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THE FORMATION OF GRANULES OF THE ACTIVATED SLUDGE IN AEROBIC CONDITIONS

The dynamics of granules formation after incubation of activated sludge with aeration in urban wastewater and wastewater of dairy production was monitored in laboratory. The prepared sludge mixture was incubated on Enviromental Shaker-Incubator ES-20 with the operating frequency of 140 rpm. The pH value was maintained in the range of 6.8–8.5, at temperature 20, 25 and 30°C. The detachable-filling up the mode of incubation that provided alternation of load and of sludge starvation was selected. For the purpose of selecting the largest and the most compact flakes and preservation of formed granules, the sedimentation time of activated sludge between feedings was 7 min.

Based on the distribution of microorganisms by the main indicator groups, low level of development of the original activated sludge was noted. Up to 80% of microorganisms in the activated sludge were testate amoebae. Changes in number and species composition of activated sludge biocenosis in the process of granules formation were tracked. Significant decrease in the number of testate amoebae and obvious increase in proportion of peritrichous ciliates (up to 34% after incubation in municipal wastewater and up to 61% in wastewater of dairy production) was observed. The selected recharge mode was chosen: 1 time per every 4 days for municipal wastewater and 1 time per 10 days for wastewater of dairy production. This provided greater stability of the activated sludge volume after settling. The difference in sludge sedimentation characteristics, after incubation at different temperatures was marked. With the increase in temperature of incubation, the rate of silt deposition increased and the final volume of sludge after a 7-minute settling reduced. In activated sludge incubated in wastewater of dairy production the granules were found after 70 days, and their size ranged from 1.5 to 4.0 mm. In samples with urban wastewater, the granules formation started on the 80th day, and their size did not exceed 1.5 mm.

Key words: activated sludge, formation of granules, wastewater, incubation, feeding mode, temperature, indicator microorganisms, sedimentation.

Introduction. Waste water purification is the most important environmental target. With the population growth, industrial and agricultural development, depletion of usable water resources becomes more relevant. Water purification would be not possible without microorganisms. Otherwise chemical reaction in polluted water would take a long time.

Water purification process is done with a help of a complex biocenosis of microorganisms called activated sludge. Activated sludge includes representatives of different systematic groups: bacteria, animalcule, rotifer, worm, fungi and algae. Activated sludge is represented by brown floccules up to hundreds of micrometers. At the same time it consists of 70% of living organisms and 30% of inorganic matter. Flocculus bacteria prevail among all living organisms, the number of which in activated sludge biocenosis is up to 90% [1].

In biological process of aerobic wastewater purification, high biomass growth and formation of great number of waste activated sludge takes place. That is a significant weakness, because waste activated sludge dewatering requires high power consumption and its deposition damage the environment. Thus, granulate sludge usage is the solution.

The difference between granulate activated sludge and flocculate sludge is in particle size and subsidence rate. Usage of granulate sludge lead to minor biomass excess formation; stability improvement to pollution and toxicants; possibility to use higher load per unit of volume; improvement of sedimentation characters of activated sludge and its filtration characteristics in terms of dehydration; bulking and foam forming is observed [2].

Factors affecting on activated sludge granules formation in aerobic conditions are of different nature: – biological – simultaneous presence of thread bacterium and flocculus in biocoenosis of activated sludge; – physical-chemical – hydrodynamic features (hydrodynamic stress), wastewater composition (COD up to 7,000 mg/dm^3, pH within 7–8.5), extremely short settling time, obligatory starvation after loading. Hydrodynamic stress caused by drag force of fluid and air stream in the time of vigorous aeration, helps to granulate activated sludge floccules. Active producing of extracellular polymer substances takes place [1].

The objective of the study includes condition selection and factor research that influence on formation of activated sludge granules under aerobic conditions of urban wastewater and wastewater from dairy processing plants usage as a substrate.

Main part. Research subject is an activated sludge (Fig.1), urban wastewater and wastewater from dairy processing plants. Pollution level of wastewater according to COD is equal to 450–600 mg/dm^3, wastewater from dairy processing plants – 3,500–5,000 mg/dm^3.

