Using an ejection system for supplying water and reagent in combined flotation apparatus

I I Zavodyanoy, S N Kapitonova and B S Ksenofontov

Department of Ecology and Industrial Safety, Bauman Moscow State Technical University, 105005 Moscow, Russia

zavodyanoy@mail.ru

Abstract. The paper highlights the problem of rational use of water resources, based on the increasing need for compact combined devices based on the processes of coagulation, deposition, and flotation. To improve the quality of water treatment, an original design of the ejection system for water and reagent supply has been developed. The main geometric parameters and features that allow solving the problem of “dead zones” are analysed. The use of such a system increases the efficiency of cleaning the fat-containing wastewater by supplying a water-air mixture and forming easily floated “particle bubble” complexes.

1. Introduction

The use of devices operating on the basis of the flotation and filtration processes requires significant capital investments and large occupied areas [1-9]. Therefore, from the possible alternative options, it is proposed to develop an ejection supply of water and reagent in devices that combine the flow of several processes at once [10-12].

Based on the studied designs, it has been found that the simplest and cheapest device is the ejector, but its significant drawback is limited supply zone of the water-air mixture, that is, uneven distribution of bubbles over the working volume with formation of “dead zones” [13-18].

2. Methods

To solve the problem, we have investigated the constructions of the ejectors with reagent supply and air suction in various parts of them. Modelling was carried out in ANSYS Workbench 2020 R2 program. We have considered the increase and decrease in the outlet pipes, changes in the length of the nozzle, and changes in the length and width of the mixing chamber. Various methods of supplying reagent and air to the designed ejection system were examined. Of all the options studied, three designs were chosen as the most optimal (Tables 1 and 2).

| Specifications          | Values |
|------------------------|--------|
| Air consumption, m³/h  | 0.06   |
| Regent consumption, m³/h| 0.5    |
| Water velocity, m/s    | 20     |
| Air velocity, m/s      | 0.5    |
| Reagent velocity, m/s  | 4      |

Table 1. Ejection system specifications.
Table 2. Geometric parameters of the ejection system.

| Designation               | Diameter, mm | Length, mm |
|---------------------------|--------------|------------|
| Wastewater inlet          | 6            | 25         |
| Air inlet                 | 3            | 10         |
| Reagent supply pipe       | 3            | 10         |
| Distribution chamber      | 30           | 12         |
| Mixing chamber            | 13           | 28         |
| Models 1 and 2            |              |            |
| Outlet connections        |              |            |
| Models 1 and 2            | 4.5          | 30         |
| Model 3                   | 3            | 3          |

In the first construction, air and reagent enter the distribution chamber at an angle of 45° (Fig. 1). The modelled mass flow and velocity distributions for Model 1 are shown in Figure 2. After modelling in the mixing chamber, it is clearly seen that there is insufficient mixing of the media, which is one of the main indicators of the efficiency of the system. Geometric parameters are presented in Table 2.

![Figure 1](image1)

**Figure 1.** Model 1. Ejection water supply system with a reagent dosing pipe and air supply to the distribution chamber. 1 – wastewater supply pipe; 2 – reagent dosing pipe; 3 – pipe for air suction; 4 – mixing chamber 5 – pipe for supplying water-air mixture (5 pieces); 6 – distribution chamber.

![Figure 2](image2)

**Figure 2.** Model 1. (a-c) Distribution of media in the cross section of the model in XY coordinates: (a) water mass fraction, (b) air mass fraction, (c) reagent mass fraction. (d-f) Velocity index in the cross-section of the model in XY coordinates: (d) water velocity, (e) air velocity, (f) reagent velocity.
The next considered model is an ejection system with air and reagent supply to the mixing chamber (Fig. 3). The modelled mass flow and velocity distributions for Model 2 are shown in Figure 4. The tangential arrangement of the nozzles allows you to additionally swirl the fluid flow for more efficient mixing of water and reagent solution. But an increase in the length of the pipes does not lead to anything, since there are zones without sufficient mixing, they are indicated in red. Geometric parameters are presented in Table 2.

**Figure 3.** Model 2. Ejection water supply system, with a reagent dosing pipe and air supply to the mixing chamber. 1 – reagent dosing pipe; 2 – pipe for air suction.

