Influence of the Sludge Age on Phosphorus Concentration

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Abstract
During treatment in wastewater treatment plant (WWTP), phosphorus is divided into two streams which can be used for phosphorus recovery – an excess sludge and a WWTP effluent. For our project the WWTP effluent was chosen. For that reason we were searching how to get as less as possible phosphorus in the excess sludge.
On the lab scales systems with activated sludge of 5, 15 and 30 days age were tested.

According to the chemical and microscope results it can be said that as less as possible phosphorus in activated sludge can be reached using systems with activated sludge of high age. For that reason sludge age of 30 days is more suitable for phosphorus recovery from a WWTP effluent.

Keywords
Nutrient recovery; phosphorus recovery; sludge age

INTRODUCTION

Phosphorus is a nutrient important for life. Huge amounts of phosphorus are used in fertilizers. Its demand is increasing because of increasing population in the world. However, its sources in nature are decreasing. Therefore, new sources have to be found. One of these alternatives is wastewater. During treatment in wastewater treatment plant (WWTP), phosphorus is divided into two streams which can be used for phosphorus recovery – an excess sludge and a WWTP effluent.

For our project the WWTP effluent was chosen. For that reason we were searching how to get as much as possible phosphorus in the excess sludge.

MATERIALS AND METHODS

On the lab scales systems with activated sludge of 5, 15 and 30 days age were tested. The SBR models of volume of 9 l were aerated and mixed (see **Fig. 1**). The reactors were equipped with fine bubble aeration pneumatic adequate oxygenation capacity to maintain optimal oxic conditions during the entire operation. To ensure the homogeneity of the mixture, the reactors were equipped with a mechanical stirrer with adjustable speed. Synthetic wastewater was used as the influent. WWTP where no phosphorus removal was implemented was chosen for inoculation of our reactors.

Figure 1. Lab scales used for testing influence of sludge age on phosphorus concentration in the effluent

The individual reactors were operated with different sludge age: R1 - 5 days, R2 - 15 days, and R3 - 30 days. The pH value was after dosing synthetic wastewater, which was carried out every 24 hours, always adjusted to a range between 6.0 and 8.5. Periodically oxygen concentration, suspended solids and sludge index were also measured.

Water samples were taken before and after synthetic wastewater dosing. Concentrations of $P\text{-}PO_4^{3-}$, P_{total} and COD_{Cr} were analyzed in all the samples. Concentration of N_{amon}, $N\text{-}NO_2^-$ and $N\text{-}NO_3^-$ was analyzed in chosen samples as a control of nitrification. P_{total} concentration was analyzed also in dried samples of activated sludge. The whole experiment was evaluated according to the phosphorus concentration in the activated sludge.

RESULTS AND DISCUSSION

Between 33rd and 80th day of the operation of the reactors sludge concentration slowed growth. From the 80th day until the end of the model operation sludge concentration stagnated and fluctuated around levels for R1 from 1.5 to 1.6 g/l, R2 from 3.5 to 3.6 g/l, and R3 4.3 to 4.4 g/l.

Sludge during the entire test showed a gradual improvement in the sedimentation properties, the only exception was reactor R1 in which occurred at the end of the experiment to a gradual degradation of activated sludge flocs.

The measured values show that to ensure the smallest amount of phosphorus in the stream of excess sludge is advisable to use systems with high sludge age. According to our results a system with a 30-day sludge age, in comparison with 5-day, cause 40% reduction of phosphorus concentration in the sludge stream, which leads to increase the concentration of phosphorus in the effluent and enables to increase the percentage obtained and usable phosphorus. This finding correlates very closely with literary knowledge.

