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THE ESTABLISHMENT OF MOBILE INSTALLATION FOR CONTAMINATED SOIL TREATMENT BASED ON THE TECHNOLOGY OF HYDRO-GRAVITY SEPARATION OF FINE FRACTION IN “VNIINM”

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The article describes a mobile installation designed for radioactively contaminated soil treatment via hydro-separation method. It presents the results of laboratory and pilot decontamination tests involving soils from the cleanup of radioactively contaminated areas at JSC “VNIINM”. The paper also discusses the results obtained from similar laboratory tests involving contaminated soils from JSC “AECC”. These findings can be used to estimate the efficiency hydro-separation method in the decontamination of very low-level waste.

Keywords: *radioactively contaminated soil, hydro-separation method, mobile installation, fine fraction, decontamination factor.*

Nuclear decommissioning usually results in big amounts of radioactively contaminated soils (RCS) [1, 2]. Such soils differ depending on their physical, chemical and radiation characteristics. Presence of long-lived radionuclides with long half-lives is considered to be a most common feature of radioactively contaminated soils. Due to this reason, such soils may remain potentially hazardous for a long period of time. Another distinctive feature is that large amounts of such soil may be characterized with specific activity levels being lower than the values set in relevant criteria enabling to characterize it as radioactive waste [3]. At the same time these soils are to be treated as a material intended for restricted use being contaminated with anthropogenic radionuclides and requiring specific management in keeping with national standards.

Excavation costs for large amounts of radioactively contaminated soils are high, thus, it is considered more feasible to treat such waste in-situ.

Decisions on the selection of particular RCS decontamination technics and equipment are based on the origin and activity level of radionuclides, their distribution in soils, as well as their physical and chemical properties. While choosing proper cleanup technologies account shall be taken of the following provisions:

- Minimization of operational costs during the implementation of cleanup operations;
- Minimization of secondary RW generation and relevant costs associated with their further management.

Hydro-gravity separation of fine fraction is considered to be one of the most common and widely used methods for RCS treatment [4, 5]. Up to 80 % of contaminants account for a fine fraction with a grain size of less than 150 μm, whereas their mass fraction is less than 20 %. Removal of this fraction provides a significant decrease in soil contamination level as a whole. Contaminated soil fraction is subject to concentration, dehydration and waste storage. Aqueous solutions are considered to be recyclable and are subject to multiple use.

Treatment procedure based on hydro-separation method involves a number of stages, namely: soil dispersion in aqueous medium, separation of gravel and sand components, segregation of the sand component by fractions according to the particle size,

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segregation of the most contaminated fine fraction, conditioning of secondary waste products resulting from such treatment.

RCS management is considered to be quite a challenging issue for JSC "VNIINM" as future nuclear decommissioning planned for this site may result in over 3,000 m^3 of soils (restricted use) contaminated with anthropogenic radionuclides.

In 2010—2012, cleanup of radioactively contaminated areas present at the "VNIINM" site was performed resulting in 71.9 m^3 of RCS.

Such challenges are common not only for "VNIINM" site. For example, large-scale cleaning is currently planned for JSC "MSZ" and JSC "AECC" sites with big RCS amounts to be generated.

To address the challenge of RCS management and to test relevant decontamination methods, a mobile installation enabling RCS treatment via hydro-separation method was developed at JSC "VNIINM".

Development of a mobile installation for RCS treatment

The experience from the application of hydro-separation method at other enterprises was evaluated by "VNIINM" during design development [4—6]. The use of JSC "VNIINM" installation offers some extra benefits which can be exemplified as follows:

- Modular structure enabling equipment transportation to relevant RCS sites via vehicles with further assemblage of the equipment at a prearranged site;
- High level of automatization;
- Use of standard equipment.

RCS treatment installation consists of six modules (scrubber module, separator module, conditioning tanks, thickener module, filtering module, cement cake module, auxiliary equipment), enabling to:

- Decontaminate contaminated soils providing the extraction and removal of fine material using hydro-separation method;
- Treat aqueous — sandy sludge;
- Extract and remove fine solid fraction and recycle process water after its treatment;
- Generate end-product with stable characteristics and a compact form of secondary waste.

Installation modules are assembled in a temporary structure having an area of 150 m^2 providing for 1,000 kg/h soil treatment capacity (installed capacity — 50 kW). The temporary structure is fitted with radiation control systems, local active ventilation, water supply and sewerage systems, engineering equipment.

Operational process

RCS treatment in the modular installation described above involves a number of stages.

RCS is primary fed to the grate of a loading hopper enabling the separation of a fraction with a grain size of over 100 mm, subsequently removed from the grate into a revolving container. Remaining soil is transported by conveyor to a "scrubber-sizing trommel" module where its mixing with recyclable water occurs. Scrubber provides for soil disintegration and the sizing trommel enables its separation into two fractions depending on the grain size: one — ranging from 3 to 100 mm and the other — less than 3 mm.

