Introduction of innovative water treatment technologies - the key to sustainable development of the modern city

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Abstract. The mechanism of conductivity of natural ion exchangers and resin KU-2 in ammonium and chlorine ions. On the basis of experimental data obtained dependence for pure solution and ionit-solution systems allowed to set the concentration of isoconductive solution (in which the concentration of electrical conductivity of the solution is the same as in the ionic). The method of measuring of resistance of a layer of grains of granulated ionite after removal of equilibrium solution by centrifugation is suggested. On the basis of experimental studies the types membrane backfill and determined the optimal modes of implementation of electrodialysis in the cell with membranous backfilling. The conducted researches give the possibility to implement the principle model approach to describe the conductive properties of ion-exchange materials and its experimental verification. The mathematical model of the conductivity of ion-exchange resins and columns, which combines the theoretical approaches of three wired and microheterogeneous model. To check the adequacy of the developed model was investigated the electrical conductivity of synthetic and natural ion exchangers materials, as well as columns of these materials in solutions of different salts. This has allowed us to develop a model to describe the electrical conductivity of ion-exchange materials and to measure the proportion of current which flows through the gel, solution and a mixed channel conductivity in an ion-exchange system containing two-chargers ions. The algorithm of calculation of physical-chemical parameters of water purification process by electrodialysis with ionite membranes with use of ionization in the form of granules, as a intermembrane backfilling. The use of the obtained results will predict parameters of process of ion-exchange purification of model solutions of wastewater and multicomponent industrial solutions.

1. Introduction

Water treatment and water supply are important elements of human activity in industry and in everyday life, including the rational functioning of the urban area. Cleaning and recycling are the most effective ways of treating wastewater. Achieving a high degree of water purification allows it to be reused in the production cycle. When recycling water it is possible to reuse dissolved substances. At present, membrane methods of water purification using electrodialysis are increasingly used in industry and everyday life.

With modern anthropogenic loads on the hydrosphere, increasing the quality requirements for drinking and industrial water, such traditional coagulation and settling water purification technologies are not effective enough. The use of membrane technology in industry opens wide prospects for the creation of fundamentally new energy-efficient, environmentally friendly technological schemes.
Today, water treatment systems use membrane technologies that allow to obtain water of almost any composition with a high degree of purification (removal of impurities dissolved in water can reach the value of 99.8%).

The current environmental situation contributes to the increased use of membrane systems. This is primarily due to the increased requirements for the quality of drinking water - the content of organochlorine compounds, pathogenic bacteria, fluorides, nitrates, etc. Modern membranes demonstrate unquestionable efficiency and versatility in the purification of water from various types of pollution.

The main advantages of membrane technology in comparison with traditional, physical and chemical filtration methods are:

- high degree of water purification;
- constant quality of the filtrate at the output, regardless of the change of the input composition;
- no chemical reagents required;
- technology allows you to get the maximum amount of clean water from the inlet stream.

Thus, two environmental problems are solved simultaneously: reducing the use of natural resources and reducing the amount of discharge.

Wastewater treatment using membranes makes it possible to apply waste-free water technology, low energy costs; all types of membranes are made of polymeric and corrosion-resistant materials and are therefore durable. Membrane-based installations take up minimal space, are fully automated and do not require constant maintenance.

Electrodialysis is the process of separation of salts ions in the membrane apparatus which is carried out under the influence of constant electric current. Electrodialysis is used to demineralize drinking water. The main equipment is electrodialysis, consisting of cation and anionite membranes. Electrodialysis with the resin membranes is one of the main methods in membrane technology. It is the combined method in which the processes of electrolysis and dialysis are combined [1].

The advantage of electrodialysis before other methods is the absence of phase conversion of water, which occurs during distillation, freezing or use of gas hydrated method.

The method of electrodialysis has the following drawbacks: formation of sediments of calcium carbonate, magnesium and gypsum hydroxide in the case of polarization; "Poisoning" of the comonmetabolic membranes iron, Mangan, and anionoexchange – organic substances contained in the treated water; In the case of the installation on the current with the maximum density, lower than the optimum values, the cost of the process significantly increases; Due to the absence of large single-power devices, specific capital and operating costs are increased, high selectivity of the membranes is not enough, availability of concentrated solutions and, again, the need for Water purification [2].

It is used to produce ultra clean water. An important point in the development of electrodialysis with ionic membranes was its use for demineralization of brackish water.

Most of the processes of electrodialysis are carried out in solutions, which are cleared from stiffening ions, or the concentration of which in these solutions is low.

Sewage and mine water in case of their insufficient purification getting into surface reservoirs, groundwater, and aquifers pose a threat of pollution of these environments, as Hydrosphere is one of the components of the biosphere-respectively and threat to the environment in general [3].

The process of water purification by electrodialysis is based on the division of ionized substances under the influence of Electromotive force, which is created in solution on both sides of membranes. It is due to the migration of ions through the membrane under the effect of the attached potential difference. In order to exclude the diffusion process, it is necessary that ionopermeable membranes are owned by the selectivity, i.e. the ability to pass ions with a charge of one sign. In other words, the positively charged membranes (anionactive) should pass only the anions, but negatively charged (cation-active) – only cations (Fig. 1).
Figure 1. Schematic diagram of the process of electrodialysis.

Electrodialysis differs from conventional electrolysis in that semipermeable partitions (membranes) are installed between the electrodes, the pore sizes of which allow the penetration of solute ions through them, but impede the passage of larger particles, as shown in Fig. 2. Then, due to the ordering of the movement of ions, anions of solutes are accumulated in the anode compartment and cations in the cation, and thus the necessary desalination of water is achieved. From the formed concentrated solutions regeneration of valuable substances is carried out [4,5].

