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EFFECT OF APPLICATION OF POLYALUMINIUM CHLORIDE ON REDUCING EXPLOITATION PROBLEMS AT THE WASTEWATER TREATMENT PLANT IN OLSZTYN

Adam Drzewicki

Chair of Applied Ecology
University of Warmia and Mazury in Olsztyn

K e y w o r d s: *Microthrix parvicella*, sludge bulking, biological origin foam, filamentous organisms, polyaluminium chloride.

A b s t r a c t

The paper contains an assessment of the effectiveness of polyaluminium chloride (PAX-18) application in improving sedimentation properties of activated sludge at the wastewater treatment plant in Olsztyn. The causes of bulking and foaming of activated sludge have been identified. The effect of adding doses of polyaluminium chloride on the sludge volume index (SVI) and counts of *Microthrix parvicella* has been analysed. Application of doses of PAX-18 within the range of 0.63 and 2.13 g Al^{+3} kg^{-1} sdmd (sludge dry mass daily) to the system, for the duration of 10 to 89 days, proved to be an ineffective way of reducing SVI. However, in most cases, the applied treatments reduced the foaming of activated sludge in multi-functional reactors.

WPŁYW DAWKOWANIA CHLORKU POLIGLINU NA OGRANICZENIE PROBLEMÓW EKSPLOATACYJNYCH W OCZYSZCZALNI ŚCIEKÓW W OLSZTYNIE

Adam Drzewicki

Katedra Ekologii Stosowanej
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: *Microthrix parvicella*, puchnięcie osadu, piana pochodzenia biologicznego, organizmy nitkowate, chlorek poliglinu.

Address: Adam Drzewicki, University of Warmia and Mazury, ul. Oczapowskiego 5, 10-957 Olsztyn, Poland, phone +48 (089) 524 51 07, e-mail: adam.drzewicki@uwm.edu.pl

Abstrakt

W pracy oceniono skuteczność stosowanych zabiegów dawkowania chlorku poliglinu (PAX-18) na poprawę właściwości sedymentacyjnych osadu czynnego w oczyszczalni ścieków w Olsztynie. Określono przyczynę puchnięcia i pienienia osadu czynnego. Przeanalizowano wpływ dozowania chlorku poliglinu na indeks objętościowy osadu czynnego (SVI) i liczebność *Microthrix parvicella.* Dawkowanie PAX-18 w zakresie od 0,63 do 2,13 g Al^{+3} kg^{-1} smod w układzie, w przedziałach czasowych od 10 do 89 dni, okazało się nieskutecznym sposobem na obniżenie SVI. Stosowane zabiegi w większości przypadków ograniczały natomiast wpienianie osadu czynnego w reaktorach wielofunkcyjnych.

Introduction

The technological changes broadly introduced in the 1990s to Polish wastewater treatment plants operating on activated sludge that would enable improved removal of nitrogen and phosphorus from sewage and wastewater have compounded the problem of foaming and bulking of activated sludge. This is a result of the fact that the conditions which facilitate the removal of biogens promote the development of specific forms of filamentous bacteria in activated sludge, mostly responsible for its foaming and bulking. One of the most common representative of such filamentous microorganisms is *Microthrix parvicella* (KALISZ et al. 2005, DRZEWICKI et. al. 2008). Excessive growth of this bacterium creates many exploitation difficulties, such as a disturbed sludge sedimentation process, difficulties in maintaining the adequate age of sludge and recirculant concentrations, impeded dewatering of sludge, inferior production of biogas, problems related to safety in closed fermentation chambers, and many other drawbacks up to inferior visual qualities of the wastewater treatment facilities. Excessive growth of *Microthrix parvicella* in activated sludge used for removal of biogenic substances is very difficult to halt. The bacterium proliferates well owing to the long age of sludge and associated low load. The microorganism demonstrates high affinity to oxygen (LEMMER 1992). Under both aerobic and anaerobic conditions, it is capable of binding and utilizing long-chain fatty acids, present in raw sewage, as a source of carbon atoms and energy (ANDREASEN, NIELSEN 2000, SLIJKHUIS, DEINEMA 1988, SLIJKHUIS et al. 1984). All these factors make it difficult to control the causes of the growth and development of *Microthrix parvicella* in wastewater plants using technologies for improved removal of nitrogen and phosphorus from sewage. It seems that application of polyaluminium chloride could be an effective way of controlling the bacterium. However, this is an expensive method, which also involves generation of excess sludge and can be harmful to the whole activated sludge biomass as well as to the natural environment in that that is acts selectively and creates better conditions for

growth of subordinate filamentous organisms. Therefore, each wastewater plant needs to work out its own strategy for the frequency of application and concentration of used doses of this reagent.

