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ORGANICS (COD) REMOVAL IN DEPENDENCE ON LOADING OF VOLATILE FATTY ACIDS (VFA)

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Abstract: The aim of the study was to estimate the influence of volatile fatty acids (VFA) loading on the contribution of the biomass growth, cell respiration, denitrification and poly-β-hydroxybutyrate (PHB) accumulation involved in COD removal by activated sludge. Kinetics of PHB production, PHB and COD consumption were determined. Experimental series were carried out in sequencing batch reactor. The amount of air entering SBR was maintained at the stable set-point of 2 mg O_2/L, oxygen depletion phase occurred in initial hours of the reaction time. SBR was fed with the mixture of municipal wastewater and supernatant from the digesters. Feast period of the external organic substrate availability (f_1) and famine period of little organics availability (f_2) were determined. With VFA loading (r_{VFA}) increase from 0.029 to 0.052 g VFA/g VSS·d in the feast period, the effectiveness of COD removal depended on the use of organics for denitrification and internal PHB storage. PHB content in activated sludge increased from 0.2 to 0.35 C_{mol}/C_{mol}. In f_1 biomass growth and cell respiration in COD removal decreased from 21 to 14% and from 12 to 5%, respectively. In the famine period the remaining organics were removed due to biomass growth and cell respiration, denitrification and internal PHB storage was not observed.

INTRODUCTION

The study of Barnard *et al.* [2] showed that organic compounds removal by activated sludge under aerobic conditions is the result of cell respiration, biomass growth and poly-β-hydroxybutyrate accumulation. Gujer and Henze [9] reported that under steady-state conditions the main processes in activated sludge are oxidation and biomass synthesis. These two processes assure 70% removal of organic carbon compounds in soluble and particular form presented in wastewater.

Under transient conditions biomass growth becomes unbalanced and intracellular storage of organic polymers is an important adaptive mechanism to the specific conditions. Transient conditions are typical for the configuration where a substrate gradient occurs or where biomass experiences alternately high and low substrate concentrations. Under unsteady conditions in the presence of easily accessible and biodegradable organics, microorganisms able to organic substrates accumulation are promoted among others and dominated in activated sludge [18]. The biomass adapts to new conditions by increasing the growth rate and by rapid storage of the available substrate in the form of poly-β-hydroxybutyrate. Reserved substances can be used as the energy source essential for biomass synthesis and denitrification. Most of heterotrophic microorganisms are able to perform oxygen and nitrogen respiration, is lower in comparison with utilising another carbon source, i.e. methanol or acetate. However, intracellularly accumulated poly-β-hydroxybutyrate can be successfully used in denitrification under aerobic conditions [3]. Denitrification accounted for the removal of a significant fraction of the influent COD (between 15 and 20%) in the enhanced culture continuous flow system [1].

Types of carbon source and carbon to nitrogen ratio (COD/N ratio) affect the biological reduction of nitrate and nitrite. Kulikowska and Dudek [10] examined sugar-industry waste (molasses) as an organic carbon source for denitrification to determine process efficiency and kinetics. Denitrification rate at COD/N ratio of 6.0 and 5.0 was higher in the reactor with hydrolyzed molasses in comparison with SBR, where untreated molasses was a carbon source. Denitrification efficiency above 98%, irrespective of organic carbon source (untreated molasses, hydrolyzed molasses) was obtained at COD/N ratio. Several investigators have reported that short-chain volatile fatty acids (VFAs) produced through fermentation of primary sludge can be effective as a carbon source for denitrification. Organic short-chained acids as acetate or butyrate are generated in methanogenic fermentation of sewage sludge. According to Lim *et al.* [11] acetic acid is the main product of acidogenic phase of anaerobic digestion of the primary and the excess sludge and it comprises about 90% of volatile fatty acids. Oleszkiewicz and Barnard [13] reported that limitation of fermentation on the acidogenic step, and maintaining the redox potential above -350 mV are the conditions that promote the high volatile fatty acids concentration in supernatant. The sludge digester supernatant coming from the anaerobic fermentation step is usually fed into the wastewater treatment plant together with wastewater influent in order to increase availability of easily biodegradable organic compounds and promote nitrogen and phosphorus removal. In the supernatant ammonium, the nitrogen concentration ranges from 268 to 1000 g $N\text{-}NH_4/m^3$. High ammonium concentration in anaerobic sludge digester supernatant influences COD/N ratio in wastewater. Therefore, the accessibility of easily biodegradable organic compounds for intracellular storage is changing.

