

NITROGENOUS COMPOUNDS TRANSFORMATION IN SBR SYSTEM. DEPENDENCE ON THE OPERATING PARAMETERS

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ABSTRACT

Foaming and bulking of the activated sludge is still one of the biggest problem in the wastewater treatment plants. Control of filamentous bacteria growth, responsible for such properties of the sludge may be based on kinetic or metabolic selection. Bacteria selection can be obtained by changing conditions during the process as well, as by changes substrate availability. This paper presents a part of our research concerning the investigation of the effect of anaerobic and anoxic conditions and proteineous substrate concentration on the activated sludge treatment in the SBR-like system. The efficiency of nitrogenous compounds transformation and removal has been evaluated. It has been found that ammonification process proceeds not only during anaerobic phase, but also during aeration. Besides, it has been stated that the increase of peptone concentration negatively affect the nitrification process.

KEYWORDS

nitrogen removal, sludge bulking, SBR

INTRODUCTION

Poor settling properties of activated sludge results from massive growth of filamentous bacteria. It can be observed as bulking sludge or as foaming sludge and the reasons for their formation are not clearly identified up to now. There are various methods to fight these sludges however, none of it is generally effective because of the large amount of factors influencing generation of filamentous microorganisms.

The objective of this research is to study the mechanism of filamentous bacteria selection by applying different conditions in the activated sludge reactor.

Experiments confirming that substrate gradient suppress the growth of filamentous microorganism were carried out since the mid of 60's in Holland, UK and Czechoslovakia (Rensink et al., 1966, Anon et al., 1967, Chudoba et al., 1972, Wanner et al., 1987). It has been found that the higher was the substrate gradient, the lower sludge volume indices were observed. The mechanism of bacteria growth control by substrate gradient is called kinetic selection. The substrate gradient can be achieved in a fill-and-draw mode apparatus much easier than in a continuous-flow, completely mixed system. Thus, it can be improved by arrangement the inlet part of an aeration basin as compartmentalized unit (so called selector). There is also possibility to select bacteria growth by changing the cultivation conditions (anaerobic, aerobic, oxic), which stimulate the ability of microorganisms to utilize carbon and energy sources. The mechanism based on such stimulation is called metabolic selection. The researches on it have been developed since the biological nutrients removal has been introduced (Wanner, et al., 1987, Albertson et al., 1991). However, in spite of the

knowledge of the kinetic and metabolic selection mechanisms, the foaming and bulking of the sludge still remain the main problem in wastewater treatment practice (Holmstrom et al., 1996, Bojanowska et al., 2003).

The knowledge of substrate availability in consecutive stages of the treatment process as well, as the knowledge of particular groups of bacteria response to unfavorable conditions will be very useful in control of filamentous bacteria development in real systems. To gain this knowledge the researches were undertaken. It covers investigation of the effect of anaerobic and anoxic conditions, as well as the limitation of substrate availability on the growth and activity of different groups of bacteria. Different substrates were considered and in this report the results with different concentration of proteins are presented.

EXPERIMENTAL

The experiments were carried out in laboratory reactor, which operating mode was similar to that in the SBR system. The SBR process has a cycling nature, each cycle consisting of several phases. These are fill, react, settle, draw and idle phases. In the process involving nutrients removal the fill and react phases are multiple within one cycle, with successive periods of aeration and anaerobic or anoxic mixing. In our research the anaerobic mixing was followed by aeration period, and the same sludge was used in consecutive cycles (experiments presented in figs. 1 and 2). Besides, the experiments with new sludge for each process were performed (figs 3-8). In the process the sludge taken from municipal wastewater treatment plant (after 30 min of aeration) and synthetic wastewater (table 1) were used. They were mixed in the ratio 2:3 (figs 1, 2) or 1:3 (figs 3-8).

Table 1. Composition of synthetic wastewater

Component	Concentration [mg/dm³]
Tryptic soy broth	150
Soy peptone	50-1600
Starch	50
Grey soap	50
Urea	14
Sodium acetate	10
MgSO ₄ ·7H ₂ O	7
NaCl	30
KCl	7
CaCl ₂	7

In Fig 1 there are presented results of ammonia nitrogen changes in processes with different mode of aeration. The aeration has been introduced after 1, 2 or 3 hours after filling the reactor with wastewater or immediately after it, and it lasted 3 hours.

