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Chemical and mineralogical aspects of clay-salt slimes of "Belaruskali" using for the preparation of nanostructured sorbents of radionuclides

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Abstract

In the context of intensive nuclear-power engineering development there is an urgent need to solve a range of technological and environmental challenges associated with generation, treatment and disposal of radioactive waste. In this regards, the problems of radioactive waste safe management and rehabilitation of radioactively contaminated soils in the result of the radiation accidents at the Chernobyl and Fukushima Daiichi NPPs are especially significant. Concerning that, investigation of effective and low cost sorption materials for radionuclides immobilization has a special relevance.

In order to solve the above mentioned problems, it is supposed to develop a resource-saving technology for production of multi-purpose nanostructured sorbents of radionuclides (^{137}Cs, ^{90}Sr) with predetermined physicochemical properties based on the waste of potash industry – clay-salt slimes (CSS) of the JSC "Belaruskali".

The performed research has shown that the CSS samples have a high fixing ability in relation to ^{137}Cs. The main sorption-active minerals in CSS are illite and montmorillonite. The degree of sorption is 99.6%, K_d is 1.2×10^5 l/kg, RIP(K) is 6343 mmol/kg. The modification of the S-1 sample allows to enlarge the content of sorption-active minerals tentatively in 3.5 times, thereafter RIP(K) for the S-3 sample may be significantly increased.

Based on the obtained experimental data, CSS of the JSC "Belaruskali" can be estimated as a perspective initial material for production of multi-purpose nanostructured sorbents of radionuclides.

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Keywords: clay-salt slimes; montmorillonite; illite; radioactive waste; radiocaesium; immobilization; nanostructured sorbents; modification; soil amendments; rehabilitation

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1. Introduction

As a result of nuclear-power plants operation and the radiation accidents at the Chernobyl and Fukushima Daiichi NPPs, radioactive contamination of the environment occurs.

The main channels for radionuclides migration in the environment are radioactively contaminated water and soil solutions, which are usually characterized by a wide variety of chemical and radionuclide compositions. To clean the aqueous media from radionuclides the methods based on the processes of sedimentation and adsorption are mainly used. Application of natural sorption materials in these processes is attractive due to the fact that, in contrast to synthetic sorbents, they have a low cost and widely available in the environment. Environmentally safe natural alumosilicates (zeolites, clays with layered structure etc.) are the most widely used in processes of purification of aqueous media from radionuclides [1].

Natural clay minerals with high cation exchange properties are mainly used for extraction of ionic forms of radionuclides, especially ^{137}Cs and ^{90}Sr.

Scientific-based and cost-efficient selection of clay materials that can selectively adsorb radionuclides is related to the search of available natural materials, chemical industry waste and studying of the possibility of their modifications to improve sorption properties.

The purpose of the research is to study physicochemical and sorption properties of clay-salt slimes of the JSC ”Belaruskali” with the aim to develop fundamentally new and highly effective sorbents for the purification of aqueous media from radionuclides.

Nomenclature

NPP	Nuclear Power Plant
CSS	Clay-salt slimes
RIP(K)	Radiocaesium Interception Potential

2. Objects and methods of research

The research objects are clay-salt slimes. Clay-salt slimes (CSS) are the industrial waste of the JSC “Belaruskali” formed in the result of sylvinite ore reprocessing and accumulated in the special slimes storages (on January 1, 2015 the CSS volume is amounting to more than 105 mln tons). The CSS samples from the slimes storage of the 3rd mining factory of the JSC ”Belaruskali” were selected for the experiments. The S-1 sample (the initial CSS sample) is a clay suspension in a saturated salt solution. It means that clay-salt slimes consist of 2 parts: water-soluble salts (KCl, NaCl) and water insoluble residue (i.r.).

The study of the initial CSS sample (S-1) was performed according to the fundamental principle of the physico-chemical analysis of materials, which determines the following interrelation: «composition – morphology (structure) – properties».

In order to study chemical and mineralogical composition as well as particle size distribution of insoluble residue of the S-1 sample, the S-2 and S-3 samples were used. The S-2 sample was prepared as follows: the S-1 sample was washed from water soluble salts NaCl and KCl and dried to constant weight (323K°, 6h). The S-3 sample was obtained on the base of the S-2 sample by acid treatment (0,1M HCl) causing disruption of carbonates, and then repeating the same procedures as for the S-2sample.

The free specific surface area (S_s) of the S-2 sample was determined by the BET method by adsorption of N_2 vapor at 78K° on the surface area analyzer ASAP-2010 (Micrometrics, USA). Grain size analysis of the S-2 and S-3 samples was carried out on the laser microprobe particle size analyzer Analysette 22 (Fritsch, Germany).

Morphological and elemental composition of the S-1 – S-3 samples were studied by the EDX method on the scanning electron microscope JSM-5610 LV with the system of microprobe chemical analysis EDX JED-2201 (accuracy 0.5%). Phase composition of the S-2 sample was analyzed by the XRD on the diffractometer D8 Advance Bruker AXS (Germany) with CuK_α emitting. Content of K^+ and Na^+ ions in solution was determined by atomic