REMOVAL OF THE HIGH AMMONIA NITROGEN CONCENTRATION AT THE DIFFERENT SLUDGE AGES IN THE MEMBRANE BIOREACTOR

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1. INTRODUCTION

The microfiltration and ultrafiltration have become almost routine methods in biotechnologies. Some of the processes are common practices, such as recovering of the macromolecules or sterilizing liquids to remove bacteria and viruses. However, some membrane applications, which were introduced lately still require investigations (Charcosset, 2006), for example, membrane bioreactors. They offer some advantages comparing to conventional activated sludge processes: high efficiency of separation, which effect in good quality of the effluent, retention of all the biomass, which effects in facilitating of the sludge retention time (SRT) control, reliability of the unit operation, easy enhancement of the unit scale and the compactness (Rosenberger et al., 2002, Yang et al., 2006). Unfortunately, during applications of the membrane processes in wastewater treatment technologies operating and maintaining problems occurred. Usually, the COD and nitrogen removal reach the high levels, however in some cases the nitrification process was disturbed, especially with high concentration of ammonia nitrogen. Most likely, it could be connected with following aspects. Firstly, the interaction of the high ammonia and nitrite nitrogen concentration, pH and temperature can influence the nitrification process, what can lead to inhibition of nitrification (Anthonisen et al., 1976, Balmelle et al., 1996). Secondly, the effect of predators (Ghyoot et al., 2000), which are presented in usually higher numbers in membrane bioreactors, grazing on the activated sludge bacteria can have a more negative effect on the slow – growing nitrifiers than fast-growing heterotrophs, what can result in rapid decrease of nitrification performance.

In this paper, the nitrification of high ammonia nitrogen concentration at the different sludge ages (SA) (8, 12, 24 and 32 days) in membrane – assisted bioreactor (MBR) was investigated and possible influence of the protozoa and metazoa on the nitrification performance was examined.

2. MATERIAL AND METHODS

For purpose of this studies five membrane- assisted bioreactors (MBRs) were started up. The synthetic wastewater was used as a feed, with high concentration of ammonia nitrogen, with exception of MBR5, which was fed by wastewater containing ammonia nitrogen concentration characteristic for municipal wastewater.

Before the investigation phase, the activated sludge was adapted to the proper sludge age.

Kubota membrane with pore size equal to 0,4 μm and the total surface area of 0,116 m^2 was used.

The samples were grabbed from influent, effluent and mixed liquor at least three times a week. The pH was measured by portable WTW pH-meter, dissolved oxygen and temperture by portable WTW DO-meter, COD was measured by dichromate method, Kjeldahl nitrogen and ammonia nitrogen were determined by means of Kjeltec System 1026 Tecator, nitrite and nitrate nitrogen were determined colorimetrically. The number of higher organisms was detected by direct microscope observation. Additionally, according to Anthonisen's tolerance graph and equation the free ammonia and free nitrous acid concentrations were calculated.
The operation conditions are given in table 1.

Table 1. Operation conditions of the MBR1 – MBR5

Parameter	Unit	**MBR1**	**MBR2**	**MBR3**	**MBR4**	**MBR5**
		Value				
Reactor volume	L	36	36	25	25	30
Flow rate	L/d	12	12	9	9	12
Sludge age	**d**	**8**	**12**	**24**	**32**	**12**
Hydraulic retention time (HRT)	d	3	3	2,8	2,8	2,5
Sludge NH_4^+-N loading rate	**g NH_4^+-N/g MLSS d**	**0,110 – 0,191**	**0,087 – 0,152**	**0,062 – 0,142**	**0,057 – 0,087**	**0,015 – 0,037**
pH		7 - 8	7 – 8	7 – 8	7 - 8	7 – 8
Average biomass concentration	g MLSS/L	1,2	1,2	3,0	2,3	1,6

3. RESULTS AND DISCUSSION

The average concentration of the ammonia nitrogen in the influent varied from 491 mg NH_4^+ - N/L to 640 mg NH_4^+ - N/L, with exception of the reference bioreactor (MBR5), which was fed by the wastewater with ammonia nitrogen concentration below 100 mg NH_4^+ - N/L. The nitrification process in this case was full and did not meet any obstacles. The main purpose of the starting up of the reference reactor was to compare the microbial communities present in the membrane bioreactor treating high ammonia concentration and low ammonia concentration (results not shown).

