The experience of laboratory flotation equipment for treating wastes from dairy

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Abstract. This article presents the test results of the laboratory flotation equipment LFM-001 for the treatment of model wastewater simulating sewage dairy production. To simulate effluents, 200 ml of goat milk was mixed with 4800 ml of tap water, which made it possible to obtain a chemical oxygen demand of 2000 mg/dm³. For each test, simulated drains were mixed in different proportions with the air-water mixture obtained in LFM-001 and tap water. To intensify the flotation processes, we used the coagulant Aqua-Aurat with alumina A1₂O₃ and the flocculant Praestol of various modifications.

1. Introduction

Dairy production has developed significantly in the Udmurt Republic nowadays. About milk production, Udmurtia is at 3rd place in the Volga Federal District and 6th in the Russian Federation [1]. Among the enterprises producing the largest volumes of dairy products, the following can be distinguished: Glazov-milk (Glazov), Kezsky cheese factory (Kez), Milkom (Izhevsk), Dabrovich (Mozhga city), Uva-Milk (Uva), etc.

There is a tendency in the republic to increase the number of dairy enterprises, which has a positive economic effect, since there is a constant high demand for dairy products both among the population of the region and in the federal district. However, some questions and problems arise related to the need to treat industrial effluents from enterprises. Created enterprises, as usual, small workshops and production facilities, are located far from large municipal sewage treatment plants. Therefore, such enterprises need to solve problems related to the disposal of wastewater to the required standards, which is often difficult to do due to the specific features of the resulting effluent [2].

The main problem of wastewater treatment of production dairy products is that they are a stable water-in-oil emulsion, which includes washes from equipment, special vehicles, workrooms, household wastewater [3, 4]. The specific consumption of effluents is from 5 to 7 m³ per ton of processed milk [1, 5]. If these drains are turned to biological treatment, then there is a need to remove fats from the sewage and decompose the water-fat emulsion. The presence of fats in the effluent makes it difficult, and more often cause the death of activated sludge due to the blocking by fats of the oxygen necessary for the respiration of bacteria [6].

With a constant discharge of fats with excess of permissible levels, biological treatment systems lose their working capacity. With volley emissions of fat-containing effluents, the operation of biological
treatment systems can be stopped for more than 20 days (until the bacteria are restored to working capacity). In addition, fats are deposited on the inner surface of pipelines and equipment, which complicates the operation of treatment facilities [7–9]. As a method of solving this problem, it is possible to use local treatment facilities for cleaning waste water from fats.

An analysis of the literature resulted that flotation is one of the promising methods for treating wastewater from dairy enterprises. [10–12]. It is characterized by: universality, high efficiency of wastewater treatment (almost 100%), persistent process, wide range of applications, low capital and operating costs, ease of processing, selectivity of pollution, high speed of the process, the possibility of obtaining flotation sludge (sediment) at low humidity (90–95%) and the possibility of recovering concentrated pollutants.

2. Theoretical basis
Flotation is based on the emergence of dispersed particles along with air bubbles. The cleaning process consists of the formation of “particle - air bubble” complexes, the emergence of these complexes on the surface of the liquid with the formation of a foam layer containing impurities, and the subsequent removing of this layer from the surface of the liquid. Flotation wastewater treatment can be carried out in various ways, i.e. it is the formation of air bubbles that occurs using various methods. There are following types of flotation treatment of industrial wastewater [13, 14]:

- flotation with the release of air from solution (vacuum, pressure and airlift flotation) – the method is used to treat wastewater containing very fine particles of contaminants. Idea of this method is to create a supersaturated air solution in the wastewater and, when the pressure decreases, air bubbles are released from the solution which float contaminants, depending on the method of creating a supersaturated air solution in water, vacuum, pressure and airlift flotation are distinguished;

- flotation with mechanical dispersion of air (impeller machines, pressureless and pneumatic flotation units) – the formation of air bubbles mechanically occurs under the influence of vortex movement created by the movement of an air stream in an aqueous medium;

- flotation with air supply through porous materials – passing air through small holes, it is possible to obtain microbubbles that can float the contaminants contained in the liquid. To implement this method, a relatively low air velocity from the hole, a sufficient distance between the holes, and the presence of foaming agents in the liquid are required;

- electroflotation – wastewater is saturated with air due to bubbles constantly emitted from the cathode surface;

- biological and chemical flotation (better to apply at the place of compaction of sewage sludge).