In this work, the influence of volatile fatty acids loading on the processes performance and kinetics of organic substrate removal was investigated. This is of significant importance on modeling and design of activated sludge treatment plant. The biological removal of organic matter from municipal and industrial wastewater can be accomplished by various process configurations. One of the systems that has demonstrated a good potential in biological processes is sequencing batch reactor (SBR) that offers various advantages, including minimal space requirements, easiness of management and possibility of modification during trial phases through on-line control of the treatment strategy. It allowed the development of techniques and operation strategies able to optimize the treatment plants both in terms of removal efficiencies and costs.

METHODS

Experimental design

The experiment was carried out in a sequencing batch reactor BIOFLO 3000 type, with a working volume of 5 L. The BIOFLO 3000 included a temperature probe, stirring control, pH and DO control. The temperature of the reactor was maintained at 20°C using water jacket, the pH was maintained at 7.0. The reactor was equipped with a controlled air supply system. The gas flow rate was controlled by a thermal mass flow controller (TMFC). The constant rate of air entering the sequencing batch reactor was automatically adjusted to a stable set-point (set value was 2 mg O_2/L without oxygen consumption by the microorganisms), but it meant that DO concentration in the reactor changed accordingly with the oxygen demand in activated sludge). The dissolved oxygen concentration in the reactor was measured online as a percentage of air saturation. The DO electrode showed changes in oxygen concentration in wastewater during the reaction time. The initial oxygen depletion phase in wastewater was a result of oxygen use by activated sludge. The oxygen depletion phase, despite constant air supply, enhanced PHB accumulation.

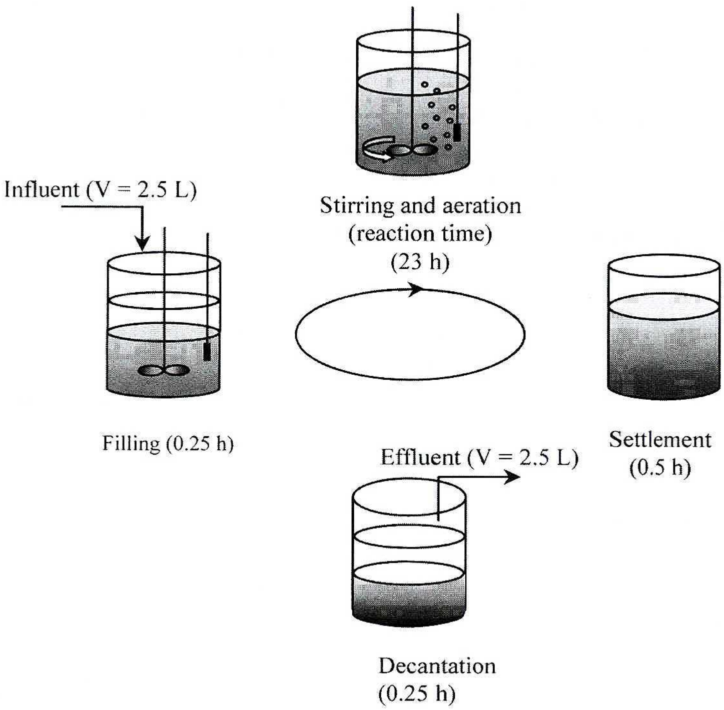


Fig. 1. Operating cycle of the BIOFLO 3000

The operating cycle of the bioreactor is shown in Figure 1. Reactor volumetric exchange rate (n) was 0.5 1/d, which means that a half of the treated wastewater was left in the reactor. Four experimental series were performed. SBR was fed with the mixture of municipal wastewater and supernatant from the digesters collected from the municipal WWTP. Supernatant was used as a source of easily biodegradable organic compounds. The content of supernatant from the digesters in the mixture with municipal wastewater increased from 125 to 500 ml (5-20% v/v). However, the high ammonium concentration in supernatant caused the VFA/TN ratio decrease in the mixture. Table 1 presents the characteristic of the substrate feed.

Table 1. Characteristic of the SBR influent

Parameters	Series 1	Series 2	Series 3	Series 4
Supernatant content in wastewater [%]	5	10	15	20
Ammonium nitrogen [mg $N-NH_4/L$]	54.72	77.5	110.1	148.6
Organic nitrogen [mg N_{org}/L]	29.96	35.34	57.54	56.6
VFA [mg CH_3COOH/L]	80.95	94.3	128.03	135.25
r_{VFA} [g VFA/g VSS·d]	0.03	0.034	0.046	0.052

COD consisted mainly of easily biodegradable compounds expressed as volatile fatty acids. Along with the increase of supernatant content in the mixture with wastewater, VFA loading (r_{VFA}) increased from 0.03 to 0.052 g VFA/g·d. Activated sludge from a conventional nutrient removal wastewater treatment plant was used as inoculum. The sludge concentration was maintained at around 3 g VSS/l with the age of about 35 d.

