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Immobilization of radionuclides into thermal insulation waste

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Large amounts of low-density thermal insulation mineral wool waste contaminated by radionuclides arise from NPP operation. Melting of this waste reduces its volume by more than 10 times. Mineral fibers begin to lose their elastic properties at 440 oC and to soften at 700 oC. The minimum process temperature for molten fiber formation is ~ 1500 oC. Experiments were performed on mineral wool mats with specific activity of Cs-137(4.0-8.8)×108 Bq/kg. The experiments employed an industrial induction furnace as a waste melter. The melter was a graphite crucible with an opening provided at the bottom, through which the formed melt flowed down by drops into a receiving container. During the experiment, the melt discharge rate was from 1.8 to 2.2 kg/h, the melt temperature was 1350-1370 oC, and the rate of power consumption was 8.3 kW×h/kg. The solid-aerosol carry-over was not larger than 0.5 % and volatile loss of Cs-137 was only 2.8 % from the melting process. To reduce the mineral wool melting temperature from 1350-1370 oC to 1170-1190 0C, a low-melting fluxing agent, namely FeO (at least 10 wt. %), was used. The true density of the "frozen"mineral wool melt without addition of fluxing material was 2.7 g/cm3 and with addition of 10 % CaF2 the density increased to 2.8-2.9 g/cm3. Additional experiments were performed with crushed mineral wool incorporated into Portland cement modified by Cambrian clay as a sorption agent. The crushed wool was admixed to cement slurry with water-to-cement ratio of 0.7 and claycement ratio of 0.1. The density of produced cement compounds was about 1.8 g/cm3. Measurement of Cs-137 leaching from the thermal insulation waste forms has shown that addition of a fluxing agent to melt increases (almost by an order of magnitude) the radiocesium leach rate from the conditioned waste. But in any case this leach rate is of 10-7 g/cm2×day order after 150 days of the experiment. For comparison, Russia's regulatory maximum value for Cs-137 leach rate from vitrified high-level waste is 1×10-7 g/cm2×day. For low- and intermediate-level wastes stored in standard concrete facilities, the acceptable rate of radiocesium leaching after 150 storage days is not higher than 1×10-3 g/cm2×day. Cemented thermal insulation waste forms with addition of clay comply with this requirement (the leach rate is ~1.0×10-4 g/cm2×day after 150 days).

Primary authors: Dr MYSIK, Sergey (Grigorievich); Prof. EPIMAKHOV, Vitaly (Nikolaevich)

Presenter: Prof. EPIMAKHOV, Vitaly (Nikolaevich)

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