New Remote Method for Estimation of Contamination Levels of Reactor Equipment – 13175

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ABSTRACT

Projects for decommissioning of shutdown reactors and reactor facilities carried out in several countries, including Russia. In the National Research Centre «Kurchatov Institute» decontamination and decommissioning of the research reactor MR (Material Testing Reactor) has been initiated. The research reactor MR has a long history and consists of nine loop facilities for experiments with different kinds of fuel. During the operation of main and auxiliary equipment of reactors it was subjected to strong radioactive contamination. The character of this contamination requires individual strategies for the decontamination work. This requires information about the character of the distribution of radioactive contamination of equipment in the premises. A detailed radiation survey of these premises using standard dosimetric equipment is almost impossible because of high levels of radiation and high-density of the equipment that does not allow identifying the most active fragments using standard tools of measurement. The problem can be solved using the method of remote measurements of distribution of radioactivity with help of the collimated gamma-ray detectors. For radiation surveys of the premises of loop installations remotely operated spectrometric collimated system was used [1, 2, 3]. As a result of the work, maps of the distribution of activity and dose rate for surveyed premises were plotted and superimposed on its photo. The new results of measurements in different areas of the reactor and at its loop installations, with emphasis on the radioactive survey of highly-contaminated samples, are presented.

INTRODUCTION

The equivalent dose rate created by contaminated equipment in the technological premises of the reactor is from 20μSv/h to 3mSv/h. This dose rate was caused both direct radiation from contaminated internal surfaces of equipment and scattered radiation from the walls and equipment. A survey of contaminated areas with help of a collimated spectrometric system (gamma locator) provides information about the features of the radiation fields. This information can be used to the activity rating of radionuclides that contaminate the equipment located in the inspected area. Contaminated equipment is a distributed source of radiation. The collimated detector allows registering the radiation from a given direction defined by the axis of the collimator. This direction can be associated with a particular object, which allows estimating the level and character of contamination.

EXPERIMENTAL METHOD

The scintillation crystal CsI (Tl) of 20 cm^3 was used as a detector in the gamma locator in the survey of research reactor's technological premises. When premises with high dose rate surveyed, the background radiation (passed through the side protection and registered in the detector) can significantly affect on the measurement results. To account for the impact of the background radiation two series of measurements was conducted. Initially scanning of the premises was carried out on the specified angular coordinates with opened pinhole. Next pinhole was closed by lead plug, and then re-scan of the premises was carried out in the same angular coordinates. As a result, two spectrums were obtained at each measurement point (main and background spectrum). The difference spectrum obtained by subtracting the background spectrum from the main and processed in two methods.

The first processing method of the difference spectrum provides a picture of the distribution of radionuclides activity in the angular coordinates of the scan. In the calculation it is assumed that radioactive contamination is in the surface (Fig.1). The size of pceudosources is determined by collimator angle **Ω** and the distance to the wall of the room R. Activity of the surface pceudosources for each direction was calculated by measuring the count rate at the complete absorption peak of the radiation for the appropriate radionuclide.