Among all types of flotation, pressure flotation is quite widespread in wastewater treatment processes. [11, 13]. Pressure flotation is carried out using reagents to intensify the cleaning process, and without adding various chemicals.

The widespread use of pressure flotation is due to the high efficiency of wastewater treatment and simple equipment design of the process. Pressure flotation allows wastewater to be treated with an initial pollution concentration of 4–5 g/l or more.

The use of pressure flotation in technological schemes at a certain stage of treatment is determined mainly by the quantitative and qualitative characteristics of the wastewater, and requirements for purified water, as well as economic indicators (capital costs, operating costs).

3. Materials and methods
To determine the effectiveness of flotation industrial wastewater treatment, a laboratory flotation equipment LFM-001 was developed (figure 1) by the staff of department “Water Supply and Water Treatment” (Kalashnikov Izhevsk State Technical University) Currently, this equipment is used in the research laboratory at one of the enterprise in the region.

Laboratory flotation equipment LFM-001 is intended for receiving a working fluid – a water-air mixture (water saturated with fine air bubbles with a diameter from 60 to 100 microns). To prepare the
working fluid (water-air mixture), tap water (from 35 to 40 dm$^3$, depending on the test tasks) is supplied to the aeration chamber, after which water saturated with air is supplied to the flotation chamber, where wastewater is treated. The air flow rate for obtaining a water-air mixture is up to 5% of the water flow rate. The size of the resulting bubbles is determined by the experimentally determined pressure in the aeration chamber and the flow rate of the air-water mixture in the flotation chamber.

![Figure 1. Overall structure of the laboratory flotation unit LFM-001: 1, 5, 10, 12, 22 – ball valve; 2 – wing counter SVU-15; 3, 8, 19 – shutoff valve; 4 – aeration chamber; 6, 7 – thermometers; 9 – pressure regulator (gear); 11 – flotation chamber; 13, 14, 15 – sampler; 16 – compressor; 16.1 – pressure gauge; 16.2 – pressure regulator; 17, 21 – pressure gauge; 18 – check valve; 20 – safety valve; 23 – diffuser.](image)

### 4. Results

A series of tests were carried out to determine the effectiveness of the treatment of wastewater from milk production by pressure flotation at the LFM-001 laboratory unit. For every test, model solutions were prepared based on the averaged composition of milk production effluents [4, 15–17]:

- concentration of suspended solids up to 350 mg/l for dairies and enterprises for the production of milk powder, and up to 600 mg/l for cheese making;
- fat concentration up to 100 mg/l;
- $\text{BOD}_{\text{total}}$ (total biological oxygen demand) for the drains of cheese-making enterprises up to 2400 mg/l, with COD (chemical oxygen demand) 3000 mg/l;
- $\text{BOD}_{\text{total}}$ milk processing plants up to 1200 mg/l, with a COD of 1400 mg/l;
- $\text{BOD}_{\text{total}}$ milk powder production up to 1000 mg/l, with a COD of 1200 mg/l.

For the experiments, model solutions of simulated drains ($V_{\text{wastewater}}$) from dairy production were prepared. For this 200 ml of goat milk was mixed with 4800 ml of tap water in a five-liter container. Analysis of contaminated liquid by COD showed that the initial COD of the liquid is 2000 mg / dm$^3$, which corresponds to the level of COD for real milk production effluents. For each experiment, simulated effluents were mixed in different proportions with a water-air mixture ($V_{\text{water-air}}$), obtained at the LFM-001, and tap water ($V_{\text{tap water}}$). In addition, to intensify the flotation processes, Aqua-Aurat and А12О3, Praestol flocculant of various modifications were used. Amount of components of model solutions and reagents used are shown in table 1.
After flotation in LFM-001, model solutions were settled in laboratory containers for 15 minutes (figure 2), and after this time visual and chemical analyzes (table 2) of model solutions were carried out:

