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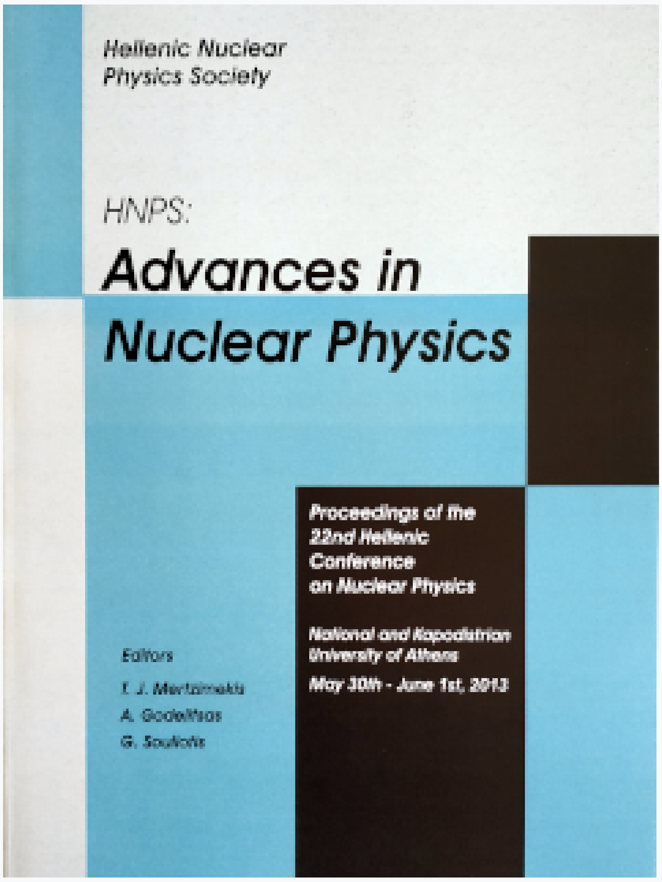

Radiation Protection Calculations for the New Radioactive Waste Interim Storage Facility of NCSR "Demokritos"

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Radiation Protection Calculations for the New Radioactive Waste Interim Storage Facility of NCSR "Demokritos"

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Abstract

The present study concerns the determination of the maximum acceptable contact dose rate per radioactive waste package for safekeeping at the New Radioactive Waste Interim Storage (NRWIS) of the National Centre for Scientific Research "Demokritos" (NCSR "D"). The NRWIS facility is used for temporary storage of spent/ orphan sealed sources, devices like lightning rods and primary radioactive waste. The contact dose rate per package is determined in a level that even in case the highest radiation background is built up inside the storage facility, the doses to the workers will not exceed the maximum permissible doses. The total dose that a worker receives inside the facility should not exceed one half of the annual occupational dose constraint of 6 mSv. Furthermore in cases of the highest radiation background inside the facility, shielding calculations are performed.

Keywords: dose rate, shielding calculations

1. Introduction

The present study concerns the determination of the maximum acceptable contact dose rate per radioactive waste package for safekeeping at the New Radioactive Waste Interim Storage (NRWIS) of the National Centre for Scientific Research "Demokritos" (NCSR "D"). Shielding calculations for the compartment A1 of the NRWIS were also performed in the case of fill.

2. Materials and Methods

The contact dose rate per package is determined in order that the highest background, that will be built up inside the storage facility, to be permissible for 50 hours work per year, that means a permissible dose rate of 3 mSv/50h = 60 μSv/h. The configuration of the sources inside the facility is in a way that ensures uniform dose rate. The most common geometry of the activity inside the items is that of the point source. The sources are put at the rear one half of the room. To simulate the configuration of the items inside the compartment A1, 100 point sources of the same dose rate are considered to be distributed homogeneously on a rectangle 5.4×5.4 m^2 surface (Fig. 1).

Analytical calculations were carried out for estimation of the maximum acceptable dose rate at the distance x from a point source based on the maximum permissible dose at the centre of the rectangular. The maximum acceptable dose is given by the formula:

$$d = \frac{60}{x^2 \cdot 0.005} \tag{1}$$

where x is the distance from the point source.

Furthermore, calculations using the MCNPX code were performed. A dose rate meter at the centre of the rectangular (Fig. 1 was modelled as a water ball of 20 mm diameter. In order to obtain the dose d within the dose rate meter, the MCNPX tally (F6) was used.

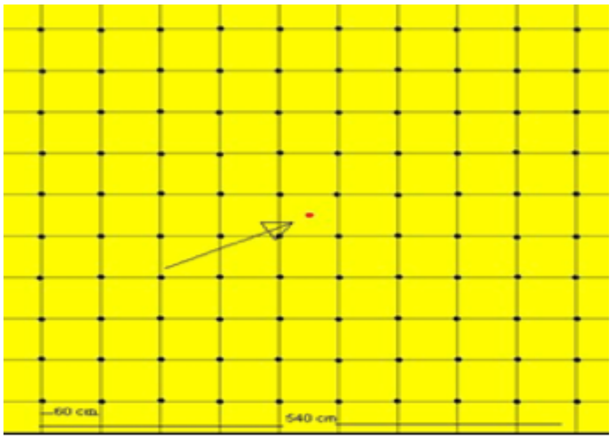

Figure 1: Sources configuration

Shielding calculations were performed making the assumption that all the sources (100 alike ^{60}Co point sources of the maximum acceptable dose rate), are placed at the centre of the rectangular which is placed at the rear part of the compartment A1. Then the dose rate at 0.14 m from the centre of the rectangular (see formula 1) will be $6 \cdot 10^3$ μSv/h. The hourly exposure P (μSv/h) at a distance X (m) from this point that is considered to fit in with the centre of the rectangular is:

