Definition of an optimum method of water preparation for needs of the enterprises

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Summary. Results of technical and economic calculations for various methods of water desalting are presented in article. The prime cost of the desalted water received by each of the considered methods is calculated (in costs of thermal and electric energy). On the basis of the obtained data conclusions are drawn on applicability of each of the considered water desalting methods.

Research objective
The research objective consisted in definition of the most optimum and economic method of preparation of water for needs of the enterprise. The following methods of water desalting have been considered: electrodialysis, method of the return osmosis, evaporator of instant boiling up.

Description of a research objects
Technical and economic calculations of electrodialysis installation (EDI), installation of the return osmosis (RO) and the evaporator of instant boiling up (EIB) with a consumption of water from 10 to 100 t/h have been made.

For each of devices the following indicators have been calculated:
- for electrodialysis installation – consumption of electric energy;
- for reverse-osmotic installation and the evaporator of instant boiling up – consumption of thermal and electric energy.
- for all installations calculation of cost of receiving the desalted water has been made (in costs only of thermal and electric energy).

Table 1. Salinity of initial water (Kazan)

| Cation   | Maintenance of ions | Anion | Maintenance of ions |
|----------|---------------------|-------|---------------------|
|          | m/kg                | mg-eq/kg | m/kg | mg-eq/kg |
| Ca²⁺     | 72                  | 3,6    | SO₄²⁻  | 140     | 2,92   |
| Mg²⁺     | 14,5                | 1,21   | Cl⁻     | 15      | 0,42   |
| Na⁺      | 10,15               | 0,44   | HCO₃⁻   | 140,3   | 2,30   |
| K⁺       | 10,15               | 0,26   |         |         |        |
| Total    | 106,8               | 5,51   | Total   | 295,3   | 5,64   |
Basic data for calculation of electrodialysis installation were the following indicators [4]:
- ionic composition of initial water, mg/kg;
- a consumption of initial water before giving on installation: G: 10, 25, 50, 75, 100 t/h;
- salinity of initial water (Table 1);
- characteristics of the used ionite membranes. In EDI ionite membranes of the Russian production of the MK and MA types 0,7 mm thick, are used by the size 500×1500 mm. A pro-masonry framework are made of a paronite 0,8 mm thick. In membrane space turbulize grids – separators from the viniplast are laid.

Basic data for calculation of the evaporator of instant boiling up [4]:
- consumption of unboiled water G: 10, 25, 50, 75, 100 t/h;
- reference temperature of unboiled water ts=10°С;
- water temperature before an entrance to the installation tm=30°С;
- the specific heat of initial water, c=4,19 kJ/kg · °C;
- temperature of the heating steam ts1=130°С.
- temperature of the initial clarified water (the summer mode): tsi=30 °С;
- temperature of boiling of solution in the last step: tб=47 °С.

Basic data for calculation of reverse-osmotic installation [4]:
- consumption of unboiled water G: 10, 25, 50, 75, 100 t/h;
- reference temperature of unboiled water ts=10°С;
- water temperature before an entrance to the installation tm=30°С;
- the specific heat of initial water, c=4,19 kJ/kg · °C;
- temperature of the heating steam ts1=130°С.

Calculation of consumption of electric energy for reverse-osmotic installation has been executed in the ROSA program.

The ROSA program is developed by the DOW CHEMICAL company for calculation of reverse-osmotic and nanofiltrational installations with application of the membrane FILMTEC elements.

For calculation of prime cost the following data have been used:
- cost of electric energy: \( C_{el} = 4,3 \text{ rub/kW} \cdot \text{h} \);
- for heating of initial water before an entrance on installations it is used pairs of low parameters from a technological production line. Steam parameters are: \( p_s=4 \text{ atm.} \); \( t_m=130 \text{ °C} \). The cost of steam is: 67,98 rub/t.

**Results of numerical researches and their discussion**

![Fig. 1. Dependence of consumption of electric energy on a water consumption](image-url)
According to the diagram submitted in fig. 1 it is visible that with increase in a consumption of initial water, consumption of electric energy increases during using of all considered methods. However the smallest consumption is the share of the evaporator of instant boiling up. The greatest consumption of electric energy is the share of electrodialysis installation at water expenses, it is less than 75 t/h. At expenses, it is more than 75 t/h, the greatest electricity consumption is the share of installation of the return osmosis. Also it is worth noticing that when using reverse-osmotic installations at water expenses less than 50 t/h electricity consumption is lower, than during using evaporators. However at expenses more than 50 t/h at the return osmosis electricity consumption sharply increases as a result of use of high-pressure pumps for water transmission through membranes [5].

![Diagram](image1)

Fig. 2. Dependence of thermal energy consumption on a water consumption

On the diagram submitted in fig. 2 it is visible that thermal energy consumption increases during using both methods of a desalting. However during using evaporators of instant boiling up of heat it is consumed more, than at the return osmosis owing to more high reference temperature [5].

![Diagram](image2)

Fig. 3. A power component of prime cost of the desalted water

According to the schedule submitted in fig. 3 it is possible to draw the following conclusions: at expenses of water from 10 to 75 t/h the greatest prime cost of the desalted water is the share of electrodialysis installations, and at expenses, more than 75 t/h – of the return osmosis installations. At the return osmosis sharp increase in prime cost at water expenses is observed, it is more than 50 t/h. The smallest values of prime cost fall on a method of the return osmosis at expenses of water from 10
to 50 t/h. It is necessary to notice that for the evaporator of instant boiling up at increase in a water consumption, the prime cost decreases [6].

Conclusions

Thus, it is possible to consider reliable that at expenses, from 10 to 50 t/h are more economic to apply a method of the return osmosis to a water desalting, and at expenses from 50 to 100 t/h – the evaporator of instant boiling up.

However in view of the high cost of chemical reagents for washing of reverse-osmotic membranes, the prime cost of the desalted water with method of the return osmosis can grow considerably. Thereof the most optimum method of an water desalting is the evaporator of instant boiling up in all considered range of expenses of water.

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