Analytical methods

In every series the adaptation period lasted about 30 days and was considered complete when the range of changes of particular parameters in the effluent (COD, TKN, $N-NH_4$, $N-NO_3$, $N-NO_2$) within 7 days' time did not exceed 5-10%. After activated sludge adaptation to the experimental conditions, the cultivation of the biomass was conducted for about 4 weeks. During this time chemical analyses and PHB measurements (g/g VSS, C_{mol}/C_{mol}) were carried out. Finally, at the end of each series, kinetic analysis, concerning organic substrate transformation, was conducted.

When effluent parameters were established and deemed to have reached a steady state, the research was carried out to determine PHB production rate, PHB consumption rate, and the COD removal rate. In the working cycle of the reactor, periodic sampling and measurements of COD and nitrogen compounds were conducted.

It was assumed that PHB synthesis proceeds with zero-order rate, PHB degradation with first-order rate in PHB concentration and that the active biomass concentration was constant for each series. COD consumption was divided in feast and famine period and was found to follow zero-order kinetics in both periods.

The reaction rate constants were determined based on the experimental data by linear (zero-order) and non-linear (first-order) regression. In order to evaluate the fit of the model to the experimental points, the coefficient φ^2 was used. If the coefficient φ^2 is closer to zero the fit is better.

Respirometric activity of activated sludge was determined with a respirometer OxiTop® Control (WTW Wissenschaftlich-Technische Werkstätten Gmbh, D-82326 Weilheim, Germany). Respirometric measurements were done three times for each series, and the average values were calculated. At the beginning of the reaction time, when the subsequent reactor cycle started, a sample was directly taken from the SBR. The substrate conditions in the respirometric vessels were identical as in the reactor (VSS, organic and nitrogen loading rate). In order to determine the oxygen uptake for organics and endogenous respiration, an autotrophic nitrification inhibitor (allylthiourea) was added. Allylthiourea was shown to be a strong, selective inhibitor of ammonia and nitrite oxidation without affecting other activity [8]. The oxygen uptake for endogenous respiration was determined in a measuring vessel with activated sludge washed twice with distilled water. Wastewater was replaced by distilled water. The system, operating at temperature of 20°C, registers changes of the pressure in measuring vessel as a result of oxygen uptake by microorganisms. Changes of the pressure were automatically converted to the oxygen uptake expressed as mg O_2/L [PN-EN ISO 9408:2005]. Respirometric calculations are presented by Bernat and Wojnowska-Baryła [3].

Chemical analyses

Daily measurements of the effluent of the reactor included: chemical oxygen demand (COD), total Kjeldahl nitrogen, ammonia nitrogen, nitrite, and nitrate. The activated sludge was analysed for total suspended solids (TSS) and volatile suspended solids (VSS). PHB content in activated sludge was controlled. The analyses were performed according to APHA (1992). PHB measurements in activated sludge cells were determined with chloroform and sulphuric acid, as described by Gerhardt [7].

Calculation methods

In order to make a balance of organic compounds in the reactor during the reaction time, the concentrations of organics used for the biomass growth, internal accumulation, cell respiration, and for denitrification were required. All the calculations to make a balance were according to Bernat and Wojnowska-Baryła [3].

The PHB fraction of active biomass (f_{PHB}) in C_{mol} per total C_{mol} can be calculated according to Third *et al.* (2003), as:

