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ANAEROBIC AND AEROBIC TREATMENT OF WASTEWATER OF MILK PLANTS

OCZYSZCZANIE ŚCIEKÓW MLECZARSKICH W WARUNKACH TLENOWO-BEZTLENOWYCH

Abstract: Wastewater of milk plants contain high concentrations of inorganic and organic pollutants such as suspended solids - 2000 g/m^3; COD - 3700 g/m^3; BOD_{20} - 2500 g/m^3. The disadvantage of aerobic biological dairy wastewater treatment plant (WWTP) technologies is the high costs of electricity for the air supply to aeration tanks, high rate filters and others. High concentrations of organic matters cause the overload and the bulking of activated sludge and perturb the work of secondary sedimentation tanks. In this work the effective stage anaerobic-aerobic treatment technology of milk plants wastewater is proposed. Treatment plants were equipped with the carriers in order to increase the concentration of biomass in bioreactors. Microorganisms of the activated sludge at this stage of treatment are attached to the proposed load carriers made of artificial fibers of the VIYA (Eyelash) type. The high efficiency of anaerobic-aerobic method in section bioreactors with carriers for immobilization of microorganisms was observed. Due to the design of bioreactors section and the single wastewater pass through the system the microorganisms biocenosis was formed in bioreactors separate sections. The formed biocenosis are typical for occurred conditions and the sewage quality in given section. The wastewater is being treated gradually and the growth of microbial biomass decreases due to the formed, so-called, "bioconveyer". The system of microorganisms based on the food relation type "predator-victim" reducing the excess of biomass is formed in the particular elements of WWTP system. The outflowing activated sludge may be characterized by quick sedimentation, small amounts, high ash content (up to 60%) and significant dewatering.

Keywords: milk plants wastewater, anaerobic-aerobic treatment, microorganisms immobilization, bioreactor, bioconveyer

Wastewaters generated in milk plants contain high concentrations of inorganic and organic pollutants such as: suspended solids - 2000 g/m^3; COD - 3700 g/m^3; BOD_{20} - 2500 g/m^3 [1-3]. As a result, dairy wastewater treatment is a complicated task. Its solution requires considerable financial funds [4]. Milk plant wastewater treatment is conducted with the use of biological methods [5]. For example, in aeration tanks, in high rate filters, in circulative oxidizing channels or in two step schemes with aeration tanks.

The disadvantages of aerobic biological wastewater treatment technologies of milk plants are: the high costs of electricity in the aeration tanks of air supply, high rate filters and the other above-mentioned treatment plants; the high growth of surplus activated sludge biomass difficult to dewatering and needs a process of stabilization. Instability of the work of aeration tanks is caused by the periodic and seasonal operation of the dairy industry (in summer the average flow rate can be increased up to 100 m^3/day or more, and in winter it can be decreased to 20 m^3/day). High concentrations of organic matters cause the

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overload and the bulking of activated sludge and violate the work of the secondary sedimentation tanks.

In this work the gradual anaerobic-aerobic treatment technology of milk plants wastewater was proposed. The studied treatment plants were equipped with the carriers made of the artificial fibers in order to increase the concentration of biomass in bioreactors. Microorganisms of activated sludge at this stage of treatment are attached to the proposed carriers [6-8].

Description of experiment and results

The study was conducted on the laboratory installation (Fig. 1). It consists of two anaerobic and three aerobic sequentially connected bioreactors.