All examined bioreactors showed high efficiency of the ammonia nitrogen oxidation. The average value exceeded 99% (fig. 2). However, a disturbance of the nitrification process was observed in the bioreactor at the sludge age 8 days. After 148 days of the research, the nitrite nitrogen was detected in the effluent and the value of the ammonia nitrogen oxidation dropped to 96%. In this period, the nitrification collapsed; the second stage of nitrification was incomplete. The concentration of the nitrite nitrogen peaked even to 482 mg NO_2^- - N/L. In the other bioreactors, the average concentration of the NO_2^- - N did not exceed the maximum value 1 mg/L, and the average nitrate

nitrogen concentration varied from 367 to 550 mg NO_3^- - N/L. Therefore, it could be stated, that the full nitrification of the high ammonia nitrogen concentration was observed in membrane-assisted bioreactor at the sludge age from 12 to 32 days. The reason of the nitrification disturbance in bioreactor at the sludge age 8 days could be connected with high amount of the free ammonia. Its calculated value varied from 1,5 to 4,8 mg/L (the average was equal to 2,7 mg/). Such quantity of the free ammonia caused the inhibition of the Nitrobacter – like species, hence the second stage of the nitrification in this case collapsed.

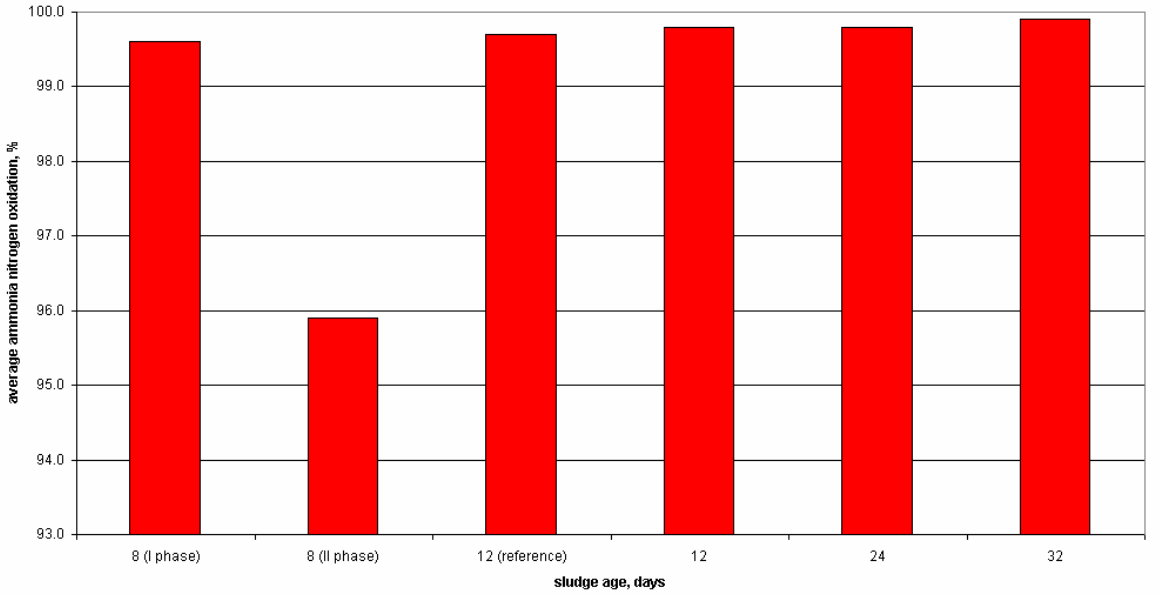

Figure 2. Ammonia nitrogen oxidation at the examined sludge ages.

In comparison to the literature data, the disturbance of nitrification in membrane-assisted bioreactor was observed at sludge age 2 days (Cicek et al., 2001) and 5 days (Fan, 2000). However, in mentioned cases, the research concerned the ammonia nitrogen concentration, typical for municipal wastewater. Moreover, in previous author's investigation, the inhibition of the nitrification of the high ammonia concentration in MBR has been observed at the sludge age of 12 days. This situation was explained by the fact, that the activated sludge was not entirely adapted, what was also confirmed by presence of the microorganisms typical for start-up period (Żabczynski et al., 2002).

It can be stated, that the reduction of the sludge age from 32 to 12 days did not cause collapsing of the nitrification in the investigated membrane-assisted bioreactors and the nitrification performance in the mentioned reactors was similar. The average ammonia oxidation was around 99 %. Only with the sludge age 8 days, the ammonia oxidation dropped to 96 % and in the effluent from the reactor the nitrite nitrogen was still present.