The purpose and scope of the study

The purpose of this study has been to assess the effectiveness of adding doses of polyaluminium chloride PAX-18 in improving sedimentation properties of activated sludge in the wastewater treatment plant in Olsztyn.

The study involved:

– determination of the causes of foaming and bulking of activated sludge;

– analysis of the effects produced by the applied doses of polyaluminium chloride on sludge volume index (SVI) and population of *Microthrix parvicella*.

Materials and Methods

The wastewater treatment plant

The Łyna Wastewater Treatment Plant in Olsztyn receives from 32 to 37,000 m^3 d^{-1} of municipal sewage from the towns of Olsztyn and Barczewo as well as from four rural communes: Barczewo, Dywity, Gietrzwałd and Stawiguda. Of the total volume of received sewage and wastewater, only 0.35% is delivered in septic vehicles. Some of the characteristics of the received sewage can be found in Table 1. The plant facilities were refurbished in 2004, and now the technological line consists of two automated dense stepped screens, a horizontal grit chamber with two parallel channels, two circular Dorr type primary sedimentation tanks, a primary sludge digester, a recirculated sludge denitrification chamber, a dephosphatation chamber, five

Table 1

Physicochemical characteristics of sewage according to the data supplied by the WTP laboratory

Parameters	Units	Raw sewage			Treated sewage		
		2006	2007	2008	2006	2007	2008
BOD_5	mg O_2 dm^{-3}	401	583	583	5.5	7.5	4.3
COD_{Chr}	mg O_2 dm^{-3}	664	954	973	40	50.8	58
Suspended soilds	Mg dm^{-3}	224	476	516	3.1	18	4.5
Nitrogen	mg N_{og} dm^{-3}	72	81	90	11.3	9.2	14
Phosphophrus	mg P_{og} dm^{-3}	11	17	16.8	1.5	1.3	0.9

All data are presented as means from 12 analyses performed at monthly intervals

multi-functional chambers of bioreactors each equipped with four Passavant rotors, and three secondary sedimentation tanks. Sewage sludge is inactivated in two closed fermentation chambers and three open fermentation tanks to be finally dewatered on a mechanical press. The post-fermentation waters are discharged to the Łyna River. The values of pollutants in the treated wastewater are presented in Table 1.

Exploitation problems

The analysis of the collected information and results of own observations enable us to conclude that the exploitation problems encountered at the wastewater treatment plant in Olsztyn are related to the poor properties of the activated sludge. This becomes particularly evident in winter and spring, when the SVI exceeds 190 $cm^3\ g^{-1}$ (Figure 1). Bulked sludge has an adverse effect on

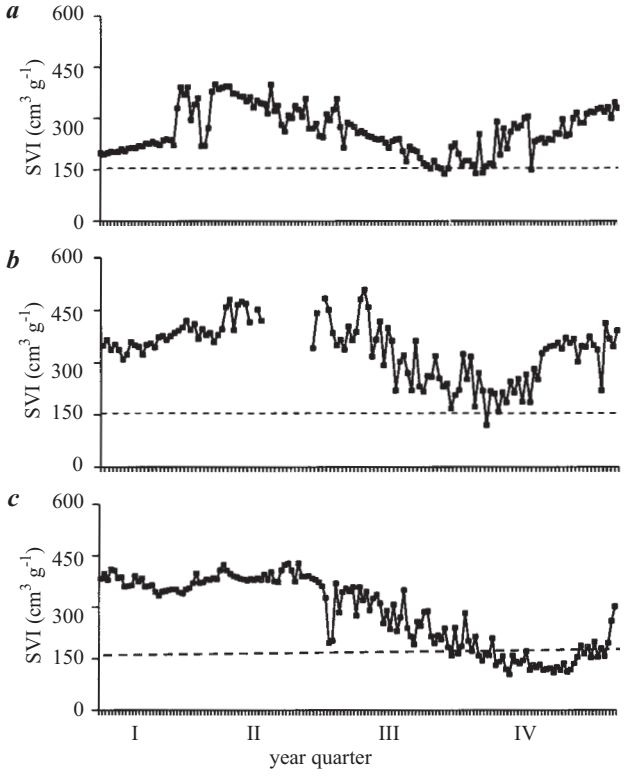

Fig. 1. The curve of the sludge volume index in: *a* – 2006, *b* – 2007, *c* – 2008

the operation of the sludge processing facilities. It is more difficult to dewater sludge on filter presses, which causes the hydraulic overload of these devices. During the fermentation process in closed fermentation chambers thick foam is created, which disturbs inner recirculation and makes it difficult to transport fermenting sludge to open fermentation tanks. Foam causes periodical blockage of gas pipes and airlocking of the pumps.