Table 1. Phosphorus amount in excess sludge on 39th day of the experiment

Parameter	**Unit**	**R1**	**R2**	**R3**
Sludge age	day	5	15	30
Sludge concentration	g/l	1.2	2.9	4.1
P_{total} in sludge	%	1.92	1.84	2.01
Excess sludge volume	ml/day	1.8	0.6	0.3
P_{total} in excess sludge	**g/week**	**0.249**	**0.192**	**0.148**

Regular monitoring of the operation of reactors R1 – R3 was also carried out for evaluating microscopic image of the activated sludge and its sedimentation properties in relation to different sludge age. Three samples of the activated sludge were taken and analyzed: inoculum from WWTP Dublovice and samples of R1 – R3 on 34th and 84th day of operation. The reactor R1 having the lowest sludge age (5 days) showed the least favourable microscopic image - flakes were current in comparison with other samples of larger sizes and the sludge contained a lower proportion of small, hardly separable fragments biomass, however the structure of the flakes were inadequate (diffused) and the total rate of filamentous microorganisms reached the highest grade. Reactors R2 and R3 were comparable with one another while microscopically activated sludge showed striking differences, however, in terms of overall character flakes (especially small fragments of biomass) and the occurrence of filamentous microorganisms was evaluated as favourable microscopic picture of the reactor R3 (see **Fig. 2**). In either model reactors prevent development of microorganisms associated with increased biological removal of phosphorus. Assuming that at a higher sludge age required phosphorus purposes for the synthesis are lower and relative to the previous point, it was for the purpose of follow-up experiments recommended to use sludge age of approximately 25 days, which corresponds to the results of chemical analysis.

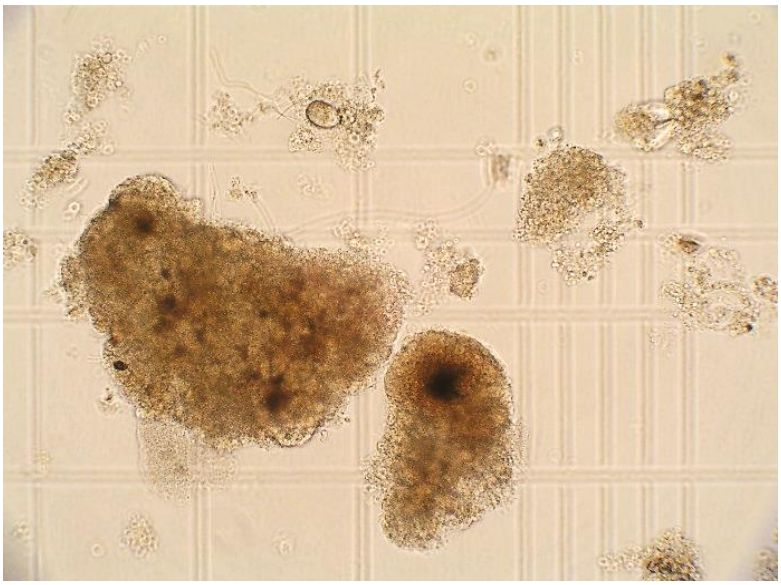

Figure 2. Characteristics of flakes - R3, day 84 (native preparation 125x)

For sample assessment of the activated sludge also fluorescence *in situ* hybridization (FISH) was used. In total three samples of activated sludge were collected and analyzed: Dublovice inoculum from wastewater treatment plant and specimens from R1 - R3 on 34th and 83rd day of operation. The inoculum used for laboratory models contained by the results of FISH analysis of nitrifying bacteria two stages (AOB and NOB). The reactor R1 was on 83rd day of the decrease AOB and NOB over the previous sample. In the reactors R2 and R3 significant changes between samples were observed. We can say that in these reactors nitrification bacteria prospered.

CONCLUSION

According to the results it can be said that as less as possible phosphorus in activated sludge can be reached using systems with activated sludge of high age. For that reason sludge age of 30 days is more suitable for phosphorus recovery from a WWTP effluent.

ACKNOWLOGEMENTS

Financial support from specific university research (MSMT No 20-SVV/2016) and from the Technology Agency of the Czech Republic (TA04020217).

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