$$f_{PHB}(C_{mol}/C_{mol}) = \frac{PHB(Cmol)}{X_{net}(Cmol) + PHB(Cmol)}$$

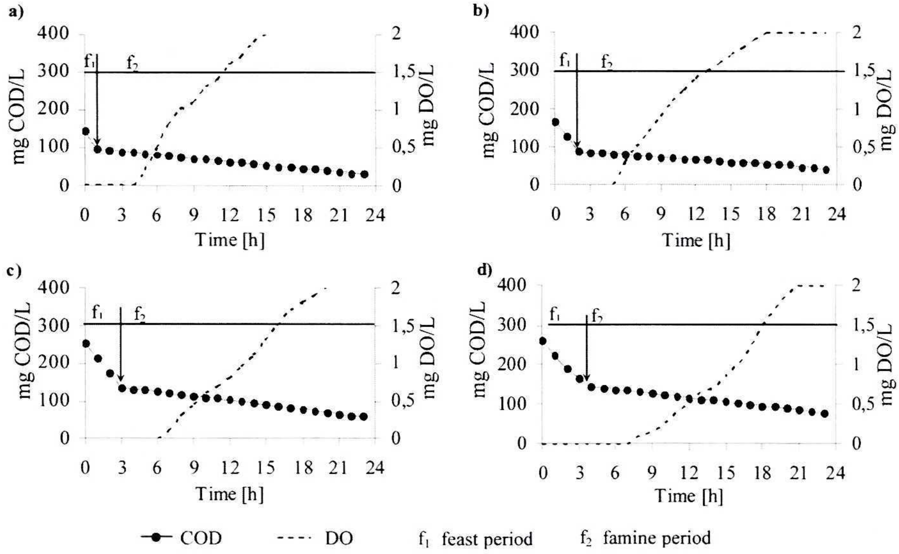
$$X_{net}(g/L) = DW(g/L) - PHB(g/L)$$

Calculation by this method considers a slightly different composition and molecular weight of PHB ($CH_{1.5}O_{0.5}$, 21.5 g/Cmol) and net biomass ($CH_{1.8}O_{0.5}N_{0.2}$, 24.6 g/Cmol). Net PHB-free biomass (X_{net}) was calculated by subtracting the PHB content of the cells from the apparent biomass concentration obtained from dry weight (DW).

RESULTS

The work presented was performed in a sequencing batch reactor Bioflo 3000 with controlled air supply rate (constant set value was 2 mg O_2/L). DO concentration in the reactor changed ambiently with oxygen uptake by activated sludge, because of oxygen requirements changing with time. During the filling period and some hours of the reaction time DO concentration was nearly zero. Correspondingly, the substrate uptake by the organisms in the reactor had changed with time. At the end of feeding, the substrate concentration in the reactor reached its highest point, and then started to decrease along with the reaction time.

Upon the curves of organic compounds removal and dissolved oxygen profiles, the feast and famine periods during the reaction time in series 1-4 were appointed. In the feast period, a high rate of COD removal and intensive oxygen consumption by activated sludge was observed. During the period of higher substrate concentration there was a high oxygen uptake by activated sludge and the oxygen requirements surpassed the amount of available oxygen. Therefore, the DO concentration in the reactor diminished to a level below detection. The duration time with DO concentration below detection level was termed oxygen depletion time. Famine period was characterized by low COD removal rate and an increase in dissolved oxygen concentration in wastewater (Fig. 2).

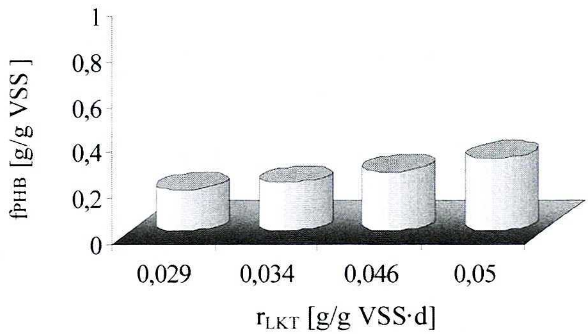


r_{VFA}			0.029	0.034	0.046	0.052
COD removal rate	f_1	k=r [mg COD/L·h]	46	40	39	38
	f_2	k=r [mg COD/L·h]	3.0	2.0	3.8	3.5

Fig. 2. Changes in DO and COD concetration durings the reaction time a)series 1, b) series 2, c) series 3, d) series 4; (the rates of COD remoral in relation to the reaction period are shown in the table)

The length of the feast period at 5% content of the supernatant in the mixture with wastewater was 1 h. Along with the increase of the contribution of the supernatant to 20% of the content in the mixture, the duration of the feast period extended to 4 h. Correspondingly, oxygen depletion phase extended from 4 h to 7 h at volatile fatty acids loading changing from 0.029 to 0.052 g VFA/g VSS•d, respectively. In the feast period in series 1 at 0.029 g VFA/g VSS•d more than 40% of totally removed COD diminished. In series 2-4 at 0.034-0.052 g VFA/g VSS•d it was more than 60% of COD removed in this period. The specific COD consumption rate in the reactor, both in the feast and famine periods, proceeded according to zero-order kinetics. Along with the increase of the length of the feast period the specific COD consumption rate was reduced from 46 do 38 mg COD/L•h. There were no significant differences in the specific COD consumption rate in the famine period, the values oscillated around 3 mg COD/L•h (Fig. 2).

