Hybrid Wet Technology for Soil Decontamination - 10294

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ABSTRACT
Hybrid Wet Technology (HWT) was developed and tested in the Chornobyl exclusion zone for decontamination of sandy soils. It was shown that most part of radionuclides (~90%) and all hot particles is concentrated on fine-dispersed fractions of soil and makes about 5% of total RW volume. For confirmation of HWT two types of contaminated soils were used: 1) accident soil samples from the Shelter object industrial site and 2) soil samples from the temporary RW storage in Chornobyl exclusion zone. Maximal effect was achieved in first case where hot particles were main contaminant. Radionuclide extraction was on the level 97% - 99% of input activity for ^{90}Sr (69% + 30%), ^{137}Cs (65% + 32%), ^{241}Am (87% + 12%) and ^{238,239,240}Pu (72% + 27%) isotopes (in parenthesis first figure is hydro-separation contribution, second – leaching contribution to the total effect). Clean-up for soil samples from temporary RW storages in Chornobyl exclusion zone was about 80%. Technological fluids are circulating in the closed loop producing minimal volume of liquid operating RW. Industrial facility with rated capacity 10 ton of soil per hour may be assembled using commercial equipment.

INTRODUCTION
Main objects for environment remediation are contaminated soils. Contaminated soils are not waste by definition because they may be used for biomass production. It is well known that fitoremediation is one of the most attractive methods for soil decontamination. However, during remediation works after radiation accidents, contaminated soils are forming the most part of radioactive waste (RW). For example, in the Chornobyl exclusion zone (CEZ), they produced about 800 thousand m^3 of RW, or 60% of all RW localized in temporary storage (dumps). Having in mind future remediation of CEZ, the retrieval of RW from some dumps is urgent. Disposal of such volume of waste requires huge economical, technical and human resources. Therefore, development of safe and cost-effective processing for reduction of disposed RW volume is an important task. Hybrid Wet Technology (HWT) was developed and tested in the CEZ for decontamination of sandy soils from Shelter Object industrial site, contaminated mostly by hot particles. Currently such technology becomes urgent due to the expected construction of New Safe Confinement for Shelter Object at Chornobyl NPP. During building of the New Safe Confinement foundation and some auxiliary objects of its infrastructure about 100-150 thousands of cubic m of contaminated soil and contaminated fragments planned to be retrieved. Part of contaminated soil (with dose rate less than 0.3 mSv/hour) might be used for backfilling. But considerable part of removed contaminated soil must be disposed in radioactive waste storage. Temporary safe storage of retrieved contaminated soil and subsequent disposal of expected volume of radioactive waste will require considerable current and capital expenditures.

HYBRID WET TECHNOLOGY FEATURES
Implementation of Hybrid Wet Technology based on non-uniformity of activity and hot particles distribution between granolumetric fractions of contaminated soil (Table 1).

Table 1. Granulometric Composition of Contaminated Soils and Calculated Distribution of Hot Particles on Fractions.

Grain size, mm	Mass percent of fraction,%	percentage of Cs-137 activity in fraction, %	percentage of hot particles, %
<0,001	<0.1	1	<0.1
0,001-0,005	1	6	10
0,005-0,01	2	10	18
0,01-0,05	12	34	58
0,05-0,1	14	20	14
0,1-0,25	32	17	<0.1
0,25-0,5	32	5	<0.1
0,5-1,0	6	3	<0.1
>1,0	1	4	<0.1
Total	100.0	100.0	100.0

Most part of radionuclides and all hot particles are concentrated on fine-dispersed fractions of soil. In the case of predominant contamination of soil with hot particles, as it was immediately after Chornobyl accident, separation of soil grains with dimensions < 0.05 mm ensured 90% decontamination due to removal of hot particles (Table 1, column 3). Currently contamination of soil is caused not only by hot particles but also by radionuclides adsorbed on soil grains. Decontamination of such soil requires separation 60% of grains with dimensions < 0.25 mm (Table 1, column 2). Evidently that such decontamination is inefficient because it does not decrease the volume of waste. This was a reason to use two-stage decontamination process. On the first stage (hydroseparation) fine-dispersed fraction and hot particles were separated. On the second stage (leaching) the residual soil is washed in acidified solution for desorption of radionuclides. Hence, extraction of fine-dispersed fraction (grain size down to 0.1 mm) will ensure practically total clean-up of soil from hot particles and further to essential decrease of of soil contamination provided by radionuclides retained on soil grain surface. Processing of contaminated soil with pH<5.0 solutions produces leaching of absorbed radionuclides. Sedimentation rate of hot particles and fine-dispersed fractions is much less than the same for major fractions that account for 95% of RW volume. This was a reason for use of hydro-separation processing resulting elimination of radionuclides, centrifugal separation of fine-dispersed fraction enriched with hot particles and subsequent washing and leaching of the remain major-fraction soil.
Simplified lay-out of HWT pilot facility is shown on the Figure 1.