In Fig 2 the results of nitrates concentration in the same processes are presented. Each point presents mean value from three experimental results.

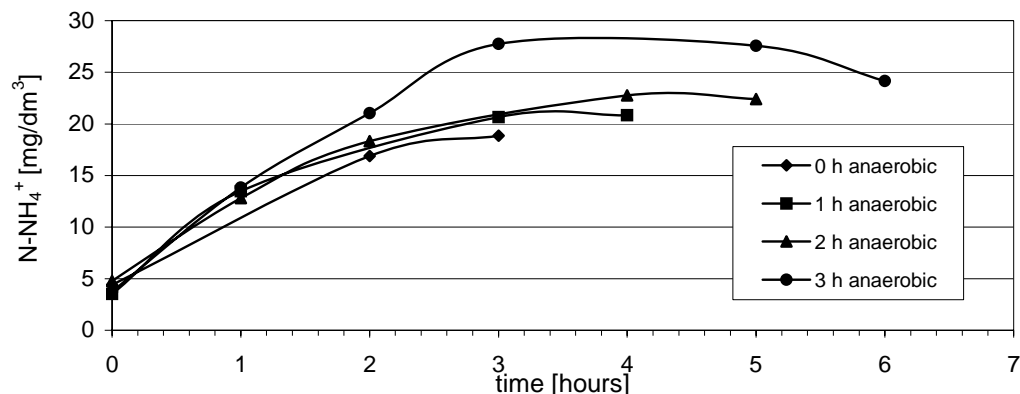


Figure 1. Changes of ammonia nitrogen concentration during the processes with different anaerobic mixing period followed by 3 hours of aeration phase. Soy peptone concentration – 50 ppm.

The rate of ammonia nitrogen concentration increase depends on the anaerobic phase span (fig 1), and it was the highest in the case, when this phase lasted 3 hours, while the lowest increase in ammonia nitrogen concentration was observed when aeration began immediately after filling up the reactor. However, as it can be seen from Fig 1, the ammonia concentration increases also during aeration period and its maximum is reached after about 3-4 hours, independently on anaerobic period time, which confirm the almost constant rate of ammonification process.

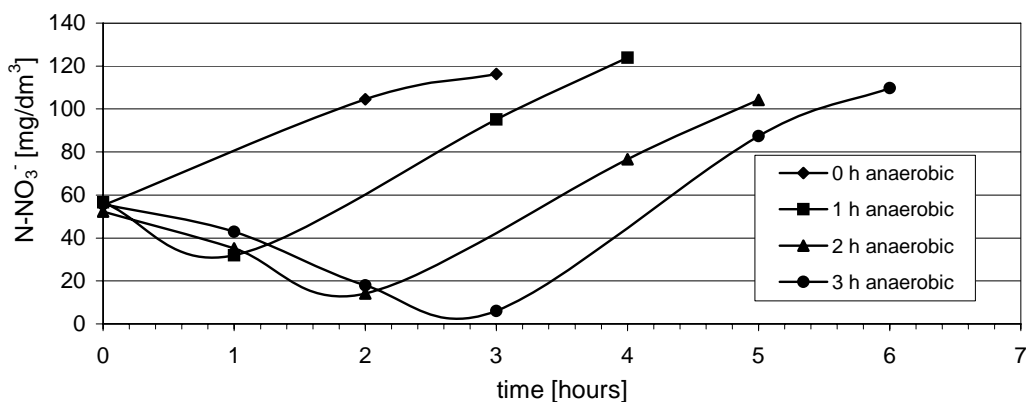


Figure 2. Changes of nitrates concentration during the processes with different anaerobic mixing period followed by 3 hours of aeration phase. Soy peptone concentration – 50 ppm.

As it can be seen from Figs 2 a very strong effect of anaerobic phase duration on nitrates concentration took place. Decrease of nitrates concentration was observed only during anaerobic period and the concentration was the lower, the longer lasted this phase (which of course was expected as a result of denitrification).

In Figs 3 and 4 the results of ammonia nitrogen concentration during process in which 3 hours of anaerobic period were followed by 10 hours of aerobic conditions, are presented. In these series the elevated concentration of Kjejdahl nitrogen was applied (400 or 1200 ppm of peptone instead of 50 ppm as it was in former experiments).

