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THE INFLUENCE OF MIXING PROCESS ON WASTEWATER TREATMENT

WPŁYW PROCESU MIESZANIA NA OCZYSZCZANIE ŚCIEKÓW

A b s t r a c t

The paper deals with an influence of an aeration time on morphology of an activated sludge and Chemical Oxygen Demand (COD). The sludge tested came from a treatment plant belonging to a food industry factory.

Keywords: *mixing process*, *aeration*, *sludge*, *sequencing batch reactor (SBR)*, *morphology*

S t r e s z c z e n i e

W artykule przedstawiono wpływ czasu napowietrzania na morfologię osadu czynnego oraz na chemiczne zapotrzebowanie na tlen. Badany materiał pochodził z zakładowej oczyszczalni przemysłu spożywczego.

Słowa kluczowe: *mieszanie*, *napowietrzanie*, *ścieki*, *reaktor SBR*, *morfologia*

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1. Introduction

Mixing process makes it easier to trap harmful substances by increasing a contact area between a flocculant and an undesirable substance. Mechanical agitators within a few minutes perfectly mix sewage with the flocculant so that it is able to combine with a greater number of dirt particles. The complex increases its weight and settles down at the bottom, which leads to clarifying water surface much faster. The mixing process can also affect the morphology of an activated sludge by shear stress interference or ensuring it more favorable aerobic conditions [1]. Shear stresses disintegrate the sludge granules and increase their active surface, which may adsorb a greater amount of dissolved solids. The mixing process may also be accomplished by the process of aeration, because the compressed air causes the circulation of the waste water. In addition, this process provides more available oxygen for life processes of organisms, which degrade the organic compounds contained in the wastewater. Air nozzles may also be used. Compressed gas is introduced to the lower part of the chamber, its center or to its perimeter. This results in the effective mixing of the sludge without fragmentation of fibers. Specific volume of the gas supply to the lower zone of the chamber moves upwards in approximately the same volume of waste water [2]. It provide better contact of the substance with the greatest sludge microbial biomass (which use adsorbed colloidal particles and other solutes as food source) but above all, its goal is to oxidize the activated sludge to provide it with favorable conditions for metabolic activity [3].

The efficiency of biological wastewater treatment process depends mainly of carbon, nitrogen and phosphorus content. SBR technology (*Sequecing Batch Reactors*) was used in the experiment because it allows to modify the system in order to influence the process of removing different types of contaminants. SBR are industrial processing tanks for the treatment of wastewater. SBR reactors treat wastewater such as sewage or output from anaerobic digesters or mechanical biological treatment facilities in batches. SBR technology also allows us to adjust the duration of the various phases of the cycle during processes of nitrification, denitrification, phosphorus removal and the elimination of carbon compounds [4, 5]. SBR technology uses method of activated sludge which is based on cultivation of microorganisms. The reactor content is intensively mixed and aerated to prevent falling and provide oxygen for organisms. Sewage that flows into the reactor is mixed with the activated sludge. It encounters an expanded surface of bacterial flocs which quickly adsorbs solutes and colloidal particles. Monomers can be directly assimilated by the bacteria. Macro-particles are previously hydrolyzed by enzymes secreted outside the bacterial cells. Part of assimilated substrates is used as an energy source during mineralization. The remaining part is consumed for the production of new biomass. Sludge particles condense and fall to the bottom of the secondary settling tank under conditions conducive to sedimentation. Thickened sludge is returned to the reactor, and the clear, purified sewage is discharge into the river [6].

In case of wastewater from agro-food industries shortening oxygen phase for extended mixing time does not affect the deterioration of the quality of treated wastewater [5].

Prolongation of the mixing phase in one cycle improves effectiveness of the removal of carbon compounds in the case of dairy wastewater treated in the chambers SBR in a high concentration of activated sludge and low load of pollutants [5].

The result obtained may be evidence of rapid adaptation of activated sludge under changing environmental conditions.

