Electroflotation treatment of wastewater from paint-and-varnish production

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Abstract. The paper presents the results of experimental studies of electroflotation treatment of wastewater from the paint-and-varnish production. Based on the obtained data the electroflotation device was developed and patented and the optimal time intervals of the treated liquid stay in this device were established.

With the increasing demand of industrial enterprises for process water, the prerequisites for the introduction of repeated and recycled water supply are created [1]. This problem could be solved comprehensively with the construction of industrial wastewater treatment facilities, modernization, and replacement of obsolete equipment. But some effluents are difficult to treat, for example, wastewater from paint-and-varnish production, which is difficult to bring even to the parameters of process water. The amount of paint-and-varnish production wastewater, types, and concentrations of water pollutants vary widely and depend on the manufactured product and the method of its production, so the composition of pollutants is multicomponent [2].

Wastewater from the paint-and-varnish production, taken for analysis, is the residues of raw materials or semi-finished products formed during the manufacture of products, as well as products of physical-chemical or mechanical processing of raw materials. The suspended matter is the highly dispersed part of pigments with a particle size of 1-15 µm. The approximate speed of their sedimentation does not exceed 0,05-0,2 mm/s. To intensify the process of sedimentation of suspended matters in wastewater from paint-and-varnish production in some cases it is advisable to use electroflotation treatment [3-6].

The electroflotation process is based on the electrochemical phenomena occurring on the electrodes, as well as on the physical and chemical phenomena occurring in the treated liquid, where the dispersed phase is present [7]. This method of purification is the most effective when dealing with multi-component complex effluents, it has a high rate of flow and the purification process control. A significant advantage of electroflotation (EF), for example, on pressure flotation is the possibility of unlimited saturation of the treated liquid with air bubbles, as well as the simplicity of the gas saturation process.

The highest degree of wastewater treatment is achieved in electroflotation devices, having along with the flotation chamber electrocoagulation chamber [8]. In this case, wastewater is preliminarily exposed to both electric fields and metal oxides formed during the process of electrocoagulation, which are products of dissolution of anode electrode plates. When dissolving the anode made of duralumin, aluminum hydroxide is formed in the form of flakes, sorbing particles of contaminating impurity and simultaneously sticking with hydrogen and oxygen bubbles [9-11].
In the electroflotation chamber, the purification process is based on the surfacing of particles of the dispersed phase due to gas bubbles: hydrogen and oxygen. Under certain conditions in the treated water, a large number of tiny gas bubbles are released, which collide with particles of impurities during surfacing and rise to the surface due to the action of molecular and electrostatic forces that promote sticking of particles of impurities with gas bubbles [12-14].

Given the above, the task was set to develop an electroflotation device with an electrocoagulation chamber to purify wastewater with highly resistant contaminants, to find the optimal residence time of the treated water in the chambers.

To carry out the above-described mechanism of wastewater treatment, a laboratory setup consisting of two chambers: an electrocoagulation chamber (EC) (Figure 1) and an electroflotation chamber (EF) (Figure 2) was created.

Figure 1 shows an electrocoagulation chamber for wastewater treatment of paint-and-varnish production with the vertically mounted package of duralumin electrodes with bipolar inclusion. Under the action of electric current, there is an intense dissolution of the anode and enrichment of water with aluminum hydroxide, which sorbs particles of contaminating impurity with the formation of flakes (Figure 3).

Laboratory electroflotation chamber (Figure 2) consists of a body with electrodes installed in the chamber: an anode of graphite, a cathode of steel. The electroflotation chamber is filled with the initial liquid to be treated liquid and supernatant (1:1) with the produced hydroxide after the electrocoagulation chamber. When a constant electric current pass through the liquid to be treated, gases are released at the electrodes, and hydrogen and oxygen bubbles stick together with the flakes formed, flotation complexes (consisting of particles of contaminating impurity, coagulants, gas bubbles), rise and form a foam layer.
The test results of electroflotation treatment with preliminary electrocoagulation of a part of liquid presented in table 1 - 2, was carried out on wastewater of paint-and-varnish production. Table 1 shows that the highest efficiency of water treatment by electrocoagulation is achieved within 15 minutes but this time is not enough for the formation of necessary hydroxide in the electroflotation chamber, so it is advisable to increase the time to 20 minutes.

**Table 1. EC chamber test results.**

| №  | Current, A | pH input | pH output | NTU, input | NTU, output | t, min | U, V | Effectiveness, % |
|----|------------|----------|-----------|------------|-------------|--------|------|------------------|
| 1  | 6,4        | 7        | 8         | 2719       | 33          | 15     | 14,8 | 98               |
| 2  | 6,9        | 5        | 7,5       | 1990       | 1079        | 20     | 14,5 | 46               |
| 3  | 6,13       | 5        | 8         | 2318       | 1020        | 20     | 15,3 | 78               |
| 4  | 6,89       | 5        | 7,8       | 2606       | 1320        | 20     | 14   | 50               |

The optimum time of electroflotation, at which the highest value of efficiency of wastewater treatment of paint-and-varnish production is achieved, is 40 minutes (Table 2).

**Table 2. EF chamber test results.**

| №  | Current, A | pH input | pH output | NTU, input | NTU, output | t, min | U, V | Effectiveness, % |
|----|------------|----------|-----------|------------|-------------|--------|------|------------------|
| 1  | 1,5        | 5        | 6         | 1408       | 41          | 40     | 14,8 | 97               |
| 2  | 1,1        | 5        | 6         | 1270       | 27,6        | 40     | 15,5 | 98               |
| 3  | 1,9        | 5        | 5         | 1230       | 53          | 40     | 15,3 | 96               |
| 4  | 2          | 7        | 6,5       | 1240       | 66          | 30     | 14   | 95               |

Figure 5 presents a diagram of the experimental dependence of the effectiveness of the model of combined electroflotation device from the operating time (together with the electrocoagulation and electroflotation chamber). The diagram shows that the time of treatment of paint-and-varnish production wastewater in the combined electroflotation device should be 60 minutes to ensure the highest efficiency.
Intensification of water purification processes can be achieved by using more energy-intensive methods, in particular, described in [18-21] and other works.

Based on this research, an electroflotation device was developed and patented. Its main distinction is the division of the flow of liquid to be treated into two parts, one of which is fed into the electrocoagulation chamber, where hydroxide is formed, which passes into the chamber of electroflotation and mixes with the main flow and sorbs particles of contaminating impurity while sticking air bubbles. Hydroxide has a higher sorption efficiency than the known ones used in the reagent industry - it is a coagulant in its pure form, without impurities. As a result, strong flotation complexes are formed, which floated into a foam layer. The resulting foam is also resistant to destruction. The efficiency of water purification in the assumed electroflotation device is 93-99%, and the known (analog) 89-90% at the specific power consumption of 0.8 – 1.4 in the assumed and 2.1 – 4.9 in the known. Therefore, the use of the proposed electroflotation device allowing significantly improves the efficiency of water treatment at lower specific energy costs [17].

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