ASSESSMENT OF GAMMA DOSE RATE FOR WASTE PACKAGES WITH RADIOACTIVE CONCENTRATE USING MICROSHIELD SOFTWARE

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Abstract
In nuclear activities, the MicroShield program is very useful in assessing the dose rate as well as in radiological characterization of different radioactive sealed source and conditioned radioactive waste packages for their final disposal. The purpose of this paper was to verify the applicability of MicroShield program in the assessment of gamma dose rate for drums containing radioactive concentrate resulted from evaporation of β-γ liquid radioactive waste generated by TRIGA reactor operation. In order to assess the dose rate using MicroShield software, for each radioactive concentrate drum input data were created. Also, using a BERTHOLD radiometer dose rate measurements at contact from the analysed drums were performed. The results obtained shown that MicroShield is a rapid and useful program for dose rate assessment, limiting the exposure time of the working personnel.

Keywords: *MicroShield software, dose rate, activity, radioactive concentrate*

Introduction

MicroShield is a useful computer program with a wide range of applications, including designing shields for photon and gamma rays, dose assessment, and minimizing exposure of the workers. It is useful to health physicists, waste managers, design engineers, and radiological engineers and requires only a basic knowledge of radiation and shielding principles [1].

Integrated tools provide graphical representation of the results, material and source file creation, source inference with decay (dose-to-Ci calculations accounting for decay and daughter build-up), projection of exposure rate versus time as a result of decay, access to material and nuclide data, and decay heat calculations.

MicroShield software allows the modelling of simple source geometries and simple shielding layouts, leading to very accurate results with low computer time consumption compared with more advanced methods such as the Monte Carlo transport codes [2, 3], among others.

The MicroShield computer program provides 16 fixed geometry models, easy to update to the geometrical configuration analysed, for radiation shielding evaluation of point, line, and volume sources, respectively, using the Point Kernel method. The fixed geometry model approach reduces the effort required to numerically express the geometry for shielding evaluation, and can be applied to most problems, except when an accurate evaluation of complex geometry is required [4].

The basic concept of the MicroShield program is Point Kernel deterministic method which involves dividing the volume of the source into a large number of small point sources and summing up each contribution of the defined point sources.

In the characterisation process of different waste packages resulted both from decommissioning activities and from waste treatment and conditioning, MicroShield software is extremely useful for activity and dose rate estimation. Therefore, to establish the applicability of MicroShield in the radioactive waste characterisation performed in RATEN ICN, input data were created based on characteristic data for drums with radioactive concentrate for which the dose rates were experimentally measured. To quantify the accuracy of the gamma dose rates obtained by MicroShield numerical simulation, the results were compared against the measured values.

In present study, the experimental measurements and MicroShield numerical simulation were performed for standard drums (220 l steel drums) containing radioactive concentrate resulted from the evaporation of β-γ liquid radioactive waste generated by TRIGA reactor operation.

MicroShield Software Set-up

To get the dose rates by using MicroShield software, the input data created contain the radiological characteristics of the radioactive concentrate, density of shielding materials, drum configuration and source dimensions, as well as the spatial coordinates of the points where the dose rate is estimated.

The main parameters used for MicroShield simulations were established based on the geometrical configuration, and the concentrate volume and radioactivity; they are presented in Table 1.

Table 1. . Set-up Parameters for MicroShield simulations

Source Input: Grouping Method - Linear Energy				
Geometrical Configuration: Cylinder Volume-Side Shields				
Dose Points			Integration Parameters	
No.	X (cm)	Y (cm)	Radial	10
#1	32	0	Circumferential	10
#2	32	12	Y Direction (axial)	20
#3	32	25		
#4	132	0		
#5	132	12		
#6	132	28		

As presented in Fig. 1, the first three points selected to estimate the dose rate are at the contact with the waste drum, while the last three are placed at one meter distance from the analysed drum.

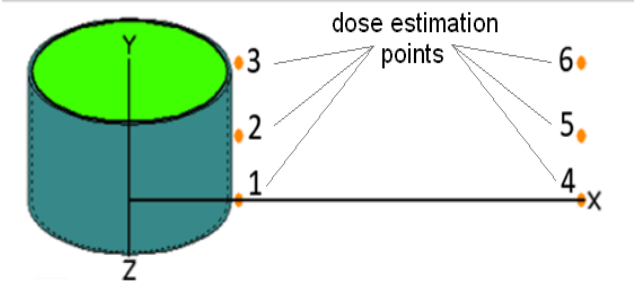


Fig. 1. Overview of geometrical configuration with MicroShield software

The MicroShield numerical simulations were performed for drums containing radioactive concentrate with different densities and radioactivities (S1, S2 and S3) resulted in the evaporation campaign performed at the RATEN ICN, in 2021: two drums (S1B1, S1B2) from S1 concentrate lot, three drums (S2B1, S2B2, S2B3) from S2 concentrate lot and two drums (S3B1, S3B2) from S3 concentrate lot.