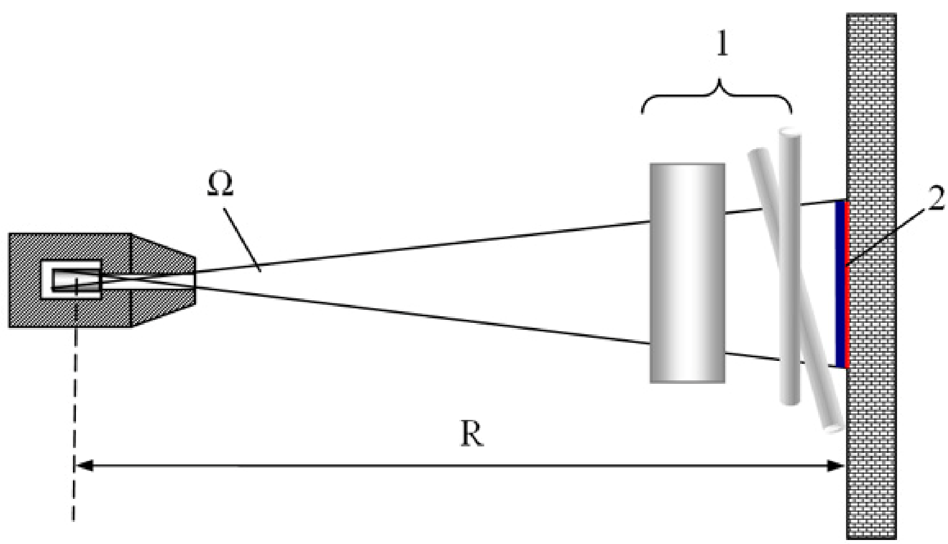


Fig. 1. The scheme of the method implementation. 1 - Technological equipment (piping system, etc.). 2 - The equivalent surface pceudosource (red) with additional steel filter (blue).

The next step for the implementation of this approach is the determination of the coefficient of proportionality between the counting rate and the surface activity of the source. These calibration coefficients were determined using a plane source with a known surface activity of Cs-137 and Co-60.

The difference spectrum obtained at each point of measurement is analyzed to determine the count rate in the energy range that is typical for non-scattered radiation of Cs-137 and C0-60 (Fig.2). The area used for cesium was in the range from 560keV to 740keV. Energy range used for cobalt was from 800keV to 1420keV and included the total absorption peaks 1173 and 1332keV and the high-energy part of the Compton plateau. The Compton part of the spectrum is mainly formed by unscattered radiation, so to improve the efficiency of registration it is also included to estimate the activity of Co-60. The surface activity of Cs-137 and Co-60 obtained for each direction is normalized to the solid angle defined by the angular step of scanning.

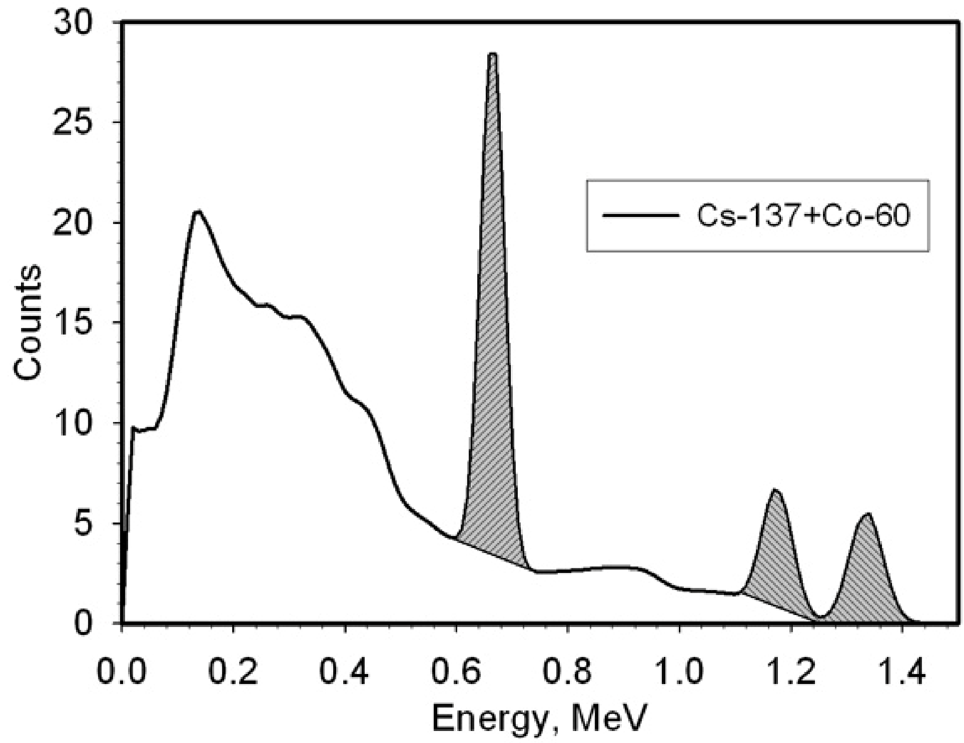


Fig.2. The emission spectrum of Cs-137 and Co-60. The shaded areas define the count rate in the total absorption peaks.