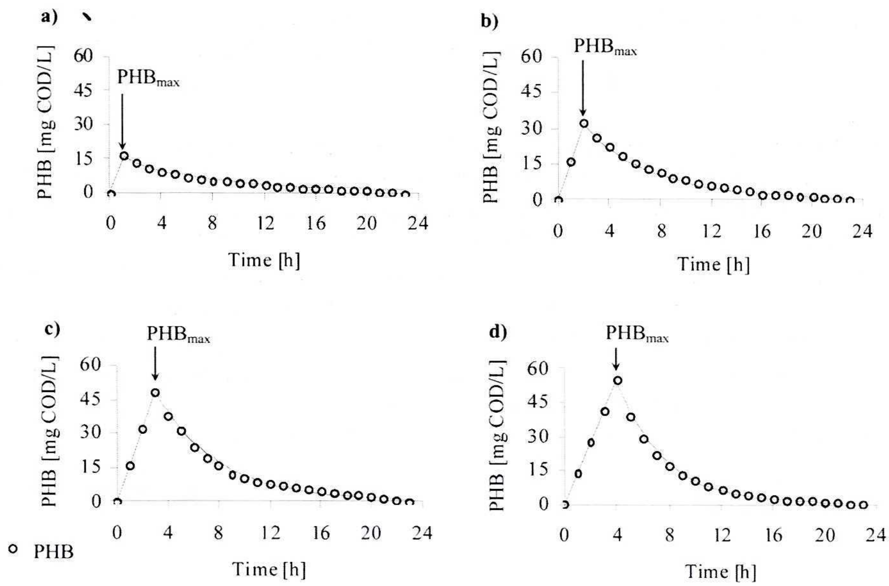
Under constant aeration conditions with the oxygen depletion phase in the initial hours of the reaction time intracellular poly-β-hydroxybutyrate accumulation of the organic fraction from wastewater in biomass cells was observed. Fig. 3 shows poly-β-hydroxybutyrate content in activated sludge cells (f_{PHB}) at t = 0 h depending on the volatile fatty acids loading. The lowest PHB concentration in the biomass – 0.18 g/g VSS. (0.2 C_{mol}/C_{mol}) was noted at r_{VFA} on the level 0.029 g VFA/g VSS•d. The higher contribution of the supernatant in the mixture with wastewater (more easily biodegradable compounds were supported) correlated with higher PHB content in the biomass cells. At r_{VFA} of 0.052 g VFA/g VSS•d in series 4 there was almost 2-fold higher PHB concentration in activated sludge cells (0.32 g/g VSS; 0.35 C_{mol}/C_{mol}), in comparison with series 1.



r_{LKT} [g VFA/g VSS·d]	0.029	0.034	0.046	0.052
f_{PHB} [$C_{mol}/C_{mo}l$]	0.2	0.23	0.29	0.35

Fig. 3. Poly – B – hydroxybutyrate (PHB) froction in biomass cells depending on the rolatile fatty acids loading rate in series 1-4

Poly-β-hydroxybutyrate content in the biomass cells at the beginning and at the end of the reaction time for each series was on the same level. Accumulation process of the reserved substances started in the feast period (f_1), directly after feeding time, when the COD concentration was the highest. It was noted that with the increase of volatile fatty acids loading rate the time of PHB accumulation extended from 1 to 4 h. PHB accumulation took place under constantly aerated conditions, when oxygen depletion phase occurred. PHB production rate proceeded according to zero-order reaction (Fig. 4). At r_{VFA} ranging from 0.029 to 0.046 g VFA/g VSS•d poly-β-hydroxybutyrate accumulation rate was stable on the level of about 16 mg COD/L•h. PHB production rate was lower in series 4 and equalled 13.7 mg COD L^{-1} h^{-1} at r_{FVA} of 0.052 g VFA/g VSS•d. It was calculated that for poly-β-hydroxybutyrate synthesis activated sludge used 16.6, 32, 48.3 and 54 mg COD/L in series 1-4, respectively.



r_{VFA} [g VFA/g VSS·d]		0.029	0.034	0.046	0.052
PHB production	k = r [mg COD/L·h]	16.60	16.00	16.10	13.70
PHB consumption	k [1/h]	0.15	0.19	0.21	0.28
	r [mg COD/L·h]	2.40	6.16	10.10	15.12