Experimental Measurements

To create the characteristic input data in MicroShield it is necessary to know the activity concentration for each radionuclide present in the analysed samples. The radioactive concentrate resulted from the treatment by evaporation of β-γ liquid radioactive waste is evacuated when the density is around 1.2g/cm^3 and usually, in an evaporation campaign, the concentrate is evacuated in three lots. For each concentrate lot representative samples were collected and measured by gamma spectrometry.

The representative samples were measured using a gamma ray spectrometer consisting of a HPGe detector GEM15P4 model (46.9 mm diameter and 54.8 mm length) with Pop Top vertical cryostat configuration. The main components of used gamma ray spectrometer system are, as follows: detector interface module (DIM-ORTEC), DigiDART portable multichannel analyser and Gamma Vision 32 software. The operational parameters of the detector measured at the shaping time of 6 μs and the high voltage of 3300V were: relative efficiency 15% and 1.80 keV resolution at 1332 keV ^{60}Co [5].

The activity concentrations of each radionuclide measured by gamma spectrometry on representative samples were correlated with the volume of the radioactive concentrate from each drum to determine the total activity of each radionuclide in the analysed drum (Bq/drum).

The experimental dose rates at contact with the analysed drums were measured using a UMO LB123 Berthold radiometer (at the middle of the volume of radioactive concentrate poured in each drum). The measured dose rate values for the analysed drums were compared with the values obtained by MicroShield simulations.

Results obtained from experimental measurements

The radioactivity of the analysed drums comprises mainly in Cobalt radioisotopes (Co^{58} and Co^{60}), Mn^{54}, Sb^{124} and Cs^{137} (see the total activity in Fig. 2) with Co^{60} representing about 80-86% of the total radioactivity for each analysed drum. Other two relevant radionuclides are Co^{58} that counts for around 8-13% of the total activity, and Mn^{54} representing 5% from the total activity of the drums, while Co^{57}, Cs^{137} and Sb^{124} represent only about 1% from the total activity.

The experimental results show that in all analysed samples each particular radionuclide is characterized by a radioactivity value of the same order of magnitude, and we can say that it is almost constant for all the drums obtained from the same lot of radioactive concentrate.

The small differences in radioactivity between the three lots of concentrate is mainly due to the small differences in density, while the small differences between the radioactivity of different drums with radioactive concentrate from the same lot is mainly due to small differences in the volume of the concentrate dosed in each drum.

Fig. 3 presents the measured values for contact dose rate as a function of the total activity for all samples analysed.

The dose rate values are directly proportional with the total activity of the concentrate, aspect highlighted in Fig.3. The small discrepancies are due to the measurements statistics of the radiometer, background in the measurement area and also from small differences in mass of the concentrate poured in each drum.

