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SCIENTIFIC AND TECHNOLOGICAL SUBSTANTIATION OF CONDITIONING USED ION-EXCHANGE RESINS BY INCORPORATION INTO A POLYMER BINDER

Specialty 2.6.8. - Technology of Rare, Trace, and Radioactive Elements

Dissertation Abstract for the Degree of Candidate of Technical Sciences

Domestic nuclear industry enterprises (nuclear power plants, ship repair yards and other facilities) have accumulated a large amount of technogenic secondary radioactive waste (RW) in the form of spent ion-exchange resins (IER), industrial methods of handling which are not currently used due to the lack of developed technological methods of immobilization and subsequent handling of IER. Existing industrial technologies in the world based on destructive processing methods have such disadvantages as the formation of aggressive gases, a large loss of radionuclides and a specific activity of the final product exceeding the level of requirements for certified packaging. When IER is immobilized in matrix materials, such as cement, the degree of inclusion does not exceed 20 mass%; the material is susceptible to biodegradation during storage, as is the case with bitumen.

The most suitable for reliable fixation of IER is a polymer compound, the possible problems with the application of which are mainly related to the uneven distribution of the binder, the lack of equipment for precise dosing and uniform supply, which leads to heterogeneity and worsens the characteristics of the final product. In Russia (RADON FSUE), a technology has been developed and an experimental-industrial installation has been created for incorporating IER into a polymer binder based on epoxy resins, which solves the above-mentioned problems. However, in order to implement this method on an industrial scale, it is necessary to conduct a scientific and technological study to determine whether it is possible to improve the pilot-scale installation and use it for conditioning various types of real-world IER.

The purpose of the work is to provide a scientific and technological basis for the conditioning of IER by inclusion in a polymer binder.

To achieve this goal, the following **scientific objectives** were set and solved:

1. To justify the method of pre-treatment of IER before inclusion in a polymer compound.

2. To identify changes in the properties of a polymer compound based on IER that ensure safety during storage in near-surface conditions.

3. To substantiate the absence of gas release from a polymer compound based on IER, which has been dehydrated to a residual moisture content of 50-53 mass%.

4. To develop a scheme for a pilot-scale installation for conditioning real IER, using the Kalinin NPP as an example.

Scientific novelty

1. It is shown that the pre-treatment of IER by the method of dehydration to the residual humidity of 50 - 53 mass. % allows to obtain a polymer compound, the storage of which is safe in conditions of near-surface placement;

2. It was found that the mechanical strength and water resistance of a polymer compound based on IER increased when it was irradiated with a dose of up to 10^4 Gy and subjected to cyclic temperature exposure in the range of 0 to 100 ºC, with a pre-treatment method of dehydration to a residual moisture content of 50 to 53 mass%.

3. It has been established that the polymer compound based on dehydrated IER with a residual moisture content of 50-53% does not undergo degradation processes that cause gas release and volume increase.

Theoretical and practical significance

– it is shown that the polymer compound with immobilized IER (RW class 3), with pre-treatment by dehydration method to residual humidity of 50 - 53 wt. % and specific activity in the range of 10^7 - 10^8 Bq/kg when placed in near-surface disposal sites, is characterized by an increase in mechanical strength and chemical water resistance due to cross-linking and post-curing of the polymer compound during storage;

– it has been established that when a polymer compound based on dehydrated IER with a residual moisture content of 50-53% is placed in a near-surface disposal facility, there is no gas release or volume increase due to the absence of chemical and radiation-related degradation processes;

– it has been shown that it is possible to separate small fractions and process real IER from nuclear power plants by adding a washing process for the IER and a small fraction separation unit to implement the impregnation of the IER in a container with a polymer binder;

– the following have been developed and certified methods for determining the characteristics of a polymer compound to confirm its compliance with the regulatory requirements of MI-206-2022 (FR.1.28.2022.44467), MI-207-2022 (FR.1.28.2022.44463), MI-208-2022 (FR.1.28.2022.44465), MI-209-2022 (FR.1.38.2022.44462), MI Rad/NPC 214-2025 (FR.1.38.2025.51233), allowing to perform confirmation of the compound's compliance with regulatory requirements;

– the technology and conditioning unit have been adapted and tested for the processing of real IER waste, introduced at RADON FSUE in 2025 (implementation certificate dated May 20, 2025), which allowed for the processing of 33.2 m^3 of real NPP waste.

– The technology and air conditioning unit were adopted for use at the Kalinin NPP (Decision of Rosenergoatom Concern JSC dated 06.08.2019 1.2.2.06.001.0526-2019). A project has been developed for the installation at the Kalinin NPP, which will allow the processing of the entire volume of resins accumulated during its operation).

The main provisions to be defended:

1. Justification of pre-treatment of IER by dehydration method to residual moisture content of 50 - 53 wt.%, which does not lead to an increase in the volume of the polymer compound at fluctuations of humidity under the conditions of the point of near-surface disposal.

2. Change in the properties of the polymer compound with immobilized IER (RW class 3), with pre-treatment by dehydration method to residual moisture content of 50 - 53 wt. % and specific activity in the range of 10^7 - 10^8 Bq/kg under storage conditions at near-surface disposal sites, characterized by:

• increased mechanical strength and chemical water resistance due to cross-linking and post-curing of the polymer compound;

• absence of gas release and volume increase due to the exclusion of chemical and radiation-induced degradation processes.

3. Technological substantiation of the experimental and industrial conditioning plant for real IER, based on the Kalinin NPP, which includes a unit for separating small fractions, a unit for pre-treatment of IER by dehydration, a unit for conditioning dehydrated IER into a polymer compound, and a unit for conditioning small fractions by cementation.