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PROCESSING OF URANIUM-BEARING PROCESS SOLUTIONS AND HANDLING TECHNOLOGIES FOR VERY LOW-LEVEL RADIOACTIVE WASTE GENERATED AT JSC «PA ECP»

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The paper discusses the process of very low-level radioactive waste (VLLW) generation and the procedure applied to manage VLLW generated at Joint Stock Company "Production Association "Electrochemical plant" (JSC "PA ECP"). It presents technical changes introduced into VLLW processing cycle, as well as analytical methods being in place to monitor the activity of the managed VLLW.

Keywords: *radioactive waste, very low-level radioactive waste (VLLW), VLLW generation, VLLW compaction, VLLW activity control, gamma-spectrometry.*

Joint-stock company Production Association Electrochemical Plant is one of four enterprises belonging to the separation and sublimation complex of the Russian nuclear power industry supplying nuclear fuel cycle facilities of the State Atomic Energy Corporation Rosatom with power-grade uranium.

Separation production is seen as a main activity of the enterprise producing low-enriched power-grade uranium with ^{235}U content of up to five percent, which is used to manufacture fuel for nuclear power plants. Uranium enrichment is implemented based on gas-centrifuge method being considered as the most efficient industrial uranium enrichment method.

In addition to power-grade uranium, this process results in the generation of a by-product – uranium hexafluoride depleted of ^{235}U (DUHF). DUHG defluorination is performed at PA ECP facilities resulting in the production of uranium oxide (U_3O_8) being a stable chemical compound inert in air and hydrofluoric acid considered as a commercial product of the process.

As a result of the aforementioned activities, similar to any other production activities, PA ECP generates uranium-containing process waste that are handed over to the regeneration facility for further processing.

Processing of the generated waste

At the first stage of the processing, all waste handed over to the regeneration facility is treated using different methods to convert the uranium contained therein into a soluble form.

The processing provides for deep extraction of uranium enabling its recycling in separation facilities and generates waste solutions at the outlet with a minimum concentration of uranium ranging from 1 to 2 mg/dm^3. This process method involves reception, pre-treatment and extraction processing of uranium-containing solutions resulting from the production of uranium isotopes, conversion of uranium hexafluoride, washing of the main and auxiliary equipment constituting to the separation production, namely flow routes and sections of the regeneration facility, decontamination of the regeneration facility and separation units, its process equipment and production premises.

Figure 1 presents the management flow chart for uranium-containing solutions.

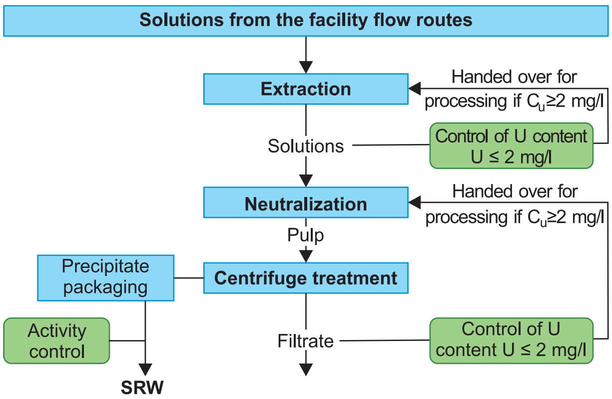

Figure 1. Management flow chart for uranium-containing solutions

Pre-treatment of solutions preceding the extraction processing provides for their conditioning by nitric acid allowing to bring their acidity to a specified level (in this case, poorly soluble uranium compounds are converted into well-soluble uranyl nitrate) followed by heating and filtration.

Following the extraction treatment, solutions with uranium content of less than 2 mg/dm^3 are sent to the neutralization station. If the content appears to exceed 2 mg/dm^3, the solution is subject to re-extraction [2]

Lime milk is used to neutralize effluent solutions. Lime pulp resulting from such neutralization is reanalyzed to monitor the concentration of uranium and determine its specific activity.

To evaluate the potential of reducing the generated RW volume, ECP performed a research to study the distribution of radioactive substances in the pulp resulted from the neutralization process.

The studies have shown that as the neutralization process occurs, uranium isotopes are concentrated in the solid phase of the pulp. The liquid phase contains only short-lived uranium decay products and by its characteristics cannot be categorized as liquid radioactive waste (LRW).

Specific activity of uranium isotopes in the liquid phase amounts to 0.8—1.2 Bq/m^3, which is clearly lower than the intervention level specified based on the content of uranium isotopes in drinking water [1].

