The research of mixing reagents with wastewater process using ejectors

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Abstract. The article presents the results of studies on the use of an ejector as a device for supplying and mixing a reagent with treated water. New design-improved models of ejectors are proposed to intensify the mixing process and to improve the quality of reagent-water mixture received at the outlet. The models' operation parameters were studied using the ANSYS software. Visual results of modelling processes inside the ejectors of different types are shown in the article. Based on the results, it can be concluded that the economic and energy costs of wastewater reagent treatment can be reduced by using the proposed ejector model as a device for supplying the reagent into the treated wastewater.

1. Introduction
The use of reagent water treatment is one of the most common methods of water treatment [1-5]. In the reagent treatment of wastewater, it is important to select not only the dose of reagents, but also the process of mixing reagents (coagulants and flocculants) with water. Rapid mixing of reagents with water, as a rule, increases the efficiency of their use in further purification by flotation and coagulation methods [6-7]. Nevertheless, the use of devices with mechanical mixers for these purposes, as the most effective technical means, leads in some cases to the destruction of the resulting aggregates, which requires strict compliance with the mixing time interval. The ejector is the easiest and at the same time the most effective device in this case, but it was not previously considered in this way [8-11].

In this study, an ejector was considered as a device for feeding the reagent into purified water, which functions as a jet pump and allows dosing and mixing the reagent with the water being purified.

The coagulation process is quite fast, so it is important to distribute the reagent in the water as evenly and quickly as possible to achieve the best result of wastewater treatment. In this regard, the controlled parameters in this study were the homogeneity of the mixture, which characterizes the quality of mixing, and Camp’s criterion, which characterizes the intensity of mixing.

To intensify the mixing process due to the greater twisting of the flows, the use of two improved (in comparison with the classical model – model #1) ejector models has been studied: with a tangential reagent feeding nozzle (model #2) and with two tangential symmetrical nozzles (model #3). Numerical and visual simulations in the ANSYS software package were used to study the mixing processes.

2. Methods
As a part of a series of experiments [12-14], three ejector models were designed in ANSYS, in which two flows with unequal fluid characteristics were fed: active flow – wastewater and passive flow – reagent. Functions of heat exchange (energy) were not considered in the experiment; turbulence (k-ε standard model) was taken into account; solid surfaces in contact with liquid are rough (5 μm);
Hydrodynamic parameters were set as follows: \( Q = 0.22 \text{ l/sec} \) – input wastewater consumption; \( Q_2 = 1/5Q \) – reagent consumption; \( P \) absolute = 1.5 bar – wastewater input pressure. The calculation showed fast and stable output to the stationary mode in 60 seconds.

The main parameter studied in the experiment (modelling) was the homogeneity (reagent concentration distribution) of the mixture directly related to the effectiveness of wastewater treatment, because the better the reagent (floculant and coagulant) is distributed in the treated wastewater, the higher the efficiency of the further stage of flotation/coagulation treatment.

From the reagent concentration distribution in the classical model #1 (Fig. 1), we can see that mixing proceeds in a spiral, due to the perpendicular (relative to the active flow) feed of the reagent. As the reagent passes through the mixing chamber, the flow acquires a more and more consistent shade of blue, so the mixture becomes more homogeneous. At the same time, it is clearly noticeable that on the opposite sides of this “spiral”, the colour of the liquid is deep blue, which means a complete absence of reagent in it, i.e. not enough mixing. Figure 1 in section B-B shows the distribution of the reagent in the plane of the ejector outlet section, and it is clearly seen that good mixing is achieved only on 1/3 of the outlet section area. It can be concluded that the homogeneity of mixing depends on the number of turns of the spiral, which forms the reagent, passing the mixing chamber. Thus, to intensify the mixing process in order to obtain a more homogeneous mixture at the outlet, it is necessary to twist the flows more.

For this purpose, the model #2 with a tangential reagent flow pipe relative to the axis of the ejector was designed. It can be seen from Figure 2 that this model allowed achieving the greatest swirling of the reagent flow and led to a better mixing (homogeneity of the liquid) at the outlet of the ejector (section B-B), while maintaining the size and design of most of the ejector elements.

To achieve the most equal mixing, the model #3 with symmetrically located tangential reagent delivery nozzles (Fig. 3) was designed and studied. The amount of feed reagent remained unchanged for the purity of the experiment.

The second important parameter characterizing the mixing process is the gradient of velocity or Camp’s criterion, which is:

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Ca = G \cdot \tau
\]

where \( G \) – gradient of velocity, \( s^{-1} \), \( \tau \) – time of mixing, s.

Therefore, the main objective of the ejector design is to provide the highest values of this parameter to obtain the maximum efficiency of the ejector as a mixer, which causes the importance of modelling the operation of various ejector designs.

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**Figure 1.** ANSYS simulation of model #1. Classic ejector (factory design).
The velocity inside the ejector and, as a result, the velocity gradient will depend on the feed rate of water and reagent, so the experiment was conducted with a gradual increase in the feed rate of active flow from 0.4 m/s to 2.4 m/s with step 0.4 m/s every 7 sec of model “working”.

3. Results
From the results of modelling the distribution of reagent concentration inside the ejectors of different designs, it is visible that twisting the flow with tangential pipe leads to a good mixing of reagent with water even at minimum flow rate (speed 0.4, time 7 sec.): in the ejector outlet section in the plane Y0Z (section B-B) mixing of reagent with water is characterized by a uniform colouring almost over the entire area, which indicates the effectiveness of the ejector as a reagent supply device in wastewater treatment. To get even greater efficiency of using the ejector, i.e. to distribute the reagent in the mixing chamber more evenly, a model with two symmetrically arranged tangential nozzles has been proposed. The result shown in Figure 3 demonstrates almost uniform colouration over the entire area of the outlet.
section, i.e. uniform distribution of the reagent in the same concentration at the outlet of the ejector. A comparison of the homogeneity in outlet section of three ejector models is clearly shown in Figure 4. In addition, simulation of different variants of the ejector-mixer in the software package ANSYS allowed the most accurate and rapid assessment of the most important parameter – the velocity gradient characterized by the Camp’s criterion and, therefore, the intensity of mixing. Simulation results are presented in the form of a graph (Fig. 5), demonstrating that the most effective in terms of mixing intensity is model #3.

![Figure 4. Comparison of three simulations (ejector models) by homogeneity.](image)

![Figure 5. Comparison of three simulations (ejector models) by Camp’s criterion.](image)

4. Conclusion

Thus, the above studies demonstrate the efficiency of using the ejector as a device for feeding and mixing the reagent with the treated wastewater. This indicates the advantage of using the ejector with two nozzles with tangential flow of the reagent supply. The use of the ejector with two tangentially mounted nozzles allows to intensify also the processes of oxidation of organic pollutants presented in wastewater by feeding into the treated water both oxidant solutions and pH regulators. Other applications of the ejector as a mixer of reagents with the treated water are also possible, for example, simultaneous introduction of two reagents into the water, when it is required.
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