**Figure 4.** Model 2. (a-c) Distribution of media in the cross section of the model in XY coordinates: (a) water mass fraction, (b) air mass fraction, (c) reagent mass fraction. (d-f) Velocity index in the cross-section of the model in XY coordinates: (d) water velocity, (e) air velocity, (f) reagent velocity.

**Figure 5.** Model 3. Ejection water supply system, with a pipe for dosing the reagent into the mixing chamber and supplying air into the distribution chamber, with straight outlet pipes. 1 – reagent dosing pipe; 2 – pipe for air suction.
Finally, a model of an ejection system is presented with air supply to the distribution chamber at an angle of 45° and the reagent supply tangentially to the mixing chamber with reduced outlet pipes located horizontally (Fig. 5). The modelled mass flow and velocity distributions for Model 3 are shown in Figure 6. The study of an ejection system with reduced outlets shows that this design feature allows for a more uniform mixing quality. Geometric parameters are presented in Table 2.

3. Results
At the Bauman Moscow State Technical University at the Department of Ecology and Industrial Safety, the design of a combined apparatus with an ejection system for supplying water and reagent has been developed (Fig. 7).
The essence of the apparatus is as follows. Wastewater enters the body of the skimmer 1 through the inlet 2 with an ejection water supply system 8. The ejection system (Fig. 8) operates as follows. In the narrowing section of the distribution head 1, a reduced pressure is created, which causes air to leak through the nozzle 4 and, as a result, a water-air mixture is formed. This mixture enters the apparatus through the distribution pipes of system 2 (Fig. 5) and provides the greatest uniform coverage of the entire volume of liquid, which solves the problem of “dead zones”. Large hydrophobic impurities (fat particles) and the formed “particle-bubble” complexes float to form a fat layer. Solid particles entering with the initial flow settle to the bottom of the apparatus from where they are periodically removed through the unloading device 6.

**Figure 8.** Ejection system for supplying water and reagent. 1 – distributor head; 2 – pipe for supplying water-air mixture (5 pieces); 3 – branch pipe for waste water supply; 4 – branch pipe for air suction; 5 – branch pipe for dosing reagent.

Further, the clarified water enters the thin-layer clarification block 14, which serves not only to stabilize the flow of water velocity in the apparatus, but also to intensify the extraction of flotation complexes [2]. The flotation complexes trapped in the inter-shelf space quickly reach the upper shelf due to the small distance between the shelves (50 mm). The flotation complexes adhered to the upper shelf are combined (coalesced) into large aggregates, which contributes to the appearance of a large buoyancy force and the rapid floatation of these complexes into the upper foam layer.

The main technical characteristics of the combined flotation apparatus with an ejection aeration system are presented in Table 3.

**Table 3.** Technical characteristics of the combined apparatus with ejection aeration system.

| Specifications                        | Values         |
|--------------------------------------|----------------|
| Wastewater consumption, m³/h         | 5              |
| Reagent dose 5% FeCl₃, ml/l          | 2.5            |
| Current density, mA/cm²              | 10             |
| Electrode material                   | Graphite       |
| Loading type in filter element       | (UVIS-AK-V)    |
| Cleaning efficiency, %               |                |
| Suspended matter                     | 97             |
| Fats                                 | 99             |
| Fe                                    | 82             |
The developed apparatus differs from the others. First, at the end of the ejector a special nozzle is attached, which is not present in other existing flotation plants at the moment, due to which the “dead zones” in the chamber are removed. Second, a filter made of UVIS-AK-V material provides a higher and more efficient wastewater treatment.

Purification efficiency can reach up to 3 mg/l for suspended solids, 0.63 mg/l for iron, 5.5 NTU for turbidity, and up to 0.05 mg/l for fats and oil products.

4. Conclusion
The main geometrical parameters of ejectors with reagent supply and air extraction in different parts of the ejector are investigated and analysed. As a result, the Model 3 was chosen with air supply to the distribution chamber at an angle of 45 degrees and reagent supply tangentially to the mixing chamber with reduced exhaust pipes located horizontally.

This design provides a more uniform mixing quality, solves the problem of dead zones, and reduces capital costs by eliminating additional bulky mixers.

The developed flotation device with an ejection water supply system can be used in meat processing plants, dairy plants, poultry farms, creameries, breweries, vegetable oil production plants, etc. To achieve a high level of wastewater treatment.

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