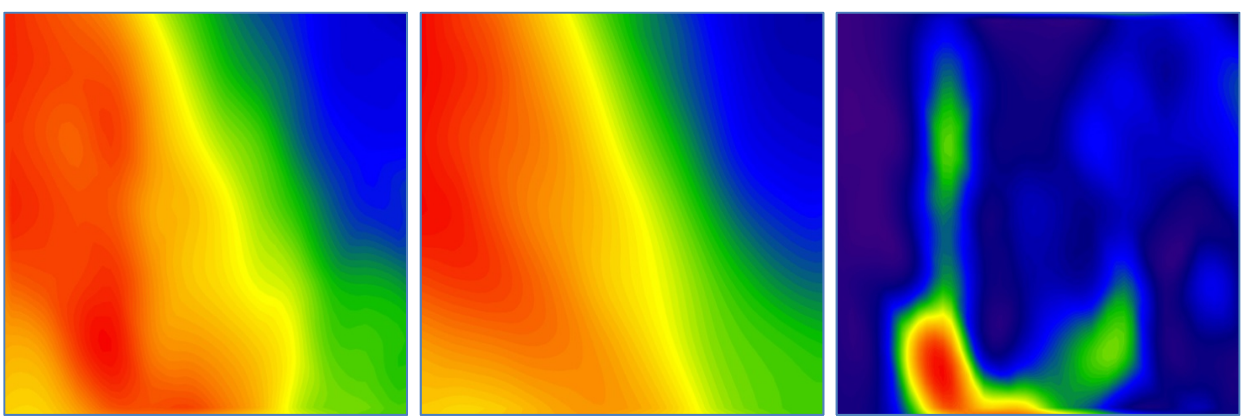
The second processing method of the difference spectrum allows to estimate the contribution of various radiation sources to the dose rate produced at the point the detector, and to build a picture of the distribution of dose rate for the surveyed premises. Method essence consists in calculating of the functional of the instrument spectrum with some weight function that compensates the dependence of scintillation detector's sensitivity of energy. These data, normalized to the solid angle of the scan, allow construct a picture of the distribution of dose in the angular coordinates. The sum of the normalized values for all directions of measurement determines the total contribution to the dose rate at the detector's placement point from the radiation came from the scan area.

RESULTS

The remote-controlled spectrometer system was used in the survey of technological rooms of the reactor. The system (Fig. 3) consists of a spectrometric collimated gamma-ray detector (the scintillation crystal CsI (Tl) of 20 cm^3, optocoupled with photodiode), a color video camera and a control unit, mounted on a rotator, which are mounted on a tripod with the host computer. The angle of view of the collimator is about 10 degrees.

Fig.3. The remotely operated portable spectrometric system.

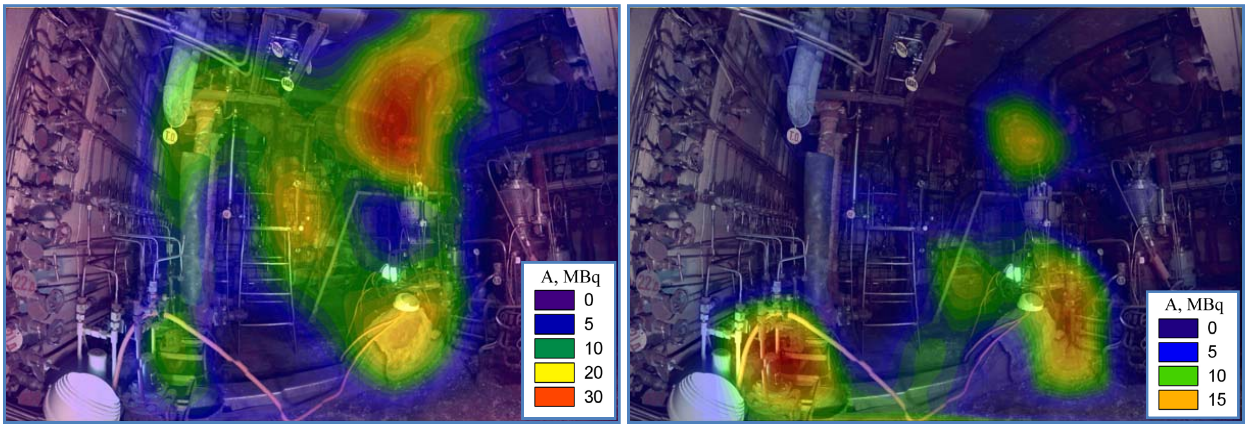
Contaminated equipment (piping, valves, etc.) installed in technological rooms represent a large number of radiation sources distributed within the volume of the room. This leads to the fact that the radiation passing through the detector side protection has a significant impact on the result. Therefore, measurements were carried out in two stages. Initially the room was scanned with an open collimator. Then the collimator was closed by plug, and scanning was repeated. As a result, two spectrums (for opened and closed detector) were taken for each direction. After measurement results processing, a set of difference spectra was obtained and the maps of activity distribution and angular dose rate distribution in the rooms were plotted. The scan results of one of the premises are presented on Figure 4. The collimated detector was placed near the contaminated pipe. The dose rate at the point of installation of the instrument was 200μSv/h.