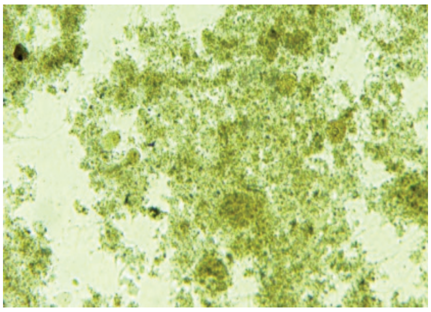


Fig. 1. Initial activated sludge (10×)

Initial mixed liquor was prepared as follows: activated sludge was put in a measuring cylinder then it was settled during 7 minutes, 60–70 ml of supernatant liquor was decanted, after that the batch volume was brought to the required extent (100 ml) by a volume of urban wastewater or wastewater from dairy processing plants and after all it was put into conical vessel of 250 ml volume.

For aerobic granular sludge formation, mixed liquor was incubated with the help of Environmental Shaker-Incubator ES-20 with operating frequency of 140 r/min. The pH level was within 6.8–8.5, temperature – 20, 25, 30°C. For incubation sequencing batch regime was chosen. For each type of wastewater and each temperature value, incubation was made in 3 flasks.

After each stage of incubation, mixed liquor settling was made same as described above. Activated sludge was fed with a fresh portion of wastewater. COD and pH value of supernatant liquor was set.

During the experiment pH target value of urban wastewater fluctuated within the limits of 6.8–7.7. COD level was equal to 50–100 mg/dm^3. For wastewater from dairy processing plants these indicators were within the limits of 6–7 and 250–400 mg/dm^3.

To observe nodulization proceedings microscopic examination of sludge was made.

Microorganism distribution for indicative groups in initial activated sludge can be seen in Fig. 2. Low development level of activated sludge should be also mentioned.

The highest percentage of microorganisms (up to 80%) is testate amoebas. In the process of nodulization changes in quantity and species composition according to indicative groups of microorganisms was observed. After 14 days of mixed liquor incubation, the number of testate amoebas significantly reduced.

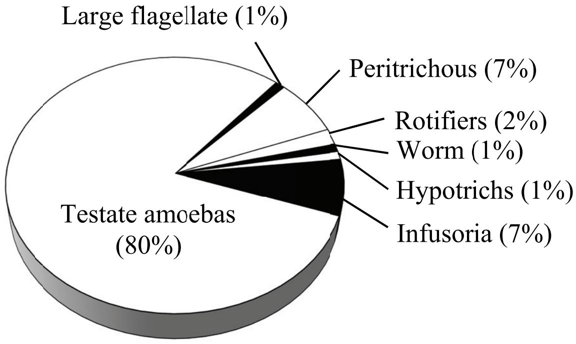


Fig. 2. Microorganism distribution for indicative groups in initial activated sludge

Peritrichous percentage due to incubation on urban wastewater increased to 34% and up to 61% on dairy processing plants (Fig. 3). The number of infusorian also decreased. Oligochaetes extinction was observed. After 30 days from the beginning of incubation, some difficulties with composition analysis of activated sludge biocoenosis appeared. It happened because of microorganism concentration on the surface of granules, which hindered the calculation.

In the beginning of activated sludge incubation process nutrition regome 1 time in 4 days was chosen. However, as it can be seen on the Fig. 4, activated sludge volume, that was incubated on urban wastewater, began strongly decrease because of the lack of nutritional chemicals. At the same time, due to high content of nutritional chemicals activated sludge on the dairy processing plants wastewater grew intensively.

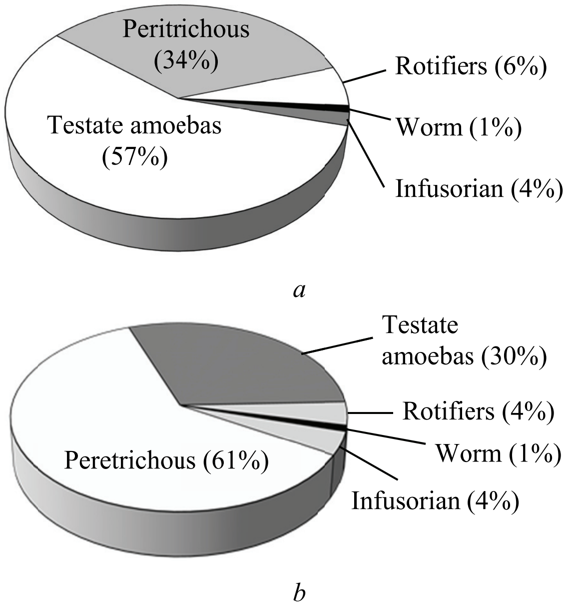


Fig. 3. Microorganism distribution for indicative groups in initial activated sludge in 14 days of incubation:
a – incubation on urban wastewater;
b – incubation on wastewater from dairy processing plants