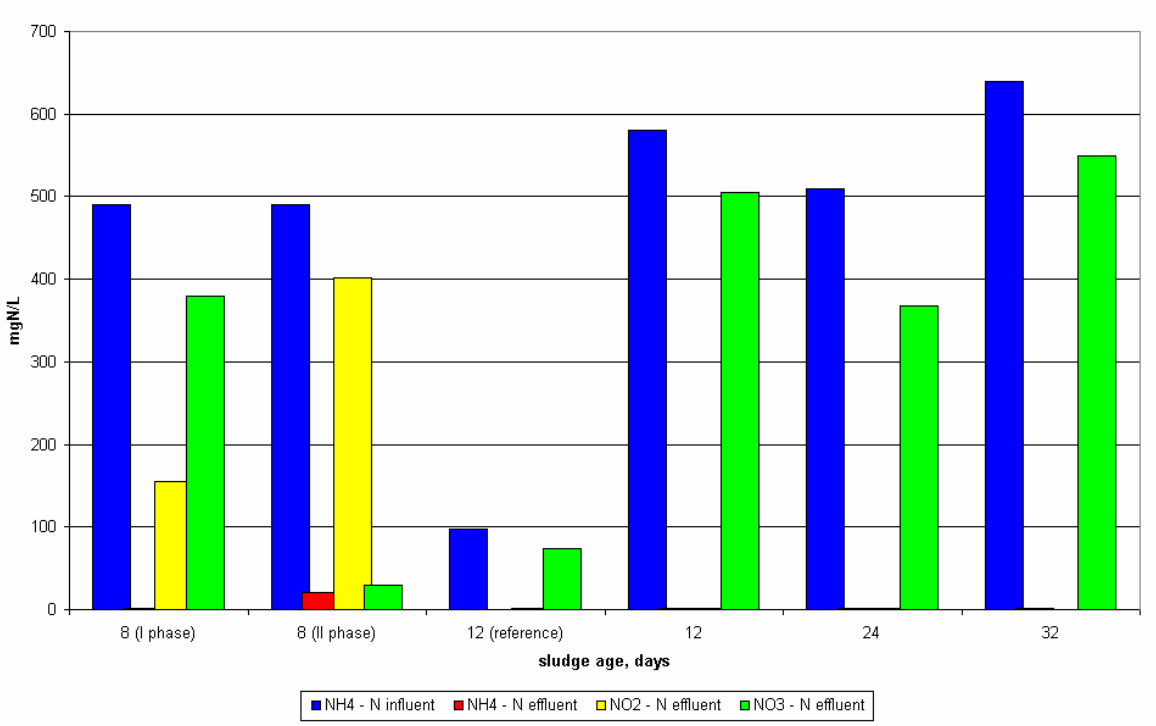

Figure 3. Nitrification performance in the membrane assisted bioreactors.

The second objective of the study was to determine the possible influence of the protozoa and metazoa on the nitrification performance. For all examined bioreactors, as the prominent organisms were observed free ciliata. Its domination and presence of rotifers might be connected with larger number of smaller flocs and dispersed bacteria in the membrane systems in comparison to conventional activated sludge processes (Zhang et al., 1997, Luxmy et al., 2000), which are the optimum prey for predators. The sessile ciliata were noticed in the all bioreactors and, surprisingly, in rather higher number. This is in contradiction of the literature data, because sessile ciliata do not tolerate the high ammonia concentration. Amoebina and Testacea organisms were also detected in all bioreactors. They are typical for long sludge ages, however, like sessile ciliata, they usually are present in the systems, which treats the wastewater with very low ammonia concentration. The last groups of organisms observed in the examined bioreactor were rotifers. They were present in all cases, but did not manage to play a main role as accompanying species.

The negative influence on bacteria population and, further, on nitrification performance has been not detected in all cases. The disturbance of nitrification at the sludge age 8 days was rather connected with the presence of the free ammonia.

CONCLUSIONS

1. It is possible to obtain full nitrification of the high ammonia nitrogen concentration wastewater in membrane-assisted bioreactor at the sludge ages from 32 to 12 days.
2. At the sludge age of 8 days the first stage of nitrification was complete, but the second stage was disturbed. It was probably caused by the presence of the free ammonia in the bioreactor, what inhibited the activity of Nitrobacter like species.

3. The negative influence of higher organisms on nitrification performance has been not observed in the range of sludge ages from 8 to 32 days.

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