Electrochemical water treatment plant for food production

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Abstract. The development of new methods or equipment for water purification in recent years has been an important task. Of the existing methods as promising ones, we can distinguish electrochemical non-reagent purification methods. A design of a water treatment plant has been developed, the main elements of which are a device for electrochemical treatment with electrodes made of titanium alloys and a filter for fine mechanical cleaning. This plant has passed a set of laboratory tests and testing as part of a mobile integrated water treatment plant. According to the test results, it has been found that electrodes made of titanium alloys with the highest titanium content have the best resistance to electrochemical destruction. The rational current density and the range of the gap between the electrodes are determined, which ensure effective water purification with an extended overhaul cycle and sufficiently low metal consumption and energy consumption.

1. Introduction
In various branches of the food industry, water is a key technological or raw material component that affects the quality of the final product [1-4]. Depending on the purpose, the requirements of the relevant regulatory documents are presented to the water quality.

In the process of water treatment, various methods and equipment can be used [5]. The configuration of the water treatment system and the selection of its elements depend on the source of water supply of the enterprise, the composition of the source water, the volume of its consumption and quality requirements for each technological process. Moreover, one of the indicators of the effectiveness of a water treatment system is the reliability, safety and harmlessness of each piece of equipment [6]. These requirements correspond to the design of filters, the housings of which are made of corrosion-resistant steels using rotary rolling [7]. The use of this process in the manufacture of filter housings provides their high strength and durability with low metal consumption, and eliminates possible focus of pollution in the vicinity of welds due to their smoothing [8-10].

Electrochemical methods are the promising ones for water purification and are used for purification from iron, heavy metals, chlorine, fluorine, phenol, organic compounds, for disinfection, clarification, and bleaching [11-12]. Plants for the implementation of these methods are quite compact, high-performance; control processes are relatively easily automated. The development of equipment for electrochemical water treatment is associated with the search for new electrotechnical materials that are low-wear and resistant to anodic polarization of electrodes.
2. The purpose of the study
The purpose of the study is to develop a structure and determine the optimal structural and technological parameters of the plant for electrochemical treatment of water with titanium electrodes.

3. Equipment, materials and methods
During the research, an experimental electrochemical water treatment plant was used, consisting of a water supply system, a device for electrochemical water treatment, a fine mechanical filter for subsequent removal of oxidized impurities and a control system.

A device for electrochemical water treatment (Figure 1), made of AISI 304 steel, contains electrodes made of titanium alloys coated with ruthenium. The electrodes were made of titanium alloys VT1-0, VT1-00, PT-7M and OT4-0.

Water with a dissolved iron content of 2.8 mg/l was used as the initial solution. Electrochemical treatment of water was carried out at a flow rate of 4 l/s and a current density of 96, 121 and 145 A/m².

Checking the concentration of iron in the source and treated water was carried out according to GOST 4011-72 «Drinking water. Methods for determination of total iron».

4. Discussion of the results
During electrolysis, hydrogen bubbles are formed in the gap between the electrodes, which rise up and are removed from the device for electrochemical water treatment. The rate of rise of hydrogen bubbles depends on the size of the gap between the electrodes. It was found that, with a gap of δ<6.0 mm, hydrogen bubbles filled the interelectrode space so tightly that the foam formed in the process prevented the normal course of the electrolysis process, reducing the rate of oxidation reactions, and at very small gaps led to the complete cessation of the electrochemical treatment of water. At δ> 9.5 mm, hydrogen bubbles are no longer an obstacle, the efficiency of water treatment increases, but a larger
amount of energy is required. This leads to an increase in the cost of processing 1 liter of water. In addition, an increase in the current strength on the electrodes leads to more rapid destruction of the coating first, and then the base metal of the electrodes. It was found that electrodes made of titanium alloys containing a larger amount of impurities have low resistance to electrochemical destruction. As a result, it was noted that under the same conditions, the electrodes made of titanium alloys VT1-0 and VT1-00 have the same durability, which is 5-7 times higher than the durability of electrodes from OT4-0 and PT-7M.

Table 1 shows the results of studies evaluating the effect of the gap between the electrodes of titanium alloy VT1-0 and current density on the concentration of iron in purified water.

