Improvements of choice of the water-chemical regime of reserve osmosis installation

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Abstract. The effectiveness of monitoring the composition and intensity of deposits on reverse osmosis membranes is shown. The use of test installations of the NGO "NPK Mediana-Filter" speeds up and significantly reduces the labor intensity of monitoring deposits in the conditions of industrial operation of reverse osmosis installations. The effectiveness of determining the composition and intensity of deposits on the membrane surface using the energy dispersive analysis method was revealed. The effectiveness of commercial formulations for cleaning intensely contaminated membranes is not always sufficient. The use of ready-made solutions from various manufacturers excludes the possibility of a targeted selection of the concentration of a solvent to remove deposits from the membrane surface, provided that these solutions are safe for the operating parameters of the membranes. The monitoring results made it possible to implement a targeted choice of compositions of detergent mixtures, their combinations and the regime of their effect on deposits on membranes, provided that the pH of the solutions is stable throughout the entire cleaning time. Controlling the intensity of the formation of deposits according to the data of test installations will reduce the laboriousness of choosing the optimal water-chemical regime of an industrial reverse osmosis plant, which will reduce the rate of formation of deposits, increase the service life of membrane elements of an industrial water treatment plant with a consistently high quality of demineralized water.

1. Introduction
The interest in using reverse osmosis in desalting water is caused by the low quantity of consumed reagents (acids, alkalis, sodium chloride) and the consistently high quality of purified water [1]. Over time, during operation, reverse osmosis (RO) membrane elements are exposed to contamination by suspended or slightly soluble substances present in the source water [2]. The nature and speed of deposits on the membrane surface depends on the ionic composition of the source water and the stability of the pre-treatment system.

2. Research methodology
To determine the composition and quantity of pollutants the following was carried out:
- an analysis of the source water and prediction of possible pollution;
- a visual inspection of the ends of the membrane elements;
- an analysis of the composition of acidic and alkaline solutions after chemical washing of the test setup;
- dismantling (opening) of the membrane element and direct analysis of deposits from the
membrane surface.

To comply with the operating conditions, the production and test plants were connected in parallel, to the concentrate of the first stage of the reverse osmosis installation (ROI) (figure 1) [3].

![Hydraulic diagram of the production ROI.](image)

**Figure 1.** Hydraulic diagram of the production ROI.

### 3. Key results

In the course of the work, the following parameters of the test setup were monitored: flow rates, pressure on mechanical filters, conversion value, and selectivity of membrane elements. After 800 hours of operation of the test setup, the membrane selectivity decreased by 19%, the salt content of permeate increased by 15 times (table 1).

**Table 1.** Test results when connecting a test setup.

| Indicators          | Source water | Concentrate | Permeate | Source water | Concentrate | Permeate |
|---------------------|--------------|-------------|----------|--------------|-------------|----------|
| SDI                 | 8.81         | -           | -        | 9.65         | -           | -        |
| Total hardness, meq/dm³ | 3.8          | 6.8         | 0.04     | 3.9          | 5.2         | 0.58     |
| Calcium hardness, meq/dm³ | 2.8          | 4.9         | 0.03     | 3.0          | 3.8         | 0.36     |
| Magnesium hardness, meq/dm³ | 1.0          | 1.9         | 0.01     | 0.9          | 1.4         | 0.22     |
| Total alkalinity, meq/dm³ | 2.9          | 4.8         | 0.2      | 2.9          | 3.8         | 0.6      |
| Chlorides, mg/dm³ | 26.6         | 50.2        | 1.06     | 38.4         | -           | 8.90     |
| Salinity, mg/dm³ | 690          | 1421.8      | 15.30    | 745.9        | 1025.7      | 41.90    |
| pH                  | 6.7          | 7.7         | 5.7      | 7.0          | 7.6         | 6.3      |
| Flow, dm³/h         | 39.2         | 28.6        | 10.5     | 38.5         | 32.7        | 5.8      |
| Recovery, %         | 27.0         |             |          |              | 15.0        |          |
| Selectivity, %      | 96           |             |          |              | 77          |          |
An increase in the salt content of permeate was a criterion for the chemical washing of membranes. To implement chemical cleaning, the membrane element was connected to a chemical washing station [3].

Chemical washing of membrane elements was carried out in several stages:
- the circulation of an alkaline solution;
- soaking the membrane element, followed by the circulation of the alkaline solution;
- the acid solution circulation;
- soaking the membrane element with a subsequent circulation of the acid solution;
- washing the membranes with distilled water to pH = 6-7 after the circulation of alkaline and acid solutions.

The duration of chemical washing of the membrane element of the test setup was from 6 to 19 hours.

The composition of the deposits was determined by the pollution of the washing solutions (table 2) and by the analysis of precipitation from the surface of the membranes (table 3).