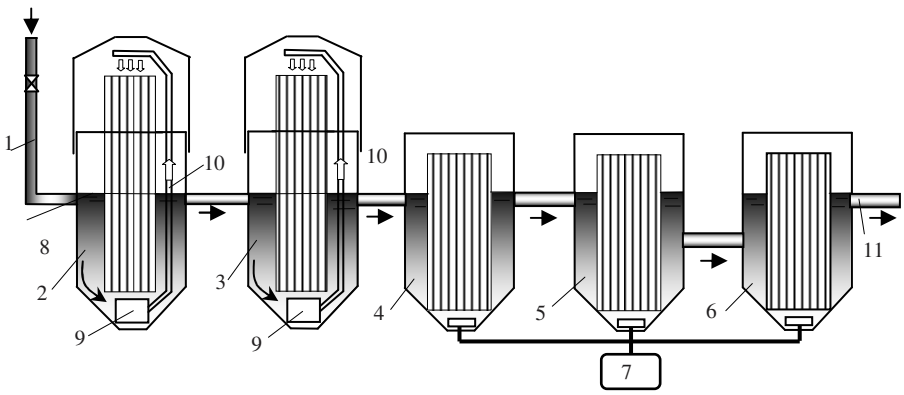

Fig. 1. Scheme of laboratory installation: 1 - supplying of model solution; 2, 3 - anaerobic bioreactors (sect. No. 1 and sect. No. 2); 4, 5, 6 - aerobic bioreactors (sect. No. 3, sect. No. 4 and sect. No. 5); 7 - microcompressor; 8 - fibers carriers installation; 9 - pump; 10 - recirculation pipe; 11 - treated water pipe

Table 1

Characteristics of used model solutions in the anaerobic-aerobic treatment

Name	Concentration of organic matters [g in 100 g of milk whey]				Concentration of organic matters [kg/m^3]	Dilution [-]	Concentration of organic matters in model solution [kg/m^3]
	proteins	lipids	carbo-hydrates	Σ			
Model solution 1	1.0	-	3.5	4.5	45	1:9	4.5
Model solution 2	0.6	0.4	0.11	1.11	11.1	1:2	3.7
Model solution 3	0.6	0.4	0.11	1.11	11.1	1:1	5.55
Model solution 4	0.6	0.1	4.0	4.7	47	1:9	4.7

Model solution was prepared for a milk plants sewage simulation (Tab. 1). This solution was supplied to the first anaerobic bioreactor and then passed through the

following anaerobic and aerobic bioreactors. Because solutions were prepared from milk, so they contain almost all the ingredients of dairy wastewater.

The mixing of reacting masses in the anaerobic bioreactors was made by means of the pumps at the bottom and recirculation pipe with holes for water sprinkling. Air was supplied with microcompressor to the aerobic sections to maintain dissolved oxygen concentrations within range of 1.6÷2.5 g/m^3. The carriers of loading were made of artificial fibers of the VIYA (Eyelash) type were installed into bioreactors for the immobilization of biomass [8]. The design parameters of the laboratory installation are presented in Table 2.

Table 2

Design parameters of laboratory installation

Parameter	Total	Section number				
		1	2	3	4	5
Volume [cm^3]	3925	785	785	785	785	785
Diameter of carrier fiber [mm]	-	3	3	3	3	3
Length of fiber [m]	-	0.12	0.12	0.12	0.12	0.12
Number of fibers	-	260	255	220	80	70
Volume that fibers occupier [cm^3]	-	281	275	238	86	76
Part of section volume that fibers occupier	-	0.48	0.47	0.3	0.11	0.1

At the beginning of the work of laboratory installation the activated sludge from Kyev WWTP “Bortnitskaya” was carried to the bioreactors to increase biomass.

Figure 2 presents the dependence of total nitrogen (N_{tot} - N) to the operation time. A significant reduction of total nitrogen has been observed on 45th day of work. Treatment effects of model solutions from total nitrogen were noted, as follows: in section No. 3 - 61.4%, in section No. 4 - 73.8%, in section No. 5 - 82.3%.