Biological assay methods

The microscopic analysis of sludge and foam samples collected from the multi-functional chambers was performed on live material, immediately on receiving the samples at the laboratory and in preparations stained with Gram and Neisser methods. For identification of the microorganisms, we referred to publications by EIKELBOOM (2000) and JENKINS et al. (2004). Counts of filamentous microorganisms were assessed according to the estimation scale elaborated by Jenkins, which comprises the range FI = 0–6.

Analytical methods

The results of the physicochemical analysis of activated sludge, such as dry matter of activated sludge, temperature of sewage in multi-functional chambers, sludge volume index, have been obtained from the laboratory at the wastewater treatment plant in Olsztyn.

Results and Discussion

Problem of activated sludge and foam

Analyses of activated sludge and foam have demonstrated that the cause of the high SVI at the wastewater treatment plant in Olsztyn and resultant exploitation problems is the excessive growth of filamentous bacteria *Microthrix parvicella*. The microscopic images revealed very numerous and long filaments of *M. parvicella* inside flocs (Table 2, Figure 2). They impede sedimentation and compaction of flocs, and periodically make sludge particle adhere to gas bubbles, which causes permanent foaming of sludge (Figure 3).

Table 2

Estimated counts of filamentous microorganisms

Filamentous microorganisms	Date				
	2006	2007	2008		
	5. 04	7. 05	18. 03	31. 03	22. 04
Microthrix parvicella	5	5	5	5	5
Type 0092	–	–	2	2	2
Typ 0041	2	–	2	1	1
Nostocoida limicola	–	–	–	–	1
Haliscomenobacter hydrossis	–	1	–	–	–
Typ 021 N	–	1	–	–	–
Thiothrix sp.	–	1	–	–	–
Typ 0411	–	1	–	–	–

1 – few, 2 – some, 3 – common, 4 – very common, 5 – abundant

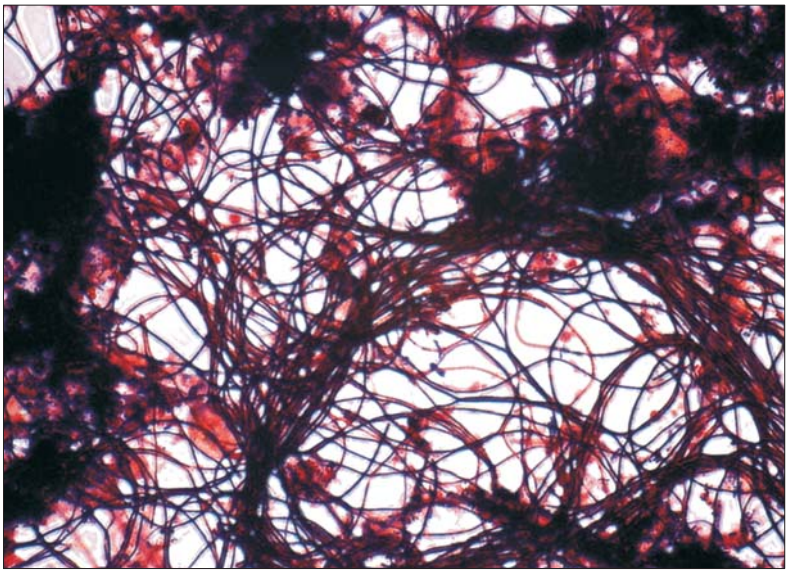

Fig. 2. The Gram stained filamentous microorganism *Microthrix parvicella* dominant in the activated sludge and foam, 1000x

Fig. 3. Foam produced by *Microthrix parvicella*

Experiments with doses of PAX

In order to depress the index of activated sludge and eliminate foam, polyaluminium chloride PAX-18 was introduced to the discharge canal, situated between the multi-functional reactors and secondary treatment tanks. The frequency, duration and rates of applied doses (expressed as aluminium ions) of the compound are presented in Table 3. The effect of the treatments on the sludge volume index (SVI) is illustrated in the Figure 4 a–c).