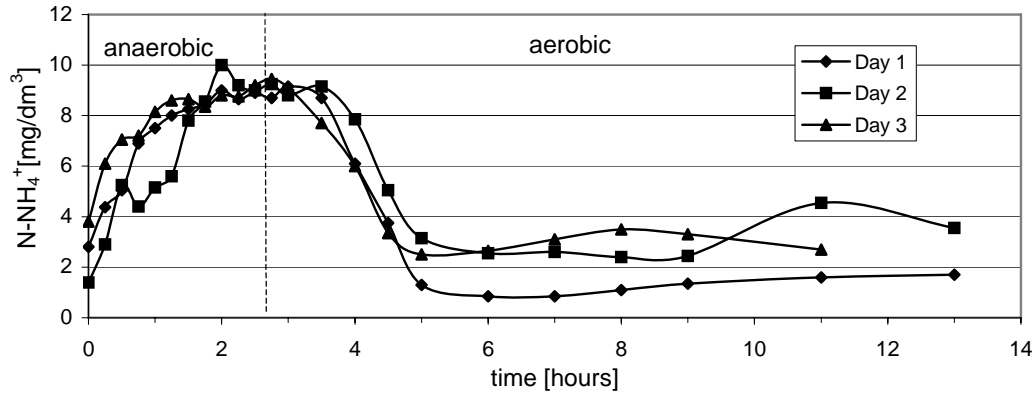


Figure 3. Changes of ammonia nitrogen concentration during treatment of wastewater containing 400 ppm of peptone.

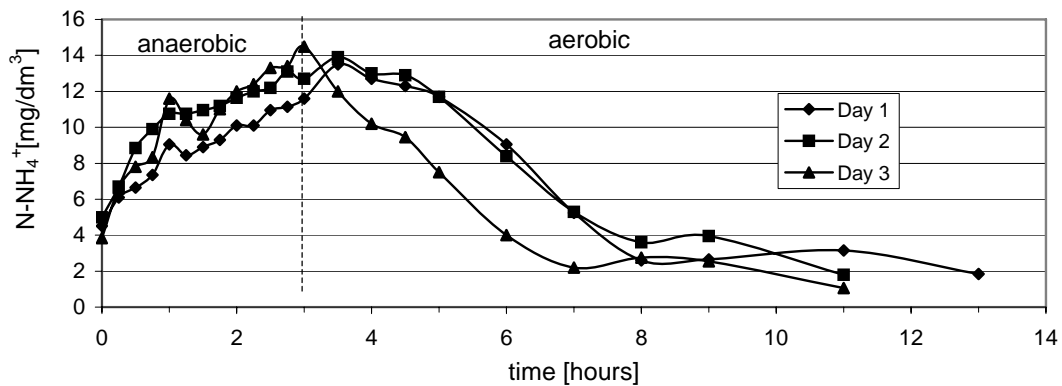


Figure 4. Changes of ammonia nitrogen concentration during treatment of wastewater containing 1200 ppm of peptone.

As it can be seen from Figs 3 and 4 the concentration of ammonia nitrogen increases during anaerobic mixing up to about 9 and 14 mg/dm³, as a maximum values. There in series with 400 ppm of peptone the concentration of ammonia nitrogen very sharply drops when aeration has been on, and it reaches the lowest value after 2 hours of aeration. In series with higher content of peptone (1200 ppm) the decrease of ammonia nitrogen is not so sharp, and the lowest value is obtained after 4-5 hours of aeration (7-8 hours of the process).

In the Figs 5 and 6 there are presented nitrates concentrations during the same processes (with 3 hours anaerobic and 10 hours of aerobic periods).

