CdZnTe Detector Using for Characterization MR Water Cleanup System before Dismantling. – 17005

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ABSTRACT

The Kurchatov Institute's MR research reactor water cleanup system comprises 20 containers with ion-exchange resin. Each container is 25 cm in diameter and 130 cm high. These containers are placed under the floor with 50 cm concrete protection. Access to container is provided via technological hole with protective covers. A CdZnTe detector was chosen for spectrometric investigation due to high exposure dose level from containers. A collimated spectrometric system on the basis of a semiconductor detector CdZnTe (volume of a crystal of 20 mm^3 or 60 mm^3) and a multichannel analyzer InSpector 2000 was developed. It was determined that 8 of the 20 containers were filled with the ion- exchange resin in aqueous solution. The main dose forming radionuclide was ^{137}Cs. Specific activity was from 10^7 Bq/kg to 10^9 Bq/kg in different containers. Measurements were carried out in high radiation fields and the background radiation reached the detector even through the lead shield, which created difficulties in the interpretation of collected data. For verification of the results some samples of ion-exchange resin was taken from containers. The concentration of γ-ray radionuclides was estimated by the Canberra Company spectrometric complex that included a semi-conductor detector made of HP Germanium. Obtained data had good correlation with the data of the CdZnTe collimated spectrometer. Our investigation has shown that remote mechanisms must be used to remove the containers with ion-exchange resin.

INTRODUCTION

From 2011 specialists of the NRC "Kurchatov Institute" carried out the dismantling of the multiloop research MR reactor. The MR reactor and its elements from reactor hall were dismantled. At the present time current activities consists of decommissioning and dismantling contaminated support facilities and equipment.

Water cleanup system of the MR reactor is in the room № 86 near the reactor hall (Fig.1). The system comprises of 20 containers with ion-exchange resin. Each container is 25 cm in diameter and 130 cm high. The containers are connected by piping system which is part of the water cleaning system. These containers are placed under the floor of room № 86 with 50 cm concrete protection (Fig. 1). Access to the containers is provided via technological hole with protective covers.

The dosimetric measurements showed exposure dose rates up to 400 μSv/h in the room and 160-200 mSv/h under protective covers near containers. The β-contamination of the room surfaces were from 10 to $2 \cdot 10^4$ counts per second per square cm.

Fig.1 Room №86 (left), technological hole with open protective cover (right).

The survey objectives were to define the level of filling of the containers, estimate specific activity of ion-exchange resins, and make recommendations for the removal of the radioactive objects from the room.

METHODS

The new collimated spectrometric system was developed for measuring the specific activity of the containers. The main elements of system are: a measuring unit, a digital multi-channel analyzer InSpector 2000, and the control computer. The measuring unit consists of a semiconductor detector - CdZnTe (CZT) crystal placed in a lead shield with collimator. The exposure dose rate near the containers with the ion-exchange resin was 160-200 mSv/h. Radioactive irradiations from nearby containers passes through the lead shield and has a significant effect on the results of measurements. To reduce the background radiation a collimator with a lead screen was used and two measurements with open and closed screen were made. The scheme of the collimator is shown in Figure 2.

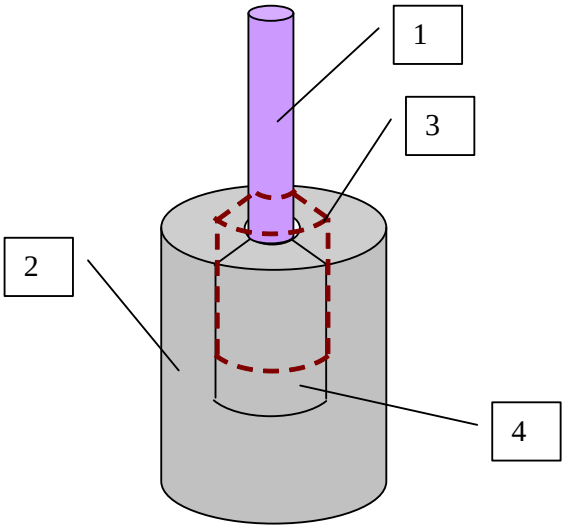

Fig.2. The scheme of collimator: 1- detector, 2- lead shield, 3 – movable lead screen, 4- slit of collimator.

