

Wastewater Treatment System Using Nanomodified Natural Sorbents

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Abstract. *Protection of water resources from contamination is a global problem of modern age. Wastewater of almost all economic entities contain oil products, heavy metal compounds and other pollutants. Many effective wastewater treatment systems ensuring high purity up to 99.9% exist today, but operation of such systems entails significant costs, so many economic entities neglect environmental protection standards despite heavy penalties. So, creation of cost-effective wastewater treatment systems ensuring high purity is one of the most pressing problems in all countries today.*

This paper suggests a multi-stage treatment system using nano-activated natural sorbents applied in a closed-loop water cycle. The advantage of using such a treatment system as compared to the existing ones is demonstrated on the example of economic entities operating in the machine building industry of Russia, the USA and Israel.

Keywords: *natural sorbents, wastewater, ecology, water treatment, water treatment method, nanoactivation, closed-loop water cycle, activation, zeolite, diatomite, modification, nanotechnology.*

The issue related to the construction of a water treatment system is solved differently at different economic entities, because the technology of water treatment depends not only on the requirements for the quality of treated water, but also on the technological and economic feasibility of water treatment. Such methods as water treatment using biological sludge, centrifugation, sorption, flotation, ultraviolet water treatment or ozonization, micro- and nanofiltration are successfully used for the treatment of wastewater. The most popular and effective methods of water and wastewater treatment are as follows: physicochemical treatment methods, biological methods, both aerobic and anaerobic, wastewater treatment using membranes, thermal methods of water treatment, wastewater treatment using ozone, absorption methods of treatment using activated carbon, ion-exchange methods for the selective extraction of contaminants. Each of the methods above has its advantages and disadvantages. Selection of one or another method depends on a number of factors, such as the scale of contamination, its specificity and economic feasibility. The existing environmental protection standards require economic entities to implement new treatment facilities or modernize the existing ones [1-8].

In Russia the most popular methods of wastewater treatment are chemical and physicochemical methods. Chemical treatment is carried out using a variety of chemical reagents that react with contaminants. As a result of their action insoluble deposits form. Physicochemical treatment of water combines several methods: coagulation - adding of coagulants to effluents during reaction that produce deposits in the form of flakes, which can simply be removed, flotation - passing of air bubbles through effluents. When moving up they take oils, surfactants and other contaminants with them. As a result foam is formed on the surface of effluents, and sorption - the use of materials

that can absorb contaminants. First, mechanical treatment is carried out.

Israel was recognized as the best country in terms of industrial wastewater treatment in 2010 and subsequent years. Today Israel remains one of the world leaders in this area. The main methods are as follows: chemical, mechanical, physicochemical, and biological. In addition to the traditional methods of water and wastewater treatment, new and more environmentally friendly and economically viable methods have been developed in Israel: membrane, electrochemical, magnetic treatment, ozonation, treatment with selective sorbents. Each of these methods allows to remove various contaminants effectively with minimal harmful effect on the environment.

In the United States the most popular industrial method of wastewater treatment is the membrane treatment method. Interest in the technology of ultrafiltration among US specialists is heightened by an increasing scale of its application. The method of membrane filtration is based on the following: when wastewater is passing through the membrane, it gives preference to some substances, while retaining impurities that are foreign to it. The main advantage of this method is almost complete treatment of liquid from foreign impurities and compounds. Thorough filtration prevents pollutants ingress to water.

An analysis of data on industrial wastewater treatment was conducted at economic entities of such countries as Russia, the United States and Israel. The data was collected at five economic entities of the machine building industry of each country, the results are presented in Table 1, where C_{in} - input impurity concentration, C_{out} - output impurity concentration, α - extraction degree.

Table 1

Concentrations of heavy metals in wastewater before and after treatment at economic entities of the machine building industry by country

Extracted substance	Russia			USA			Israel		
	C_{in} , mg/l	C_{out} , mg/l	α , (%)	C_{in} , mg/l	C_{out} , mg/l	α , (%)	C_{in} , mg/l	C_{out} , mg/l	α , (%)
	pH = 3-11								
Fe	150.4	0.3	99.8	75.9	0.1	99.9	75.0	0.1	99.9
Cu	10.3	0.4	96.1	9.7	0.35	96.4	13.6	0.3	97.8
Zn	22.8	0.8	96.5	20.6	0.5	97.6	21.4	0.6	97.2
Cr_{total}	95.3	0.3	99.7	89.5	0.2	99.8	90.7	0.2	99.8
Ni	1.06	0.07	93.4	1.09	0.06	94.5	1.15	0.07	93.9
Pb	2.6	0.1	96.1	2.9	0.08	97.2	2.2	0.04	98.2
Cr^{6+}	3.5	0.1	97.1	2.5	0.05	98.0	2.5	0.05	98.0
Other	6	0.2	96.6	4.5	0.02	99.6	4.7	0.01	99.8

The data in Table 1 was developed based on the average value of concentrations at the selected economic entities in the industry most polluted with heavy metals. The above results indicate that the methods used for treatment in Russia are inferior to the level of wastewater treatment at economic entities in the United States and Israel. All the methods used are quite expensive, especially in the USA and Israel. Searching for and development of new economically viable and highly effective water treatment methods is of top-priority importance for these countries.

