Probiotics as one of methods for dairy wastewaters’ treatment intensification

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Abstract. Despite the rapid production growth, creation of new technologies improving production quality, the problem of increasing amounts of wastewaters with specific composition and qualities has not solved yet. Wastewaters formed at dairy plants have high concentrations of some contaminations. Qualitative indices of these wastewaters, such as pH, COD, anionic surfactants, nitrogen and phosphorus compounds, differ dramatically from domestic wastewaters’ ones. Wastes and product residuals, dumped into sewage system, aggravate this situation. Nowadays, many plants do not have any local treatment plants, which can cope with polluted effluents, while existing ones cannot provide with required degree of wastewater treatment. This article presents the research of probiotics’ influence on the qualitative composition of dairy wastewaters using Belgian probiotic “Pip Plus WATER”. Besides, based on the experimental research results, a technological scheme of local treatment plant that can be realized at dairy plants is proposed.

1. Introduction

The absence of local treatment facilities at dairy plants is the main reason of dumping highly concentrated wastewaters into water objects or domestic sewage system. In both cases industrial wastewaters do not correspond to standard requirements for pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), anionic surfactants, nitrogen and phosphorus compounds. Some dairy plants remove their effluents to containment ponds that create negative environmental situation due to objectionable odor and groundwater seepage. That is why, it is necessary to find modern solution for treatment and wastewater utilization by construction of new local treatment plants or reconstruction of old ones.

Classical technological schemes of dairy wastewaters treatment include the primary mechanical treatment, the facilities for biological and physicochemical treatment [1-3]. However, these technologies have a number of disadvantages: they are difficult in aerobic treatment facilities exploitation, high electric power consumption and a large amount of the hard-to-treat sludge.

The modern approach to the dairy wastewater treatment problem has several solutions, such as anaerobic digestion of effluents in special bioreactors with methane production [4-8]; treatment in SBR-reactors [9]; usage of membrane technologies [3,10-13] (nanofiltration, ultrafiltration, reverse osmosis); electrochemical oxidation and electrocoagulation [14-16]. However, these technologies have not become widespread in Russian Federation yet.

Besides, biological method of anionic surfactants degradation by pure cultures of microorganisms is of great interest [17]. It is determined, that some bacteria, for example, Ps. aeruginosa, Serratia
marcescens, Escherichia coli, Aerobacter aerogenes, Salmonella enteritidis, Paracolobactrum aerogenoides, use anionic surfactants as the only carbon source, decompose them, and so, decrease their concentration in wastewaters.

One of the perspective possible technologies of dairy wastewaters treatment and sludge processing is the usage of probiotics with high amount of probiotic microorganisms and ferments, which can destroy organic components of wastewaters. Probiotics are nonpathogenic, nontoxic microorganisms, which can absorb organic matters and so, do not leave the nutrient medium for pathogenic microorganisms and putrefactive bacteria [18-19]. Nowadays, probiotics are widespread in medicine for wards disinfection [20-21], in cosmetology, food industry, as detergents.

Most probiotics consist of facultative anaerobes (Bifidobacterium и Lactobacillus) and sporogenous aerobes (Bacillus subtilis, Bacillus subtilis var. amyloliquefaciens, Bacillus licheniformis, Bacillus pumilus, Bacillus megaterium, etc.). Anaerobic bacteria influence wastewater impurities at mechanical treatment, decreasing decay processes and objectionable odor. Besides, they produce hydrogen peroxide that while decomposing in aerotanks, increases the concentration of dissolved oxygen in wastewater [19]. As a result, it becomes possible to reduce the air supply in aerotanks and, as consequence, electric power consumption.

There are three ways of adding probiotics into wastewaters: before sand catcher, before first settling tank and before aerotank. The most effective way is adding probiotic into wastewater before first settling tank for intensification of sedimentation, decreasing the raw sludge volume, decreasing decay processes in first settling tank [18].

Besides, the research on the probiotics dose impact on COD change in model wastewater solution, on reduction of organic matters and suspended solids in wastewaters of Tyumen treatment facilities as well as probiotics impact on sedimentation characteristics of active sludge [22] has been conducted. According to the obtained data, addition of probiotics in first settling tanks reduces COD on 12.2%, suspended solids on 84.2%. In addition, sedimentation characteristics of active sludge improved significantly.

The aim of this research is to determine the influence of probiotics on dairy wastewaters treatment as well as to suggest the technological scheme of such wastewaters treatment.

