ADSORPTION OF HEAVY METALS USING ELECTRO DISCHARGE METHODS FOR WASTEWATER TREATMENT

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The adsorption of heavy metals using electro discharge methods presents an innovative approach for the effective treatment of wastewater. This process leverages electric fields to enhance the removal of toxic metals such as lead, mercury, cadmium, copper, and zinc from contaminated water. Techniques such as electrodialysis, electrochemical adsorption, and electroflotation utilize electrical energy to improve the efficiency of heavy metal removal by promoting the movement and accumulation of metal ions onto electrodes or specialized adsorbent materials. These methods offer significant advantages in terms of high efficiency, environmental friendliness, and the potential for low chemical usage. Despite the potential benefits, challenges such as energy consumption and system maintenance remain, which necessitate further research for optimization in large-scale applications. This paper explores the principles, advantages, and limitations of electro discharge-based adsorption techniques for heavy metal removal and discusses their applicability in real-world wastewater treatment systems.

Keywords: industrial wastewater, heavy metals, sorption purification methods, electric discharge methods.

INTRODUCTION

Water pollution is a critical issue for all living beings on Earth – a global problem. One of the most pressing environmental concerns worldwide is the pollution of the hydrosphere by industrial wastewater. Currently, the primary cause of water pollution in aquatic basins is the discharge of untreated or inadequately treated industrial, textile, and leather production wastewaters into water bodies [1]. In the basin of the Kura and Aras rivers, approximately 350 million cubic meters of contaminated water are discharged annually from Armenia, and around 330 million cubic meters from Georgia, containing high levels of heavy metals, phenols, and petroleum products. This, in turn, causes damage to the population, as well as problems for nature reserves and wetland areas that are enriched by these waters. Pollution of the Kura and Aras rivers with heavy metals poses a serious environmental issue for Azerbaijan and neighboring countries. The primary sources of pollution include industrial and domestic wastewater discharges, as well as mining activities. The lack of effective treatment facilities leads to the discharge of untreated wastewater into the rivers, contributing to the accumulation of heavy metals and other pollutants. Increased concentrations of heavy metals such as lead, arsenic, copper, and molybdenum in the water and sediments of the rivers exceed safe levels, threatening the health of the population and ecosystems. Research shows that pollution of the rivers with heavy metals is associated with an increased incidence of cancer in coastal areas [2], [3].

Wastewater treatment from ecotoxicants is a crucial stage in the technological process for any industrial enterprise. Contaminated industrial effluents pose a threat to water bodies as they contain highly toxic substances, among which heavy metal compounds are the most dangerous. When these metals enter natural water bodies and interact with other elements, they form highly toxic compounds, and even small quantities of these can lead to harmful consequences for human health and the environment. Moreover, heavy metals do not undergo biological degradation and tend to accumulate in living organisms, causing various diseases and disorders [4].

Many industrial sectors generate wastewater containing heavy metal ions. These aqueous solutions typically contain ions such as Fe^{2+}, Cr^{6+}, Cu^{2+}, Ni^{2+} and Zn^{2+} . The presence of these contaminants in water bodies poses a significant threat to both human health and the environment [5]. A key challenge in designing a wastewater treatment system for such effluents is reducing the concentration of pollutants to very low, sometimes trace amounts. One effective method for neutralizing wastewater containing heavy metal ions while achieving the required standards, in the volumes of an industrial facility, and minimizing costs, is adsorption.

In modern conditions of development of social progress, waste waters of chemical, petrochemical, industrial, textile, tannery industries are the most dangerous sources of pollution of surface water bodies. Development of modern science and technology leads to increase of industrial production, as a result of which the amount of wastes thrown into the environment in the form of waste waters increases accordingly. Typical pollutants of waste waters are ions of heavy metals, pollutants such as oil, oil products, phenols, pesticides, various organic substances included in oil and oil products, discharge of untreated or insufficiently treated waste waters of industrial enterprises into water bodies. Harmful chemical elements and substances get into water bodies, worsening their sanitary condition and causing the need for special deep purification of water before using it for household and drinking and some industrial purposes [6], [7].

