ASSESSMENT OF GAMMA RADIATION DOSE RATE FROM A CONTAINER WITH RADIOACTIVE WASTE

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Assessment of personnel exposure from various operations performed inside radioactive waste (RW) storage facilities is seen as an essential task under the safety assessment of such storage facilities. However, radiation scattered from the structures inside the premises of RW storage facilities is often not taken into account in the assessment of personnel exposure doses. Characteristics of the radiation field from RW containers have been calculated under a few studies. For example, the radiation fields were calculated based on some engineering approaches and the Monte Carlo method using specialized software.

This paper focuses on the Monte Carlo calculations of the gamma radiation dose rate from a volumetric cylindrical source located in a RW storage facility. The study evaluates the contributions of scattered radiation from the walls, floor and ceiling of a storage premise to the absorbed dose also considering the case of a flooded floor. The paper compares the calculated radiation dose rates with those evaluated by integrating the source volume for axisymmetric geometries with no account taken of scattered radiation. The calculations show that depending on the distance from the source if no scattered radiation from all the wall, floor and ceiling structures of a storage facility is accounted for, the dose rate may be underestimated by up to two times.

Keywords: *gamma radiation, container with radioactive waste, radiation dose, modifications of Monte Carlo method, calculation methods, contributions of scattered radiation from the storage walls to the radiation dose, radioactive waste.*

Constantly growing number of nuclear facilities being at their final life cycle stages and the corresponding increase in the intensity of decommissioning efforts result in a considerable buildup of radioactive waste (RW) streams exacerbating the problem associated with the management of such waste and their radiation safety.

Assessment of personnel exposure doses from operations performed in the repository is seen as an important task in the development of the RW management system. [1] provides evidences supporting this statement based on a dose rate study performed at workplaces.

Therefore, it appears still relevant to estimate the distribution of radiation dose rates from volumetric sources containing RW [2]—[6]. Thus, [2] explores the relationship between the radiation dose rates and the geometric dimensions of waste packages, which is done based on Monte Carlo methods and integration over the source volume. Radiation safety during temporary RW storage was discussed in [3], [4], namely, relevant safety aspects associated with non-returnable protective containers in light hangar-type storage facilities. Based on the MicroShield software [5] and some other purposely developed software, two other studies, [6], [7] demonstrate the need of considering albedo in the biological shielding designs.

Radiation safety of personnel being directly engaged in RW management operations is seen as a key RW management challenge [8]. TUK-44 is the primary package (200-liter drum) most commonly used for waste storage purposes. Therefore, a volumetric term source of a cylinder shape is often considered in relevant calculations.

This paper demonstrates the contribution of scattered radiation based on fields calculated with an account taken of the premise with the RW container and its geometry, which is needed to assess the safety of the storage facility.

Dose rates on the RW package surfaces depend on the specific and total activity of the radionuclides and the properties of the waste form with the radionuclides distributed in it, as well as the material and the thickness of the container walls.

A 1.5 m-high cylindrical container with a radius of 0.5 m and ^{137}Cs radionuclides uniformly distributed in the concrete (concrete density of 2.35 g/cm^3) was considered as a model of a volume gamma radiation source. Its specific activity was taken equal to 1,000 kBq/kg, which is the upper limit for low-level radioactive waste [8].

In the calculations, it was assumed that a cylindrical container **S** was located symmetrically with respect to the side walls of a 10 × 10 m premise (5 m high) near the rear wall **I** (the distance from it to the container surface accounted for 0.5 m), and the detectors were fitted radially along the y axis towards the front wall **II** (Figure 1). Detector **D** was fitted above the floor at half height of the source.

In the Monte Carlo method, advanced non-analogue algorithms providing increased efficiency when modelled is the radiation transfer process are used to solve various problems in radiation physics. In this study, the flow was estimated locally with some algorithms applied to replace the true physical distributions with the skew ones. In the probability density distribution for the mean free path, the skew cross section was chosen based on the condition of the minimum random variance being proportional to the contribution of the next scattering point to the point detector (the MD method) [9].

Assuming the general concept providing reduced variance of the estimated values [10], altered was the sample of the polar scattering angle based on some particular feature of the estimated quantity that was included into the distribution density [11]. This modification has an important advantage in terms of locally estimated flows, which is the better convergence of the results compared to conventional simulations. The developed software was fitted with these algorithms, and the results were verified based on relevant calculations performed in the BRIZ software [12] considering an infinite geometry source, as well as taking into account the albedo from the source plane according to the PENELOPE software [13]. Comparison study of the results obtained has revealed their good agreement. The developed software provides such benefits as short computational time and the functionality necessary for the detailed analysis of various modeling domains in terms of their value seeking to optimize the parameters of the problem.

