PHYSICAL AND MATHEMATICAL SIMULATION OF BIOLOGICAL SHIELDING

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Biological shielding physical simulation and angular distribution measurement method within the "Shelter" object conditions using "Ekran" facility was considered. Method for biological shielding mathematical simulation using data obtained with ShD-1 facility is presented. It is shown that results of mathematical simulation have satisfactory agreement with those obtained with "Ekran" facility.

PACS: 28.41Te

When conducting experimental researches with ionizing radiation sources and implementing works at radioactively hazardous facilities and polluted areas, the issue of arrangement of optimal biological shielding of personnel from external exposure becomes a very important one. Practical development of biological shielding imposes need for effective methods for its experimental and theoretical simulation. This problem is especially urgent for the "Shelter" object (SO) because a number of measures on SO implementation and new safe confinement creation are planned to be conducted here.

This report covers the issues of biological shielding simulation within the"Shelter" Object conditions. Both physical and mathematical simulations are considered. The aim of physical simulation was to obtain experimental data on spatial, angular and energetic characteristics of gamma radiation fields with and without shielding near the "Shelter" object. Physical stimulation of biological shielding was made using the "Ekran" facility, which is described further. Mathematical simulation was directed primarily on development of adequate EDR calculation method behind shielding. Angular distributions of gamma-field obtained with the help of ShD-1 facility were used as an input for calculation method. Results of calculations were compared with experimental data in order to verify the developed method.

The procedure for measuring angular distributions and physical simulation of biological shielding is based on EDR measurement during time-shared or simultaneous screening from different sides with lead shields of diverse thickness of dosimeter sensor (radiometer). For these purposes, "Ekran" facility was designed and fabricated (Fig. 1).

Design of "Ekran" facility allows screening the internal space that is sufficient to place a sensor from different sides with lead changeable shields. Initially, "Ekran" facility construction was designed to measure the EDR attenuation with possible change of shield thickness from each side within the limit of 7,0 to 19,0 mm. In the course of investigations of radiation conditions in different SO areas, deficiency was revealed of maximum possible total thickness of shields being placed. This caused impossibility to use facility in places with high gamma-fields.

The detected lacks were eliminated in the design of next option of "Ekran" facility. In new design, sliding groove sizes were made as more wide that enabled installing of changeable shields with more total thickness from each direction [1]. For this new facility lead shields of two types: 7.5 and 12 mm were manufactured. Shielding maximum thickness made 31.5 mm. Further measurements have proved such parameters to satisfy enough the SO conditions.

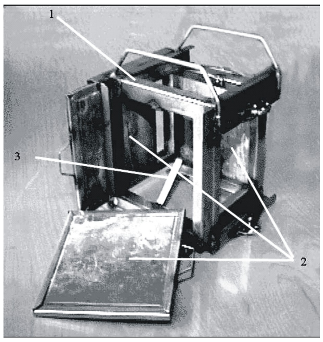


Fig. 1. *"Ekran" facility: 1 – facility body; 2 – lead shields; 3 – bracket to fix derecting un*it

When investigating spatial, angular and energetic characteristics of gamma radiation fields in assumed WIZ (work implementation zones) for NSC (new safe confinement) erection, as a radiometer the device RKS-01 "Stora-TU" was applied. This device has chosen due to high sensitivity in EDR lower range (measurement range of equivalent dose rate of ^{137}Cs gamma radiation 0.1 …999 µSv/h, measurement error of equivalent dose rate of ^{137}Cs gamma radiation ± 15%).

The procedure for experimental modeling of biological shielding covered as regards. In a selected point, "Ekran" facility body was installed and oriented in relation to "Shelter" object structures. EDR without shielding was measured. Further, by turns from different sides (including from above and below, if required), lead shields of diverse thickness were inserted. EDR value read-outs inside the facility were fixed. In first turn, the directions of more intensive radiation sources were shielded in conformity with angular distribution chart.

Measurements using "Ekran" facility were conducted in the places were biological shielding most likely will be implemented and have given a valuable information on personnel radiation protection.

