Development of software product for processing of operating parameters of reverse osmosis systems for the purpose of mathematical determination of water chemistry management methods

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Abstract. The article considers the problems of enterprises using baromembrane water treatment technologies in technological processes. At present, the basic operational data required to monitor the operation of the equipment and to further analyze the efficiency of its use are collected manually, with the collected parameters recorded in the paper operational statements. To avoid the introduction of erroneous indicators and reduce the labor intensity of the process during manual data collection, it is proposed to develop and implement a software product that allows normalizing the parameters of the reverse osmosis installation by recalculating operational indicators taking into account correction factors. In addition, the developed software product allows you to build graphical dependencies of normalized performance, selectivity and pressure differences of reverse osmosis systems. In the future, the program code of the electronic program tracks critical deviations of the calculated normalized parameters and signals to the user the need for corrective actions. The article presents a study of the operation of the membrane plant for the life cycle of membrane elements (3 years). The results of the study of these processes with the help of the developed software product showed a high efficiency of identifying possible problems during the operation of reverse osmosis plants in the early stages, such as the formation of deposits and contaminants on membrane elements, which will significantly increase the service life of membrane elements in various industries.

1. Introduction

At present, at various enterprises using baromembrane water treatment technologies in technological processes, the collection of basic operational data, which are necessary for monitoring the operation of equipment and further analysis of its use efficiency, is carried out manually, with the collected parameters recorded in paper operational statements.

As a rule, this leads:
- to errors and typos related to the human factor;
- labour intensity of analysis of the obtained data, since all parameters before comparison must be recalculated to normalized, taking into account correction factors;
- complexity of operation because it is difficult to quickly detect changes in operating parameters and make the necessary decisions on further operation (for example, send the plant for chemical washing). The experience of using such water treatment equipment shows that
the chemical washing performed on time significantly shortens the service life of the membrane elements [1].

In addition, the studies carried out showed that most optimization measures at enterprises operating reverse osmosis plants mainly include the selection of chemical reagents for washing. We propose an integrated approach that includes:

- analysis of operational data for the purpose of computer prediction of processes, training of the model to identify flushes at actuations of reverse osmotic installation, calculation of their duration and quantity;
- laboratory monitoring;
- introduction of automated data collection and control system.

2. Materials and methods

To solve this problem, it is proposed to implement a software product that allows processing the operational parameters of reverse osmosis plants. In the first step of creating a software product, it is possible to input operational data into the user interface of the program. At the same time, the possibility of entering erroneous information is excluded. This is facilitated by established boundary conditions. After that, the program analyzes the collected data, builds the corresponding graphical dependencies and provides recommendations for further operation of the reverse osmosis plant. In particular, it is necessary or not to wash the membrane elements, whether or not they need to be replaced. The remaining service life of the membranes is reflected in this mode of operation.

Another problem with the operation of baromembrane plants is the issues related to chemical washing, which must be carried out when one of the parameters is reached:

- reduction of plant productivity by 10-15% taking into account temperature correction at constant pressure;
- increase of membrane unit resistance by 10-15% while maintaining constant productivity;
- decrease of membrane selectivity by 10-15%.

In addition, chemical washing can be carried out after a given period of operation of the plant, which is determined experimentally [2-4].

A study of processes related to improving the efficiency of water treatment suggests the need to normalize the operating parameters of the plant, because this procedure allows you to identify possible problems in the early stages (for example, the formation of deposits or contaminants), if such normalized data will be recorded daily [5]. It should be borne in mind that corrective actions are much more effective if implemented early.

3. Results

With the help of the developed software product, a study of the performance of the membrane plant over the life cycle of membrane elements for three years was carried out. This plant is operated at a thermal power station in the Irkutsk region. Graphical dependencies of normalized productivity, selectivity and pressure differences are built. These dependencies are shown in figures 1-3.

At the second stage of research, a laboratory reverse osmosis plant was connected to an industrial plant. The plants operated in parallel on the same water.

The developed program product also allows calculating the required flow rate of water, permeate, the specific conductivity of permeate and concentrate in all nodes of the circuit, the amount and percentage of wastewater produced. In addition, the software product allows you to determine and calculate the optimal operating modes of reverse osmosis plants, which will reduce the amount of wastewater generated.

The programme can be adapted to specific water treatment schemes in different industries.
Figure 1. Change in normalized capacity during the life of the baromembrane system.