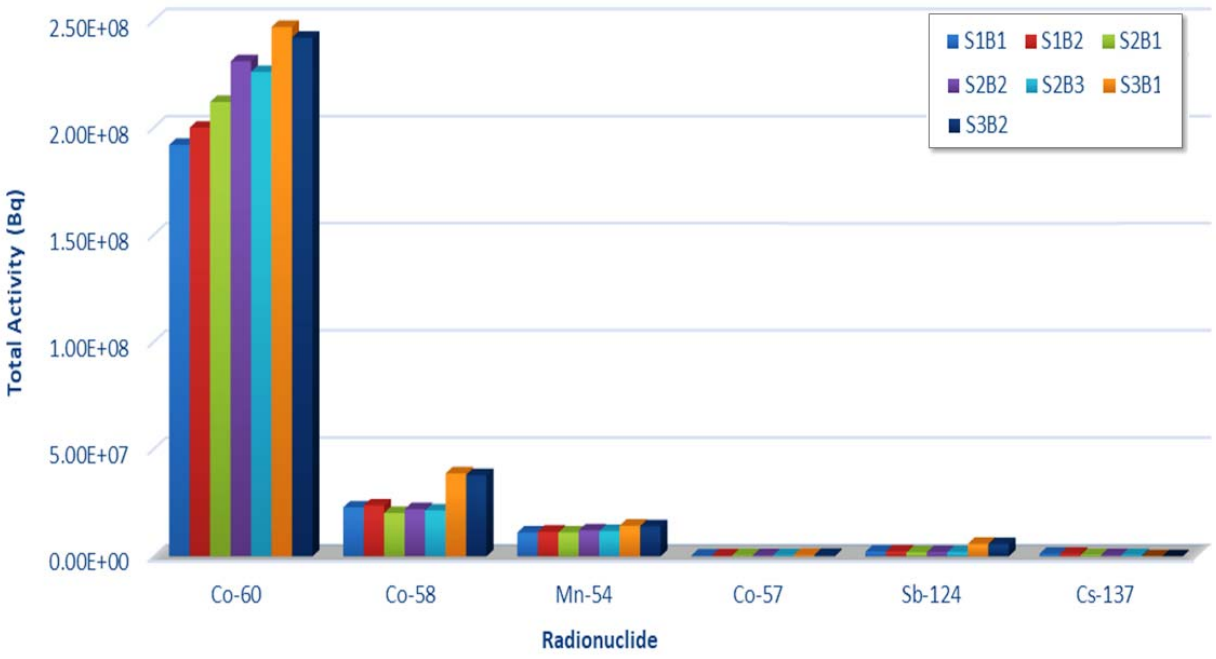


Fig. 2. The distribution of gamma ray emitters in the analysed samples

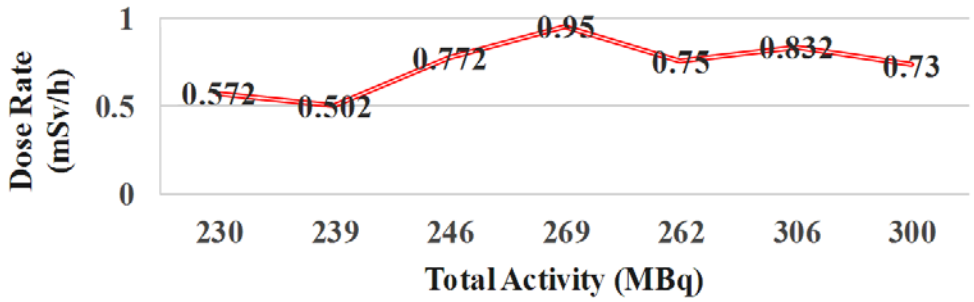


Fig. 3. The distribution of dose rate as function of total activity for all samples analysed

Results obtained with MicroShield

Using the information characteristics for each waste package containing radioactive concentrate, input data specifying the six points for dose estimation (three at contact and three at one metre from the drum) were created for all the drums analysed and dose rate values were obtained.

The simulations performed for the six points were aimed to determine the dose rate profile of the drums as function of activity. The polynomial equations determined for each lot of concentrate can be applied in future tests to establish the profile of the concentrate drums for which the dose rate no longer needs to be measured.

The dose rate values measured for each drum resulting from the same lot of radioactive concentrate were averaged. The average dose rate profile characteristic for each lot of radioactive concentrate drum analysed in this study is represented in Fig. 4.

In Fig. 5, the effect of the measurement distance on the dose rates estimated by MicroShield simulations is shown. As it was expected, the dose rate decreases linearly with increasing measurement distance, a correction factor of R = 0.98 being applied.

To verify the applicability of MicroShield software in radiological characterisation process of different waste packages, the results obtained with the code were compared with the dose rates measured at contact with the drum. In this comparison, the dose rate values obtained with MicroShield for point 2 were used, because the dose rate measurements were performed at the same point. In Fig. 6, the experimental and simulated values for dose rate for each drum analysed are plotted.

The relative errors obtained when compared the two sets of values for dose rate are ranging between 25% and 35% for concentrate drums resulting from lot S1, between 1% and 15% for lot S2, and between 8% and 25% for drums resulted from S3 concentrate lot, respectively.

Based on the two data sets, experimental and MicroShield calculated dose rate values, a correlation between the total activity and the corresponding dose rate in point 2, averaged for each concentrate lot, was also realised and this correlation results are illustrated in Fig. 7.

