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Management of process performance at low water temperatures in respect of filamentous organisms

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Abstract: The management of sludge-settling properties in Nordic conditions is of importance during the low temperature (spring) season because of the peak settler load. A survey was made in 10 Finnish waste water treatment plants(WWTP's) and the total extended filament length and DSVI in half of the plants exceeded the limits, which indicates sludge bulking(15 km/g SS and 150 ml/g respectively). The dominant organism was *Microthrix parvicella*, the abundance of which was 59.22% of total extended filament length on average. Chemicals were tested to control the filaments, and it was found that special attention has to be paid to maintaining the nitrification at low temperature. A dosage of(H_2O_2-based) oxidants controlled the growth of *Microthrix parvicella* effectively and rapidly, whereas with the use of aluminium hydroxidechloride a 2 to 5-week period was needed to decrease the filament length.

Keywords: low temperature; activated sludge; bulking; *Microthrix parvicella*; chemical control; nitrification

Introduction

When nitrogen removal is applied in the activated sludge process in Nordic conditions, a rather long sludge retention time(SRT) is required in winter and springtime, when the process temperature is 6—12℃ for several months. To ensure a stable nitrification, over 10 d SRT's are used. From the basis of a preliminary survey it was found that this leads to some problems with filamentous organisms, especially *Microthrix parvicella*. Therefore a more extensive study was started to get a more comprehensive picture of the problems.

Earlier experience has shown that, when *Microthrix parvicella* is the dominant organism and nitrification has to be maintained at low temperature, there are rather few options available to manage the filament growth, such as operation with the shortest possible SRT to allow nitrification, which means increasing the food to microorganism ratio (Dillner, 1998; Knoop, 1998). The SRT can be shortened by an additional 20%—30%, when the pH is maintained at a higher level of 7.2—7.6, to favour the growth of nitrifiers in the system (Pelkonen, 1999) for example during the most difficult period. However, in this way the problems may still remain and bulking and/or foaming can require additional control actions. Therefore, the use of chemicals has been studied to evaluate how the manipulation of the population could be managed to decrease the abundance of filaments, without negatively affecting the nitrification. Since the nitrification is very sensitive to temperature effects, the possible decrease of nitrification activity can lead to a long period with unstable nitrogen removal, which may lead to problems with the effluent requirements. On the other hand, the settlers have their highest load during the low water temperature(spring) period, which is why the control actions have a high impact on the plant performance.

1 Methods

Samples from a total of 10 activated sludge plants were analyzed for the abundance of different filamentous organisms in the sludge. The survey was conducted during springtime, when the process temperatures were 11—16℃. A more detailed survey was carried out for two plants to monitor the abundance during several months in winter and in spring. The filament length was determined in a microscope as total extended filament length, m/g SS by calculating crossings of filaments in a grid in a known amount of sample (50 μl) under cover slip by using usually 200× magnification. The organisms were identified with staining 2 procedures(Jenkins, 1993; Seviour, 1993). The relative abundances of different species were estimated by using the grid and crossings calculation.

Batch tests were made to estimate the impact of oxidants on the total extended filament length and nitrification rate. Activated sludge batches were aerated in 1-L beakers and different dosages were added in parallel test vessels. The samples were taken 3 h after dosage to determine the filament length and 2.5 h after dosage to analyze the viability of the sludge with ATP (adenosine triphosphate) measurement by using the bioluminescence method (Kahru, 1991). The same batches were also used to monitor the nitrification rate by adding NH_4-N (50 mg/L) and HCO_3 buffer one hour after the oxidant dosage. Samples were taken between 1.2 and 3 h after the oxidant dosage and filtrated. The sum of NO_2-N and NO_3-N was analyzed from the filtrated samples with FIA(flow injection analysis) to calculate the nitrification rate. The nitrification tests were repeated after 24 h. The tests were performed at room temperature (20℃). Oxidant dosages below 20 mg/L are considered a medium-level dosage, and over 20 mg/L a high dosage. Two different oxidants, A and B, were used, and H_2O_2 as the main oxidant compound in both.