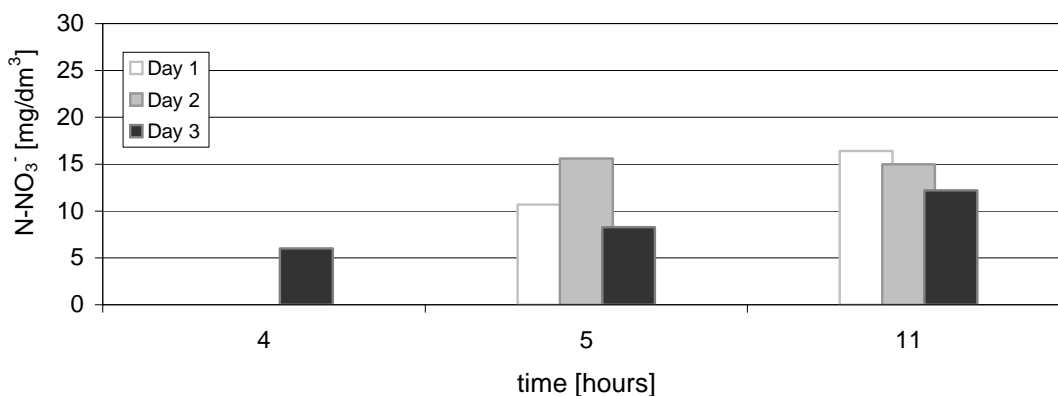


Figure 5. Changes of nitrates concentration during treatment of wastewater containing 400 ppm of peptone.

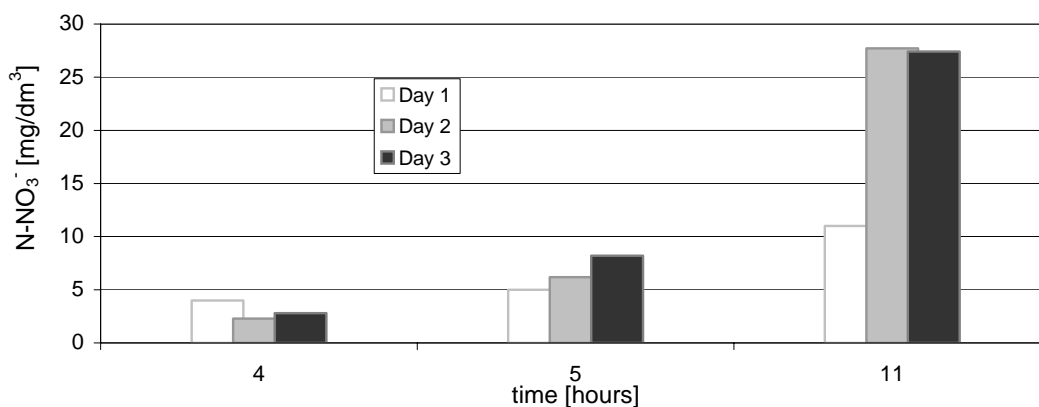


Figure 6. Changes of nitrates concentration during treatment of wastewater containing 1200 ppm of peptone.

It has been found that the increase of nitrates concentration was rather slow (figs 5,6). Besides, one can observe that at the beginning of the process the nitrates concentration increase was slower when peptone content was higher. Thus, after 4 hours of the process (1 hours of aeration) $\text{NO}_3\text{-N}$ content was about 9 – 16 mg/dm^3 and about 5-8 mg/dm^3 when peptone initial concentration equals 400 ppm and 1200 ppm, respectively. However, after 11 hours of the process (8 hours of aeration) the relation was opposite, and the $\text{NO}_3\text{-N}$ concentration was about 12-16 mg/dm^3 and 27 mg/dm^3 , for 400 and 1200 ppm of peptone, respectively.

Figs 7 and 8 present total nitrogen content at the beginning and after 3 and 11 hours of the same processes.

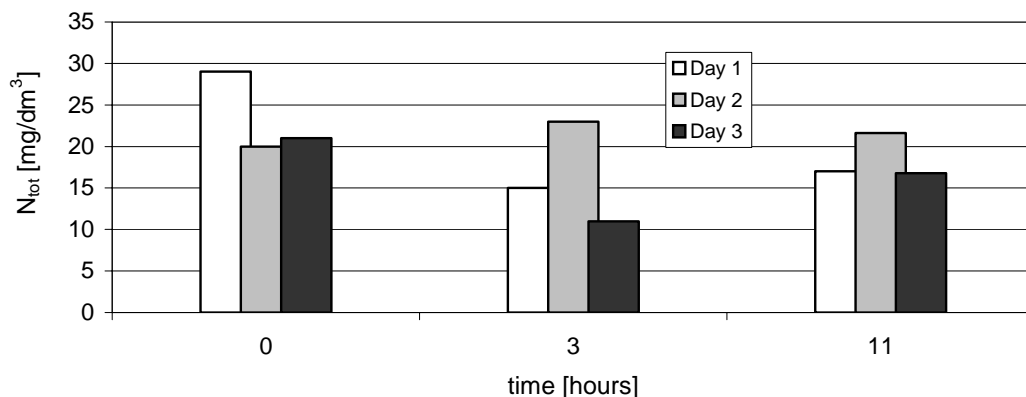


Figure 7. Changes of total nitrogen concentration during treatment of wastewater containing 400 ppm of peptone.

