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# Magnetic Modification of Ion Exchange Processes

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***Abstract*— *Today, the ion exchange method is widely used in water treatment systems. Ion exchange systems are used to correct the mineral composition of water to the required standards; wastewater treatment; desalination and softening of natural waters. To present day, there are technical solutions to improve the process of water purification, treatment, softening and demineralization. They include: improvement of physical and chemical conditions; intensification of the ion exchange process; use of new ion exchange materials; modification of ion exchange resins; combination with other water treatment methods; modernization of equipment and designs of ion exchange devices. In order to improve the flow conditions and reduce the burden on the environment, it is promising to implement technologies aimed at intensifying the ion exchange process by activating the components of the process. The paper investigates the effect of magnetic modification on the intensification of ion exchange processes during the adjustment of the mineral composition of natural waters. The obtained results demonstrate the influence of the magnetic field on the ion exchange process.*

*Keywords*— ***ion exchange, magnetic modification, intensification, natural waters, correction of mineral composition, purification, softening, demineralization.***

## I. INTRODUCTION

Modern approaches to water treatment in water treatment systems include the use of physical, chemical and physicochemical methods. The most common problems that arise are associated with the formation of an additional load on the environment when using chemicals and low productivity. A popular method of water treatment is the use of ion exchange. Improving the conditions of this process is a promising direction of environmentalization the water treatment process.

The use of ion exchange in adjusting the mineral composition of natural waters to meet specific needs is rational in terms of economic and technical support. Ion exchange is a stoichiometric exchange of ions between an ion exchange material and mineralized water. The advantage is the possibility of modifying ion exchange resins for selective removal of heavy metal ions from which water treatment is required.

In the operation of ion exchange plants, it is important to take into account the intensity of the process when adjusting the mineral composition of natural waters. The most well-known methods of ion exchange intensification aimed at improving the physical and chemical conditions of the ion exchange process include the following:

- the use of ultrasound - due to the phenomenon of cavitation during the pretreatment of water, the existing cells of microorganisms and coarse particles are destroyed;
- chemical catalysts and activators - when reagents are added, compounds are formed that are retained by ion-exchange materials, as well as modification of natural ionites for selective removal of ions present in water;
- electrodeionization - the principle of operation is the transfer of ions to the electrodes removed by

ion-exchange resins and in the process of regeneration of ion-exchange materials, when the polarity of the cathode and anode is reversed.

- the use of a magnetic field - involves a certain change in the structure and physical properties of the water-dispersed system and ion-exchange material.

The intensification of ion exchange by magnetic modification during demineralization of natural waters is considered as a promising way to ecologization of the process of heavy metal ions extraction.

## II. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The effect of a magnetic field on the physical properties of water to be treated has been considered in many studies. The dependence of changes in the physical and chemical properties of water on magnetic field treatment has been experimentally established. The main effect of magnetic treatment is accelerated adsorption, changes in salt solubility, ion hydration, changes in pH and the rate of chemical reactions. [1-3]

The studies indicate the approximate optimal parameters for water treatment with a magnetic field. When water passes through a magnetic field with an intensity of 0.8 Tesla, the alkalinity of the water increases, which prevents the formation of sulfates and calcium crystals. The change in the concentration of ions in the treated water was experimentally demonstrated. There was an increase in $Na^+$ and $Cl^-$ ions and a decrease in $Mg^{2+}$, $K^{+,}$ $Ca^{2+}$, $SO_4^{2-}$, which is explained by a change in the hydration shell around certain ions. [4, 5]

The effect of magnetic field on water properties was investigated. Fluctuations in the pH value were demonstrated. It is also noted that the flow rate and water temperature have a significant impact on magnetic treatment, especially on the change in pH after passing through magnetic devices. [6, 7]

The experiments on the effect of magnetic treatment on well water demonstrate a slight change in pH - up to 9% when using an electromagnetic field with a voltage of 0.09 Tesla and a change in pH - up to 24% when using a double magnetic field. The concentration of NaCl decreased under electromagnetic field treatment, and increased under double magnetic field treatment. [8]

The effect of magnetic treatment on adsorption materials in water treatment was investigated on the adsorption of dye on graphite carbon using electric currents to generate different magnetic field strengths.

Dyes were removed from water on graphite carbon under the influence of a magnetic field. The results indicate that dyes with cationic properties are better adsorbed due to an increase in the frequency of collisions between the dye molecules and the adsorbent surface. At the same time, anionic dyes begin to adsorb worse, which is assumed to be due to the adsorbent acquiring a negative charge when current is applied. [9]

When bentonite was treated with an electromagnetic field, the formation of new adsorption centers was observed, which improved the process of copper ion extraction [10]. The improvement of the sorption of biogenic ions on bentonite treated with an electromagnetic field is also noted. This indicates possible ways of using the magnetic field for complex water treatment in water treatment systems. [11]

The operation of modern magnetic water softening devices is based on the effect of a magnetic field on hydrated metal cations dissolved in water, the structure of hydrates and water associates, which leads to a change in the rate of electrochemical coagulation by stimulating the formation of crystallization centers. [12]

The use of magnetic treatment in water treatment has also found application in the process of water clarification.