Table 3

Frequency and duration of the application of PAX-18 as well as its rates converted to aluminium ions in 2006–2008

Time period		g AL^{3+}/kg dsm/d
2006	13.01–22.01	1.06–1.70
	31.03–1.05	1.06–1.70
	27.10–6.11	0.64–1.06
2007	28.02–15.03	1.06–1.70
	27.03–29.04	0.85–1.70
	12.05–01.06	1.70–2.13
	17.10–29.10	0.85–1.70
2008	8.01–22.01	1.06–1.70
	01.02–0 6.05	0.85–1.70
	13.10–22.12	0.85–1.70

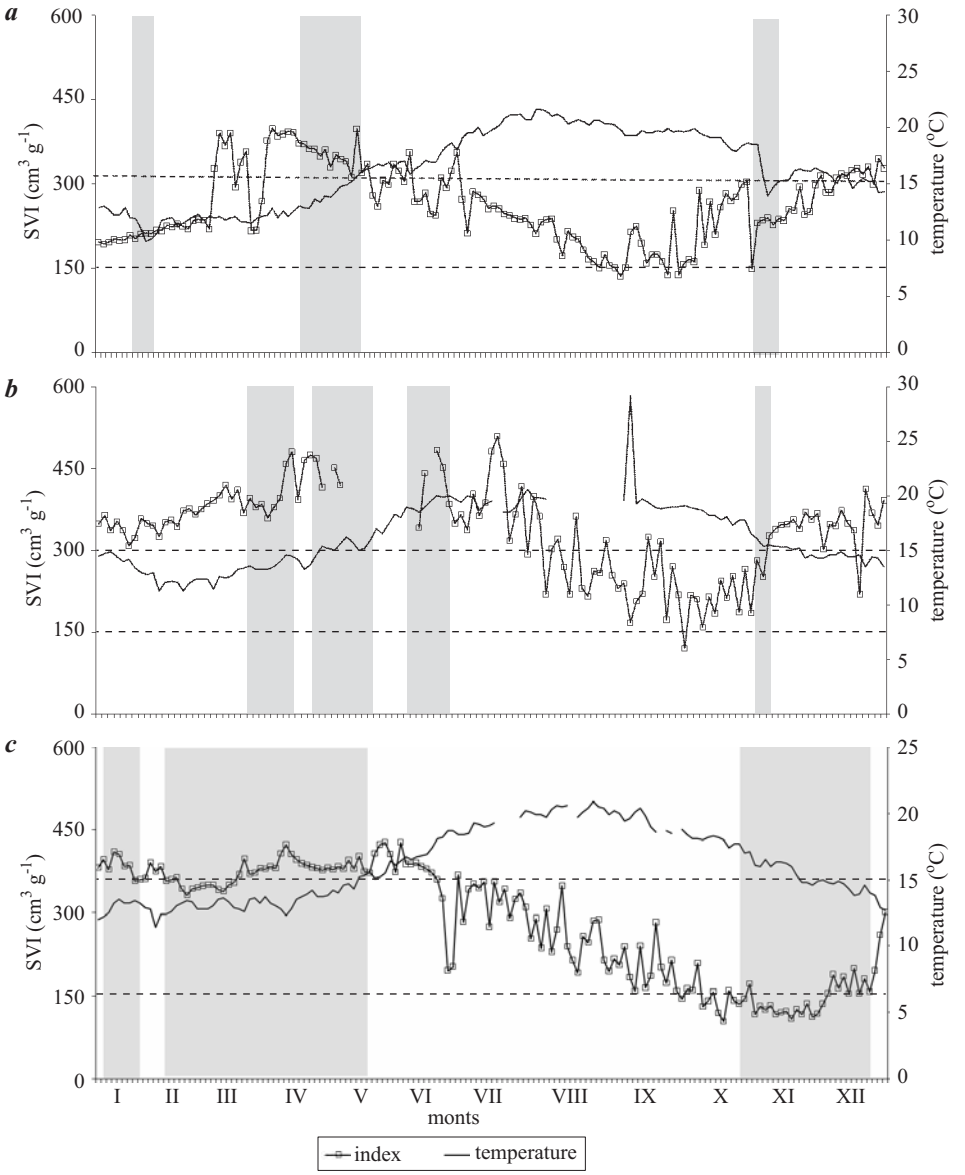

Fig. 4. The curve of the sludge volume index and temperature in: *a* – 2006, *b* – 2007, *c* – 2008; the grey colour indicates when PAX-18 was applied

In 2006, PAX was dosed three times, using between 0.64 and 1.70 g Al^{+3} kg^{-1} of sdmd (sludge dry mass daily). Despite the application of the reagent, in all the cases the value of SVI considerably exceeded 150 cm^3 g^{-1}. The index did

not tend to fall. On the contrary, during the longest, 32-day, application of the compound, it rose from 392 to 398 $cm^3\ g^{-1}$.