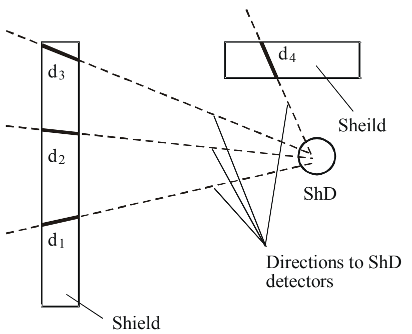
Mathematical stimulation of biological shielding is based on applying the data on EDR angular distribution that were obtained using the ShD-1 facility. It allows defining, more precise, shielding direction, shield sizes for selected direction, EDR value degradation factor. On top of that, an opportunity appears to diversify shielding combinations with different geometrical parameters for specified workplace in dependence on directions to main radiation sources.

When calculating EDR behind the shielding, geometry shown in Fig. 2 is applied. EDR survey point is estimated from the formula as follows

$$H = \sum_{i=1}^{32} H_i e^{-\mu d_i}, \tag{1}$$

where H_i is EDR before shielding, which is coming from the i-th direction (appropriate directions are defined by direction to ShD detectors); μ is linear attenuation factor; d_i is shielding thickness in corresponding direction.

Fig. 2. EDR estimate geometry behind shield



In mathematical simulation, as attenuation factor dependence of gamma radiation intensity of shielding thickness the data approximation was used that was obtained underway investigations for real exposure within the “Shelter” object conditions. As an approximation of attenuation linear factor the Weibull distribution was used:

$$\mu(x) = a - be^{-cx^d}, \tag{2}$$

where a=94.343 mm^{-1}, b=93.343 mm^{-1}, c= 0,005, d = 1,182.

The results of estimates that were made with the help of this program were compared to experimental data on integral EDR measurements conducted under particular shielding from different directions. One should note, satisfactory fit is observed, divergence of results is within the range of 15…30% (Figs.3,4).

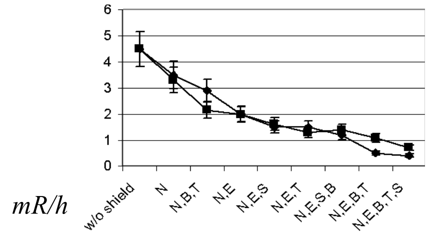


***Fig. 3.** Results of biological shielding stimulation (□) and EDR experimental measurements(□). Point Э16, 30 mm shielding thickness*

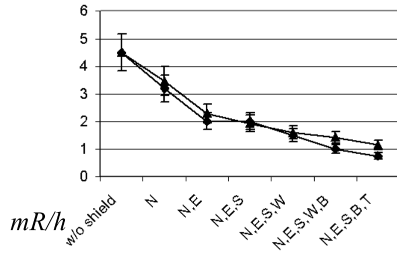


***Fig. 4.** Results of biological shielding simulation (□) and EDR experimental measurement (□). Point Э16, 7.5 mm shielding thickness*

Thus, mathematical model being proposed describes at a sufficient rate the EDR values being surveyed and can be effectively used in biological shield modeling, especially within the conditions of strong radiation fields, where the use of physical modeling will bring to considerable dose loading of personnel.

REFERENCE

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ФИЗИЧЕСКОЕ И МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ БИОЗАЩИТЫ

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Рассмотрен метод физического моделирования биозащиты и измерения углового распределения гамма-излучения в условиях объекта “Укрытие” с использованием установки “Экран”. Представлен метод математического моделирования биозащиты с использованием данных прибора ШД-1. Показано, что результаты математического моделирования биозащиты удовлетворительно согласуются с экспериментальными данными, полученными при помощи установки “Экран”.

ФІЗИЧНЕ ТА МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ БІОЗАХИСТУ

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Розглянуто метод фізичного моделювання біозахисту та вимірювання кутового розподілення гама-випромінювання в умовах об’єкта “Укриття” з використанням пристрою “Екран”. Представлений метод математичного моделювання біозахисту з використанням даних приладу ШД-1. Доведено, що результати

математичного моделювання біозахисту задовільно погоджуються з експериментальними даними, які одержано за допомогою пристрою “Екран”.