$$P = \frac{6 \cdot 10^3 \cdot T \cdot U}{X^2} \tag{2}$$

Where
T: the occupancy factor for the area
U: the use factor of the source. The transmission factor K is given by the following equation:

$$K = \frac{P}{P_{max}} \tag{3}$$

And the necessary thickness of barrier $\mathfrak{L}$ at the point of interest can be calculated by:

$$\mathfrak{L} = HVL_{material} \cdot \#HVL \tag{4}$$

where $\#HVL = \frac{\ln K}{\ln 2}$

Additional MCNPX calculations were also carried out. Two sources configurations where examined by Monte Carlo simulations: (i) for the point sources configuration that is given at Fig. 1, (ii) for the case that all the sources are put at the centre of the rectangular of Fig. 1.

3. Results

If the maximum acceptable dose rate at the centre of the rectangular is 60 μSv/h (that is the maximum acceptable dose rate at any point of the facility) then the maximum acceptable dose rate at the distance x from the point source is given by the formula 1. By using this formula, the acceptable dose rate was calculated at several distances from the point source. The results are presented in the Table 1 and the Fig. 2.

The results for the shielding calculations for the walls of the compartment A1 are given in the Table II. The MCNPX calculations for the dose in case the 100 sources distributed homogeneously on the rectangular are 12% higher than the dose of the 100 sources at the centre of the rectangular.

Table 1:

x (cm)	d analytical results (μSv/h)
10	120
15	53
20	30
25	19
30	13
40	7.5
50	4.8
60	3.3
70	2.5

Figure 2: The acceptable dose rate at several distances from the point source. Analytical results are presented by the solid line and MCNP simulation results by the points

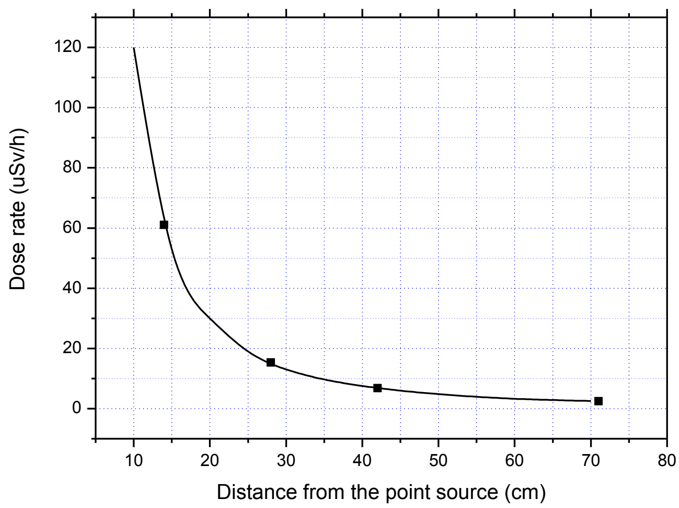

Table 2: Results of the shielding calculations for the compartment A1

WALL	Co-60	Extra Concrete Shielding
AB	174	74 mm
BΓ	131	31 mm
ΓΔ	94	No need
ΓΔ - steel door	32	No need
ΔA	106	6 mm
LAB	26	62 mm
Roof	–	No need
Floor	–	No need

4. Conclusion

The calculations for determination of the dose rate criterion for the radioactive waste packages as well as the shielding calculations for the facility were carried out analytically as well as by the Monte Carlo method using the MCNPX code. The results of the two independent methods used for estimation of the dose rate criterion for packages were in absolute agreement. Monte Carlo simulations showed that at a point of interest outside of the storage compartment, the ratio of the dose for the 100 point sources configuration to the dose for the simplified configuration, when all the sources, are at the same point is 1.24. So the extra shielding presented at the Table II should be increased appropriately.

The acceptance criterion for the contact dose rate of a radioactive waste package should depend on the dimension of the shell/ container of the radioactive source. Point source or equivalently line source is considered at the geometrical centre or on the main axis of symmetry of the shell/ container. So the acceptable contact dose rate is a function of the distance from the geometrical centre or equivalently from the main axis of symmetry to the cell/ container surface (Table 1, Figure 2).

In case of higher contact dose rate than the prescribed from the formula 1 and given at Fig. 2, shielding is necessary. In the case of shell/ container with radius lower than 15 cm even if the contact dose acceptance criterion is satisfied, the dose on the surface may exceed the 60 μSv/h. In this case the radioactive waste should be put and stabilized inside a larger container so that the dose on the surface to be lower than 13 μSv/h (see Table 1, at 30 cm the acceptable dose rate is 13 μSv/h).

It should be stressed that all the assumptions for the dose rate inside the compartment A1 were done under the conservative considerations: (i) the compartment is full; (ii) all the sources are of the maximum acceptable dose rate (Table 1, Figure 2); (iii) all the sources are of ^{60}Co. Furthermore, the effect of radiation attenuation through the shell/container materials has not be taken into account.

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