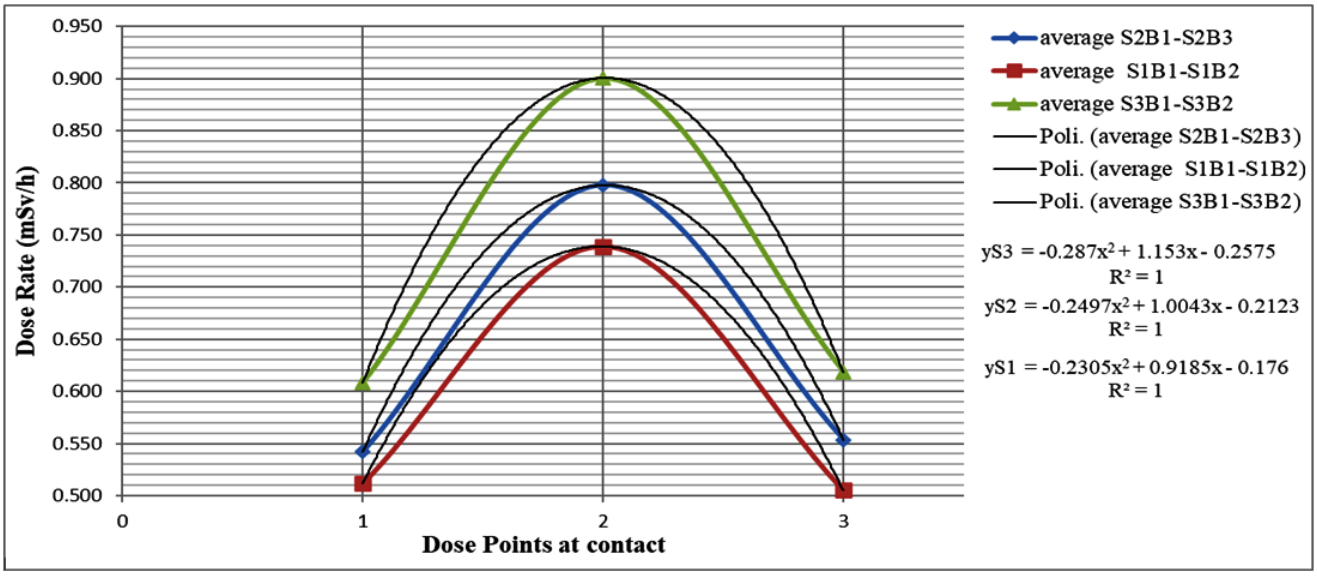


Fig. 4. The average dose rate profile obtained with MicroShield for each lot of radioactive concentrate

