The settling behaviour of an activated sludge with simultaneous nitrification and dentrification

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Abstract. Sedimentation properties of activated sludge from the bioreactor with simultaneous nitrification and denitrification are studied in this paper. MLSS was about 2 g/l in the bioreactor, F/M ratio less than 0.4 gCOD/(gMLSSd), average dissolved oxygen concentrations were 0.35–0.75 mg/l. Latin square design method was used in this experiment. The results show that biomass at SND is characterized by high settling velocity. Sludge settling velocity function for this biomass was obtained.

1 Introduction

Simultaneous nitrification and denitrification is a very complicated process. It involves physical and microbiological interactions of components of activated sludge [1, 2]. According to preliminary studies, a stable process of simultaneous nitrification and denitrification is preceded by an adaptation of the biomass to operating conditions [3]. Simultaneous nitrification and denitrification occurs at low concentrations of dissolved oxygen and is often laid in the technology scheme with the planned low organic loads and low C/N ratio [4]. Thus, nitrifying inoculating activated sludge is under stress in the bioreactor (due to lack of oxygen and organic matter). In most cases, these conditions cause the filamentous bulking of an activated sludge and further technological failure of the entire biological system.

To estimate the potential of the technology of simultaneous nitrification and denitrification it is necessary to study the state of the biomass in the period of adaptation to the operating conditions [5, 6]. It has been shown previously a definite change of sludge volume index and species composition of the adapted activated sludge [7, 8, 9]. New research has made it possible to assess comprehensively the activity of the biomass at start of the process and changing its sedimentation properties.

The study of the process of simultaneous nitrification and denitrification is carried out in the investigation of a fundamental possibility of increasing an energy efficiency of biological wastewater treatment in oxidation ditches. Oxidation ditches have a number of features that should be considered when carrying out the construction of new and reconstruction of existing wastewater treatment plants [10, 11]. These features also affect the structure of the activated sludge and its sedimentation properties.

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2 Methodology and research

Research was carried out in the laboratory of Moscow State University of Civil Engineering (NRU MSUCE). Lab-scale stands have been designed for the experiment. They were model-bioreactors with different hydraulic characteristics. Lab-scale stands allow simulating the operating conditions of the process of simultaneous nitrification and denitrification in a view of the characteristic features of oxidation ditches [12, 13].

Latin square design method was used in the second stage of the research [14]. Average dissolved oxygen concentration (DO), hydraulic retention time (HRT) and organic load (F/M ratio) were the factors. Each of them had three different levels. The design table is shown in Table 1.

Table 1. Design of the experiment

Item	Factors		
	HRT, h	DO, mg/l	F/M ratio, gCOD/(gMLSSd)
1	6.5	0.35	0.40
2	6.5	0.5	0.25
3	6.5	0.75	0.10
4	7	0.35	0.25
5	7	0.5	0.10
6	7	0.75	0.40
7	7.5	0.35	0.1
8	7.5	0.5	0.40
9	7.5	0.75	0.25

The study was carried out on a model wastewater, similar in composition to the wastewater of the Moscow region. The experiment involved a low organic content in the substrate and a low value of C/N ratio. MLSS in the bioreactor was kept constant for the equivalence series of settling tests. Therefore, the different levels of the factors were achieved by varying the flow rate and composition of the influent.

Complex settling tests were carried out in a variety of operating conditions. During the course of each stage of the experiment sludge, volume index was measured regularly. Changes in the sludge volume index talked about the biomass response to the certain conditions. After receiving information about changing sludge volume index (compared to the previous value) by more than 15%, additional tests were performed. These include the stirred specific volume index (the SSVI3.5 is determined by performing an SVI test at a specific concentration of 3.5 g/L while the sludge is gently stirred at a speed of about 1 rpm), the batch settling curve with hindered settling velocity definition (Vhs), Vhs-X relation, Dispersed Suspended Solids/Flocculated Suspended Solids (DSS/FSS) tests [15].

Dispersed Suspended Solids (DSS) are defined as the concentration of SS remaining in the supernatant after 30 min of settling. Thus, the DSS test determines the ability of activated sludge to the flocculation at the moment and at the place of sampling.

Flocculated Suspended Solids (FSS) are defined as the concentration of SS remaining in the supernatant after 30 min of gently stirring at 50 rpm and then 30 min of settling .FSS test shows the bioflocculation potential of activated sludge by flocculation sample under ideal conditions before settling.