Many pollutants are not extracted from water mechanically, are not neutralized during biological treatment, and are not removed by traditional water treatment methods such as settling, coagulation, and flotation. This necessitates the introduction of a

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sorption post-treatment stage into the integrated water treatment process flow chart. As a rule, this stage is the final step in the water treatment process [6]. Heavy metals are also classified as persistent chemical pollutants with cumulative action and specific toxic properties. The most environmentally hazardous heavy metals are chromium, lead, mercury, and cadmium. When processing ores, burning energy sources, and consuming heavy metals, huge quantities of them enter the atmosphere and water bodies as waste. Entering the aquatic environment, heavy metals interact with other components of the environment, forming hydrated ions, oxyhydrates, ion pairs, and complex inorganic and organic compounds. The specific form of existence of metals depends on their nature, the nature of the ions and molecules competing for the ligand place, pH, temperature and ionicity of the environment. Many heavy metals form so-called synergistic mixtures, which have a toxic effect on aquatic organisms that significantly exceeds the sum of the effects of individual components. Therefore, the release of heavy metals into the atmosphere, water bodies and agricultural fields must be stopped and taken under strict control. All sources of heavy metals can be eliminated by organizing wastewater treatment and reuse systems at enterprises [8],[9],[10]. Pollution of the environment with heavy metals leads to an increase in the incidence of chronic dermatoses, eczema, and dermatitis. The harmful effect of heavy metals on the functional state of the thyroid gland has been identified [7]. Long-term exposure to lead and mercury can impair memory and verbal skills. Lead also disrupts reproductive function and affects the cardiovascular system. High doses of cadmium reduce calcium absorption by bone tissue, which leads to bone fractures. Systematic absorption of zinc in the body leads to inflammatory processes in the lungs and bronchi, and disruption of carbohydrate metabolism. Copper causes disorders of the nervous system, liver, kidneys, and decreased immunity [9].

ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

The purpose of this work is to summarize data from open sources on industrial wastewater pollution with heavy metals, assess statistical data on the level of pollution and develop proposals for water purification and environmental protection. To achieve this goal, it is necessary to develop a technology that could cleanse the specified pollutants. Among modern methods that ensure effective purification of wastewater from various pollutants, including heavy metal ions, a special role belongs to physical and chemical technologies [5], [8], [11]. Currently, for wastewater treatment, the industry knows methods for cleaning water from heavy metals and other pollutants using adsorption and electrical methods. The main criterion for the adsorption method of wastewater treatment is the choice of material, or more precisely, based on its sorption qualities, porous structure and efficiency. The electric discharge method is more economical, effective and provides a high degree of extraction of heavy metals from industrial wastewater [1].

ADSORPTION METHODS

Adsorption methods of industrial wastewater treatment are among the most environmentally friendly methods. The main criteria for a material are its adsorption qualities, porous structure, and cost-effectiveness. The most popular sorbents for industrial wastewater treatment from heavy metal ions are zeolite, carbon sorbents, peat etc. Various grades of active carbon absorb heavy metal ions, exhibiting different absorption capacities. The main factor determining the efficiency of sorption is the pH value [4]. Adsorption methods are economically advantageous only if the adsorbents are used repeatedly. After sorbent regeneration, a large number of highly toxic and highly concentrated eluates are formed, which must be subjected to additional neutralization and disposal. In addition, the problem of disposal of spent sorption material also arises. Therefore, increasing attention is being paid to purification methods based on ion exchange using natural and synthetic materials, which allow not only to extract heavy metal ions from wastewater, but also to reuse wastewater in circulating water supply [12],[13],],[17].

ELECTRIC DISCHARGE METHODS

The electric discharge method is based on the electrical treatment of adsorbents under the influence of electric fields and discharges. Electric discharge treatment of adsorbents is one of the promising reagent-free methods of wastewater treatment to the required parameters. Electric discharge treatment of adsorbents for wastewater treatment ensures: removal of the vast majority of toxic components, including heavy metal ions, as well as organic reagents. The mechanism of electric discharge treatment of wastewater is determined by the processes occurring on the surface and in the structure of natural adsorbents under the influence of electric discharges. During the adsorption process, forces act similar to the nature of the forces involved in chemical interaction, that on the surface of the adsorbents there are areas with free residual valences. If the adsorbed molecule gets to the corresponding unoccupied active center of the surface, the molecule binds to the latter. Under the influence of the discharge, the molecules of the substances are ionized, and the process of binding to the surface of the adsorbent is facilitated [1]. The method of thermally stimulated relaxation allows identifying the charged state of the material under study, as well as studying its most important electrical properties by determining the depth of charge, the density of charge traps and their energy [14], [15], [16]. The resulting graph of the dependence of the thermally stimulated current on time reveals a certain set of peaks, the analysis of which provides information on the electrophysical properties of the sample material Fig. 1. The area enclosed under the curve of the current TSR as a function of time corresponds to the total charge relaxed in the sample. The charges of the sample, immobile at low temperatures, acquire higher mobility upon heating.