- in the first container, a small concentration of flakes in the liquid was observed, the size of the flakes was from 2 to 4 mm, low turbidity, high transparency, the precipitate was loose with a clear boundary;
- in the second tank, the turbidity of the liquid was the highest, which was due to the presence in the liquid of a large number of small flakes, ranging in size from 0.5 to 2 mm, the precipitate was loose with unclear boundaries;
- in the third tank, the model solution had the smallest turbidity, flakes ranging in size from 0.5 to 2 mm, the concentration of flakes was low, the precipitate was loose with a clear boundary;
- in the fourth container, the flakes were less than 0.5 mm, there was no sediment, but there was a foam layer on the surface 7 mm thick, the layer was dense, with small air bubbles on the surface, less than 0.5 mm in size;
- in the fifth container, flakes smaller than 0.5 mm in size, an 8 mm thick upper layer of foam also appeared with a higher concentration of bubbles than in the previous container;
- in the sixth, capacity of flakes ranging in size from 3 to 6 mm, sediment was observed at the bottom 5 mm high, loose with uneven borders, a dense layer of foam 10 mm thick with a clear boundary was also observed.

Table 1. The ratio of components in model solutions and amount of reagents.

| № container | V_{wastewater}, ml | V_{water-air}, ml | V_{tap water}, ml | Aqua-Aurat, ml | A12O3, mg/dm³ | Praestol 2500, ml | Praestol 650, ml |
|-------------|---------------------|------------------|-------------------|----------------|----------------|----------------|----------------|
| 1           | 250                 | –                | 750               | 2              | 100            | 4              | –              |
| 2           | 250                 | –                | 750               | 2              | 100            | –              | 4              |
| 3           | 250                 | –                | 750               | 4              | 200            | –              | –              |
| 4           | 250                 | 750              | –                 | 2              | 100            | 4              | –              |
| 5           | 250                 | 750              | –                 | 2              | 100            | –              | 4              |
| 6           | 250                 | 750              | –                 | 4              | 200            | –              | –              |

Table 2. The results of the analysis of clarified liquid.

| № container | Aqua-Aurat, ml | A12O3, mg/dm³ | Praestol 2500, ml | initial value of COD, mg/dm³ | COD after purification on LFM-001, mg/dm³ | Cleaning efficiency, % |
|-------------|----------------|---------------|-------------------|-----------------------------|-------------------------------------------|------------------------|
| 1           | 2              | 100           | 4                 | 2000                        | 500                                       | 75                     |
| 3           | 4              | 200           | –                 | 2000                        | 540                                       | 73                     |
5. Conclusions

As a result of using a laboratory flotation unit - LFM-001 for the treatment of wastewater from milk production, the use of coagulants Aqua-Aurat and aluminum oxide Al₂O₃ with a combination of flocculant Praestol 2500 gives the greatest cleaning efficiency, when using Praestol 650, the cleaning effect was lower. Also we have to mention, that when the dose of Aqua-Aurat is doubled, the cleaning efficiency decreases by 2 percent.

Adding a water-air mixture to the model solution did not show significant differences in the cleaning efficiency of model solutions, which is confirmed by the results of Petrov V G, Shumilova V F, Pereira M dos S, Borges A C, Heleno F F et al [1, 12].

However, the use of flotation units in the process of cleaning wastewater from dairy production allows avoiding increased loads on sedimentation tanks, since contaminants float in the form of foam when water-air mixture is added. In this case, it is better to use horizontal or radial sedimentation tanks with integrated flotators.

Acknowledgments

The authors would like to express their sincere gratitude the head of the training laboratory, German Svalov, for organizing and assisting in the development and installation of the laboratory flotation equipment LFM-001.

The work was carried out at the financial support by Kalashnikov Izhevsk State Technical University within the framework of the grant no. DMY/20-70-24 and supported by the DAAD (German Academic Exchange Service) and by the Ministry of Science and Higher Education of the Russian Federation under “Mikhail Lomonosov – B 20” – Programme.

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