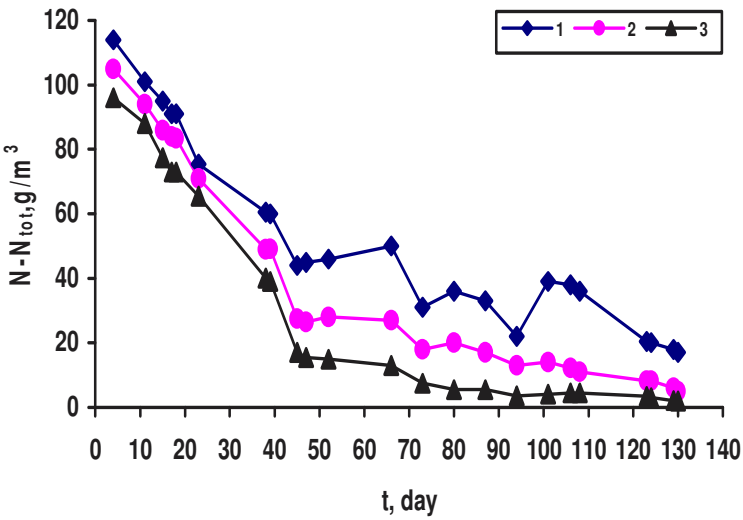

Fig. 2. Dependence of total nitrogen (N_{tot} - N) from the operation time: 1 - in section No. 3; 2 - in section No. 4; 3 - in section No. 5

Figure 3 presents the dependence of COD in model solutions to the operation time after anaerobic and aerobic treatment: after bioreactor No. 2 and bioreactor No. 5. The high degree of wastewater purification was observed. Concentrations of organic matters due to COD in the treated wastewater were: after bioreactor 2 - 300 g/m^3; after bioreactor 5 - 20 g/m^3.

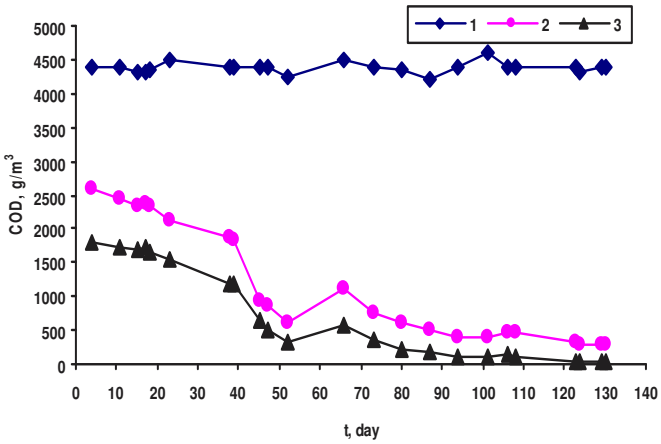

Fig. 3. Dependence of COD in model solutions after anaerobic and aerobic treatment from the operation time: 1 - inlet water; 2 - after bioreactor 2; 3 - after bioreactor 5

Discussion

The results of the laboratory research show the high degree of dairy wastewater treatment. The following degrees of reduction were achieved for the pollutants indicator: COD - 86.7÷93%, total nitrogen - 96.9÷97.9%.

The high efficiency of anaerobic-aerobic method in section bioreactors with carriers for microorganism immobilization was observed. Due to the design of bioreactors section and the single flow of wastewater through them the microorganisms biocenosis was formed in separate bioreactors sections. This is typical for studied conditions and the quality of the sewage in given section. The wastewater is treated gradually and the growth of biomass of microorganisms decreases due to the formed so-called “bioconveyer” [8]. The system of microorganisms on the food type “predator- victim” is formed in a chain of sections, thus it reduces the excess of biomass. The higher trophic level of predator decreases the number of its forms [9].

The results of our biological studies show the presence of large number of microorganisms such as *Bodo*, *Vorticella microstoma*, *Arcella discoides*, *Oligoheta* and others in section No. 3. These microorganisms are typical to highly polluted water environment with large concentration of organic matters as a result of anaerobic destruction of proteins, carbohydrates and others. The small flagellata are consumed by the infusoria, rotifers, predatory infusoria and others (section No. 5) in examined wastewater purification process from organic matters.

The concentration of organic matters and biomass of bacteria decreased in section of bioreactors. At the end of purification process quantity of excess biomass is small therefore its self-oxidation and self-regulation as a result of consumption by higher levels organisms of trophic chains. The decrease of biomass concentration from 3.8 (in section No. 1) to 1.5 g/g carrier (in section No. 5) in water clarification process was observed.