Fig. 1. The unit for Flocculated Suspended Solids test.

Each test of the experiment (items from design of the experiment table) lasted a month. In total, this phase of the research took 5 months.

3 Results

By regular measurements of sludge volume index, timelines for each of the experiments were obtained. The graphs show the crisis points that correspond to the sludge bulking.

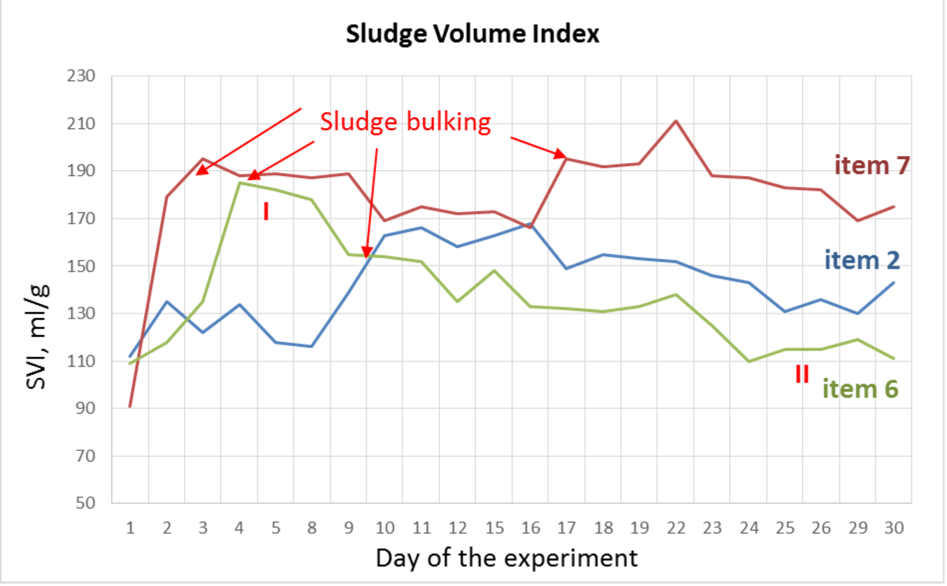

Fig. 2. Changing the sludge volume index in time (for Items 1, 6 and 7 from Table 1).

As can be seen, Item 6 (HRT = 7 h, DO = 7.5 mg/l, F/M ratio = 0.4 gCOD/(gMLSSd)) is the most optimal from the point of view of sedimentation properties. Two points were considered, point I (filamentous bulking zone) and point II (stability zone), for Item 6.

Point I. Day 5 of the experiment. X_{TSS} = 1.895 g/l, SVI = 182 ml/g. $SVI_{3.5}$ = 174 ml/g.

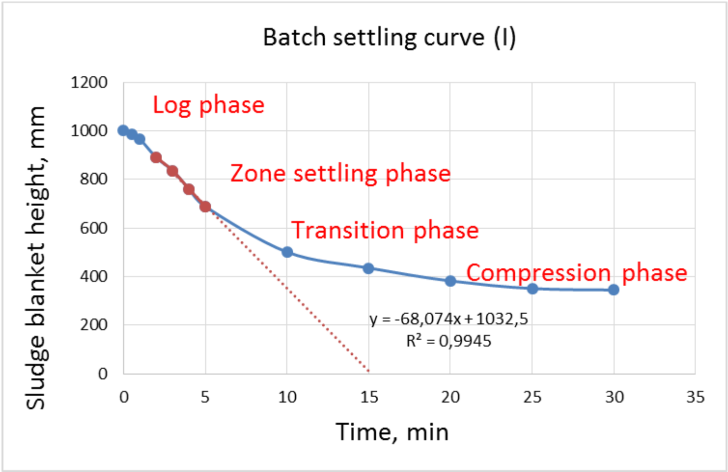

Fig. 3. Batch settling curve for point I.

The hindered settling velocity V_{hs} = 4.08 m/h. As seen, the filamentous bulking was not critical; the hindered settling velocity remains high. But anyway, this regime cannot be called the operating mode.

For the point I capacity assessment was carried out. The value X_{TSS}-ex (ESS) was measured. DSS/FSS tests were made.

