Modernisation of filter design with bulk dispersed media

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Abstract. The object of research in this article is the design of the filter with bulk dispersed media; this type of device has a wide application within the framework of water treatment for technological needs of food enterprises. On the basis of the data of the previously obtained complex of theoretical and experimental studies of the process of bulk filtration of mechanically activated aqueous solutions, the main purpose of the work is to find effective options for modernisation of the filter design with bulk dispersed media, allowing one to improve the filtration process, namely to increase productivity and improve the quality of filtrate. The research methods included both theoretical (methods of analysis, comparison, etc.) and experimental measures aimed at studying vibromechanical activation of the initial solution in the process of filtration, studying the physical and chemical properties of the activated solution, and determining the rational modes of mechanical action. The results obtained in the course of the research are determined by the basis of the modernisation of the device, the changes made in the design had a positive effect on its operation, and the cycle time changed by 20-22%. The achievements of the device modernisation are represented by: built-in vibromechanoactivators; washing and regeneration without the use of reagents; measurement by sensors of indicators in the device tanks before and after the filtering process; improved wear resistance and durability of the casing coating inside and outside. On this basis, further plans are focused on the realisation of the design ideas into an experimental industrial unit and subsequent research in laboratory and industrial conditions.

Keywords: modernisation, design, filter, dispersed media, mechanical activation, aqueous solutions, seawater

1 Introduction

Comprehensive analysis of the study results of domestic and foreign scientists I.G. Bereza, M.A. Vashchenko, E.N. Kal'sina, V.A. Klyachko, G.A. Pankovskiy, V.V. Sapozhnikov, N.K. Khristoforova, N. Ueki, Z. Ikeda, etc., as well as the experience of processing of hydrobionts (of fish and non-fish origin) at fish processing enterprises of freshwater and sea type have shown that one of the most important stages is water treatment, which allows removing...
foreign impurities from water, representing suspended (roughly dispersed), colloidal and dissolved state (Table 1).

**Table 1. Phase-disperse characterisation of impurities according to L.A. Kulskiy**

<table>
<thead>
<tr>
<th>No.</th>
<th>Impurities group</th>
<th>Impurities group name</th>
<th>Impurities class</th>
<th>Impurities content, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Suspended solids</td>
<td>heterogeneous sand particles, poorly soluble metal hydroxides, petroleum products, plankton, bacteria</td>
<td>&gt;10⁻³ ≤10⁻⁷</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Colloids</td>
<td>mineral and organomineral particles of topsoil and subsoil, colloidal iron compounds humus, viruses</td>
<td>&gt;10⁻⁷ ≤10⁻⁸</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Molecular solutions</td>
<td>homogeneous products of life activity and decomposition of bacteria, algae and other aquatic organisms, as well as phenols</td>
<td>&gt;10⁻⁸ ≤10⁻⁹</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ionic solutions</td>
<td>salts, the concentration of which determines the degree of mineralisation of seawater, anions, cations</td>
<td>&gt;10⁻⁹ ≤10⁻¹⁰</td>
<td></td>
</tr>
</tbody>
</table>

The main mass of insoluble impurities (from coarse particulate matter to microheterogeneous colloidal dissolved substances and high-molecular humus compounds) are removed from water as a prerequisite for its preparation for technological needs of fish processing plants. At the same time such organoleptic indicators as turbidity and transparency are improved.

**Fig. 1.** Comparative analysis of dispersibility of filtering materials: 1 - bio-balls; 2 - expanded clay; 3 - electrocorundum (alund); 4 - gravel (sea); 5 - zeolites; 6 - bioceramics; 7 - plastic loading in paraffin (edible); 8 - plastic loading; 9 - sulphocarbon; 10 - sand (sea)
At present, various methods and devices for filtering (as coarse and fine purification) are widely used by fish processing enterprises for water treatment. In practice, multilayer bulk filters with multidisperse filtering granular materials of natural and/or artificial origin (Figure 1), laid in layers on a separating partition, have proved their efficiency. They have a large contact surface with solutions and adsorb macromolecular structures [1].

The selection of bulk dispersed media is guided by the factors shown in Figure 2.

Fig. 2. Factors to be taken into account when selecting granular materials for bulk filtration

Fig. 3. Filter cycle time for granular materials
Such factors may include:

- characteristics of the filter case material (the material from which the case is made must be resistant to the influence of the processed media on it, neutral, strong, durable, etc.);
- the method of regeneration, which should ensure qualitative washing of the filter medium from accumulated contaminants (during a certain period of time during filtration the disperse material loses its barrier property to retain contaminants and thus there is a need for regeneration);
- inclusion in the design of additional elements effective in reducing the rate of overgrowth of pores of granular loadin

However, unbalanced modes of exposure can adversely affect the economic feasibility and lead to increased energy consumption, complicating and weighing the device and others.