Based on the research performed, in 2008 a decision on upgrading the neutralization station was made. Thus, a unit enabling pulp separation into solid (sediment) and liquid (centrate) phases using a H-350 vertical centrifuge manufactured by Sverd-NII-Khimmash plant was planned to be introduced (Figure 2).

Figure 2. Centrifuge

In 2014, the pulp separation unit was put into commercial operation (Figure 3).

From the centrifuge unit, centrate is fed into tanks located inside a premise of the pulp separation unit. After their filling, the centrate is

Figure 3. Pulp segregation facility

sampled. If uranium content does not exceed the permissible concentration, the centrate is handed over to a storage facility. Otherwise, it is sent for reprocessing.

Precipitate from the centrifuge is poured into a plastic bag installed inside a transport container being located under a discharge pipe of the centrifuge. After being filled, the bag is sealed. Container containing the filled bag is closed by a lid, placed in a purpose designated temporary storage facility which is followed by the measurement of its radiation characteristics.

As the number of filled up containers grow, they are transported to the solid radioactive waste (SRW) storage facility: bags with sludge are accepted for storage, whereas empty containers are returned to the pulp separation unit.

Summing up, it can be stated that pulp separation into sediment and centrate by centrifuge treatment, as well as subsequent storage of the sediment in sealed packages was the first step in addressing the challenge of the generated LRW deep processing enabling to:

- evade of LRW generation;
- minimize the risk of uncontrolled release of radioactive materials into the environment;
- to record and control the inventory of RW activity sent for storage.

Opportunities for treating the centrate to remove the chemical impurities with the treated water that could be subsequently discharged into the sewage system are currently being investigated.

Management of very low-level SRW

Very low-level radioactive waste is generated both directly from process operations and from the maintenance and operation of production equipment of nuclear facilities.

The resulting solid VLLW (SRW) is collected, segregated by type (PPE, polymers, etc.), packaged and, following specific activity measurements, handed over for storage.

To reduce the amount of SRW handed over for storage, a decision was made on arranging for a waste compaction unit based on the designs of a pressing plant manufactured by JSC SverdNIIkhimmash:

The main characteristics of the installed press are as follows [3]:

- pressing force — not less than 300 kN;
- stroke of the stamp — not more than 1,200 mm;
- production from a raw product — from 0.7 to 2.0 m^3/h;
- power of installed electric consumers — not more than 35 kW;
- weight — not less than 1,600 kg.

Operation of the press enabled a 3-fold reduction in the amount of SRW handed over for storage.

The following types of SRW are subject to compaction (pressing):

- rubber products, plastic;
- respirators, personal protective equipment, shoes;
- small construction debris and other waste materials;
- filters, rags.

After a certain amount of SRW is accumulated, the waste is packaged into 200-liter drums sent directly to the pressing facility.

Then the drum is tightly sealed and the specific activity of the pressed SRW is measured.

Operation of the pressing unit (Figure 4) designed for SRW compaction reduced the amount of SRW being sent for storage, whereas hermetically sealed drums ensure the compliance with radiation safety requirements at all stages of waste management.

Figure 4. Compaction unit

Radiation monitoring is performed on a mandatory basis each time before the compacted SRW is shipped to the storage site.

VLLW activity control

Natural uranium isotopes — 238, 235 and 234 constitute to the radioactive contamination of solid waste generated at PA ECP site.

Alpha spectrometry, being considered as a standard method in the identification of uranium isotope specific activities, cannot be applied when it comes to pulp filtering or SRW compaction flow charts due to necessary long-term radiochemical pre-treatment of samples.

It has been demonstrated that it's the gamma spectrometry method that provides adequate promptness in measuring the specific activity of uranium isotopes [4].

ISOCS gamma-ray spectrometric system (Canberra) appeared to be a most suitable tool for addressing the difficult task of identifying the specific activity of uranium isotopes in SRW with low densities (solid sediments from the pulp separation unit) and uneven densities (SRW pressing in drums). The system features a coaxial HPGe-detector with an efficiency of at least 40% fitted with a rotating weighing platform.

This gamma-spectrometric system is applied by PA ECP demonstrating high efficiency and effectiveness of SRW measurements.

Findings and conclusion

The policy of VLLW management followed by PA ECP is based on the implementation of classical RW processing methods.

Nevertheless, this approach enabled to achieve very good results suggesting complete purification of the generated liquid process waste from radionuclides and complete elimination of further LRW generation.

It is also important that the method implemented to treat uranium-containing process solutions does not at all affect already applied uranium recycling methods, solely impacting the quality of the final liquid process solutions generated from the operation of the enterprise.

Ongoing activities performed at the enterprise on further upgrading of the resulting solution purification methods demonstrate great prospects of the RW management strategy being followed by PA ECP.

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