M. Dębowski, W. Janczukowicz and J. Peste results show that [5]:

– Longer mixing phase affects the pH of wastewater in the reactors. Extension of the mixing phase is likely to favor the fermentation process, which leads to lower pH. In addition, there are favorable conditions for denitrification and removal of orthophosphates.
– The efficiency of purifying and concentrating wastewater discharged from individual reactors did not differ significantly. It is therefore possible a long-term operation of the chamber in the technological system SBR with a long phase of mixing, or alternate system without the risk of reducing the quality of wastewater.
– In case of the chambers in which anaerobic conditions prevail (with a longer phase mixing) conditions are more favorable for denitrification.
– Researchers have shown that extending mixing phase (temporary or permanent) does not significantly alter the quality of treated wastewater. The result is higher efficiency of removing phosphorus, nitrate nitrogen, slightly higher levels of Chemical Oxygen Demand (COD) and ammonia nitrogen. The ability to remove nitrogen remains at a comparable level.

M. Wojnicz proved that the introduction of the initial raw sewage aeration improves the quality of treated wastewater for all tested forms of pollution. Introduction of an additional anoxic phase during the aeration phase improves the quality of the purified waste water in comparison to the operating system without the modification with respect to the phosphate, total phosphorus and nitrate nitrogen [4].

The effect of shear stress on granulation, morphology, and bioactivity of the activated sludge was repeatedly tested. It turned out that the relatively high frequency of the mixing helps to create a more regular and more bioactive granules. Shear stress ranging from 4.2 to 6.5 N/m^2 increases the speed of the granulation process and additionally the granules become larger. However, one cannot increase shear stress too much, since at 7.7 N/m^2 granulation process speed is reduced and the granules become smaller. It was also shown that the granular, oxygen sludge have the ability to remove nitrogen and phosphorus from waste water. In case of nitrogen and phosphorus its effectiveness is up to 89.8% and 54.5%, respectively due to mixing sewage with sludge [1].

2. Materials and methods

The sludge tested came from a treatment plant belonging to a food industry factory. Because of the presence of a significant amount of impurities in post-production sludge, which are difficult to remove, three-step treatment was applied. Raw sludge is purified threefold by the activated sludge working under different reactant and oxygen conditions. Basic study performed daily include following:

– determination of sedimentation of sludge sample taken from the individual reactors,
– determination of Chemical Oxygen Demand (COD) concentration in the pre-treated wastewater flowing between the tanks,
– sludge microscopic observations from the individual reactors,

– checking pH and temperature of treatment,
– measurement of dissolved oxygen in the mixture of sludge in the individual reactor.

Schedule of water quality tests with requirements is presented in Table 1.

Table 1

Studies of treated sewage

Features tested and methods	Internal Requirements	Legal requirements	Frequency of tests
Flow	2000 m^3/d	2000 m^3/d	Daily
pH	6.5–9.5	6.5–9.5	Daily
Temperature	30°C	35°C	Daily
Total suspended solids	35 mg/l	35 mg/l	1 time a week
The concentration of total phosphorus	2 mg P/l	2 mg P/l	2 times a week (more often if needed)
The concentration of total nitrogen	10 mg N/l	30 mg N/l	1 time a week
The concentration of total iron	10 mg Fe/l	10 mg Fe/l	1 time a week
COD	90 mg O_2/l	125 m O_2/l	Daily
BOD (Biochemical Oxygen Demand)	20 mg O_2/l	25 m O_2/l	1 time a month

In case of exceeding the recommended concentrations of pollutants, the operator stops the release of treated wastewater and recycles it into first tank (A).

3. Results and discussion

During the discharge of treated wastewater, the 1 L sample was taken from the bioreactor with capacity of 1200 m^3 and filled to half with sewage, which was aerated for 1, 2, 3 and 4 hours. Compressed gas was put in the lower part of the tank by disk diffusers. Before taking appropriate samples for testing, measuring vessel was flushed with the sewage.