Table 2. Measured DSS, FSS and ESS values for point I.

DSS, mg/l	FSS, mg/l	ESS, mg/l
22.1	21.5	23.6

These results indicate poor flocculation; the problem is most likely of a biological nature.

Point II. Day 26 of the experiment. X_{TSS} = 1.936 g/l, SVI = 115 ml/g. $SVI_{3.5}$ = 119 ml/g.

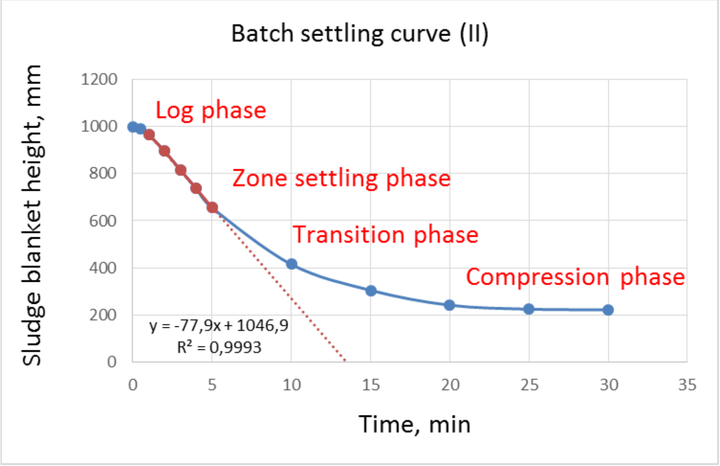

Fig. 4. Batch settling curve for point II.

The hindered settling velocity V_{hs} = 4.67 m/h. After AS stabilization has occurred V_{hs} increased. Since in this case the biomass was in the operating mode, a function $V_{hs}(X)$ has been obtained. Batch settling curves were constructed at different initial concentrations. The biomass diluted or concentrated to the desired values of X_{TSS}.

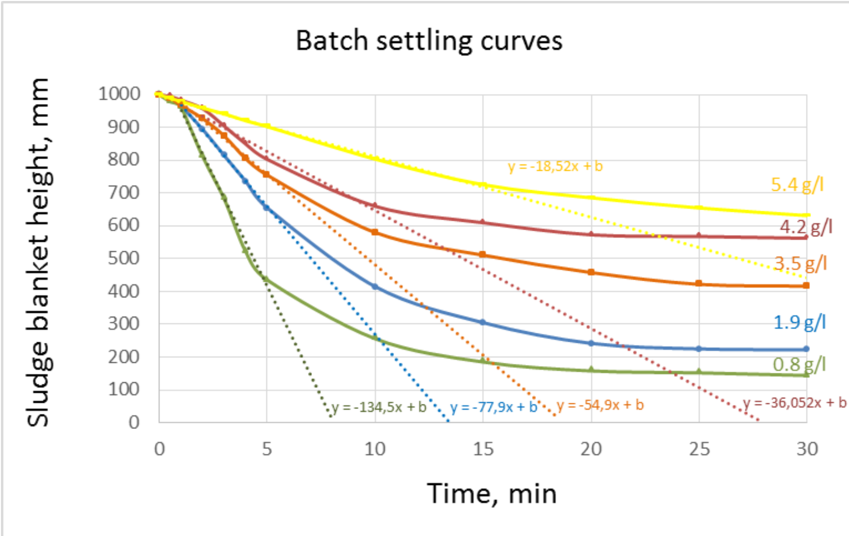

Fig. 5. Batch settling curves at different initial concentrations.

V_{hs} at different initial concentrations are shown in Table 3.

Table 3. Measured V_{hs} at different initial concentrations.