a b c

Fig.4. The map of angular dose rate distribution: a – the collimator was opened; b - the collimator was closed; c – the final image.

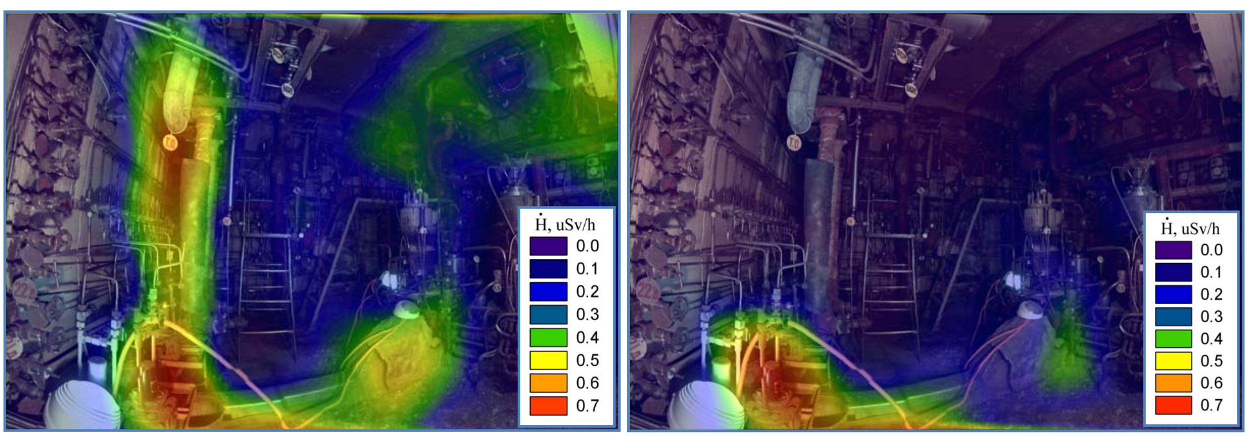
For the surveyed premises maps of the activity distribution of radionuclides Cs-137 and Co-60 were plotted and superimposed on the room's photos. The example of results is shown in the figure 5. The calculated activity of Cs-137 and Co-60 in the surveyed room was total $2.29 \cdot 10^8$ Bq and $4.53 \cdot 10^8$ Bq respectively.



a b

Fig.5. Maps of activity distribution of Co-60 (a) and Cs-137 (b) superimposed on the room photo.

The example of maps of angular dose rate distribution is shown in the figure 6. The figure clearly shows that the largest contribution to the dose is made by several sources. Removing these sources first will help to reduce the dose rate in the room.



a b

Fig.6. Maps of angular dose rate distribution, created by Co-60 (a) and Cs-137 (b) superimposed on the room photo.

CONCLUSIONS

The application of remotely operated collimated spectrometric system for survey of contaminated premises of research reactor in high dose conditions has proven successful. The radioactivity measuring device for operation at high, non-uniform dose background was tested in the field and a new data of measurement of contamination distribution in the premises and installations were obtained. Knowing the equipment activity and its weights, it can be predicted how much radioactive waste and what activities will be removed from the premises by dismantling, the types and number of containers required for packaging of radioactive waste. As well knowing the equipment activity and dimensions of the premises, the dose rate at any point in the premises and forecast the change of the radiation situation in the room can be calculated. According to the map of dose rate distribution the plan for the safest execution of dismantling can be drafted. Application of remote-controlled systems and devices has significantly reduced radiation doses for personal.

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