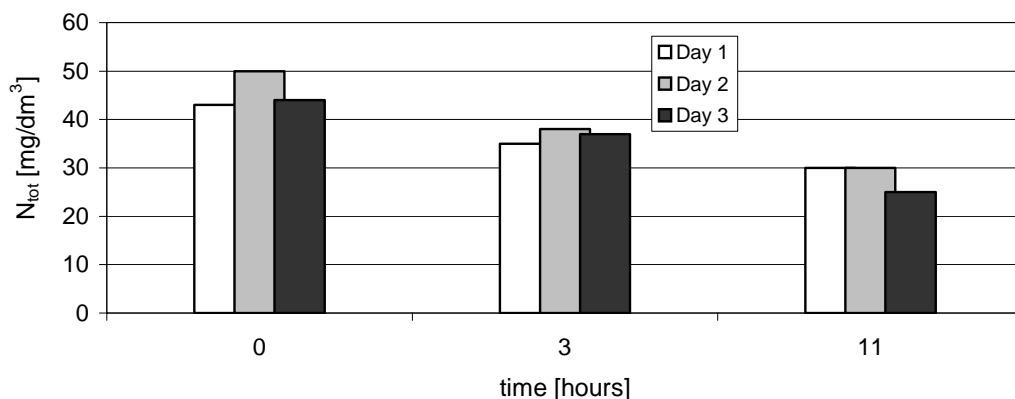


Figure 8. Changes of total nitrogen concentration during treatment of wastewater containing 1200 ppm of peptone.

As it can be seen from Figs. 7 and 8 the total nitrogen concentration in treated wastewater depends on initial peptone content and it was about 21% when peptone content was 400 mg/dm³ and 38% when it was 1200 mg/dm³. Besides, the N_{tot} reduction is a little higher in anaerobic period than in aerobic phase.

In Fig 9 there are presented nitrates and ammonia nitrogen concentration obtained in processes with different initial concentration of peptone in wastewater (400, 800, 1200, 1600 mg/dm³). The results relate to different periods of aeration phase.