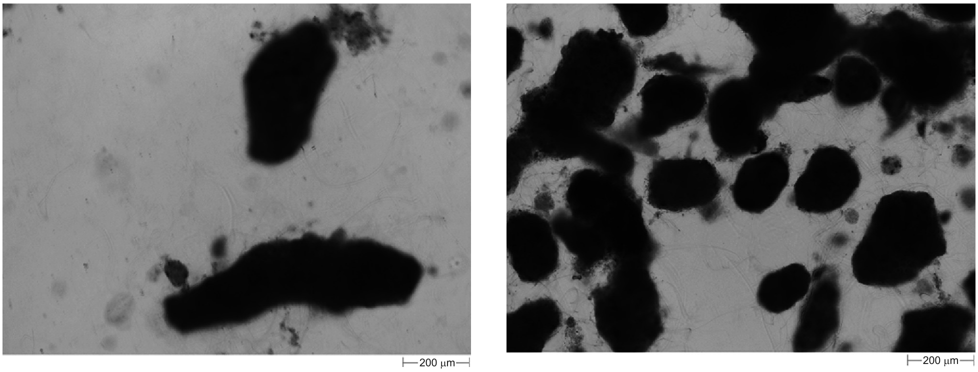
Effluent characteristics were examined after all stages of the wastewater treatment (the filling, mixing, aeration and sedimentation) for two different times of the aeration phase (3.5 and 12.5 h).

An attempt has also been made to identify certain species of protozoa, which were present in the sludge samples. The sedimentation test was performed at the end of study.

In addition, the morphology of activated sludge was performed after 1 and 3.5 h aeration. Fig.1 illustrates the results of the experiment.

The longer aeration time the more regular shapes of granules are. The larger forms divide into smaller ones (Fig. 1).

Studies show that with the length of wastewater aeration time, the condition of the sludge improves because COD decreases (Table 2). The result of a COD test indicates the amount of water-dissolved oxygen (expressed as parts per million or milligrams per liter of water)



aeration 1.5 h   aeration 3.5 h

Fig. 1. Microscopic photograph of aeration sludge

consumed by the contaminants, during two hours of decomposition from a solution of boiling potassium dichromate.

This experiment shows the positive effect of extended aeration time on the quality of wastewater.

Table 2

Effect of aeration time on the COD of wastewater

Raw sewage 1850 mg/l	
Aeration time [h]	Examined COD [mg O_2/L]
1	1270
2	910
3	540
4	310

Table 3

The results of aeration during 3.5 h

Aeration 3.5 h			
PIX	flow: 1110 m^3/d	pH = 8.16	T = 22.2°C
	Raw sewage	B	Treated wastewater
COD [mg/l]	2954	233	10
Phosphorus [mg/l]	6.1	–	0.6
Nitrogen [mg/dm^3]	8.9	–	0.5
Total suspended solids [mg/m^3]	10		
Total dry solids [kg s.m./m^3]	8.58		
Microscopic analysis	colonies Epistylisa's plicatilis, single Acineria uncinata, Apsidisca cicada, Euplotes affinis, Epistylis chrysemydis, Holophrya, Opercularia articulate, Rotatoria		

Colonies of epistylis provide a good and stable work of well oxygenated activated sludge. Euplotes affinis also presents a good oxygenation and low loading rate. The presence of representatives of Rotatoria and Apsidisca cicada indicates a long sludge age. Rotatoria improve effluent quality by removing dispersed bacteria between the sludge floc. They have an important role in maintaining the activated sludge bacteria in good condition in the phase of rapid growth. Viscous and mucilaginous substances, which are secreted by Rotatoria assist in a formation of a floc. Together with time of the aeration, a size of granules decreases, which leads to better penetration of oxygen into the interior of the floc and increase the adsorption surface area. On the other hand too long time of the process is unfavourable, since too small granules interfere with the process of sedimentation. Activity limitation of Rotatoria gives some information about the presence of toxins [6].