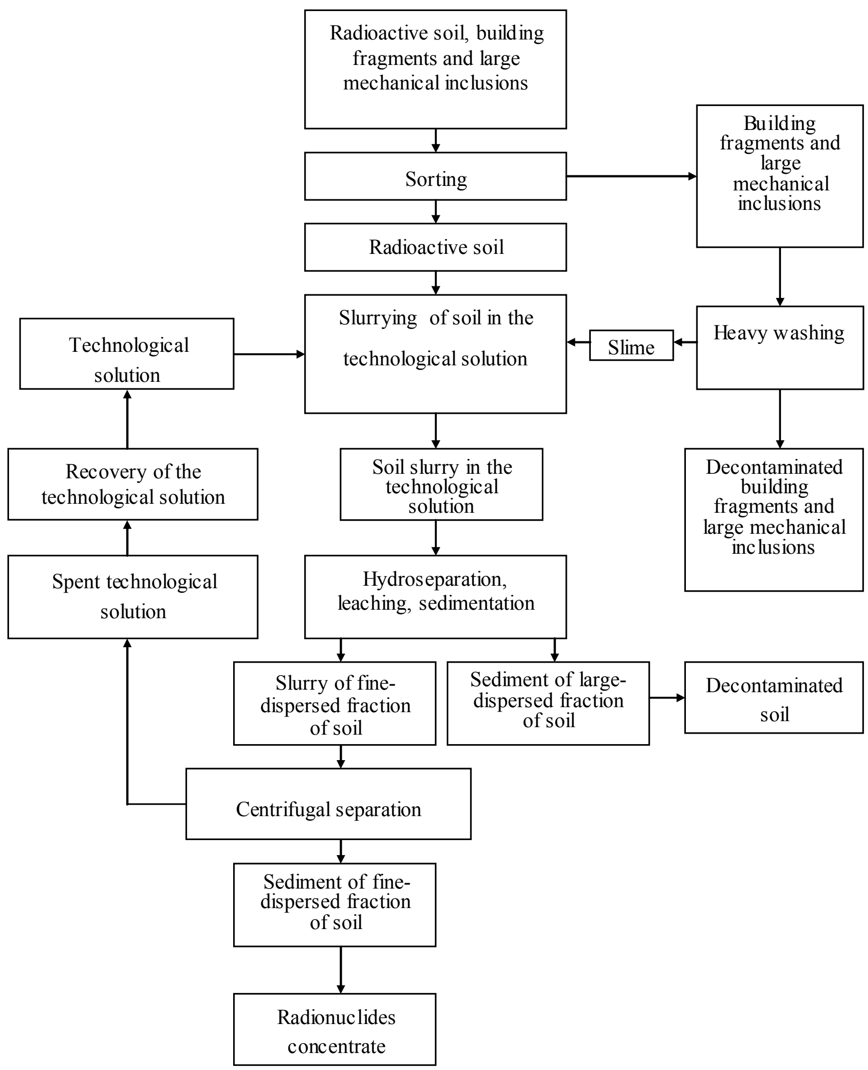

Figure 1. Simplified lay-out of hybrid wet technology.

Engineering activity for contaminated soil processing includes the following steps: 1) soil excavation; 2) sorting of excavated soil on exposure dose rate; 3) temporary storage of low-level activity soil for future backfilling after regulatory permit; 4) segregation of fragments and soil; 5) intensive washing out of fragments to remove loose contamination and pumping of radioactive liquor to the unit of soil slurry; 6) hydraulic classification of soil suspension during which fine-dispersed soil fraction enriched with hot particles and sediment of large scale soil fractions are generated; 7) leaching of absorbed radionuclides from large scale soil fractions sediment with acidified technological solution; 8) centrifugal separation of fine-dispersed fraction suspension on fine-dispersed fraction sediment and hot particles; 9) residual technological solution comes back to circulated in loop technological liquids for reuse after recuperation, including restoration of pH.

HYBRID WET TECHNOLOGY DEMONSTRATION TEST

The demonstration test was performed on the pilot facility with the productivity 100 kg of contaminated soil per hour. For confirmation of HWT two types of contaminated soils were used: 1) accident soil samples from the Shelter object industrial site and 2) soil samples from the temporary RW storage in CEZ. Maximal effect was achieved in first case where hot particles were main contaminant. Efficiency of decontamination was determined by comparison of activities of the input (original) soil and the activity of residual radioactive waste (radionuclide concentrate in the Figure 1). Experimental results are shown in the Table 2.

Table 2. Hydraulic Classification and Leaching Efficiency for Processing of Soil from the Shelter Object Industrial Site

Processing stage	Decontamination efficiency (radionuclide extraction), % of input activity in soil			
	Cs-137	Sr-90	Am-241	Pu-238,239,240
Specific activity of the input (original) soil, Bq/g	$2.6*10^{+3}$	$0.8*10^{+3}$	$5.6*10^{+1}$	$2.8*10^{+1}$
Hydraulic classification	69	65	87	72
Leaching	30	32	12	27
In total	99	97	99	99

Radionuclide extraction was on the level 97% - 99% of input activity of soil from the Shelter object industrial site. Results of clean-up for soil samples from temporary RW storages in CEZ are shown in the Table 3.

Table 3. Efficiency for Processing of Soil from the Temporary RW Storage in CEZ

Sample	Specific activity, Bq/kg			
	Cs-137	Sr-90	Am-241	Pu-238,239,240
Contaminated soil	$2.7*10^{+4}$	$5.4*10^{+3}$	$2.2*10^{+2}$	$1.6*10^{+2}$
Decontaminated soil	$3.3*10^{+3}$	$9.6*10^{+2}$	$4.0*10^{+1}$	$2.9*10^{+1}$
Decontamination efficiency, %	88	82	82	82

Technological fluids are circulating in the closed loop producing minimal volume of liquid operating RW. After manifold circulation and recuperation not more than 0.002 cubic m of intermediate level RW per 1 ton of contaminated soil is generated. Industrial facility with rated capacity 10 ton of soil per hour may be assembled using commercial equipment.