In 2007, the dose of PAX applied during four treatments ranged from 0.85 to 2.13 g $Al^{+3}\ kg^{-1}$ of sdmd. As in 2006, the value of SVI was much above 150 $cm^3\ g^{-1}$. One day before the termination of the longest, 34-day, application of PAX, the SVI reached 420 $cm^3\ g^{-1}$.

In 2008, the applied dose of PAX reached 0.85–1.70 g $Al^{+3}\ kg^{-1}$ sdmd. The compound was applied three times. The treatments did not bring about any desirable effects. Although the reagent was added for nearly the whole first half-year, the values of SVI would typically exceed 350 $cm^3\ g^{-1}$. In all the cases, however, while dosing PAX the foaming was observed to be less intense.

Discussion

The references (ROELS et al. 2002, CZERWIONKA et al. 2003) suggest that dosing polyaluminium chloride is an effective method for limiting the consequences of excessive growth of *M. parvicella*, such as foaming and bulking of activated sludge. The analysis of our results, however, indicate that application of polyaluminium chloride PAX-18 at the wastewater treatment plant in Olsztyn failed to lower values of sludge volume index (SVI) below 150 $cm^3\ g^{-1}$. The improvement of sedimentation properties of sludge observed in the second half-year is attributable to higher temperature of sludge in multi-functional chambers. *Microthrix parvicella* prefers the temperature < 15°C (KNOP, KUNST 1998). A possible reason for the failure of the applied treatments is the insufficiently low doses of PAX-18 introduced to the facilities, which did not guarantee an adequate concentration of the metal relative to the quantities of activated sludge. Another possible reason is that the duration of the treatments was too short. Most of the observed filaments of *M. parvicella* in activated sludge did not reveal any morphological changes under the influence of the reagent (Figure 5). According to the reference data, the minimum application period for PAX should be three weeks (ROELS et al. 2002). The initial rate should be no less than 3 g $Al^{+3}\ kg^{-1}$ sdmd (GENEJA, CZERWIONKA 2003). The treatments carried out at the Olsztyn Wastewater Treatment Plant did result, however, in the visible reduction of foaming in the multi-functional chambers. Nonetheless, they were unsuccessful in eliminating the cause of the negative event such as the excessive growth of *M. parvcella* in activated sludge.

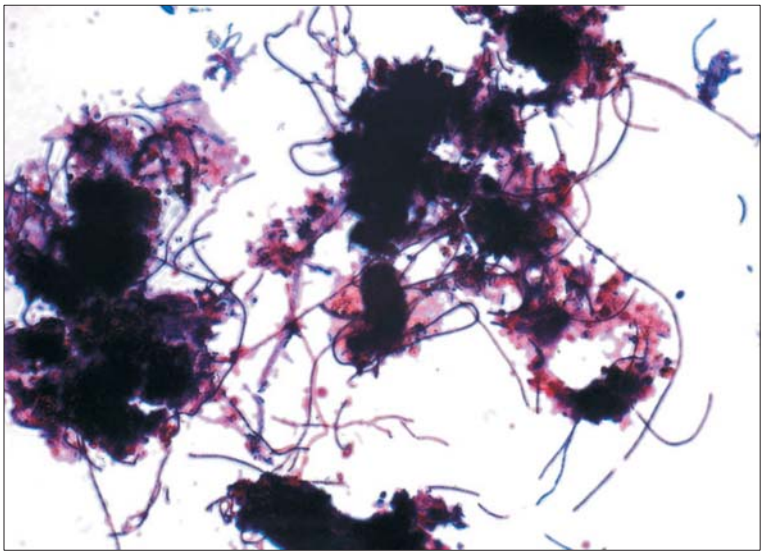

Fig. 5. Image of a Gram stained population of *Microthrix parvicella* during the application of polyaluminium chloride, 1000x

Conclusions

1. The cause of the main exploitation problems encountered at the Olsztyn WTP such as bulking and foaming of activated sludge was the excessive growth of a population of the filamentous bacteria *Microthrix parvicella*.

2. Application of polyaluminium chloride (PAX-18) in the rates of 0.64 to 2.13 g Al^{+3} g^{-1} sdmd (expressed as aluminium ions) did not lower the SVI. The sludge volume index would typically remain at a level above 150 cm^3 g^{-1} sdm.

3. Most of the observed filaments of *M. parvicella* sampled from activated sludge revealed no changes in their morphology caused by the prolonged application of PAX.

4. In most of the cases, the application of PAX reduced the foaming of activated sludge n the multi-functional chambers.

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