Based on these and many other factors there is a need to search for new alternative solutions to improve the efficiency of filtering devices. The authors in the process of scientific research came to the conclusion that it is necessary to apply mechanoactivation (mechanical impact) on the initial water solutions during filtration:

- bottled water “Berdovskaya tae
zhnaya”;
- aqueous salt solution NaCl (3.33 %);
- complex water-salt-flour solution (with addition to 3.33 % salt solution 1 % of wheat flour of the highest grade);
- distilled water with CaCO$_3$ addition;
- seawater (with salinity $S > 35\%$)

Preliminary experiments have shown that pre-mechanoactivation of solutions gives an increase in productivity ($P, m/s$) for 52-55%, reduced filtering time ($\tau, s$) for 44-46%, amount of impurities ($TDS, ppm$) for 11-13%, density reduction ($\rho, kg/m^3$) for 0.1-0.19, viscosities ($\mu, Pa\cdot s$) for 4-6%, surface tension ($\sigma, N/m$) for 15-17%, etc.

Fig. 4. Change in the amount of impurities ($TDS$)
2 Methods and materials

Fig. 5. Principle scheme of the filtering unit: 1, 9 - seawater inlet and outlet branches; 2, 21 - symmetrical wash water outlet branches; 3 - cylindrical body; 4, 5, 6 - layers of granular materials; 7 - eccentric vibration motors; 8 - sealer; 10, 12 - symmetrical spigots of rinsing water supply; 11 - stand; 13, 20 - lower and upper tanks; 14 - observation windows; 15, 16 - start and stop buttons; 17 - potentiometer; 18 - light switch button; 19 - control panel

Fig. 6. Principle scheme of the device for seawater purification: 1 - body; 2, 3 - upper and lower covers, respectively; 4 - branch pipe for sea water supply; 5 - symmetrical branch pipes for rinse water outlet; 6 - filtrate outlet branch pipe; 7 - symmetrical spigots for rinse water supply; 8 - mesh separating partition; 9 - sealing circuit; 10 - layer of granular material; 11 - bubbler (spiral-shaped); 12 - two pneumatic cylinders; 13 - connecting rods; 14 - supply pipes; 15 - sealing sleeves; 16 - air preparation unit; 17 - temperature converter; 18 - temperature probe; 19 - flanges; 20 - bolt pins; 21 - nuts; 22 - support
3 Results and discussion

Fig. 7. Schematic diagram of the installation
The device includes a cylindrical body (1) with upper (2) and lower reservoirs (3). In the upper part of the device there are built-in vibromechanoactivators (4) in the form of plate knives (this form of knives was selected experimentally, showing its efficiency), providing layer-by-layer vibrodispersing of liquids fed for filtration (e.g., sea water) together with impurities in them, at a speed of 2000 min\(^{-1}\) (Figure 8).

Taking into account aggressive properties of sea water, the case was treated inside and outside with special anti-corrosion paint.

The filter provides a spigot for feed of initial seawater (5) and filtrate discharge (6), symmetrical spigots for washing water discharge (7). In the inner part of the device layers of granular materials (8, 9) are poured on a mesh separating partition (10), with a sealing rubber contour (11), resistant to the effects of aggressive media.

Fig. 8. Vibromechanoactivator oscillation amplitude at 2000 min\(^{-1}\) measured by the applications: a – Smart Vibration Meter; b – Smart Meter Pro, Vibration

4 Conclusions

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Built-in vibromechanoactivators provide a change in the properties of the initial solution (shear deformations (flow) in the layers are created, which leads to the breakage of intermolecular bonds, the internal energy of the system increases, surface tension and viscosity decreases, etc.).

- Availability of washing and regeneration without the use of reagents, which reduces the consumption of washing water and filter media;
- Periodic measurement by sensors of parameters in the device tanks before and after the filtering process for operative monitoring of values (TDS, t, pH);
- More wear-resistant and durable coating of the casing inside and outside, aimed at protection against external environmental influences.

In the search for alternative ways to improve the efficiency of bulk filtration of aqueous solutions, attempts were made to apply mechanoactivation and hydrophobic granular materials together. Experiments have shown a negative result, the throughput decreased (by 32÷34\%) in comparison with the throughput when filtering unactivated aqueous solutions through layers of ordinary granular materials (by 39–41\%) and through layers of hydrophobic materials. Also, in the process of filtration it was noticed that the density of filtrate after preliminary vibro-, vibromechanical activation increased (by 0,47–0,49\%). Additional treatment with hydrophobiser inside the filter chamber did not work, because impregnation is not provided for metal surfaces, and this composition assumes porosity of the treated surface.

The proposed improvements allow to apply this device at the sites of water treatment for technological needs of fish processing enterprises, using sea water from the nearest water area and maximum approximation of production conditions to natural ones.

The conducted researches are directed on embodiment of constructive ideas in the experimental industrial installation and the subsequent carrying out of researches in laboratory and industrial conditions.

References