Fig. 4. Variation of poly – β – hydroxybutyrate content in microbiol cells in fealt and famine periods depending on rolatile fatty acids loading rate: a) series 1, b) series 2, c) series 3, d) series 4, (table below the pictures presents constants rates (k) and the rates of PHB accumulation and degredation)

When the moment of the limitation of COD removal started, in the famine period (f_2), PHB consumption began. In the table below (Fig. 4) the values of constant rate (k) and the initial rate of the PHB degradation in the famine period are presented. Poly-β-hydroxybutyrate consumption proceeded according to first-order kinetics. The initial rate of PHB degradation depended on the PHB content in the biomass cells. The increase of the polymer degradation rate from 2.40 to 15.12 mg COD/L•h corresponded to the PHB content in activated sludge cells (increasing from 0.18 to 0.32 g COD/g VSS).

Under constant aeration with oxygen depletion phase in wastewater in the reactor in feast period, all the processes that take part in carbon removal (biomass growth, cell respiration, denitrification and intracellular accumulation by activated sludge) were observed. However, in famine period only biomass growth and cell respiration were the processes responsible for COD removal from wastewater. The contribution of the processes in feast and famine periods was changed depending on volatile fatty acids loading rate in series 1-4.

In feast period, an increase of r_{VFA} from 0.029 to 0.052 g VFA/g VSS•d caused the drop in the contribution of the biomass synthesis from 21 to 14% and cell respiration form 12 to 5% in COD removal. Feast period favored denitrification and PHB accumulation as the processes responsible for carbon removal. The contribution of these processes in COD removal increased from 66 to 81%.

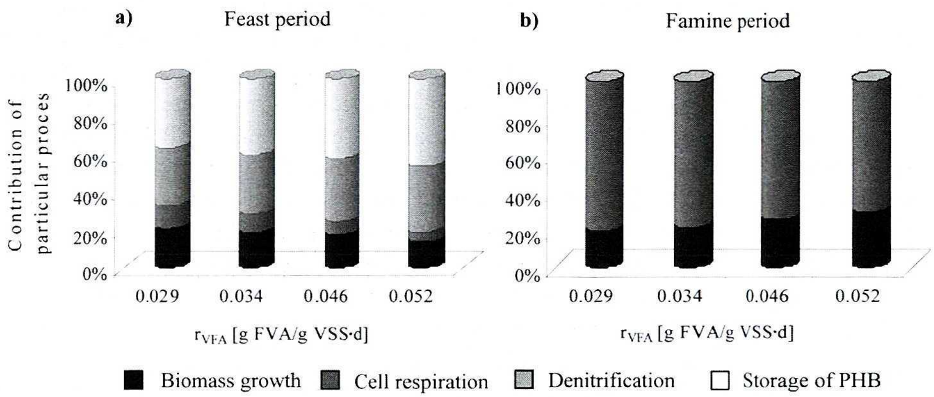


Fig. 5. The contribution of particular processes in COD removal depending on rolatile fatty acids loading rate in the feast (a) and famine period (b)

In the famine period, poly-β-hydroxybutyrate consumption took place. There was lack of COD consumption for denitrification. The only two processes responsible for COD removal contributed to 20-30% as for biomass synthesis and 80-70% as for cell respiration at the increasing volatile fatty acid loading from 0.029 to 0.052 g VFA/g VSS•d (Fig. 5).

DISCUSSION

Under constant air supply on the level of 2 mg/L organic carbon compound removal took place in feast (f_1) and famine (f_2) periods. The rate of COD removal shoved the border between the periods. The length of the feast period increased from 1 to 4 h along with the rise of volatile fatty acid loading from 0.029 to 0.052 g VFA/g VSS•d. Beun *et al.* [5] suggested feast and famine periods under dynamic conditions in activated sludge in a sequencing batch reactor. These authors considered as the beginning of the famine periods the moment when all external substrate (acetate) was consumed. During this time the rate of oxygen uptake by activated sludge was low.

Kinetics of COD removal from the mixture of supernatant and municipal wastewater in feast and famine periods, showed in presented paper, can be described with a zero-order equation. It confirmed the results obtained by Beun *et al.* [5] who found the drop of COD as a linear model. However, in contrary to their suggestion that feast period lasted to the moment of total acetate exhaustion, our results showed fast and slow COD consumption, respectively in feast and famine periods. In feast period f_1 the initial rate of COD consumption was 13-15-fold higher that in famine period. Along with the increase of the length of feast period and volatile fatty acid loading the specific COD consumption rate was reduced from 46 do 38 mg COD/L•h. In famine period there was no difference in the specific COD consumption rate (about 3 mg COD/L•h).

