Choice of sorbents for the pretreatment in the complex technology of phytoremediation

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Abstract. There was analyzed the modern state and development of nature-like technologies for revitalization (recovery) of the environment in the territories of industrial enterprises. Phytoremediation is a technology of environment enhancement by means of the plants which belongs to such technologies of revitalization (recovery). This technology is environmentally sound and economically advantageous because of the low cost as it presupposes the use of just the solar energy. The aim of the work was the choice of sorbents for the complex technology of neutralization of storm and meltwater from the territories of the copper processing enterprises of the Southern Ural, as well as the wastewater of these enterprises. There are presented the experimental data on the study of sorption characteristics of the natural materials based on aluminosilicates (glauconite), hydromicas (expanded vermiculite), volcanic glass (expanded perlite), microporous sedimentary rocks (gaize), carbonaceous materials (wood chips, activated carbon AG-3, crushed anthracite) and the production wastes (ash from heat and power plants). It is determined that expanded perlite and expanded vermiculite, glauconite and gaize can be used for the pretreatment of wastewater from heavy-metal ions, first of all, copper, zinc, nickel, and iron. The effectiveness of pretreatment makes up 75-80 %, which allows reducing the toxic load on phytoremediation treatment plants biological ponds with the aquatic vegetation.

1. Introduction

At present, the creation of nature-like technologies acquires the more significant meaning. The essence of creating the nature-like technosphere consists in the recovery of the natural self-consistent resources’ turnover, which is disrupted by the today’s technologies drawn from the natural context.

The nature-like technologies in the modern interpretation are the technologies which do not damage to the environment but exist in harmony with it and allow to recover the balance between the biosphere and the technosphere destroyed by a man. The nature-like technologies develop in different directions from biorobotic systems and bionic hybrid devices till the complex innovative technologies of revitalization (recovery) of the environment of the territories of industrial enterprises. Phytoremediation as a technology of environment enhancement by means of the plants belongs to such technologies of revitalization (recovery). Recently, this technology acquired great popularity preeminently due to the low cost as it presupposes the use of just the solar energy [1-19].

Phytoremediation is used for the treatment of contaminated lands and wastewater, and it is especially effective for the high volumes of water with the low concentration of contaminants. Heavy
metals accumulated in the plants can be later extracted and further used. Restriction to the use of phytoremediation are the cases of high concentration of heavy metals in wastewater what can inhibit plants growth and limit the possibilities of the technology. The main limitation of the concentration of toxic elements is the maximum level that can accumulate in plants. The problem of reducing high concentrations of heavy metals in wastewater can be solved by means of traditional technologies, namely sorption on natural sorption materials. Introduction of the pretreatment stage and the creation of a combined sorption-phytoremediation technology will allow for an effective revitalization of the environment. At present, the use of a wide range of materials of natural and synthetic origin is recommended as sorbents [5-10].

The aim of the work was the choice of sorbents for the complex technology of neutralization of storm and meltwater from the territories of the copper processing enterprises of the Southern Ural, as well as the wastewater of these enterprises.

2. Objects and Methods of Investigation
Based on the concept of creating nature-like technologies, natural materials were used as sorbents. For the investigations, there were chosen the porous natural sorbents based on aluminosilicates (glauconite), hydromicas (expanded vermiculite), volcanic glass (expanded perlite), microporous sedimentary rocks (gaize), carbonaceous materials (wood chips, activated carbon AG-3, crushed anthracite) and the production wastes (ashes from heat and power plants).

The effectiveness of the use of sorbents was evaluated on imitation solutions containing copper, zinc, and iron in the concentration range from 1 to 100 mg/l [11].

The characteristics of the materials used were studied by electron microscopy using the JEOL JSM-6460LV electron microscope with an attachment for micro-X-ray spectral analysis, by the method of low-temperature nitrogen adsorption on the ASAP Micromeritics 2020 specific surface area and porosity analyzer, by differential thermal analysis.

3. Results and Their Discussion
Expanded vermiculite (a mineral from the group of hydromica) has a layered structure. Its particles are worm-like columns or filaments with a transverse division into the finest scales. Vermiculite particles have a porous layered structure and sizes from 733 to 2.84 micron.

Glauconite, a complex potassium containing water aluminosilicate, a mineral from the group of hydromica of a subclass of layered silicates has a non-constant chemical composition. Most of the particles in the sample have a smoothed surface with a large number of pores. The particle sizes of glauconite vary from 139 to 470 micron. The composition of the particles is not uniform.

Expanded perlite has a layered structure and consists of thin plates with particle sizes from 13.9 to 87 micron.

Fly-ash of heat and power plants consists of spherical aluminosilicate particles having a surface porosity. The particle sizes range from 1 to 270 micron.

Gaize is a siliceous microporous sedimentary rock. The particles of gaize have dimensions from 1.2 to 2.5 micron.

Analysis of electron microscopic research data showed that the sorbents studied have developed surface and high open porosity. The pore sizes are shown in Table 1 from the data of low-temperature nitrogen adsorption on a specific surface and porosity analyzer.

The highest specific surface area was found in activated carbon AG-3 (690.70 m2/g), gaize (83.58 m2/g) and glauconite (36.33 m2/g), lower - 4.69 and 2.13 m2/g characterize expanded vermiculite and expanded perlite, respectively. Wood chips and crushed anthracite have an extremely small specific surface area.

Table 2 shows the results of estimating the static exchange capacity of the investigated natural sorbents by cations of heavy metals at different temperatures.
With increasing temperature, the static exchange capacity of expanded vermiculite, glauconite and expanded perlite increases. The increase of temperature has practically no effect on the exchange capacity of ash and activated carbon of AG-3 grade. For crushed anthracite, the exchange capacity decreases with increasing temperature, except for the sorption of lead and zinc cations.

Calculations of the rate constant of adsorption revealed that for the materials studied, expanded perlite and vermiculite, glauconite and gaize have the highest affinity for heavy metals. They should be recommended for complex phytoremediation technology.

Experimental studies have shown that expanded perlite and vermiculite, glauconite and gaize can be used for the pretreatment of wastewater from heavy metal ions, primarily copper, zinc, nickel, and iron. The effectiveness of pretreatment makes up 75-80 %, which allows reducing the toxic load on phytoremediation treatment plants biological ponds with the aquatic vegetation.

Sorbents can be placed before feeding into biological ponds in the form of gabion facilities or a filtering charge of pressure and non-pressure filters in a wastewater treatment system. In addition, these materials can be used directly as a ground for attached aquatic vegetation.
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