2 Results and discussion

In the survey the total extended filament length was found to be rather high (Fig. 1), on average 17 km/g SS, and the variation was large 7—42 with a standard deviation of 9.92 km/g SS. In half of the plants the total extended filament length exceeded 15 km/g SS, and also in half of the plants the sludge settleability was worsened, when the DSVI was over 150 ml/g. Both these limits can be considered to indicate sludge bulking. The impact of SRT can be seen in that three of a total of four non-nitrifying plants had the three lowest abundance values. The non-nitrifying plants also exhibited the lowest proportions of *Microthrix*

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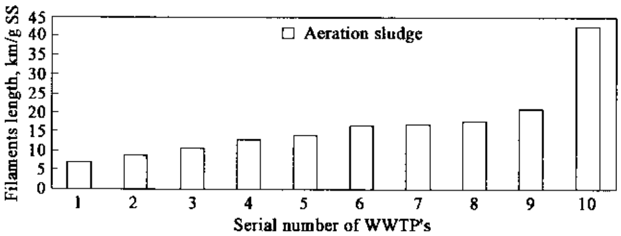

Fig. 1 The total extended filaments length in 10 Finnish WWTP's

parvicella of the total extended filament length. On average the proportion of *M. parvicella* in activated sludge was 59.2 %. Other species that were regularly found were Type0675, Type0041 and *H. hydrossis* in the nitrogen removal processes. Type021N and Type0961 were both dominant species in only one plant (both non-nitrifying). Detailed data are shown in Table 1. The results showed that efforts are needed to control the excess growth of *M. parvicella*. Based on the results of other surveys (Wanner, 2000; Eikelboom, 1998) *Microthrix parvicella* seems to be by far the most important filament. The development of filaments in the sludge is shown in Fig. 2, which indicates the most difficult situation during February-April. The period from October to May is operated with higher SRT due to the lower temperature.

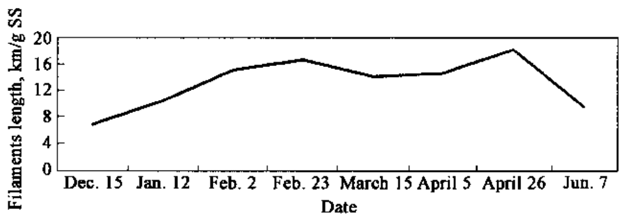

Fig. 2 The development of filaments in the activated sludge in a predenitrification plant during the cold period (average values of parallel lines)

Table 1 Types of filamentous bacteria in different stages

Filamentous bacteria	Influent liquor		Pre-settle liquor		Bulking aeration sludge	
	Occurrence	Dominance, %	Occurrence	Dominance, %	Occurrence	Dominance, %
M. Parvicella	8	20.91	7	28.92	8	59.22
H. hydrosis	1	0.45	4	1.35	4	1.20
Beggiatoa	1	0.45			3	0.96
Type0675	2	0.48	4	3.87	6	6.74
Type0041	1	0.21	1	0.14	6	5.72
Norcardia spp.					1	0.04
N. Limicola Ⅰ-Ⅲ	2	0.50	2	0.80	2	0.07
Thiothrix Ⅰ-Ⅲ	1	0.13	1	0.11	3	0.79
N. Limicola Ⅱ					1	1.43
Type0411	3	2.00	2	1.12		
Type1863	10	71.35	8	53.06	1	0.01
Type021N	1	1.28	1	1.52	3	13.27
Type0961	1	2.23	3	9.13	1	9.23
Type1701					1	1.01
Type0803					1	0.32
Number of plants	10		9		9	
M. Parvicella	4	39.12	3	68.56		
H. hydrosis	2	2.06	3	4.63		
Beggiatoa	1	0.05				
Type0675	2	5.22	3	11.12		
Type0041	1	4.59	3	12.51		
Norcardia spp.	1	0.25				
N. Limicola Ⅰ-Ⅲ	1	13.64				
Thiothrix Ⅰ-Ⅲ						
N. Limicola Ⅱ						
Type0411						
Type1863						
Type021N	1	20.00	1	3.19		
Type0961	2	15.07				
Type1701						
Type0803						
Number of plants	5		3			

The results of laboratory tests to control the filament population are shown in Fig. 3. A medium-level dosage decreased the filament length by approximately 25% with both oxidants, and a high dosage 33%—37%. The impact of oxidants on the amount of active biomass was negligible except for oxidant B, which clearly had a negative effect at a high feed level by reducing ATP-concentration 71% (Fig. 4). The impact of the high dosage of both oxidants on the nitrification rate was strongly inhibitive, whereas the middle dosage inhibited 25%—35% the nitrification rate in the first day of the nitrification tests(1—3 h after the addition of oxidant). The inhibition was 10%—15%—units higher than in the tests made the next day, the difference of which can be regarded rather small. This also indicates some recovery of nitrification on a longer time scale. These results suggested a need for careful optimization of the dosage in order to maintain the nitrification. A maximum of approximately 10%—20% inhibition can be accepted depending on the circumstances, and especially temperature.