Figure 2. Change of normalized pressure drop during operation period of baromembrane system.
Figure 3. Change of normalized selectivity operation period of baromembrane system.

To determine the qualitative and quantitative composition of contaminants of the membrane elements, their visual inspection was carried out, which showed a strong contamination of the ends of the element with a dark brown mass [6-8]. Opening of the element showed the average contamination of the membrane surface with a loose clay-like substance, the humidity of which was 85%, the total amount of contaminants in the element in terms of dry residue - 6.7 g. Chemical analysis of the contaminants of the membrane element showed the following results shown in table 1.

Table 1. Chemical analysis of contamination from the roll reverse osmosis element.

| Key figures to be determined | Content, % |
|-----------------------------|------------|
| Polysilicates               | 42,5       |
| Organic chemistry           | 31         |
| Hardware                    | 13,4       |
| Calcium                     | 5,8        |
| Magnesium                   | 2,0        |
| Sulfates                    | 0,76       |
| Manganese                   | 0,09       |
| Copper                      | 0,09       |

4. Discussion
In industrial plants, chemical washes are usually performed after a given time interval, since in practice in real conditions it is quite difficult to detect a change in operational parameters in time. This is due to the fact that these parameters of a baromembrane system are influenced by the composition
of the source water, the pressure of the source water, the temperature, as well as the degree of concentration [9]. For example, a 4 °C drop in the temperature of the source water will reduce permeate flow by about 10%. However, this is considered normal.

In order to distinguish between such normal phenomena and changes in operating parameters due to any contamination or problems, the measured permeate and salt flow rates must be presented in the so-called normalized form [10-12]. Normalization is the process of comparing actual operating parameters with some given reference parameters, while taking into account the factors of influence on operating parameters. Reference operating parameters may be calculated operating parameters or measured initial operating parameters.

Normalization, in relation to the design (or guaranteed) operating parameters of the system, is useful as a test of the fact that this unit does provide some predetermined (or guaranteed) operating parameters [13-15]. Normalization with respect to the initial operating parameters of the system is necessary to detect any kind of changes in operating parameters between the first day of operation and the current date.

The proposed software product also allows normalization of operating parameters of the reverse osmosis plant and has the possibility of graphical representation of normalized permeate flow rate, salt permeation and pressure drop [16]. The program recalculates the operating parameters of the reverse osmosis installation into normalized ones taking into account correction factors, tracks the slightest deviations of the parameters and signals the user about this. The warning signal that was heard indicates the need for chemical flushing of the equipment [17,18, 20].

5. Conclusion
Thus, the results of the studies made it possible to conclude that the reverse osmosis plant receives water with a high content of iron hydroxide, polysilicates, silicic acid and organic matter.

For the most effective regeneration of membranes and extension of their service life based on the results of autopsy, washing of membranes in several stages is proposed, namely:
1. Washing with 2% sodium tripolyphosphate solution for 1.5 hours at temperature of 30°C [19].
2. Rinse with purified water for 0.5 hour.
3. Washing with aqueous solution containing 2% ammonium fluoride and 1% citric acid for 1.5 hours at temperature of 30°C.

Such regeneration of membrane elements should be carried out in place with reduction of one of its normalized parameters by 10% of initial values after setting to operating mode.

In addition, chemical flushes of reverse osmosis membranes are carried out at the tested plant after the specified time interval determined by the experimental method. Periodicity of membrane regeneration is once every six months.

However, a study of the obtained normalized parameters of the baromembrane system showed that the need for washing occurs once every 4 months, that is, 2 months ahead of the regulated period. Carrying out the flushing after a given period of time will be more efficient, and will also contribute to better cleaning of the membrane elements of reverse osmosis plants.

Thus, this approach is now relevant, since the number of smart sensors and controllers is growing every year. In proportion to this growth, there is an increase in the amount of data coming from them that Data Scientists will work with in the field of energy. The competitive advantage of the proposed technology is complete automation of the process, excluding manual labor, the use of machine learning, which allows you to build accurate forecasts of the behavior of technological equipment, monitor the operation of the plant, as well as timely detect and quickly respond to malfunctions.

Understanding the processes and their analysis will allow solving a number of problems at thermal power plants, which will increase the reliability of water treatment equipment, increase the service life of membrane elements, as well as reduce operating costs in general.

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