**Table 2.** The composition of the contaminants of washing solutions.

| Indicators               | Alkaline solution | Acid solution |
|-------------------------|-------------------|---------------|
| Suspended solids, mg/dm³| 28                | 35            |
| Total iron, mg/dm³     | 1.0               | 1.4           |
| SiO₂, mg/dm³           | 16.3              | -             |

Deposits from the membrane surface were determined using the energy dispersive method [6] on a Versa 3D instrument at Volgograd State Technical University. The results of the analysis of deposits on the surface of the membranes of the test setup are shown in table 3. Studies of deposits allowed us to clarify the composition of the deposits on the surface of the membranes of the industrial ROI. It was revealed that organic substances, compounds of silicon, iron, and calcium accumulate on the membranes. The data obtained are consistent with the results of the analysis of models of washing solutions of the test setup (table 3).

**Table 3.** Results of the energy dispersive sediment analysis method.

| Element   | Before chemical washing | Percentage, % | Measurement error, % |
|-----------|-------------------------|---------------|----------------------|
| Carbon    |                         | 13.32         | 11.23                |
| Oxygen    |                         | 46.25         | 8.7                  |
| Sodium    |                         | 0.73          | 14.88                |
| Magnesium |                         | 1.55          | 9.2                  |
| Silicon   |                         | 14.47         | 4.75                 |
| Potassium |                         | 1.98          | 4.96                 |
| Calcium   |                         | 3.1           | 4                    |
| Manganese |                         | 0.49          | 19.11                |
| Iron      |                         | 9.17          | 3.07                 |

Chemical cleaning of the test ROI membrane elements with solutions of Nalco Company, NPK Mediana-Filter (model 1, 2) do not provide significant removal of deposits (table 4). Ineffective removal of deposits determines the low quality of demineralized water, high energy consumption of the ROI, expenses for chemical reagents and own needs of the industrial plant.

The research results (model 3) showed that the effectiveness of chemical cleaning of membrane elements depends on the contact time of the washing solutions with the membrane surface and the composition of the solution, as determined by the manufacturer. The advantages of these solutions are determined not only by a change in the composition of the solution but also by the stability of the pH value throughout the entire cleaning time of the membrane models.
Photos of membrane surfaces after the chemical cleaning of the membranes are shown in figure 2.

Figure 2. Photos of membrane surfaces after chemical cleaning (A – model 1, B – model 2).

The research results showed the high efficiency of the washing solutions of NPK Mediana-Filter (model 3). The mass of removed contaminants is 63% greater than when using another washing solution (model 2). The pH value was kept stable throughout the entire cleaning time of the membrane models. With an increase in the duration of chemical cleaning of the membranes, the mass of washed deposits increases (model 3).

The effectiveness of commercial compositions for cleaning intensely contaminated membranes is not always sufficient. The use of finished compositions of various manufacturers eliminates the possibility of directional selection of the concentration and solvent to remove deposits from the membrane surface.

The mass of washed deposits and the pH of the solutions after the chemical cleaning of the membranes are shown in table 4.

Table 4. Change in weight of membrane models using a washing solution.

| Model no. | Cleaning solution manufacturer | Trademarks for washing solutions | Total exposure time of detergent solutions, h | The mass of washed sediment per 1 m², g | pH of solutions before/after chemical cleaning |
|-----------|--------------------------------|-----------------------------------|---------------------------------------------|---------------------------------------|-----------------------------------------------|
| 1         | "Nalko Company"                | PC-33, PC-67, PC-77               | 6                                           | 16                                    | 11.8/9.9, 2.1/6.75                            |
| 2         | "NPK Median-Filter"            | MF – A – T10, MF – B – L20, MF – CRO – 220, MF – CRO – 218 | 6                                           | 20                                    | 12.1/10.35, 2.0/2.0                            |
| 3         | "NPK Median-Filter"            | MF – CRO – 218                    | 12                                          | 26                                    | 11.8/11.4, 2.1/1.6                            |
| 4         | "NPK Median-Filter"            | NaOH, MF – CRO – 218              | 19                                           | 42                                    | 11.0/10.4, 2.1/1.7                            |
The maximum number of deposits is removed from the membrane surface during alkaline cleaning with a NaOH solution (pH = 11.0) for 11 hours and with an acid solution of NPK Mediana-Filter - MF-CRO-218 (model 4). In this mode, the mass of washed deposits increases by 1.5 times.

4. Conclusions
The use of test facilities of NPK Mediana-Filter is an effective way to determine the activity of formation and the composition of the contamination of the membrane elements of an industrial ROI. Determination of the composition of deposits on the membrane elements ensures the selection of the optimal chemical treatment regime for the reverse osmosis production plant. High-quality cleaning of the membranes will reduce the rate of formation of deposits, increase the life of the membrane elements of an industrial water treatment plant with a consistently high quality of demineralized water.

References
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