The use of nanomaterials with unique physicochemical and surface properties provides new opportunities in wastewater treatment. Implementation of nanotechnologies in wastewater treatment is a promising area for the improvement of the quality of treatment. So, paper [9] proposes to use sorption treatment with the help of nanomodified natural sorbents - a nano-activated complex of zeolite and diatomite - for the treatment of wastewater containing a wide range of pollutants. Natural zeolite and diatomite are distinguished by an increased ion-exchange capacity, the ability to exchange cations, low price and high popularity.

The main component of the selected natural sorbents is silicon oxide. Its content in diatomite reaches 80%, in zeolite - about 70%. These minerals also contain oxides of aluminum, iron, titanium, calcium, magnesium, sodium, potassium, and other oxides.

According to the method proposed in paper [9], the capacity of the sorbent to absorb large concentrations of heavy metals as compared to the concentrations at the selected economic entities specified in Table 1 was tested. The results of the tests are given in Table 2.

The degree of extraction was calculated according to the following equation:

$$\alpha = (C_{in} - C_{out}) \cdot 100 / C_{in},$$

where C_{in} is - input impurity concentration,

C_{out} - output impurity concentration.

Table 2

Results of sorption of heavy metals by a nano-activated complex of natural sorbents

Extracted substance	pH = 3-11		α , (%)
	C_{in} , mg/l	C_{out} , mg/l	
Fe	200	0.1	99.9
Cu	15	0.15	99
Zn	27	0.15	99.4
Cr _{total}	105	0.1	99.9
Ni	5	0.01	99.8
Pb	5	0.01	99.8
Cr ⁶⁺	5	0.01	99.8
Other	10	0.01	99.9

According to the data presented in Table 2, the results of testing of the adsorption capacity of a nanomodified sorbent with respect to extracted substances showed that this sorbent can be

successfully used for wastewater treatment from ions of heavy metals. So, the method of industrial wastewater treatment from heavy metals presented in paper [9] is the most effective.

It is proposed to introduce water cycles based on multi-stage treatment systems presented in paper [10] with the use of nano-activated complexes of natural sorbents, as well as reuse of treated water in circulating cooling water systems, etc. This system is the most cost-effective method of wastewater treatment for economic entities, which scheme is shown in Fig. 1.

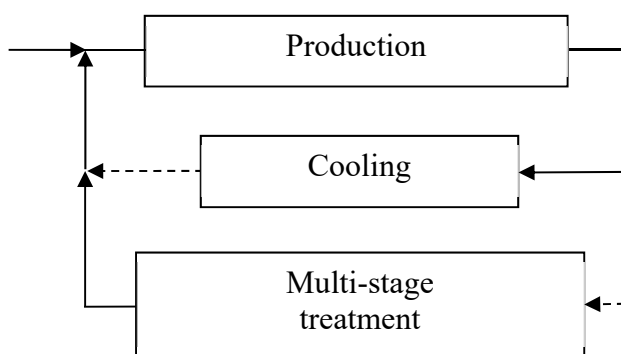


Fig. 1. Scheme of a closed-loop water cycle

As distinct from a once-through water-supply system, which is usually used in case of low water consumption and closely located water sources, a full circulating water system presupposes water reuse for the purposes of production. Technologies that allow reusing treated wastewater or regenerating process solutions are of great importance. Most modern economic entities are active consumers of water resources. For the purposes of economic and environmental expediency it is advisable to give preference to a progressive method of recirculating water supply implying the repeated use of this resource. Reuse of wastewater after its treatment for the purposes of the same process operations or for other production needs is an effective way to reduce the number of industrial effluents discharged into reservoirs, as well as reduce costs incurred by economic entities.

The main advantages of multi-stage systems in a close-loop water cycle for industrial effluents treatment using nanomodified natural sorbents are as follows: a possibility to remove various compounds of heavy metals simultaneously on the first stage, heavy metal compounds are clathrated in the form of crystalline non-leachable products, dispersed suspensions and emulsified pollutants are removed effectively with dissolved heavy metals, the process is not sensitive to the influence of other salts that may be present in effluents in large concentrations.

The results of new treatment system testing proved successful with respect to those ones used at economic entities in Russia, the United States and Israel. The degree of extraction is 99.9% combined with a high economic efficiency. Moreover, heavy metals are not released if the proposed sorbent is used, and the process of heavy metals absorption is actively continuing.

The analysis of the current state of wastewater treatment from heavy metals at the selected economic entities leads to a conclusion about the prospects of using the developed system based on nanomodified natural sorbents, as well as allows recommending them for practical use for wastewater treatment at economic entities of Russia, the United States and Israel.

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