In the presented study, the rise of volatile fatty acids loading from 0.029 to 0.052 g VFA/g VSS•d caused the drop of the effectiveness of organic carbon compounds removal. Dockhorn *et al.* [6] observed a decrease of COD removal when easily biodegradable fraction, expressed as VFA, increased.

Storage of PHB occurred to manage the surplus of external substrate. Van Aalst-van Leeuwen *et al.* [16] found out that both storage and an increase of the biomass growth occurred to manage the surplus of the external substrate at low SRT (0.5 day). Beun *et al.* [5] showed that at SRT of 9.5 and 19.1 days the specific growth rate was kept more or less constant during one SBR cycle. In this case, mainly storage of PHB occurred to manage the surplus of external substrate, thereby balancing the growth at constant rate. In presented experiment, PHB synthesis occurred in all series only in feast period. It was favoured by oxygen depletion. At SRT of 30-40 days the contribution of the biomass growth and cell respiration in COD removal in feast period decreased. However, in famine period both biomass growth and cell respiration were the only processes responsible for COD removal. It means that in the famine phase there was no denitrification and PHB synthesis.

The poly-β-hydroxybutyrate accumulation and denitrification are involved in COD removal and these processes influence cell respiration. When in the environment there are more than one of the electron acceptors, other than oxygen, the contribution of cell respiration in organics removal diminishes. In the famine period of our study there was no use of COD for denitrification because this process was not observed. The process that dominated in organics removal was cell respiration with oxygen as an electron acceptor. The contribution of cell respiration in COD removal in famine period was 70-80%. Van Niel *et al.* [17] examined the behaviour of *Thiosphaera pantotropha* regarding the NADH overflow in the presence of substantial concentrations of the substrate. Continuously grown acetate-limited cultures were exposed for short periods to excess acetate in batch. Acetate appeared to be converted mainly to poly-β-hydroxybutyrate (57% wt/wt). Respiration measurements showed that only 29% of the total acetate taken up was oxidized. The remainder (14%) was used for biomass synthesis. After acetate was completely taken up, the cellular PHB content was 42% of the dry weight. In contrary, Van Niel *et al.* [17] presented that aerobic culture *Acinetobacter calcoaceticus* oxidized up to 80% of acetate to carbon dioxide and water.

In our study, cellular PHB content in activated sludge depended on volatile fatty acid loading. Correspondingly, with the increase of r_{VFA} in the reactor the increase of PHB content in activated sludge from 18 to 32% of dry weight (0.2 to 0.35 C_{mol}/C_{mol}) was observed. In feast period, COD present in the mixture of supernatant and wastewater was mainly converted to PHB and was used for denitrification. The contribution of the biomass synthesis decreased from 21 to 14% and cell respiration from 12 to 5%. In the famine period, poly-β-hydroxybutyrate consumption took place and there was no COD consumption for denitrification. The only two processes responsible for COD removal in famine period contributed to 20-30% as for biomass synthesis and 80-70% as for cell respiration.

Beun *et al.* [5] reported that, apparently, the storage mechanism of PHB is energetically efficient. Stimulating the PHB pathway for growth will only marginally decrease sludge production. Authors showed that the reduction in the net biomass yield, with growth via the intermediate PHB, was 4-10% lower compared to direct use of acetate for growth.

Independently of substrate conditions our study confirmed the correlation between the rate of PHB consumption and the content of the polymer in microbial cells. Consumption of PHB in general could be described kinetically with an *n*th-order equation. The best fit for all data sets was obtained for reaction order $n = 1.3$ and reaction rate constant k = 0.44 [5]. Murnleitner *et al.* [12] examined reaction order of 2, 1, 2/3, and 1/2. The best results were achieved with a 2/3 order for PHB consumption. The kinetics of the enzymatic degradation reactions of the naturally produced polyesters poly-β-hydroxybutyrate (PHB) and poly-β-hydroxybutyrate-co-β-hydroxyvalerate (PHBV) were studied by Timmins *et al.* [15]. Kinetic analysis has revealed that the observed degradation behavior was inconsistent with classical Michaelis-Menten enzymatic kinetics from zero order to first order. Our study showed that PHB consumption proceeded with first-order equation and the rate of that process depended on the poly-β-hydroxybutyrate content in cells of activated sludge (f_{PHB}). The higher was the contribution of the supernatant in the mixture with wastewater (more easily biodegradable compounds was supported) the higher was PHB content in the biomass cells. PHB degradation rate increased from 2.40 to 15.12 mg COD/L•h. Buen *et al.* [4] also revealed that the rate of PHB consumption mainly depended on its content in dry weight. Apparently, PHB degradation at low f_{PHB} values occurs at a lower rate than at high f_{PHB} values.

