Hygiene water membrane treatment in a closed water supply system Nikolay Salnikov

Abstract

Currently, the chemical industry faces the problem of resource saving, which can be solved by developing of minimal waste processes, including wastewater amount reduction. This resource saving problem is critical for special industries, where the maximum possible reuse of valuable components is required, for example, in closed systems when creating an artificial habitat.

The relevance of the work

In the context of resources shortage and environmental legislation tightening, the closed loop water supply development becomes increasingly important. This paper considers the results of the studies that under conditions of severe water deficit allow to develop a closed loop of water supply, based on reverse osmosis, when separating solutions of low molecular weight organic substances. The possible use of the developed water regeneration process aboard a space station during long-term manned space missions is shown.

The aim of the work is to solve a new scientific and technical problem of water regeneration by the method of reverse osmosis with a high coefficient of clean water return in a closed loop of hygiene water supply.

Tasks solved in the dissertation work:

- Analysis of the water regeneration problem from solutions of complex composition by membrane methods and the proposed technical solutions; substantiation of a hygiene water regeneration system development by reverse osmosis with a high coefficient of pure water return.

- Development of a physical model of the processes in the pressurized channels of a reverse osmosis apparatus during water purification from impurities.

- Carrying out experimental studies of the process of reverse osmosis separation of low molecular weight multicomponent solutions of complex composition, imitating a real system, and model solutions.

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- A reverse osmosis apparatus calculating method development, considering the conditions for the purification process and the solution behavior in the system "separated solution - membrane".

- Water regeneration system flow chart development that meets the requirements of minimum size and weight of the equipment and energy consumption.

Scientific novelty:

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- A mode and a system for water regeneration from solutions of lowmolecular-weight organic substances have been proposed and tested at previously unexplored working pressures (less than 1 MPa) and polluting organic components degrees of concentration of 50 times, ensuring the degree of water return of 97 ... 98% with a selectivity of more than 99%. The method and the system for reverse osmosis hygiene water purification are protected by Russian Federation patents.

- It was found that when water is purified from detergent, the osmotic pressure of the solution at the membrane surface is determined by the layer of detergent components connected to the membrane, which was taken into account when developing a physical model of the solvent transport process.

- The previously unexplored possibility of using the analogy between mass transfer and heat transfer when calculating the external mass transfer in the channels of membrane equipment at Lewis numbers Le = 80...110 is shown. A correction was determined in the form of a function $f(Le) = Le^n$, considering the differences in the transfer coefficients and, accordingly, the diffusion and thermal Prandtl numbers.

- A method for assessing the osmotic pressure of a solution at the membrane surface and the driving force of the reverse osmosis process, based on the use of the passport characteristics of the membrane (permeability coefficient) and the actual performance of the apparatus has been developed.

Practical significance:

- The efficiency of low-pressure reverse osmosis for the hygiene water regeneration aboard a space station using conventional detergents is shown.

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- A reverse osmosis apparatus flux calculating method at high degrees of water return and selectivity tending to 100%, based on the use of an analogy between mass transfer and heat transfer and considering the interaction of the solution with the membrane material has been developed. The developed technique was been adopted by JSC NIICHIMMASH.

- A prototype of a hygiene water regeneration system has been developed and tested, which has shown its effectiveness at a high degree of water return and low energy consumption and is the basis for the design of promising hygiene water regeneration systems.

The main provisions for the defense:

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- The main results of experimental studies of reverse osmosis separation of model solutions and real hygiene water.
- Physical model of the process of the detergent mass transfer in the pressurized channel of the reverse osmosis apparatus.
- The diffusion resistance to mass transfer in the pressurized channel of a reverse osmosis apparatus calculation method, based on the use of an analogy between mass transfer and heat transfer, and a reverse osmosis apparatus flux calculating method.
- Method and flow diagram of reverse osmosis hygiene water regeneration with a degree of water return of 97-98%.