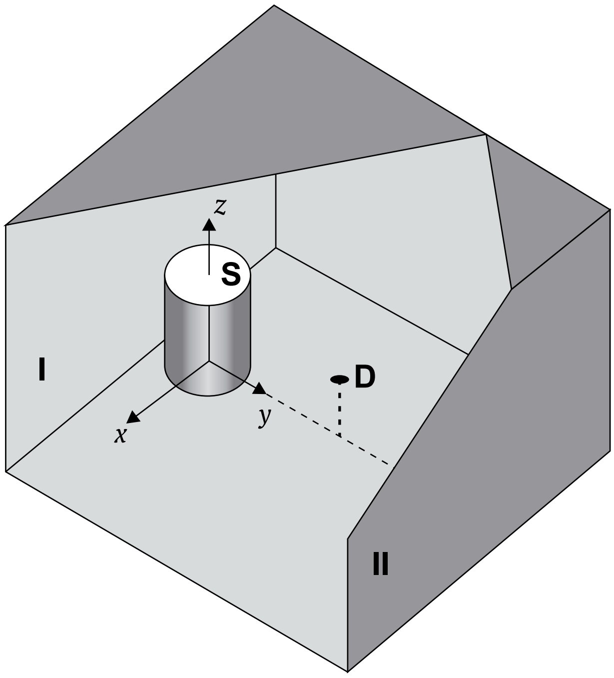

*Figure 1. Layout of a source term in the RW storage facility. The radiation source (**S**) is located symmetrically with respect to the side walls of the premise, the distance from the surface of the source to the rear wall (**I**) amounts to 50 cm*

Figure 2 presents the calculated absorbed dose rate distribution for the scattered radiation at the detection points depending on the distance to the surface of the volumetric source. The statistical error in the calculated results did not exceed 3—5 %. It also presents the results of calculations performed in the BRIZ software by integrating the elementary sources over the container volume, thereby, the radiation doses in the geometry of an infinite air medium could be calculated with an account taken of scattering occurring in the source volume alone.

The comparison shows that, when the room geometry is taken into account, the gamma radiation dose rate turns out to be greater than in case of a source in the geometry of an infinite air medium: at greater distances, a two-fold difference in its values can be attained. It's worth noting that the average contribution of scattered radiation to the total dose amounts to 70—80 %.

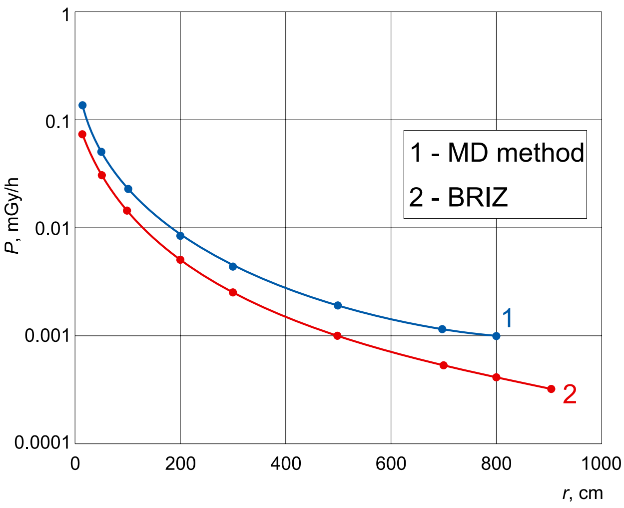

Figure 2. Dependence between the absorbed dose rates of scattered radiation and the distance to the surface of the volume source

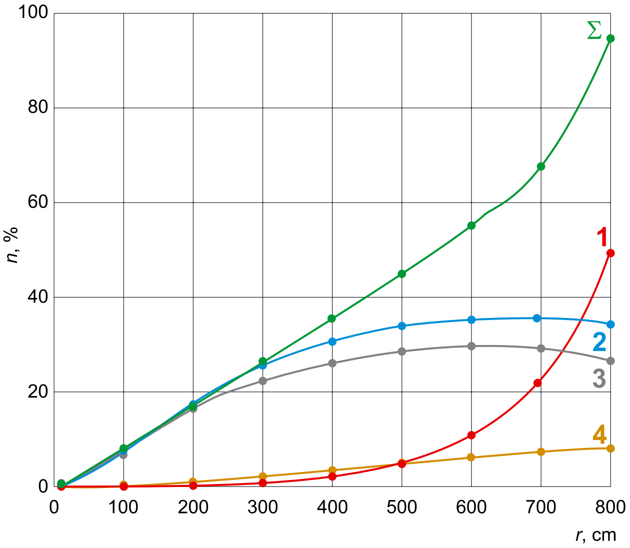

Figure 3. Contributions of scattered radiation in a premise relative to the scattered radiation in the source volume: 1 — front wall (**II**), *2 — flooded floor, 3 — concrete floor, 4 — ceiling,* Σ *— total contribution*

Figure 3 demonstrates the difference between the contributions of scattered radiation from different room surfaces (for walls, floor and ceiling, as well as the total contribution from them). Contributions of scattered radiation from various room surfaces are presented relative to the scattered radiation in the source volume alone.

As can be seen from the graph, at distances close to the source surface (less than 1 m), the dose is governed almost completely by the scattered radiation in the source volume. At greater distances from the source, the contributions of radiation from various room surfaces grow up to 30—50 %, and the largest contribution is made by the walls most proximate to the detector, as well as the floor of the room.

Figure 3 also presents the storage facility evolution scenario assuming that for some reasons the floor upon which the scattered radiation is estimated gets flooded with some water layer on its surface. In this case, the contribution from the flooded floor increases considerably compared to the scattered radiation from the concrete floor.

Thus, based on the selected model of a RW storage facility the study showed that the radiation scattered from the walls, floor and ceiling of the premise would largely (up to 50 %) contribute to the radiation doses for the personnel engaged in operations performed in different parts of the RW storage facility. The study demonstrates that this component should be accounted for: otherwise, the radiation dose rates at workplaces may be exceeded considerably, which would, therefore, necessitate the engagement of some additional personnel.

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