2. Methods

The research has been carried out at the laboratory of the Department of Water Supply and Sewage (Industrial University of Tyumen, Russia).

The studied wastewater is a mixture of industrial wastewaters from tank truck, pack and equipment washing, and fecal wastewaters from shower rooms and toilets of local dairy plant. Nowadays, wastewaters from this plant accumulate in impounding reservoir, from where the samples were taken.

Belgian probiotic “Pip Plus WATER”, taken for the experiment, is a liquid, consisting of 6.36 mln/ml bacteria Bacillus (Bacillus subtilis, Bacillus subtilis var. amyloliquefaciens, Bacillus licheniformis, Bacillus pumilus, Bacillus megaterium) in endospores and ferments.

In the laboratory the qualitative composition of initial wastewater was determined, and after that wastewater was treated according to Table 1.

| Sample | The variant of treatment | Time of treatment |
|--------|--------------------------|-------------------|
| A      | Constant aeration without probiotic | 72 hours |
| B      | Addition of probiotic (0.01 mg/dm3) | 72 hours |
| C      | Addition of probiotic (0.01 mg/dm3) and constant aeration | 72 hours |
| D      | Addition of probiotic (0.01 mg/dm3) and one-time addition of nutrient substrate (sugar solution) | 72 hours |
Wastewater quality before and after treatment was estimated according to several indices: pH, chemical oxygen demand (COD), concentrations of anionic surfactants, ammonium NH4+, nitrates NO3- and phosphates PO43-.

The pH was measured according to standard method by pH meter pH-150 MI. COD was measured with photometrical method. 3 cm3 of potassium dichromate, sulfuric acid and silver sulphate, as well as 0.2 cm3 of mercury sulfate and 2 cm3 of sample were added into vial, then vial was closed and accurately mixed. After that, vials were placed to thermoreactor “Termion”, heated before to 150°C, and held two hours. Then removable part of thermoreactor together with vials was cooled, and COD was determined with fluid analyzer "Fluorat-02".

The concentration of anionic surfactants was determined fluorimetrically with fluid analyzer "Fluorat-02". 5 cm3 of wastewater sample, 4 cm3 of distilled water, 1 cm3 of hydrochloric acid and acridine yellow as well as 5 cm3 of chloroform were placed into separating funnel. Further, extraction of anionic surfactants was realized by shaking the separating funnel during 2-3 minutes. After layers division sample was taken into cell for determination of anionic surfactants concentration.

The concentrations of NH4+, NO3- and PO43- were measured by the system of capillary electrophoresis "Kapel-150M". One Eppendorf tube with the sample, four Eppendorf tubes with buffer solution, one – with sodium hydroxide and one – with distilled water were centrifuged during 5 minutes with 5000 rpm and then placed into the system of capillary electrophoresis. According to received electrophoregram the order of peaks determines the qualitative wastewaters composition, while the area of the peaks determines the concentration of ion in wastewater.

All experiments have been conducted in three parallels for calculation of measurement error, which was not higher than 10% for all indices.

3. Results and discussions
The results of measurements of samples qualitative indices are shown in Table 2.

| Qualitative index | Initial wastewater | Samples |
|-------------------|--------------------|---------|
| pH                | 5.50               | A 1 day | B 1 day | C 1 day | D 1 day |
|                   |                    | 7.82    | 7.76    | 5.63    | 7.00    |
|                   |                    | 5.63    | 7.00    | 5.56    | 8.45    |
|                   |                    | 8.45    | 5.16    | 5.99    |         |
| COD, mgO/dm³      | 5260               | 3848    | 3660    | 4730    | 3330    |
|                   |                    | 3330    | 3630    | 770     | 4710    |
|                   |                    | 3400    |         |         |         |
| Detergents, mg/dm³| 9.24               |         | -       | 8.55    | 5.76    |
|                   |                    |         |         | 8.82    | 3.48    |
|                   |                    |         |         | 8.54    | 7.26    |
| NH₄⁺, mg/dm³      | 10.09              |         | -       | 9.94    | 5.20    |
|                   |                    |         |         | 6.36    | 5.70    |
|                   |                    |         |         | 2.92    | 0.50    |
| NO₃⁻, mg/dm³      | 6.79               |         | -       | 5.88    | 0.73    |
|                   |                    |         |         | 8.50    | 2.64    |
|                   |                    |         |         | 8.63    | 3.70    |
| PO₄³⁻, mg/dm³     | 92.49              |         | -       | 89.62   | 121.30  |
|                   |                    |         |         | 83.92   | 35.16   |
|                   |                    |         |         | 86.98   | 100.90  |

According to the results in Table 2 the dependences of wastewater qualitative indices on study duration were made. The graphs are shown on Figures 1-6.