Table 1. Test results of the electrochemical water treatment plant with electrodes of titanium alloy VT1-0

| The gap between the electrodes, mm | Current density, A/m² | The energy intensity of the process, J/l | The concentration of iron in purified water, mg/l |
|-----------------------------------|----------------------|----------------------------------------|-----------------------------------------------|
| 6.0                               | 96                   | 11.8                                   | 0.74                                          |
| 6.0                               | 121                  | 18.6                                   | 0.33                                          |
| 6.0                               | 145                  | 28.1                                   | 0.15                                          |
| 9.5                               | 96                   | 21.8                                   | 0.68                                          |
| 9.5                               | 121                  | 33.1                                   | 0.26                                          |
| 9.5                               | 145                  | 46.2                                   | 0.06                                          |

An analysis of the results shows that with a gap between the electrodes of 6.0 to 9.5 mm and a current density of 145 A/m², the content of dissolved iron in purified water is guaranteed not to exceed the maximum allowable concentration of 0.3 mg/l. It should be noted that a further increase in current density does not significantly reduce the content of dissolved iron in water, but leads to a sharp decrease in the durability of the electrodes. So an increase in current density to 165 A/m² leads to a decrease in durability of about 2 times.

The developed plant for electrochemical water treatment was tested as part of a mobile integrated water treatment plant. From the test results presented in table 2, it can be seen that all the estimated water indicators met the requirements of the sanitary and epidemiological rules and the standards 2.1.4.1074-01 “Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems. Quality control. Hygienic requirements for ensuring the safety of hot water.”

Table 2. Test results of the integrated water treatment plant

| Water quality indicator                     | Source water | Purified water |
|---------------------------------------------|--------------|----------------|
| Turbidity, mg/l                             | 400          | 1.0-1.5        |
| The iron content (total), mg/l              | 80           | 0.20-0.25      |
| The total microbial number in 1 ml          | $10^6$       | less than 2    |

5. Conclusion
As a result of the studies, the optimal design and technological parameters of the installation for electrochemical water treatment have been determined, providing integrated water treatment with an extended overhaul cycle and sufficiently low metal consumption and energy consumption.

References
[1] Vostrikov S V, Dovgan S A 2010 Water Preparation for Food Production and Quality Control: A training manual (Voronezh: Voronezh State University of Engineering Technologies)
[2] Kretova Ju I and Kalinina I V 2017 Actual aspects of quality raw materials in the production of beverage technology *Proceedings of VSUET* **79** (1) 169–177

[3] Khristyuk A V and Kasyanov G I 2018 Prospects of creation of alcohol-free drinks on light water *Proceedings of VSUET* **80** (4) 229–233

[4] Golybin V A, Fedoruk V A and Gorozhankina K K 2012 Investigation of influence of the method of preparation of the extractant on the structure of beet tissue *Proceedings of VSUET* **4** 129-132

[5] Kalashnikov G V and Atiskov I M 2017 Hydrodynamic properties of sedimentation particles decantation process in secondary recovery water *Proceedings of VSUET* **79** (3) 154–158

[6] Ugryumova S D and Krikun A I 2016 Methodology of comprehensive evaluation of the effectiveness and reliability of production lines of preparation of sea water for the cultivation of aquatic organisms *Proceedings of VSUET* **2** 175–182

[7] Egorov V G, Vasechkin M A, Maslov I N and Latyshev T K 2017 Development of a normalized range of filter housings for water treatment filters from corrosion-resistant steels *Trends in the development of science and education. Pr. of sc. works, materials of XXV intern. sc.-pract. conf. 30 April 2017* (vol 3) (Samara: Publ. house. NITs «L-Journal») pp 13 – 15

[8] Vasechkin M A, Davydov O Yu, Egorov V G and Maslov I N 2016 Shaping high-longevity components of corrosion-resistant pipes by rotary rolling *Chemical and Petroleum Engineering* **52** (5-6) 392-397

[9] Vasechkin M A, Egorov V G, Maslov I N and Kolomenskiy A B 2016 Determination of the optimum conditions at the processing of high-strength corrosion-proof pipelines *Research Journal of Applied Sciences* **11** (4) 85-87

[10] Vasechkin M A, Davydov O Yu, Egorov V G and Maslov I N 2015 Investigation of influence of extent of deformation at rotary rolling-off on cyclic life of precision corrosion-proof pipelines *International Journal of Applied Engineering Research* **10** (21) 42649-42653

[11] Filatova E G 2015 Overview of wastewater treatment technologies from heavy metal ions based on physicochemical processes *University News. Applied Chemistry and Biotechnology* **13** (2) 97 – 109

[12] Mosin O V 2012 Electrochemical water treatment *Plumbing, heating, air conditioning* **132** (12) 20-26