According to the result of laboratory test, a full scale test was engaged in a WWTP of which the schematic layouts of water lines are given in Fig. 5. The impact of oxidants on the filaments is rapid, and based on the full-scale test its impact can be seen for approximately one month, after which a high filament length value was achieved again (Fig. 6). The immediate decrease in the filament length was 35%—40%, which was in the same range as in the batch tests with the highest dosage. The decrease of filaments could be found in two days. No adverse effect on nitrification was found during this period, which was due to the optimized oxidant feed (medium level dosage). The process temperature was around 12℃. This successful full-scale experiment shows that oxidants can effectively be used to control filaments in *Microthrix parvicella*-dominant sludge. The results suggested, however,

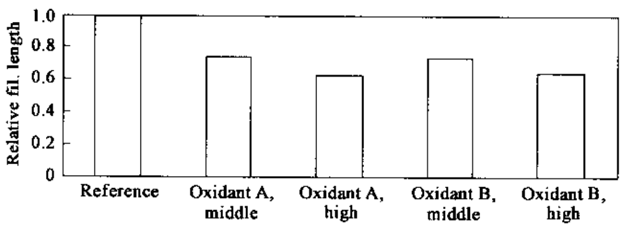

Fig.3 Impact of oxidant addition on filament length in batch tests

that frequent control actions are needed.

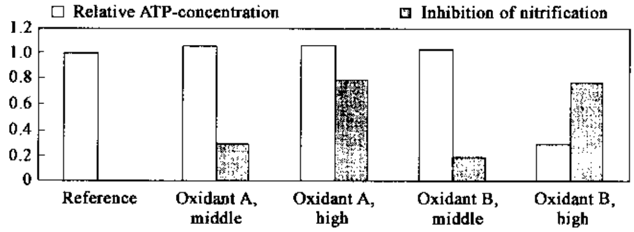

Fig.4 Impact of oxidant addition on active biomass (measured as ATP) and on inhibition of nitrification in batch tests (medium and high dosage levels)

In another full-scale experiment, aluminium hydroxidechloride was used to control filaments in sludge, in which *Microthrix parvicella* was dominant. The chemical was added to return sludge as approximately 30 mg/L influent flow for a 6-week period from the start including one week without chemical feed. In this case, the DSVI and filament length decreased considerably and the filament length was 25%—40% lower and DSVI 40%—50% lower than in the reference (closest parallel) line 5—6 weeks from the start. It took, however, 2—3 weeks before some differences could be noticed between these two lines. Nitrification was maintained during this period. This result indicates that aluminium salt can effectively be used to control *M. parvicella*. This is opposite to the result of Knapp *et al*. (Knapp, 2001), who found that the total filament abundance (and SVI) decreased, but the abundance of *M. parvicella* increased considerably during the feed period.

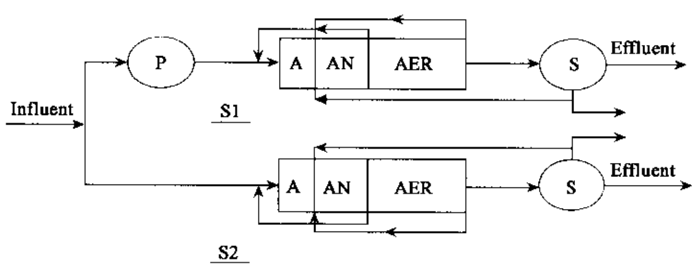

Fig.5 The schematic layouts of water lines

P—presettle basin; A—anaerobic basin; AN—anoxic basin; AER—aerobic basin; S—sediment basin

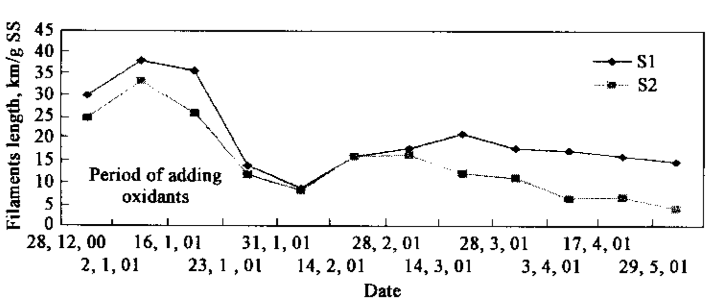

Fig.6 Result of a full-scale test to manipulate the sludge population with oxidant A using a medium-level dosage. Filament length shown in two process units (S1 and S2, connected in series)

3 Conclusions

Microthrix parvicella seems to be the most common filament in Finnish WWTP's, especially in nitrogen removal (long SRT) plants during the spring (11—16 ℃) season, and its control is of importance to manage the settler load.

Particular attention has to be paid to maintaining the nitrification, when the population manipulation is applied by chemical means at low temperature.

M. parvicella was effectively and rapidly controlled with H_2O_2-based oxidants in laboratory and full-scale experiments, and a stable nitrification could be maintained when an optimized dosage was used.

M. *parvicella*-dominant sludge could be manipulated with an addition of aluminium hydroxidechloride, but a period of 2—5 weeks was needed to achieve a significant reduction of filaments.

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