A belt conveyor enables further unloading of soil gravel fraction with a grain size of 3—100 mm from the "scrubber-sizing trommel" module. Sand fraction of less than 3 mm in size along with the fine fraction and recycled water (pulp) is accumulated in the hopper and pumped to separator module.

The latter one having a spiral shape enables water-gravity separation of the soil into two fractions: 0.15 to 3 mm in size and less than 0.15 mm in size. The pulp with the fine fraction is fed into collector tank, whereas the sand is subject to washing, dehydration with further unloading to a revolving container via a belt conveyor.

Pulp containing fine fraction material (particle size of less than 0.15 mm) is pumped into conditioning tank module fitted with a stirrer where it is mixed with flocculant solution and subsequently pumped into thickener module operated in a continuous mode. The thickener module provides recyclable water treatment and sediment thickening and consolidation. Recyclable water is accumulated in the tank and, thus, continuously participates in the soil treatment cycle. The consolidated sediment containing finely dispersed fraction is pumped to the module equipped with a belt filter press, where it is dewatered to a wet cake state that can be immobilized in the cementation module.

Spectrometric measuring complex is in place to control RCS and soil fraction radiation characteristics once the treatment operations are over.

Testing of RCS treatment installation at JSC "VNIINM"

71.9 m^3 of RCS excavated earlier during the cleanup of radioactively contaminated areas at JSC "VNIINM" site and containing Cs-137 were subject to treatment in 2017 as part of testing operations.

The operations performed to test relevant equipment and technologies enabled to extract the main products resulted from RCS processing (figure 1). Table 1 summarizes relevant findings.

Specific activity of Cs-137 in RCS subject to treatment amounted to 370 Bq/kg. Specific activity of the extracted soil fractions with a grain size of over 3 mm (gravel) and 0.15—3 mm (sand) averaged to some 79 and 75 Bq/kg respectively. Specific activity of fine fraction materials with an average grain size of less than 0.15 mm (cake) averaged to some 1,660 Bq/kg. Segregation of Cs-137 from the most contaminated fine-grained fraction resulted in an average decontamination factor of 5.

Figure 1. Unloading of processing products: a) from scrubber module with grain size of over 3 mm; b) from separator module with grain size of 0.15–3 mm; c) from filter-press module with grain size of less than 0.15 mm

Table 1. Summary of results obtained from the testing of a mobile installation for RCS treatment

Parameter	Unit	RCS	By-products from RCS treatment			Volume reduction factor	Decontamination factor
			gravel, > 3 mm	sand, 0.15–3 mm	cake, < 0.15 mm		
Amount	% vol	100	18.9	63.3	17.8	5.6	–
	m^3	71.9	13.6	45.5	12.8		
Cs-137 activity	%	100	7	11	82	–	4.8
	Bq/kg	370	79	75	1660		

The amount (final volume) of secondary waste (cake) depends on the fine fraction content in RCS. Pilot treatment of RCS involving 71.9 m^3 of soils resulted in 12.8 m^3 of fine fraction. Thus, a 5.6-fold reduction in volume was achieved. This pilot project evidenced that operational parameters of such treatment are consistent with those specified for the hydro-separation method of soil treatment.

Laboratory test installation for RCS treatment

Specific parameters of the installation treating soils via hydro-separation method and of the relevant operational process have to be specified based on particular features of the contaminated soil (including radionuclide and granulometric content). This requires preliminary study of soil properties and technology testing and elaboration using small volume samples of soil. To enable this, a laboratory test installation has been developed, fabricated and tested at JSC "AECC" (figure 2).

The laboratory test installation features the following key components: stirring vessel, separator, a continuously operating thickener vessel, filtering vacuum cell. Auxiliary equipment and devices included a washing unit, pipelines, connecting elements, shut-off valves, pumps, containers to collect the materials withdrawn from the process. It's capacity in terms of contaminated soil treatment was no more than 5 kg/h. Characteristics of its key components were set based on treatment stages specified for the full-scale modular soil treatment installation operated at JSC VNIINM. So, the operational parameters being very similar to those that could be observed in real life.