X_{TSSi}, g/l	V_{hs}, m/h
0.8	8.07
1.9	4.67
3.5	3.29
4.2	2.16
5.4	1.11

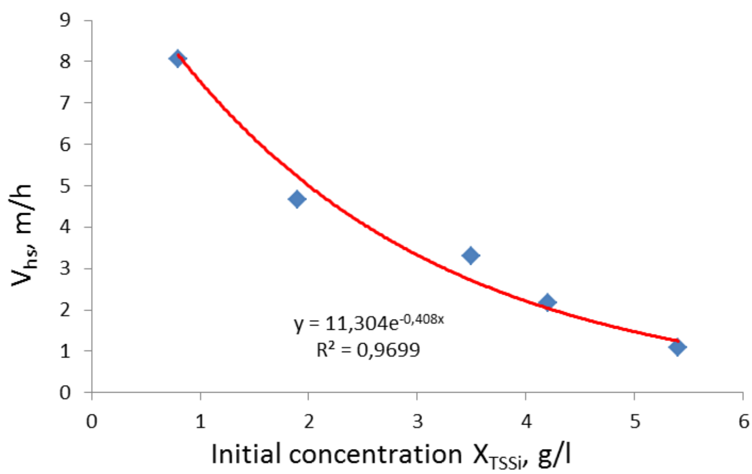

Fig. 6. Sludge settling velocity as a function $V_{hs}(X)$.

Sludge settling velocity function (1):

$$V_{hs}(X) = V_0 \cdot e^{-rv \cdot Xtssi} \quad (1)$$

where V_0 – maximum settling velocity, r_v – model parameter, X_{tssi} – solids concentration. For this biomass V_0 = 11.304 m/h, r_v = 0.408. The function has the form (2):

$$V_{hs}(X) = 11.304 \cdot e^{-0.408 \cdot Xtssi} \quad (2)$$

These data is consistent with the generally accepted estimated values.

For the point II the value X_{TSS}-ex (ESS) was measured and DSS/FSS tests were made.

Table 4. Measured DSS, FSS and ESS values for point II.

DSS, mg/l	FSS, mg/l	ESS, mg/l
4.9	4.8	5.6

ESS concentrations are low. There is no problem with a bioflocculation and a hydraulic regime in the bioreactor and the secondary settling tank.

4 Conclusions

Sludge volume index was within acceptable limits at a concentration of dissolved oxygen of at least 0.5 mg/l and F/M ratio more than 0.25 gCOD/(gMLSSd). The maximum SVI was 182 ml/g at these factors and the stable form SVI was 115 ml/g (with $SVI_{3.5}$ = 119 ml/g). Sludge settling velocity was relatively high throughout the experiment (V_{hs} = 3.29 m/h with X_{tssi} = 3.5 g/l). This may be related to high density of activated sludge flocs at SND. And this can compensate for initial filamentous bulking of activated sludge.

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References

1. N. Lesage, M. Spe´randio, C. Lafforgue, A. Cockx, Trans IChemE, Part A, **81**, 1259 (2003)
1. G. Zhu, Y. Peng, S. Wu, S. Wang, S. Xu, Journal of Environmental Sciences, **19**, 1043-1048 (2007)
2. X. Zhou, Y. Han, X. Guo, Chemical Engineering Journal, **259,** 715-723 (2015)
3. I. Gulshin, A. Kuzina, IJAER, **10**, **21**, 42618–42623 (2015)
4. E. Gogina, I. Gulshin, Pr. Eng., **117**, 107–113 (2015)
5. N. Makisha, V. Scherbakov, A. Smirnov, E. Scherbina, IJAER, **10**, **24**, 44347–44349 (2015)
6. V. Scherbakov, E. Gogina, T. Schukina, N. Kuznetsova, N. Makisha, E. Poupyrev, IJAER. **10**, **21**, 44353–44356 (2015)
7. N. Makisha, E. Gogina, AMM, **361–363**, 632–635 (2013)
8. V.N. Varapaev, A.V. Doroshenko, I.Y. Lantsova, Pr. Eng., **153**, 816-823 (2016)
9. O.A. Ruzhitskaya, E.S. Gogina, AMR, **919–921**, 2153–2156 (2014)
10. E. Gogina, N. Makisha, AMM, **587–589**, 636–639 (2014)

11. N. Makisha, Y. Voronov, E. Poupyrev, V. Volshanik, IJAER, **10**, **21**, 41919–41922 (2015)
12. N. Makisha, Pr. Eng., **165**, 1087-1091 (2016)
13. E. Gogina, I. Gulshin, Pr. Eng., **153**, 189-194 (2016)
14. P. Zhang, Z. Qi, Front. Sci. Engin. China, **1**, **1**, 49-52 (2007)
15. M.C. van Loosdrecht, P.H. Nielsen, C.M. Lopez-Vazquez, D. Brdjanovic.. *Experimental Methods in Wastewater Treatment*, IWA Publishing (2016)