Figure 2. Electrodialysis: 1 - sewage (liquid) supply, 2 - semipermeable partitions (membranes); 3 - stirrer; 4 - release of purified liquid; 5 - releases of concentrated solutions.

The efficiency of electrodialyzers increases with the arrangement of partitions of ionic materials, which are films made on the basis of polymeric materials with the addition of powders of ion-exchange resins.
2. Details experimental

We studied the system of ion exchange resin KU 2 - solution of NaCl and system of ion exchange resin KU 2 - solution NH4Cl. The results to be received during the experiments will allow us to develop an algorithm calculating physical - chemical parameters of water treatment by electrodialysis with ionite membranes using resins in the form of granules as intermembrane backfilling.

The resin was placed in the measuring cell (U - form tube) and was set in the balance with test solution. The dependencies of the pure solution reverse resistance and the resin-solution system on the concentration of solution (1 / R) were established experimentally and were presented on the same graph. The intersection point of the obtained dependencies for a clean solution and the resin-solution system allows determining the concentration of iso-conducting solution (the concentration at which the electrical conductivity of the solution is the same as in the resin).

After that the resin was transferred to a centrifuge cell (ion exchange cell with a porous bottom and two platinum electrodes, soldered against each other in the cell walls). The equilibrium solution was removed by centrifugation.

The centrifugation of the cell lasted for 15 minutes at 373 - fold increase in gravity. Using the bridge alternating current (1000 Hz) we measured the cell resistance (Rx), on the base of which the electrical conductivity of the resin was calculated. The obtained results made it possible to study the concentration dependence of the electrical conductivity of the resin in the test solutions (Fig.3).

![Figure 3. Determining of isoconductivity concentration of KU-2 resin through U-shaped cells: 1 - solution conductivity; 2 - resin conductivity with a balanced solution.](image)

The dependencies obtained for pure solution and for the ionite-solution system allowed to determine the concentration of the isoconducting solution. The intersection point of these dependencies for a clean solution and for the resin-solution system allowed to define the concentration of isoconducting solution in Fig.4.
Figure 4. Determination of the isoelectric conductivity point of KU-2 resin in a U-shaped tube:
1 - NH₄Cl solution; 2 – ionite, 3 - line of isoelectric conductivity.

The obtained data can be used to calculate the electrodialysis process of solutions with NH₄Cl, using intermembrane filling by the ion exchanger KU-2.

3. Results and discussion

The necessary condition for successful application of the gaskets from insulating materials in electrodialysis is the preliminary research of conductivity of materials that will be used for the intermembrane backfilling. Determination of electrical conductivity comes to measurement of resistance because it is inversely proportional to the resistance [6].

Electrometric method of determining the electrical conductivity allows to accelerate and to increase the accuracy of its determination in comparison to other methods [7].

On the border of phase separation electrode-liquid the polarization of contact voltage occurs, which is caused by a potential jump and has a polarity opposite to the polarity of the applied voltage. At the same time molecules seem to form a double layer, whose properties differ from the properties of molecules, polarized at a greater distance from the phase separation surface.

Therefore the criterion of the possibility for application of such an approach in a particular experiment can be one that takes into account the impact of the potential jump on the measurement results [8].

In completely dry state ion exchange resins have a high electrical resistance. When the resin swells, there appears the ability to conduct electrical current.

The known methods of measurement of specific electrical conductivity of granular resin make impossible to carry out the measurements in a wide range of concentrations of the equilibrium solution. That is why we proposed the approach to measure the resistance of the grains layer of granular resin after the removal of the equilibrium solution by centrifugation.

The purpose of setting optimal types of backfilling and optimum implementation modes of electrodialysis with intermembrane backfilling we conducted studies that were aimed at developing a model approach to describe the electroconductive properties of ion exchange materials and its experimental testing.

We developed a mathematical model of the conductivity of ion exchange resin and columns, which combines the theoretical approaches of three leading and microheterogeneous models. To check the adequacy of the developed model, the electrical conductivity of synthetic and natural cation exchange materials, as well as columns with these materials in solutions of different salts, was investigated.

This allowed us to develop a model for describing the electrical conductivity of ion-exchange materials and to estimate the fractions of current flowing through the gel, solution, and mixed conduction channel in an ion-exchange system containing two-charge ions.
4. Conclusions
On the basis of experimental data the mechanism of conductivity of natural cation-exchangers and resin of KU-2 in the form of ions of ammonium and chlorine is set. The obtained dependence for pure solution and the ionite system-solution enable to determine the concentration dependence of the specific electrical conductivity of resin in the studied solutions.

Defined and graphically confirmed the value of the concentration of isoconductive solution for which the conductivity of the solution is the same as in the ionic. This value is supported by the intersection of the obtained dependencies for Clean solution and the ionite system – solution.

Experimental studies have identified the types of intermembrane backfill and established optimal modes of implementation of electrodialysis in the cell with intermembrane backfill. The conducted researches have implemented the principle of model approach for the description of electrically conductive properties of ion-exchange materials and its experimental verification.

The method of measuring of resistance layer of grains of granulated ionite after removal of equilibrium solution by centrifugation has been developed and proposed.

The obtained results gave an opportunity to study the concentration dependence of the specific electrical conductivity of resin in the studied solutions. A mathematical model is intended for forecasting the diffusion of one and two-rechargers in ion-exchange column.

A model for describing the conductivity of ion-exchange materials and measuring the fraction of current flowing through the gel, solution, and mixed conduction channel in an ion-exchange system containing two-charge ions.

The developed algorithm of calculation of physical-chemical parameters of water purification process by electrodialysis with ionic membranes using ionization in the form of granules as a membrane filling is developed.

Using the obtained results will predict parameters of process of ion-exchange purification of model solutions of wastewater and multicomponent industrial solutions.

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