CONCLUSION

The main findings from the study are as follows:

- Under constant aeration conditions the feast and famine periods during the reaction time were shown. In the feast period, a high rate of COD removal and an intensive oxygen consumption by activated sludge was observed. The famine period was characterized by a low COD removal rate and an increase of dissolved oxygen concentration in wastewater.
- The specific COD consumption rate in the reactor, both in the feast and famine periods, proceeded according to zero-order kinetics. With the increase of r_{VFA} from 0.029 to 0.052 g VFA/g VSS•d the specific COD consumption rate in the feast period was reduced from 46 do 38 mg COD/L•h. In the famine period the values oscillated around 3 mg COD/L•h.
- The lowest PHB concentration in the biomass – 0.18 g/gVSS (0.2 C_{mol}/C_{mol}) was noted at r_{VFA} on the level of 0.029 g VFA/g VSS•d. At r_{VFA} 0.052 g VFA/g VSS•d there was almost 2-fold higher PHB concentration in activated sludge cells – 0.32 g/g VSS (0.35 C_{mol}/C_{mol}).
- PHB synthesis proceeds with zero-order rate and its degradation with first-order kinetic equation. At r_{VFA} ranging from 0.029 to 0.046 g VFA/g VSS•d poly-β-hydroxybutyrate accumulation rate was stable on the level of about 16 mg COD/L•h. Lower PHB production – 13.7 mg COD/L•h, was observed at r_{FVA} of 0.052 g VFA/g VSS•d. With higher PHB content in activated sludge cells correlated higher rate of its degradation. Polymer consumption rate increased from 2.40 to 15.12 mg COD/L•h.
- Of the total COD uptake in feast period, from 21 to 14% was used for the biomass synthesis and from 12 to 5% for cell respiration. The contribution of denitrification and PHB accumulation in organic carbon removal increased from 66 to 81%. In the famine period the only two processes responsible for COD removal contributed to 20-30% as for biomass synthesis and 80-70% as for cell respiration at the increasing volatile fatty acids loading.

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USUWANIE ZWIĄZKÓW ORGANICZNYCH (CHZT) W ZALEŻNOŚCI OD OBCIĄŻENIA OSADU CZYNNEGO ŁADUNKIEM LOTNYCH KWASÓW TŁUSZCZOWYCH (LKT)

W pracy określono udział usuwania związków organicznych (ChZT) ze ścieków w procesach przyrostu biomasy, oddychania komórkowego, denitryfikacji oraz syntezy kwasu poli-β-hydroksymasłowego (PHB) w zależności od obciążenia osadu czynnego ładunkiem lotnych kwasów tłuszczowych w ściekach. Ponadto przeanalizowano kinetykę magazynowania oraz degradacji kwasu poli-β-hydroksymasłowego.
Eksperyment prowadzono w reaktorze sekwencyjnym SBR. Ilość powietrza doprowadzanego do reaktora była automatycznie ustawiona na poziomie 2 mg O_2/L, w początkowych godzinach fazy reakcji notowano fazę wyczerpywania tlenu w reaktorze. SBR był zasilany ściekami komunalnymi z udziałem wód nadosadowych z komór fermentacyjnych.

Wydzielono fazę żywieniową (f_1), w której notowano dużą dostępność związków organicznych oraz fazę głodową (f_2) z niewielką dostępnością substratów organicznych. Wraz ze wzrostem obciążenia osadu czynnego ładunkiem lotnych kwasów tłuszczowych (r_{LKT}) z 0,029 do 0,052 g LKT/g s.m.o.•d w fazie żywieniowej efektywność usuwania ChZT zależała od ich zużycia na denitryfikację i syntezę PHB. Zawartość PHB zmagazynowanego w osadzie czynnym wzrastała z 0,2 do 0,35 C_{mol}/C_{mol}. W f_1 obserwowano spadek udziału syntezy biomasy z 21 do 14% oraz utleniania komórkowego z 12 do 5% w usuwaniu ChZT ze ścieków. W fazie głodowej pozostałe związki organiczne były wykorzystywane jedynie na przyrost biomasy oraz oddychanie komórkowe, denitryfikacja oraz syntez PHB nie zachodziły.