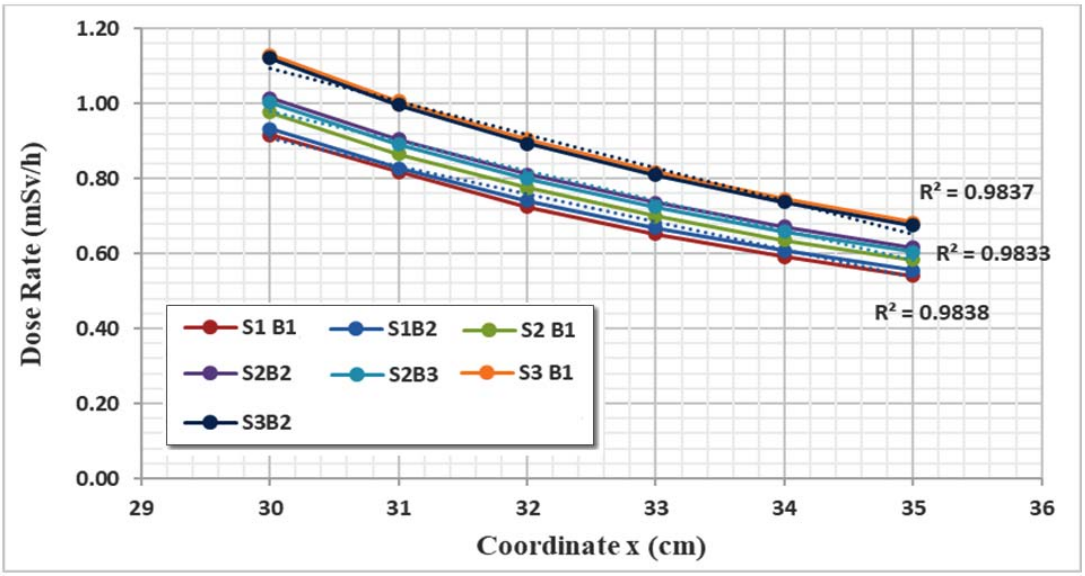


Fig. 5. Dose rate values vs. the measurement distance

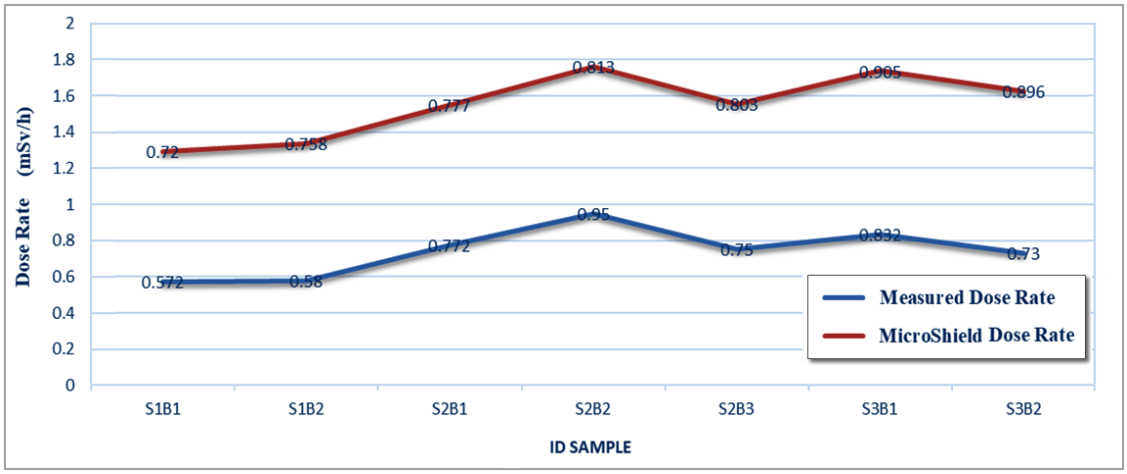


Fig. 6. Comparison between the measured dose rate values vs. MicroShield simulations results

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Based on the two data sets, experimental and MicroShield calculated dose rate values, a correlation between the total activity and the corresponding dose rate in point 2, averaged for each concentrate lot, was also realised and this correlation results are illustrated in Fig. 7.

Considering the relative errors calculated, the relationship established between the total activity and the dose rate can be applied to estimate the activity or the dose rate for waste packages with radioactive concentrate that need to be characterised.

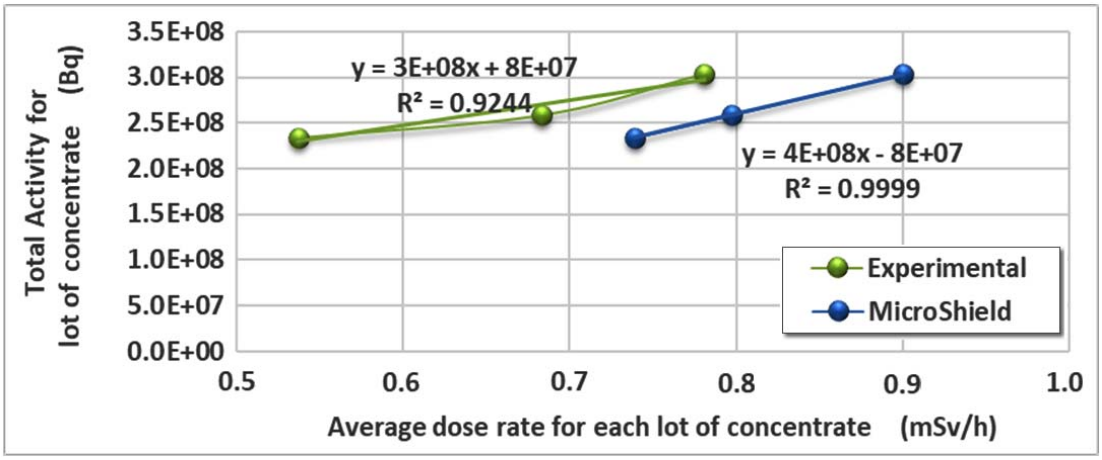


Fig. 7. Correlation between the total activity and the average dose rate for each lot of concentrate analysed

Conclusions

The discrepancy between the dose rate values obtained with MicroShield and the experimental measured ones are ranging between 1% and 35%, similar linear dependency on the measurement distance being noticed. All values obtained by MicroShield simulation overestimate the dose rate values measured at the contact with the drum.

The results obtained by MicroShield simulations depend of the accuracy of the input data and, therefore, the characteristic data of the source and the configuration geometry are extremely important in the mathematical modelling of the problem.

On the other hand, the experimental measurements are influenced by the counting statistics. Considering the uncertainties associated both with modeling and experimental measurements, the discrepancies between experimental and modeling data are acceptable.

The results of present study sustain MicroShield software as a rapid and useful program for dose rate assessment, limiting the exposure time for the working personnel. Based on the nuclide vector, the dose rates estimated by modeling can be used to evaluate the waste drums radioactivity. Further modelling and experimental measurements follow to be performed.

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