The collimator is a 3 cm thick lead cylinder with closed bottom; movable lead screen that can open a aperture of 1,5 cm high and with 60° solid angle. Figure 3 provides pictures of the collimator.

Fig.3. Collimator photos with closed lead screen (left) and open lead screen (right).

The semiconductor detector - CZT672, produced by Ritec Ltd. (Latvia) was used. Sensitive part of CZT672 detector is a CdZnTe crystal of 60 mm^3 volume and with a signal cable of 20 m in length. The detector has high energy resolution at room

temperature and is of compact size (8 mm cylinder). Also the collimator can be used with detector CZT671, which has the same geometrical size, but 20 mm CdZnTe crystal volume. The table I show the parameters of CZT672 and CZT671 detectors. Operating parameters measured at 662 KeV energy line of ^{137}Cs at the detector operation voltage under normal condition.

Table I. The parameters of CZT672 and CZT671 detectors.

parameter	CZT671	CZT672
Detector operating voltage (positive polarity)	150 V	400
Energy resolution, FWHM	8.9 KeV	12.2
Energy resolution, FWTM	38.0 KeV	41.7
Peak-to-Compton ratio	3.4	3.5
Peak-to-Valley ratio	33.6	55.1
Output signal polarity	negative	negative
Time of continuous operation	12 hours	12 hours

The signal from the detector comes to a multichannel analyzer of InSpector 2000 produced by Canberra Industries, Inc. (USA). The InSpector 2000 is a portable multichannel analyzer and includes digital alarm processor with program control. Using of the digital alarm processor allows for increasing channel capacity and controlling stability of analyzer characteristics. The analyzer connects to the computer on RS-232 and USB interfaces and works under control of Genie-2000 software.

The calibration of the detector was carried out with a ^{137}Cs volume source. As a source 22 cm diameter container with a cesium aqueous solution for uniform distribution of activity was used. Calibration was made in the same geometry as for measurements. The calibration coefficient for ^{137}Cs was calculated at $2{,}79 \cdot 10^{6}$ Bq·kg^{-1}·s^{-1}.

EXPERIMENT

The collimated spectrometer detector was used to determine fill level of containers, estimate the specific activity of ion-exchange resin, providing activity distribution versus height. The following measurement technique was used. The collimated detector was mounted on a metal rod. A thin-walled aluminum tube was placed along the side of the investigated container. Collimated detector was placed into the tube. Movement of the detector on height was controlled by using marks made on the rod. Measurements were carried out every 10-30 cm starting from the top of the container. At each point two measurements were made: with lead screen and without it. Figure 4 shows the aluminum tube, with collimated detector inside, near the container with ion-exchange resin. The results of spectrometric measurements are presented in table II.

Fig.4. Container with radioactive ion-exchange resins and aluminum tube.

Table II. Specific activity of ^{137}Cs in containers by depth.

H, cm	Specific activity of ^{137}Cs, Bq/kg.							
	№ of container							
	1	2	3	4	6	7	8	9
10	$1.1 \cdot 10^7$	$4.7 \cdot 10^8$				$7.8 \cdot 10^8$		$3.3 \cdot 10^8$
40	$6.6 \cdot 10^7$	$3.3 \cdot 10^9$	$1.1 \cdot 10^7$	$1.4 \cdot 10^7$	$2.6 \cdot 10^8$	$9.8 \cdot 10^8$	$1.0 \cdot 10^9$	$4.0 \cdot 10^9$
70	$3.2 \cdot 10^7$	$6.3 \cdot 10^9$	$3.1 \cdot 10^8$	$2.3 \cdot 10^7$	$3.3 \cdot 10^8$	$3.1 \cdot 10^8$	$1.5 \cdot 10^9$	$6.7 \cdot 10^9$
90	$5.9 \cdot 10^7$	$6.8 \cdot 10^9$	$8.3 \cdot 10^8$	$1.8 \cdot 10^8$	$4.0 \cdot 10^8$	$4.6 \cdot 10^8$	$1.6 \cdot 10^9$	$7.4 \cdot 10^9$
110	$8.8 \cdot 10^7$	$8.2 \cdot 10^9$	$8.4 \cdot 10^8$	$8.2 \cdot 10^8$	$3.8 \cdot 10^8$	$8.0 \cdot 10^8$	$1.4 \cdot 10^9$	$6.8 \cdot 10^9$
120	$6.4 \cdot 10^7$			$5.2 \cdot 10^8$			$1.3 \cdot 10^9$	$5.3 \cdot 10^9$

It was determined that 8 of 20 containers are filled with the ion-exchange resin in an aqueous solution. The spectra showed that the main radionuclide is ^{137}Cs. Containers № 3, 4, 6 and 8 probably were not filled completely. In some cases, it was impossible to make measurements of containers at the 120 cm depth due to technical difficulties.