According to obtained graphs (Figure 1), on third day pH of all samples, except sample D, became required (6.5-8.5). The pH of the sample A has already reached required value on first day of experiment.

COD decreased (Figure 2) in all samples, besides, on first day COD decreased on 10-30%. The maximum effect 85.36% was achieved in the sample C.

The effect of anionic surfactants removal from wastewater (Figure 3) achieved maximum 62.34% for sample C.

The most effect of ammonium removal (Figure 4) was 95.04% for sample D, in other wastewater samples ammonium concentration also decreased.
On first day nitrates concentration (Figure 5) increased 1.25 times in samples C and D because of transformation of organic forms into mineral ones. On third day of experiment, the nitrates concentration decreased in all samples in comparison with initial wastewater. The greatest removal of nitrates was reached in the sample B (89.20%).

![Figure 1. The dependence of samples pH on study duration.](image1)

![Figure 2. The dependence of samples COD on study duration.](image2)

![Figure 3. The dependence of samples anionic surfactants concentration on study duration.](image3)
Figure 4. The dependence of samples $\text{NH}_4^+$ concentration on study duration.

Figure 5. The dependence of samples $\text{NO}_3^-$ concentration on study duration.

Figure 6. The dependence of samples $\text{PO}_4^{3-}$ concentration on study duration.

According to Figure 6, the phosphates concentration in two samples (B and D) increased on 31% on third day. In the sample C phosphates concentration decreased during all experiment, the effect of phosphates removal was 62%.
Besides, the research on the wastewater quality change by adding probiotic, sugar and constant aeration has been conducted, however, the most effect of wastewater contaminations removal was not achieved (COD decreased on 34.05%, concentration of anionic surfactants decreased on 81.2%). Despite this fact, phosphates concentration decreased in 82.58% that was higher than in the sample C.

The possibility of two-hour sedimentation before adding probiotics into wastewater has been considered. This method can decrease the concentrations of suspended solids (76.7%), fats, anionic surfactants (66%), COD and ammonium (30-40%) that significantly reduces the capacity of biological treatment plant.

Based on conducted experiments and obtained results, following technological scheme of industrial dairy wastewaters treatment is suggested (Figure 7):

![Figure 7. Suggested technological scheme of industrial dairy wastewaters treatment: 1 - grease-removal tank, 2 - domestic sewage system.](image)

According to the scheme (Figure 7), industrial wastewaters pass through grease-removal tank, where the most part of fats and oil products is removed. Further, effluents are pumped to local treatment facilities. There effluents pass through screens (mechanical treatment) for removal of products rests, then are directed to averager/settling tank. In this facility effluents averaging (because of irregular income to treatment plant), as well as mutual effluents neutralization (because wastewaters can have pH from 5 to 11.5 due to the type of cleaning) happen. In addition, the processes of first sedimentation take place. After it, clarified water is sent to biological treatment, before which probiotic in concentration 0.01 mg/dm³ is added. Extended-aeration system is suggested for biological treatment, where organic matters are oxidized. For removing, the excess active sludge after biological treatment secondary settling tank is provided. After local treatment plant, wastewater can be dumped into domestic sewage system. Besides, treated wastewaters can be dumped into water object or partly returned to the enterprise for its needs. In this case, membrane bioreactor and ultraviolet disinfection can be added to the local treatment plant.

4. Conclusions
Thus, based on the research results of probiotic “Pip Plus WATER” influence on qualitative indices of industrial dairy wastewaters, following conclusion have been made:
- Among all studied variants of probiotics’ treatment the most effective one was using probiotic together with constant aeration, where the maximum removal of organic matters (after 3 days COD decreases on 85.36%, anionic surfactants on 62.34%) was achieved.
- According to the research, it is necessary to include in the technological scheme of local treatment plant extended–aeration system for complex wastewater treatment
- According to the conducted experiments following technological treatment scheme was suggested: Grease-removal tank – screens – averager/settling tank – Adding probiotic – Aerotank – Secondary settling tank (MBR) – UV disinfection (if it is necessary).

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