Purifying wastewater from dairy plant

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Abstract. Currently, there is a widespread expansion of existing and construction of new enterprises of the dairy industry. Sewage of dairy enterprises is characterized by a high concentration of pollution, their purification being a complex technical and scientific task. Current sewage treatment facilities do not meet the relevant standards, as a rule. This fact disrupts the municipal treatment facilities work significantly and leads to environmental pollution. Flotation and coagulation purification methods as well as their effectiveness in the application of dairy industry enterprises drains are considered. The problem of wastewater treatment of the food industry enterprises is largely related to the extraction of fats. An experimental study to determine the concentration of fat at different stages of treatment by gravimetric and IR spectrophotometric methods was conducted.

1. Introduction

The purpose of the study is to determine the concentration of fat at different treatment stages with the help of gravimetric and infrared spectrophotometric methods.

Wastewater from industrial enterprises contains a large amount of organic pollution: hydrocarbon oils, vegetable oil and animal fats, surfactants, etc. In particular, industrial wastewater of food production and of consumer service enterprises contain up to 20000 mg/l of oils, fats and other organic substances. When combined, these contaminants mix and mingle which result in the formation of a stable emulsion.

At the enterprises of the dairy industry water is used for cleaning process equipment, pipelines, containers (tanks, flasks, bottles, etc.), washing floors, panels of industrial premises, cooling milk and dairy products, for operating process and steam power plants, as well as for household needs. Some of the water is consumed in the milk powder recovery and is a constituent part of the products.

Consumption and composition of dairy enterprises wastewater are determined by the volume and range of products, production technology and are associated with the water supply system. Plantwater supply is carried out either from city or own water supply systems. Water for the technological needs of the enterprise is to comply with drinking water quality. To cool vacuum apparatuses and refrigeration compressors units, to wash transport and to water the territory of the enterprise, it is possible to use process water.

At the dairy industry enterprises there are two types of industrial wastewater: polluted and unpolluted. Contaminated wastewater is generated during the washing of equipment, process piping, road and rail tankers, flasks, glass containers, floors, panels of industrial premises. Unpolluted wastewater is formed during the cooling of milk and dairy products and equipment and, as a rule, is...
released into the circulating water supply system or for reuse for cleaning equipment, containers and other purposes [1].

The fat content in the dairy enterprises wastewater is determined mainly by the range of products and production technology. Depending on these factors, not only the concentration of fats in the wastewater but also the type of these contaminants changes. Wastewater from whole milk production contains fat in the same form as natural milk, since milk loss is the main contamination of these effluents [2, 3]. Milk fats are the smallest follicles surrounded by a hydrated protein coat that emerge extremely slowly when the sewage is settled.

The results of the control have shown that fat-and-oil industry wastewater is muddy, grey and contains flocculated suspended solids. Fats there usually take the form of vegetable oils. There small quantities cover the surface of the water, making it difficult to reaerate and dissolve oxygen. Passing through the sewer networks, these oils adhere to the walls of the channel. It causes contaminants agglutination, which reduces the cross section of stream [4]. In addition, the wastewater contains organic acids and nitrogen substances. They decay after neutralizing thus forming hydrogen sulfide from decaying proteins and regenerative sulfates.

The wastewater temperature of dairy enterprises ranges from 16 to 33 °C. The high water temperature is due to the use of hot water for equipment and cleaning. The average monthly temperature of discharged milk plants wastewater is in the winter 17-18 °C, in the summer 20-25 °C.

The pH value of wastewater is largely determined by the production technology and the range of products. For industries not related to the processes of lactic fermentation, the pH of the runoff is close to neutral (6.8-7.4 for milk canning plants, butter-making factories) [5, 6]. At cheese-making factories, city dairy plants and other enterprises producing cottage cheese and dairy products, a certain amount of whey can be discharged into the sewer network, which leads to a decrease in the pH of the wastewater to 6.2.

Fluctuations in the pH of the effluent are often also caused by discharging acidic and alkaline reagents used in equipment washing to the sewage system. A sharp short-term increase in the pH of the total runoff to 10-10.5 can be explained by the instantaneous discharge of alkaline cleaning solutions, which are mainly used in dairy plants.