Table 4

The results of aeration 12.5 h

Aeration 12.5 h			
PIX	flow: 680 m^3/d	pH = 8.37	T = 35.2°C
	Raw sewage	A	Treated wastewater
COD [mg/l]	1267	18	9
Phosphorus [mg/l]	5.1	–	1
Nitrogen [mg/dm^3]	4.4	–	1.3
Total suspended solids [mg/m^3]	6		
Total dry solids [kg s.m./m^3]	10.249		
Microscopic analysis	Epistylis chrysemydis, Holophrya discolor, Rotatoria, Gastrotricha		

Enzyme activity is closely related to environmental conditions including process temperature. According to the Arrhenius theory its growth will accelerate biochemical reactions catalyzed by enzymes. However, taking into account nature of the enzyme protein, excessive temperature can lead to denaturation and inhibit the process. The bacteria used in the experiment are mesophilic. In the aerobic processes, heterotrophic decomposition

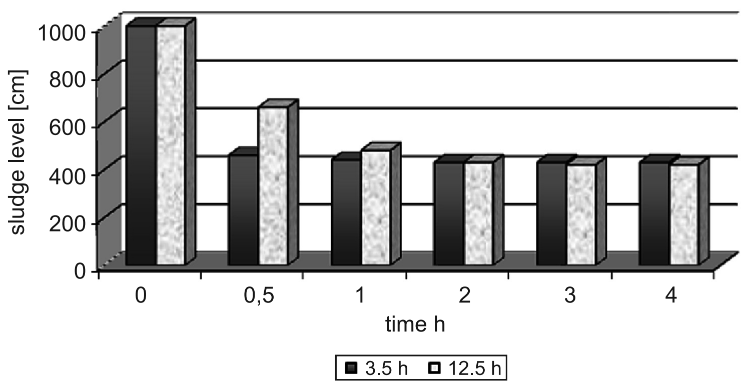


Fig. 2. Progress of sedimentation after the 3.5 and 12.5-hour aeration

of organic compounds it is assumed that the rate of the process increases exponentially in a temperature range from 0 to 32°C. It rapidly decreases to zero at 45°C According to M. Zielinski nitrification rate increases at temperatures of 30–35°C. When exceeding 40°C it drops to zero [7]. W. Jańczukowicz, M. Dębowski and J. Peste showed that the best temperature for the nitrification process is in the range 25–28°C [4]. From the above information, the temperature in the second reactor (35.2°C) is close to optimal for the most efficient waste water treatment process.

The sedimentation test shows that the 3.5 hours of the aeration leads to the sludge settling very quickly to the bottom. After 2 hours of standing it reaches the minimum level. After 12.5 hours of aeration sludge does not drop quite as fast as in the first case. This may be due to the long time impact of the various disorders and turmoil in the activated sludge, which needs a long time to stabilize. Moreover, shear tensions breaks up sludge granules and their size can be small enough to disrupted sedimentation process. A minimum level of sediment was reached after 3 h and is 420 cm (Fig. 2).

4. Conclusions

The first experiment supports the positive effect of increasing aeration intensity on the quality of wastewater. In the case presented, COD value decreases with increase in the length of time oxygenation, which indicates improving effluent quality.

In a second experiment, in both cases a reduction in COD is very close to 100% (99.7% and 99.3%). Removed 94% of total nitrogen in the effluent less aerated and 90% of total phosphorus, while in the other 70% of total nitrogen and total phosphorus of 80%.

Sludge faster sediments after 3.5 h aeration, the level of 450 cm was reached after 30 minutes. In contrast, similar level was reached after more than an hour for the 12.5 h aeration. After 4 hours of sedimentation a lower level of sludge obtained in the second case. However, there is little difference of only 10 cm and waiting an hour longer. Moreover, the production of solids is lower compared to the example of the longer aeration.

The results of the study show that neither too short nor too long aeration sludge does not affect him favorably and consequently on the quality of treated wastewater. Limitation of aeration time to 3.5 h accelerates the sedimentation of sludge, while not significantly increases its minimum level. The amount of generated dry solids is lower, and therefore easier and less expensive to remove. In addition, shorter aeration treatment reduces operating costs, because the power of the aeration device is quite high.

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