Summary and conclusions

On the basis of our studies it is possible to make the following conclusions:

- With the purpose of microorganisms biocenosis formation on the principle of "bioconveyer" the application of sectional flow scheme installation for anaerobic and aerobic purification is recommended. The growth of microorganisms biomass reduction resulted from consumption in the food chain "predator - victim" was formed in sections: from bacteria and small flagellata to predatory infusoria, rotifers, worms and other microorganisms.
- It is possible to arrange a fiber loading of the VIYA type in bioreactors to increase the concentration of microorganisms in anaerobic and aerobic purification plants. This loading is characterized by a large surface area and is able to attach a large quantity of microorganisms.
- The use of attached biomass for biological wastewater treatment allows to stabilize bioreactors work conditions. Because of that the changing the quality of input parameters (pollution concentrations) and discharges during prolonged operation time do not affect the performance quality of treated wastewater at the outlet from sewage treatment plants with selection and immobilization of microorganisms biomass.
- Anaerobic-aerobic method of treatment allows to effectively purify milk plants wastewater. The achieved concentrations of pollutants in treated water are COD - 20 g/m^3, and total nitrogen - 2÷3 g/m^3.
- The output concentration of suspended solids in treated water from laboratory plants was 5÷10 g/m^3. Suspended solids settle quickly and form dense sludge layer.
- As a result of presented anaerobic-aerobic wastewater treatment of milk plants a small amount of sludge is formed, which dewaters well.

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OCZYSZCZANIE ŚCIEKÓW MLECZARSKICH W WARUNKACH BEZTLENOWO-TLENOWYCH

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Abstrakt: Ścieki z przemysłu mleczarskiego cechują się dużą koncentracją zarówno nieorganicznych, jak i organicznych zanieczyszczeń, przykładowo stężenie zawiesiny ogólnej może osiągać poziom 2000 g/m^3; ChZT - 3700 g/m^3; BZT_{20} - 2500 g/m^3. Stąd też technologia biologicznego oczyszczania tego typu ścieków w warunkach tlenowych niesie za sobą wysokie koszty energii elektrycznej, związane przede wszystkim z dostarczeniem dużej ilości powietrza do komór biorekcji. Duża koncentracja związków organicznych powoduje często przeciążenie osadu czynnego oraz jego pienienie, co prowadzi do zakłóceń w pracy osadników wtórnych. Prezentowana praca przedstawia tlenowo-beztlenową technologię biologicznego oczyszczania ścieków z przemysłu mleczarskiego. Przedstawiona została pilotowa instalacja oczyszczania ścieków wyposażona w nośniki służące zwiększeniu koncentracji biomasy w bioreaktorze. Mikroorganizmy osadu czynnego na biologicznym stopniu oczyszczania ścieków są przytwierdzane do wspominanych nośników wykonanych z włókien typu VIYA (Rzęsa). Pozwala to osiągnąć zwiększoną skuteczność beztlenowo-tlenowej metody oczyszczania ścieków przy obecności biomasy immobilizowanej. Poprzez wykonanie poszczególnych sekcji bioreaktorów uzyskano możliwość oczyszczania ścieków przy ich jednorazowym przepływie poprzez układ, w którym biocenoza mikroorganizmów w każdej z sekcji odpowiada specyficznym warunkom technologicznym oraz jakości dopływających ścieków. W prezentowanym układzie technologicznym ścieki są oczyszczane stopniowo, zaś przyrost biomasy maleje ze względu na oddziaływanie „bionośników". W kolejnych ogniwach sekcji wytwarza się specyficzna zależność pokarmowa typu „drapieżnik-ofiara", która pozwala zredukować ilość osadu nadmiernego. Odpływający z układu osad czynny szybko sedymentuje i łatwo ulega redukcji uwodnienia.

Słowa kluczowe: ścieki mleczarskie, oczyszczanie tlenowo-beztlenowe, immobilizacja mikroorganizmów, bioreaktor, bionośnik