On the 42nd day of incubation, feed system was changed: fresh dose of urban wastewater was added 1 time in 4 days; dairy processing plants wastewater – 1 time in 10 days. Such feeding schedule enabled to ensure the stability of activated sludge volume (Fig. 4).

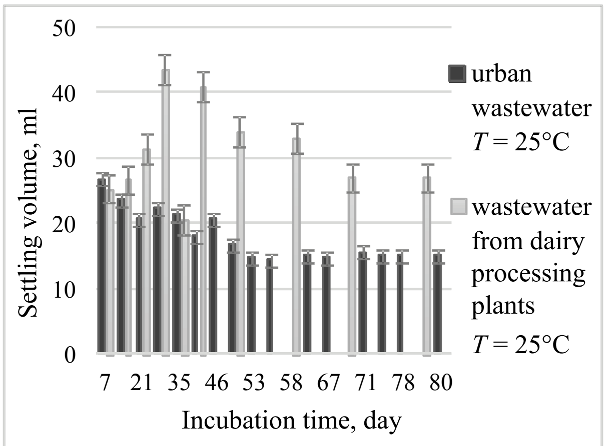
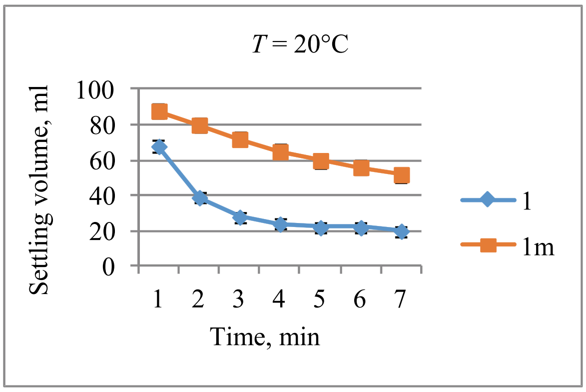


Fig. 4. Sludge volume change during incubation (settling time – 7 min)

The difference in sedimentation characteristics of activated sludge, incubated at different temperatures was also noted. Sedimentation rate of sludge with incubation temperature increase: volume change of sludge, incubated at 25 и 30°C (Fig. 5, *b*, *c*) in the first 3–4 minutes of sedimentation, almost reaching its target value to that time; sedimentation of sludge incubated at 20°C (Fig. 5, *a*), occurs gradually, with low sedimentation rate.

Similar correlation for final volume of activated sludge is observed: in 7 minutes of settling, sludge incubated at 25 и 30°C, takes 20 ml and less of the volume (for urban wastewater), while at incubation temperature of 20°C, the final volume of activated sludge, incubated on dairy processing plants wastewater, after 7 minutes of settling, is much more larger – about 50 ml. More favorable temperatures for granules formation were 25 and 30°C. In activated sludge, incubated at such temperatures on dairy processing plants wastewater first granules were discovered on the 70th day. And granules of sludge incubated on urban wastewater were discovered on the 80th day (Fig. 6). In activated sludge, incubated at 20°C to 30th day of incubation, flocculus consolidating and sedimentation with supernatant water was observed. However, further flocculus loosening and their disintegration into smaller occurred. At the temperature of 20°C granule creation weren't observed.

Size of granules, obtained on wastewater from dairy processing plants was equal to 1.5–4.0 mm. Granules created on urban wastewater are smaller, their size wasn't larger than 1.5 mm.



