waste Manage., 22: 269-282.

HERMANOWICZ W., DOŻAŃSKA W., DOJLIDO J., KOZIOROWSKI B. 1999. *Fizycznochemiczne badanie wody i ścieków*. Arkady, Warszawa.

KACZOREK K., SÓJKA-LEDAKOWICZ J., LEDAKOWICZ S. 2002. *Porównanie skuteczności metod biologicznych i technik membranowych w oczyszczaniu odcieków z wysypisk*. Inż. Aparat. Chem., 3: 67-68.

KANG K-H., SHIN H.S., PARK H. 2002. *Characterization of humic substances present in landfill leachates with different landfill ages and its implications.* Wat. Res., 36: 4023-4032.

KARAPINAR I., KARGI F. 1996. *Effect of particle number density on wastewater treatment performance of a fluidized-bed bioreactor.* Enzyme Microb. Technol., 19: 140-144.

KIM D-J., LEE D-I., KELLER J. 2006. *Effect of temperature and free ammonia on nitrification and nitrite accumulation in landfill bacterial community by FISH.* Bio. Technol., 97: 459-468.

KURNIAWAN T.A., CHAN G.Y.S., LO W-H., BABEL S. 2006. *Physico-chemical treatment for removal of recalcitrant contaminants from landfill leachate.* J. Hazard. Mater., B129: 80-100.

LOUKIDOU M. X., ZOUBOULIS A. I. 2001. *Comparison of two biological treatment process using attached-growth biomass for sanitary landfill leachate treatment.* Environ. Pollut., 111: 273-281.

OBRZUT L. 1997. *Odcieki z wysypisk komunalnych.* Ekoprofit, 5: 32-36.

SURMACZ-GÓRSKA J., MIKSCH K., KIEROŃSKA T., KITA M. 1997. *Chemiczne i biologiczne utlenianie zanieczyszczeń występujących w odciekach wysypiskowych.* V Ogóln. Symp. Nauk.-Tech. „Biotechnologia Środowiskowa", ss. 239-247.

SURMACZ-GÓRSKA J., MIKSCH K., KITA M. 2000. *Możliwości podczyszczania odcieków z wysypisk metodami biologicznymi.* Arch. Ochr. Środ., 26: 43-54.

ROSTRON W.M., STUCKEY D. C., YOUNG A.A. 2001. *Nitrification of high strength ammonia wastewaters: comparative study of immobilisation media.* Wat. Res., 35: 1169-1178.

RUSTEN B., ELIASSEN H. 1993. *Sequencing batch reactors for nutrient removal at small wastewater treatment plants*. Wat. Sci. Technol., 28: 233-242.

WELANDER U., HENRYSSON T., WELANDER T. 1997. *Nitrification of landfill leachate using suspended-carrier biofilm technology.* Wat. Res., 31: 2351-2355.

YALMAZ G., ÖZTÜRK I. 2001. *Biological ammonia removal from anaerobically pre-treated landfill leachate in sequencing batch reactors (SBR)*. Wat. Sci. Technol., 3/43: 307-314.