A common method of increasing the efficiency of water clarification is the use of a concentrated solution of aluminum sulfate coagulant. It has been established that the use of this approach reduces reagent consumption. However, there is a need to improve environmental safety when using aluminum coagulant. [13]

In the paper by Dushkin S.S. investigates the process of activation of aluminum sulfate coagulant solutions. The results show an increase in filter performance up to 40%, as well as a reduction in the content of residual aluminum by almost half. [14]

Modification with magnetite to remove magnesium ions from water. Magnetite is an effective catalyst for the oxidation of iron ions in water, in addition, this catalyst, applied to strongly acidic cationite, provides effective removal of manganese ions from water It was found that cationite KU-2-8 modified with magnetite in the Na+ form has a higher sorption capacity than unmodified cationite, which indicates a significant contribution of catalytic oxidation of $Mn^{2+}$ ions on modified cationite in the removal of manganese from water. [15]

## III. HEADINGS

The intensification process is to improve the ion exchange process in water treatment systems.

To achieve the desired effect by applying a magnetic field to the water to be purified on absorbent materials, the following ways can be used:

1. Increasing the selectivity of sorbents. Modification of the sorbent. Changing functional groups - replacing or adding functional groups to the sorbent surface can increase its selectivity. [16]
2. Optimization of the pH of the medium. Adjusting the pH of the water can affect the charge of ions and their ability to bind to the sorbent. To improve ion exchange, it may be important to maintain the optimal pH value for a particular sorbent and type of ion. Traditionally, acids or alkalis are used. This causes economic losses and is also an additional burden on the environment. [17]

The energy of the electric field during magnetic treatment will affect the rate of chemical reactions, pH changes, and ion exchange. The magnetic field affects the precipitation of hard metal crystals. The study by Karkush M. O et al. notes that the magnetic field inhibits the growth of crystalline particles. As the magnetic field strength increases, the Ca concentration decreases and the pH level increases due to the absorption of $H^+$ ions and the increase of $OH^-$ ions. [4, 6-8, 18]

Studies of the dynamics of the ion exchange process indicate an increase in the duration of the filter cycle when treating ion exchange columns with a magnetic field. [19]

Based on information from the literature, the ion exchange process is of a chemical nature. Intensification of ion exchange is achieved by using both chemical and physical methods. The use of a magnetic field does not change the chemical composition of water, but increases the speed of chemical reactions. [20]

A magnetic field can influence the movement of particles in solution through magnetically induced diffusion. This can improve the movement of ions and contaminants along the magnetic induction gradient, which can facilitate their interaction with ion exchange materials. When interacting with charged particles such as ions, the magnetic field affects their trajectory and distribution in the system, which can affect the efficiency of ion exchange. Also, in ion exchange systems where regeneration of ionic materials is required, a magnetic field can be used to maintain or improve the regeneration process.

The ordering of the motion of charged particles when using electromagnetic is explained by the phenomenon of magnetically induced diffusion. It is described by the Lawrence force equation, which defines the force acting on a magnetic particle by an electromagnetic field:

$$F=q(E+v\cdot B), \quad (1)$$

where q - the charge of the particle; E – electric field strength, (vector value); v - particle velocity (vector value); B – is the modulus of the magnetic field vector.

Based on this equation, it can be concluded that in order to increase the effect of the magnetic field on heavy metal ions in water, it is advisable to increase the intensity of the electric field.

Heavy metal ions can produce a magnetic field due to their internal magnetic moment, which usually comes from unpaired electrons in valence atomic shells or from spin-orbit interactions.

Charged particles have a magnetic moment resulting from the particle's rotation or spin.

Thus, we can express the magnetic field strength acting on the ion as:

$$F=\nabla(m\cdot B) \quad (2)$$

where ∇ denotes the gradient operator acting on the scalar product of magnetic moment and magnetic field; $qE$ corresponds to the gradient of the scalar product $m\cdot B$. The velocity of the particle is not taken into account, because the expression describes the force acting on the magnetic moment due to a change in the magnetic field in space.

From both expressions, we can see the dependence on the modulus of the magnetic field vector, which can be used to regenerate ion-exchange materials after their supersaturation.

## IV. CONCLUSIONS

The technology of intensification of ion exchange processes in water treatment is analyzed. The prospects of using magnetic treatment of ion-exchange materials, as well as the effect of the magnetic field on the water to be treated, are determined.

The influence of the magnetic field on the elements of the ion-exchange process is substantiated.

Application (1) is appropriate when using technologies with a constant magnetic field through which water to be purified from heavy metal ions will pass, (2) is suitable for describing the process of electromagnetic field influence on static elements of the water treatment system: directly on magnetite-modified or unmodified ion exchange materials.

It is advisable to use a comprehensive system for intensifying the ion exchange process by magnetic modification. Ion exchange materials treated with a magnetic field will absorb heavy metal ions more intensively, from which it is necessary to purify water, thereby the exchange capacity of cationic materials will be used more rationally. After the ion exchange materials are supersaturated, the process of their regeneration will be accompanied by magnetic field treatment, which will reduce the use of reagents.

It should be noted that the study of the mechanism of magnetic activation of the ion exchange process requires additional research to achieve better indicators of environmental safety of the water treatment process in water treatment systems.

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