The prolonged stay of wastewater under anaerobic conditions (in the sewer network, septic tanks) causes souring of the liquid as a result of lactic acid fermentation and leads to a decrease in pH.

In the production of high-fat products (cream, sour cream, butter), large fat follicles of fat are extracted from milk, they stick together and become enlarged, the destruction of the protein shell taking place[7]. Therefore, the fatty impurities contained in the wastewater of such industries differ significantly in the type and concentration of such contaminants in the wastewater of other dairies. Isolation of dairy impurities from wastewater of high-fat production, for example, by settling the liquid, is much faster and more efficient than from wastewater of other industries [4]. During chemical analysis of wastewater, the amount of fat and fat-like substances extracted by ether or chloroform are determined.

The concentration of extractable substances in the wastewater of factories and workshops specialized in the production of high-fat products is 200-400 mg / l, in wastewater of other types of production it usually does not exceed 100 mg / l [8].

2. Purification of oil and fat wastewater

Polluted wastewater is treated together with domestic wastewater of settlements or other enterprises. Self-cleaning is carried out only in the absence of technical feasibility or economic feasibility of supplying wastewater to general treatment facilities.

Particular attention in wastewater treatment should be given to the isolation of valuable food components from flush water, which, when released into sewers and into water at the decomposition stage, emit highly toxic products. Modern technologies using coagulation and flocculation of wash water to isolate proteins and fat are described in [9]. At dairy factories producing such products as cottage cheese, cheese, casein and other concentrated protein products (or their semi-finished
products), whey is formed, its selection is especially important. Wastewater treatment after whey extraction is performed by flocculation, ultrafiltration, etc.

The wastewater of any enterprise of the dairy industry is characterized by a high concentration of organic substances and biogenic elements and, in general, they can be attributed to biologically oxidized, since the ratio of BOD complete / COD is 80-84% [10].

The experience of using flotation methods for cleaning the effluents of dairy enterprises showed that flotation without the addition of coagulants is ineffective, as it reduces the concentration of fats only by 50-60%, COD by 35-45%, and suspended solids by 40-50%.

When aluminum sulphate or ferric chloride in dose of 100 mg/l (for anhydrous salt) per 1000 mg/l used as coagulants, COD contamination is at pH = 6.7, the purification efficiency for suspended substances is 75-80%, for fats 80-90%, for BOD 60-70%. However, due to the high dose of the reagent, the complexity of the reagent industry and the large volume of sludge (up to 10% of wastewater), reagent pressure flotation is not feasible according to the authors of the handbook [11]. Moreover, the flotation sludge after reagent treatment contains a significant amount of metal ions, which can inhibit the subsequent process of aerobic stabilization, and thus to complicate the dewatering of the sludge and increase the cost of liquid waste exporting. Therefore, the preference is given to non-reagent flotation.

It has also been experimentally proved that in the schemes with further biological treatment, the use of reagent flotation leads to a sharp decrease in phosphates in wastewater, which prevents the normal course of biological treatment processes.

However, reagent pretreatment of wastewater from dairy production is widely used, and studies have been directed to the selection of optimal reagents and their doses [12]. In the practice of operating the wastewater treatment plants at dairy plants, they are also treated by alumina-silicon coagulants-flocculants, modified and unmodified flocculants [13], biofloculants and coagulants based on agricultural wastes [8,9].

3. Fat determination methods
Fats in wastewater can be in three aggregative states—solid, liquid and colloidal. Depending on the formation conditions and composition of wastewater, fats can be in the form of a fatty phase, forming a film on the surface of a liquid, dispersed particles in water (emulsion) and be in a dissolved state. Most often, the all three states of fat are observed simultaneously, which makes it difficult to determine its concentration.

The literature describes some methods for determining fat in wastewater, which are based on the extraction of fat with organic solvents.

The gravimetric method using the Soxhlet extractor, where diethyl or petroleum ether is used as a solvent is the most popular [14]. Gravimetric analysis is based on an accurate measurement of the mass of the analyte or its constituent parts, obtained as a result of an analytical reaction and isolated in a chemically pure state or in the form of corresponding compounds.

The method of the refractometric analysis is based on the change of refractive index of the analyzed liquid substance (or its solution) [15,16]. The beam of light, passing from one transparent medium (air) to another (liquid), falls inclined to the surface of the section and changes its original direction, that is the beam refracts. The refractive index has different characteristics for each individual substance. It depends on the wavelength of the incident light, on pressure and concentration (in case it is a solution).