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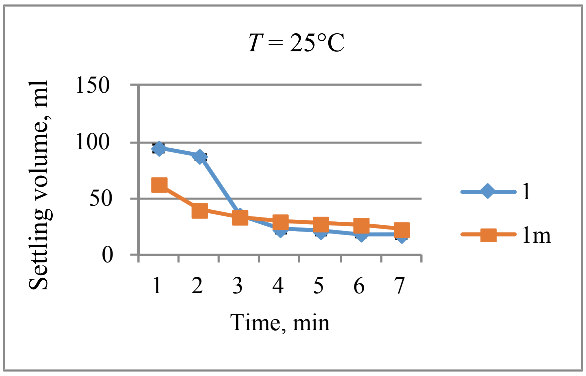

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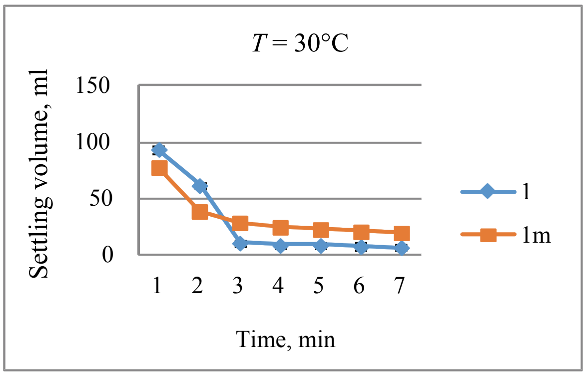

c

Fig. 5. Activated sludge precipitation dynamics in 7 minutes of settling:
a – incubation *T* = 20°C; *b* – incubation – *T* = 25°C;
c – incubation *T* = 30°C; 1 – activated sludge volume, during incubation on communal wastewater;
1m – activated sludge volume, during incubation on dairy processing plants wastewater

Conclusion. The dynamics of granules creation during the incubation process of activated sludge under aeration on urban wastewater and wastewater from dairy processing plants was observed in the laboratory.

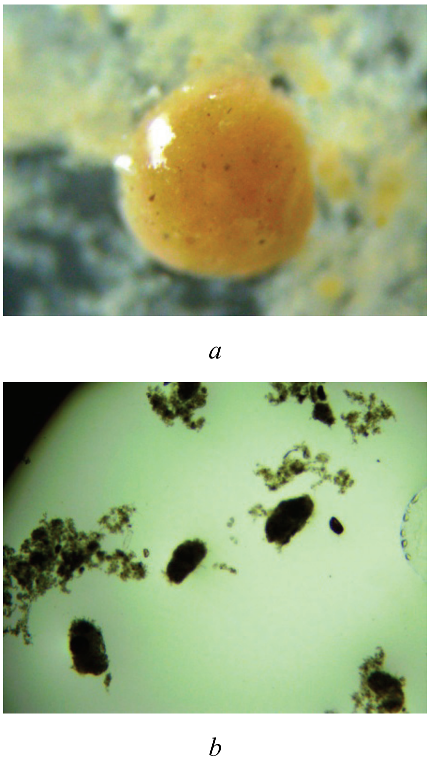

Fig. 6. Aerobic granular sludge (10×):
a – activated sludge, incubated on wastewater from dairy processing plants; *b* – activated sludge, incubated on urban wastewater

Changes in number and species composition of biocenosis of the activated sludge in the nodulization process were observed. Also was noted: essential reduction of testate amoebas, infusorian decrease, loss of oligochaetes that mellow granules.

Percentage of peritrichous increased to 34% under the conditions of incubation from urban wastewater and to 61% of wastewater from dairy processing plants. Stress effect on granules creation was determined. Under condition of stress decrease to low value as a consequence endogenic combustion, the volume of sludge decrease dramatically. Nutrient excess contribute to biomass growth but not to granules formation. Optimum feed condition, 1 time in 4 days for urban wastewater was chosen. And for wastewater from dairy processing plants it was determined to be 1 time in 10 days. The difference in sedimentation characteristics of sludge incubated in terms of different temperatures was noted. With temperature increase of incubation process, sedimentation rate increases while final volume decreases after 7 minutes of settling.

In activated sludge that was incubated at the temperature of 25 and 30°C, on wastewater from dairy processing plants first granules were discovered on 70^{th} day. Their size was equal to 1.5–4.0 mm. Under the same conditions on urban wastewater, granules began to create on 80^{th} day with not less 1.5 mm size. Both of wastewater from dairy processing plants and urban wastewater, typical granules were not created.

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