Figure 2. Laboratory test installation for RCS treatment via hydro-separation method

Table 2. Summary of results from hydro-separation method laboratory testing involving JSC AECC soils

Sample №	Parameter	Unit	RCS	Fraction with particle size of, mm			Decontamination factor	Volume reduction factor
				> 0.7	0.05 – 0.7	<0.05		
1	Granulometric composition	%	-	11.2	58.8	29.8	-	2.5
	U-238 specific activity	Bq/kg	270	630	140	400	1.9	-
2	Granulometric composition	%	-	14.8	66.7	18.6	-	3.0
	U-238 specific activity	Bq/kg	290	220	130	330	2.2	-
3	Granulometric composition	%	-	17.5	66.1	14.3	-	3.1
	U-238 specific activity	Bq/kg	320	550	90	770	3.5	-

A number of experiments was carried out at this installation to test hydro-separation treatment method. These experiments featured soil from JSC AECC primarily contaminated with uranium radionuclides. Samples № 1, 2 and 3 had different contents of fine fraction material with a grain size of less than 0.1 mm for 45—60 % (mass.), 35—45 % (mass.) and less than 35 % (mass.).

Four types of by-products resulted from this treatment process:

- Fractions with a grain size of less than 0.05 mm (cake, 60 % moisture content);
- Fractions with a grain size varying from 0.05 to 0.07 mm (characterized by the lowest specific activity of relevant radionuclides);
- Fractions with a grain size of over 0.7 mm (sand containing gravel);
- Recyclable water with gravel particle content of over 150 mg/l.

Products resulting from such treatment have been investigated and it was found that some 70 % of radionuclides had been concentrated in a fraction with a grain size of over 0.7 mm, whereas the fraction with a grain size of less than 0.05 mm accounted for 18—29 % (mass.) respectively from the initial soil content. Soil decontamination factor depends on the fine fraction content ranging from 2 to 4 for different radionuclides. Volume reduction factor for RCS from JSC “AECC” averaged to 3. Table 2 summarizes the results of the laboratory tests described above.

Total specific activity of key contaminating radionuclides contained in the treated fraction accounted for less than 300 Bq/kg enabling to release these materials from radiation control [7].

In general, laboratory tests performed to treat RCS using the hydro-separation method have shown good performance of the proposed technology and enabled to specify relevant parameters and indicators ensuring its high performance in treating soils from JSC “AECC” site.

Treatment of contaminated soil from JSC “AECC” site using hydro-separation method is still ongoing at JSC “VNIINM” to prove the effectiveness of this technology.

Conclusions

A mobile modular installation enabling radioactively contaminated soil treatment using hydro-separation method has been put into operation at JSC VNIINM. Pilot processing of these soils enabled a 5.6-fold reduction of RCS by volume. It was also shown that operational parameters of the treatment process are consistent with those required by the hydro-separation method applied, whereas relevant equipment specifications correspond to the values specified in the designs.

Minimal operational costs associated with the treatment process itself, as well as the use of standard equipment enables to perform in-situ RCS treatment using a mobile installation.

Tests performed at JSC “AECC” test installation showed that this process ensures effective RCS treatment and enabled to start pilot-industrial testing of JSC “VNIINM” module installation to treat JSC “AECC” soils. Based on the preliminary results it can be concluded that cleanup estimates for soils categorized as VLLW may be derived based on the characteristics of the operational process that had been applied to treat JSC “AECC” soils being under restricted use.

References

1. Problems of nuclear legacy and ways of their solution: in 2 vol. / Edited by E. V. Evstratov, A. M. Agapov, N. P. Laverov, L. A. Bolshov, I. I. Linge. — Moscow: «Energoatomanalitika», 2012, vol. 1, 356 p.

2. *Stepennov D. B., Strizhakova E. R., Vasileva G. K.* Problems of recultivation of lands contaminated with radionuclides and other anthropogenic pollutants, temporary storage of SNF and RW. Proceedings of the XI International Symposium «Ural Atomic, Ural Industrial» — Ekaterinburg: Institute of industrial ecology, 2006, p. 301—302.

3. Government regulation of the Russian Federation «On criteria for classifying solid, liquid and gaseous waste to radioactive waste» dated 19 October 2012, № 1069.

4. *Volkov V. G.* Handling radwastes during rehabilitation of contaminated objects and grounds of the Kirovo-Chepetsk Chemical Works / Volkov V. G., Pavlenko V. I., Chesnokov A. V., Arustamov A. E. Atomic Energy, 2009, vol. 107, no 4, pp 284—289.
5. *Velikhov E. P.* Rehabilitation of the radioactively contaminated objects and territory of the Russian Science Center Kurchatov Institute / E. P. Velikhov, N. N. Ponomarev-Stepnoi, V. G. Volkov, G. G. Gorodetskii and another. Atomic Energy, 2007, vol. 102, no 5, pp. 375—381.
6. *Mikheikin S. V.* Soil decontamination by hydroseparation. Environmental Safety, 2006, no 3, pp 48—50.
7. SP 2.6.6.2572-2010 Sanitary Rules «Radiation safety in handling industrial wastes of nuclear stations containing technogenic radionuclides».

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