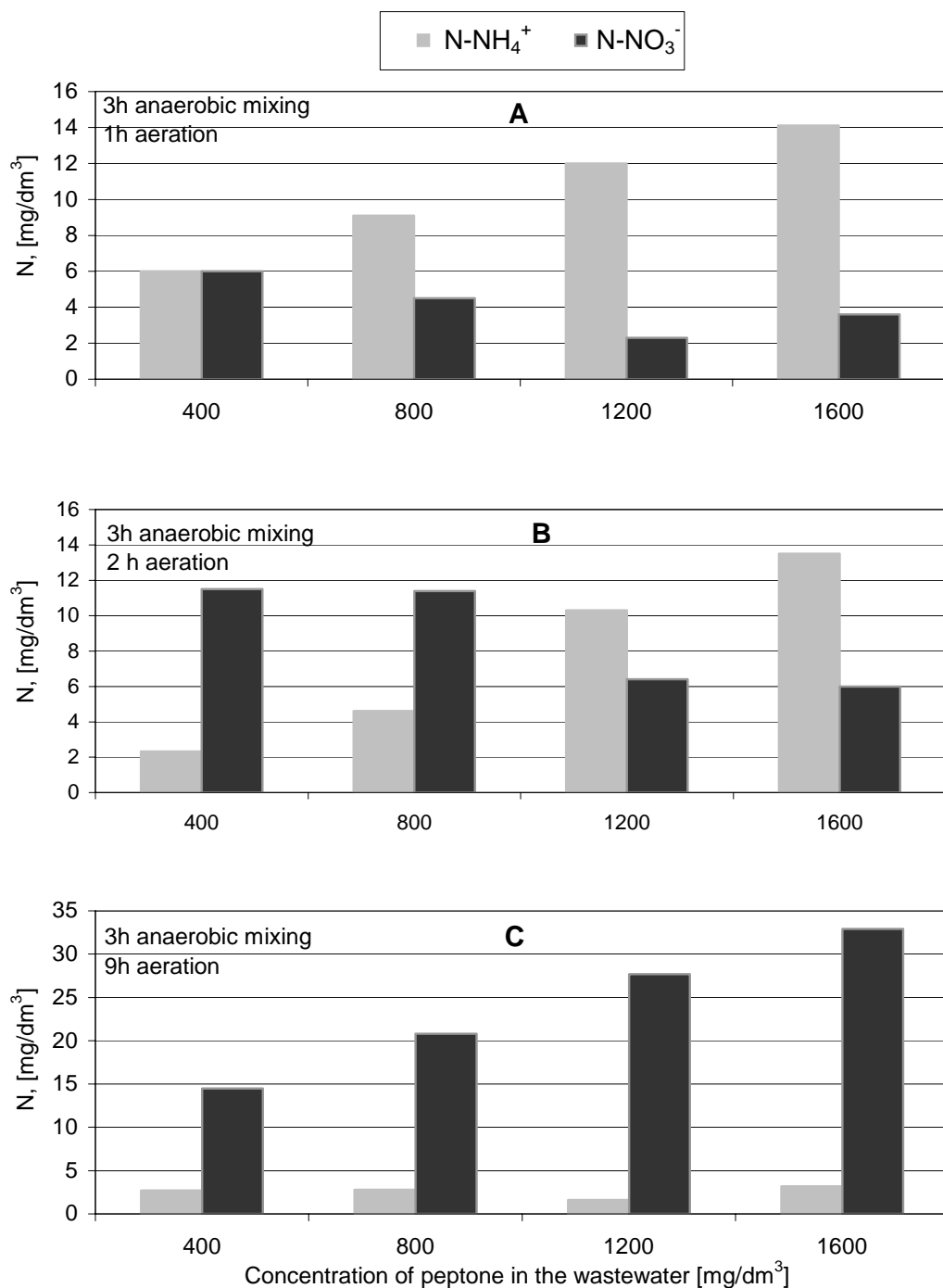


Figure 9. Changes of nitrates and ammonia nitrogen concentration during processes with different concentration of peptone in the wastewater.

As it results from Fig 9 it is evident that ammonia nitrogen is generated during aeration phase, and its concentration is the higher, the higher was initial peptone content in wastewater. After 1 hour of aeration NH₄-N concentration is 6-14 mg/dm³ depending on peptone concentration (Fig 9A). Even after 2 hours of aeration ammonia nitrogen concentration is quite high (2 –13 mg/dm³, Fig 9B), and only after 9 hours of aeration it decreases up to 2-3 mg/dm³, independently on peptone concentration (Fig 9C). Simultaneously, the concentration of nitrates observed after 1 and 2 hours

of aeration is the higher, the lower was peptone concentration in wastewater (Fig 9A, B). Only prolonged aeration gives the results which present the opposite relation, e.g. the higher was the content of peptone the higher nitrates concentration was achieved (Fig 9C). Thus, basing on the above presented results one can conclude that the rate of transformation of the nitrogenous compounds (ammonification and nitrification) depends on their content in wastewater, and that higher concentration of peptone slows down the nitrification process.

SUMMARY

The performed experiments have shown that the ammonification process proceeds not only during anaerobic period, but also during aeration, until the nitrogenous substrate is in sufficient concentration. Ammonification usually has lasted 3-4 hours if peptone content in the wastewater was 50-400 ppm. With the increase of peptone content e.g. up to 800 mg/dm³ and higher, the ammonification process has been not terminated at the end of anaerobic period, which is reflected in the fact, that total nitrogen concentration was about 2 times higher than ammonia nitrogen content, while nitrates concentration was very low (Pierzgalska K., Piasała I., et al., 2002, Hallmann E., Majewska J. et al., 2003; results not presented here). This affect negatively the rate of nitrification, and it was found that the higher was the content of peptone, the lower concentration of nitrates was stated within the first two hours of aeration phase. Prolonged aeration was required in order to improve nitrification process.

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