This study reveals the results of determination of fats and oils content in sewage water (model solution). The results are obtained by means of a photometric method, which is based on changes of the intensity of light that passes through a solution [17,18]. This measurement has been carried out with the help of special optical devices known as photocolorimeters. A part of a light stream passing through a solution is absorbed. After the light stream passed through a solution, it falls on a photocell. The light stream causes an electric current (photoelectric) in the photocell and its force is measured
with a galvanometer. Current intensity here is in direct proportion to the intensity of the light falling on the photocell.

Moreover, the measurement of the mass concentration of fats in natural and treated wastewater is performed by the IR-spectrophotometric method [18]. Measurement of the mass concentration of fats is based on the dependence of the intensity of absorption of C – H bonds in the infrared region of the spectrum on the mass concentration of fats in a solution of carbon tetrachloride [19].

This study presents the results of determining the fat content in real wastewater using the gravimetric and infrared spectrophotometric method.

4. Experimental study.
The object of the research is the wastewater of the dairy enterprises of “Uva-Milk” Ltd.

The control results showed that the production waters of dairy plants can be considered as highly diluted whole milk with whitish color and whey (sour) smell.

For the validity of the experiment, a model solution was prepared; milk was used as the main component. In the tap water, previously brought to a temperature of 40-60 °C, contamination in the form of milk was introduced and the dose of injected contamination was calculated according to certain chemical indicators. Then the model solution was cooled to a temperature of 20-22 °C.

Then the researchers examined the received data and prepared a model solution for further analysis. Vegetable oil was used as the main ingredient for the solution. The tap water was brought to the temperature of 40-60°C. The researchers added pollutants in the form of vegetable oil to this water and calculated the amount of the pollutant according to certain chemical parameters. Then the model solution was cooled to 20-22°C.

Figure 1, preliminary drawn and graduated, was used to determine the concentration of fats and oils in the solution (the model solution having a concentration of fats and oils which is closest to the concentration of run-off).

![Figure 1. Calibration graph for fats and oils calculation.](image)

The fat concentration was determined by the gravimetric method (Federal Nature Saving Normative Document 14.1: 2.122-97) and the IR spectrophotometric method (Federal Nature Saving Normative Document 14.1: 2.189-02), the research results are shown in Table 1.
Table 1. The concentration of fat at different stages of cleaning.

| No | Water treatment stages         | Gravimetric Method (mg/dm³) | IR spectrophotometric method (mg/dm³) |
|----|-------------------------------|-----------------------------|---------------------------------------|
| 1  | Input                        | 84,2                        | 79,3                                  |
| 2  | From neutralizer             | 56,8                        | 51,7                                  |
| 3  | After floatator/Redox        | 9,7                         | 3,5                                   |
| 4  | After aerotank               | 0,6                         | Less than 0,5                         |
| 5  | Output                       | Less than 0,5               | 0                                     |
| 6  | Model solution (fat concentration 100 mg/dm³) | 93                          | 98                                    |

Note * For the validity of the experiment, a model solution was prepared; milk was used as the main component. In the tap water, previously brought to a temperature of 40-60 °C, contamination in the form of milk was introduced and the dose of injected contamination was calculated according to certain chemical indicators. Then the model solution was cooled to a temperature of 20-22 °C.

Thus, we can conclude that fat concentration was determined most accurately with the help of the spectrophotometric method, since the error was 2%.

The literary review of the issue concerning dairy enterprises wastewater treatment showed that the most widely used method of local treatment is the method with the use of various reagents. One of the most common methods for the treatment of industrial wastewater is the treatment with coagulants [20].

The next stage of scientific research will be a series of experiments: the choice of the optimal scheme of reagent processing, the selection of the optimal brands of coagulants and the determination of the specific costs (doses) of reagents.

5. Conclusion
1. Wastewater from any enterprise of the dairy industry is characterized by a high concentration of organic substances and nutrients: the release of high-fat products is 200-400 mg/l, in the wastewater of other types of production it does not exceed 100 mg/l.
2. The most accurate fat concentration is determined with the help of the IR-spectrophotometric method, since the measurement error is 2%.

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