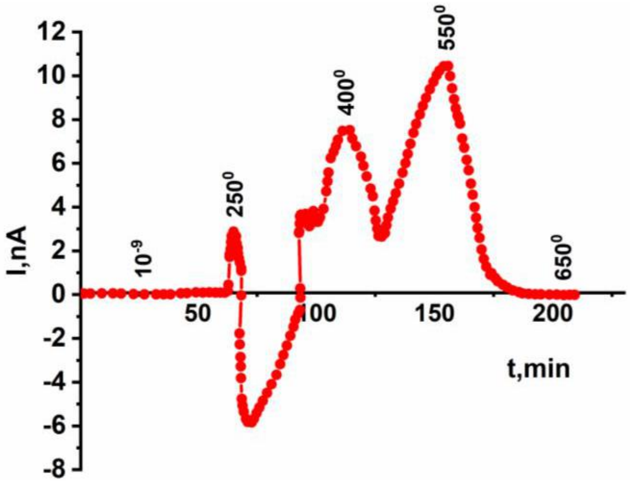
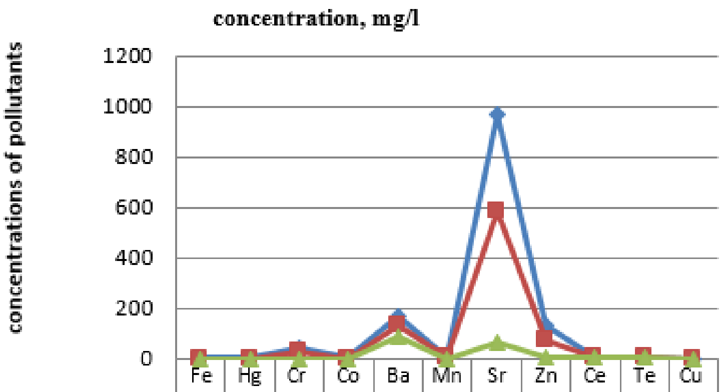


Fig. 1. Dependence of thermally stimulated current on time, treated with electric discharge.

Theoretical analysis of the formation of a charged state in the studied porous dielectric adsorbents showed that such a charged state is formed due to the diffusion mechanism of charge introduction into the structure of the material. The values of the diffusion coefficient were obtained, the value of which is in the range between the values of diffusion of neutral materials in the studied adsorbents and diffusion of ions in non-porous identical materials. This made it possible to propose a model of the adsorbent charging process, according to which the ions captured by the external surface of the adsorbent diffuse deep into the adsorbent along its pores, leading to its charging [14].

The proposed model of the adsorbent charging process made it possible to experimentally establish the fact of intensification of adsorption processes under the specified effects, manifested in a change in their selectivity in relation to different components and their maximum sorption capacity. The obtained results of the studies of maximum permissible concentrations of pollutants in industrial wastewater are presented in Figure 2, which show that under certain modes of electric discharge treatment of adsorbents, it is possible to reduce the amount of heavy metals in wastewater using the adsorption method (Figure 2). Being a type of adsorption methods of wastewater treatment, the electric discharge method compares favorably with others - simplicity of equipment design, low energy costs [11], [16].



	Fe	Hg	Cr	Co	Ba	Mn	Sr	Zn	Ce	Te	Cu
Source wate	0,83	0,9	39	0,75	165	1,2	970	127	5,2	2	0,21
without the use of EDP	0,43	0,6	24	0,5	130	0,8	580	74	4	1,2	0,08
using EDP	0,06	0,2	0,09	0,2	84,2	0,1	60	2,5	0,97	0,7	0,07

Fig. 2. Industrial wastewater pollutant concentration curve

CONCLUSION

As a result of the analysis of the presented data, it can be concluded that the main cause of pollution of aquatic ecosystems with heavy metals is the negative impact of industrial wastewater. Analysis of works on currently used technologies for removing heavy metal ions from wastewater shows that it seems appropriate to develop innovative technologies for wastewater treatment from heavy metal ions based on fundamental scientific areas of physical chemistry, which form the basis of knowledge for the creation of future purification technologies. At the same time, new technologies must meet modern requirements for an integrated approach to wastewater treatment. Based on the proposed and regulated measures, the most effective and efficient may be, on the one hand, the creation of closed production cycles using recycled water, the development and implementation of water-saving and low-waste technologies to reduce the load on industrial and wastewater.

On the other hand, the development of cheap and more environmentally friendly organic sorbents with increased adsorption efficiency, as well as the need to create new physicochemical methods for cleaning industrial water from heavy metals. The sediments formed during wastewater treatment must be low-toxic or represent compounds that can be used as secondary raw materials for processing at other enterprises or be a final commercial product.

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