Nevertheless, the interpretation of the measurements in the high radiation fields is ambiguous, due to background radiation, which reached the detector even through the lead shield (regardless of taking two measurements with the opened and closed lead screens). For control, measurements of several sample containers ion exchange resins were taken. During sampling, it was found that the contents of the containers were heterogeneous by volume. At the bottom of the containers was a layer of decayed ion-exchange resin, covered by the layer of water. The concentration of ^{137}Cs radionuclides was estimated by the spectrometric complex InSpector-2000 of the Canberra Company that included a semi-conductor detector using HP Germanium GC-4018. The analysis of the gamma-spectrum was made by the GENIE-2000 software. There is a typical spectrum of the sample from a container is shown on Figure 5. The results of the measurements are provided in Table III.

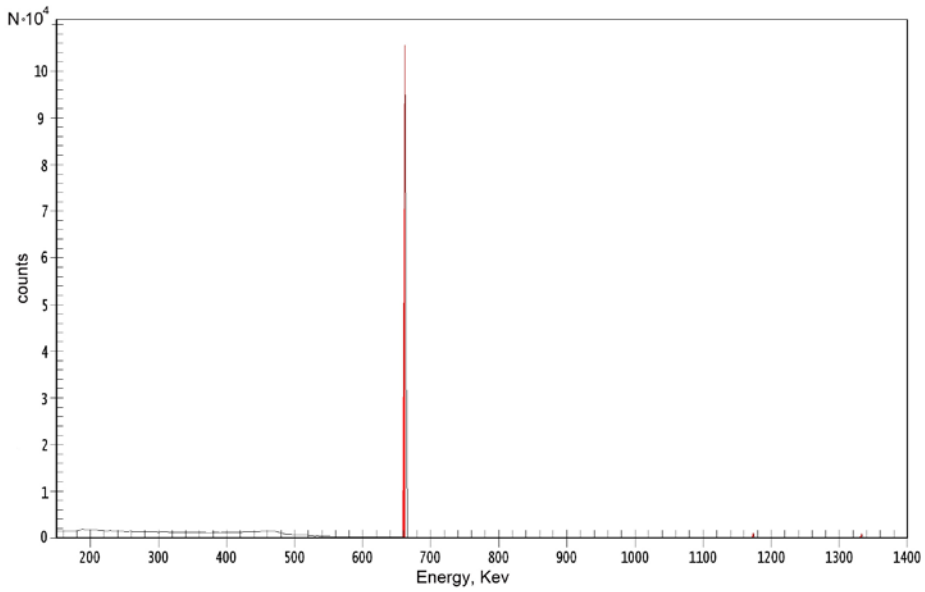

Fig.5 The spectra from container № 6

Table III. Specific activity of ^{137}Cs and ^{60}Co in containers.

№ of container	Specific activity of ^{137}Cs, Bq/kg	Specific activity of ^{60}Co, Bq/kg
1	$2,3*10^5$	$1,0*10^5$
2	$7,4*10^9$	$1,8*10^7$
3	$8,0*10^6$	$3,3*10^6$
6	$8,3*10^7$	$1,6*10^6$
7	$2,3*10^8$	$1,8*10^7$
8	$1,3*10^9$	$5,5*10^6$
9	$8,3*10^8$	$7,4*10^6$

The obtained have a good coincidence with the data obtained by means of the collimated spectrometer detector.

CONCLUSIONS

Dosimetric investigations had not identify which containers were filled with radioactive waste. In contrast, the collimated spectrometric with CZT detector allowed for non-destructive investigations of radioactive objects in high radiation fields. This method found containers with ion-exchange resin and provided its spectrometric characterization. Using of this system, allowed for determining the optimized process of container removal and identifying the necessity of using remotely-controlled mechanisms for actual removal.