# A NEW DESIGN FOR THE STORAGE AREA OF RADIOACTIVE MATERIALS AT THE BUCHAREST 9 MV TANDEM ACCELERATOR LABORATORY

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*The manipulation of encapsulated, low activity radiation sources and waste is a procedure activity when dealing with a radiological installation as a Tandem accelerator and experimental setups. Usually, in this case the specific activities of the handled materials are known, therefore can be accurately estimated the exposure risk from such radiation sources. In order to lower the probability of unwanted irradiations, the radioactive materials manipulation is limited to a certain period of time, after that being deposited in special built storages.*

*In this paper are presented results of measurements and numerical simulations used for designing a new storage for radioactive materials at the Bucharest 9 MV Tandem accelerator laboratory.*

**Keywords:** radioactive materials, storage design, radiation doses, Monte Carlo simulation.

## 1. Introduction

The Bucharest 9 MV Tandem Van de Graaff (T-9MV) accelerator is installed and operates at the National Institute for Physics and Nuclear Engineering – Horia Hulubei (IFIN-HH), Bucharest – Măgurele, Romania [1]. The ion beams delivered by the accelerator are mainly used for nuclear and atomic physics experiments. Experimental data are obtained using a wide variety of radiation detectors [2, 3]. These ones need to be calibrated before and after each experiment, using a variety of radiations emitted by standard radiation sources with known activities. Also some components of the accelerator (e.g. beam slits) hit by the ion beams are becoming radioactive in time. All the radioactive materials have a wide domain of activities, ranging from a few Bq and up to hundreds of MBq. These are deposited in a special storage built in the basement

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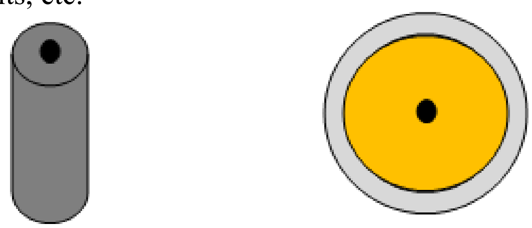
of the T-9MV building since 40 years ago, when the accelerator started operation. Due to modifications in the basement area, the old storage needed to be relocated and re-dimensioned. A new licensing is required by the regulatory body [4].

It is the goal of this work to present the design of this new storage for radioactive materials, based on results of the dose simulations compared with experimental measurements.

## 2. Radioactive sources and waste in a Tandem accelerator laboratory

The standard calibration sources used in experiments at T-9MV are composed of a small volume of radioactive substance, which is encapsulated in a very thin layer of plastic or metal material (see Figure 1) in order to ensure a protection against possible contamination from the active volume when handling the source. The layer is normally thin enough, so the quality of the radiations spectrum is not affected. These sources are placed in special boxes or shielding containers before being deposited into the storage.

Calibration sources in the storage of T-9MV are $^{60}$Co, $^{90}$Sr-$^{90}$Y, $^{137}$Cs, $^{147}$Pm and $^{152}$Eu, used as gamma standards, $^{241}$Am for alphas and $^{252}$Cf for neutrons. The total activity of gamma standards is about 1 GBq, for neutrons is 21 Bq and for the alphas is 10 GBq. All of them are placed in lead containers with a medium thickness of 2 cm (some are 1 cm, others are up to 3 cm thick), exception being the neutron source which is placed in a paraffin box. Beside the radioactive sources, in the storage are also deposited, for short terms, activated material. These are accelerator components that were irradiated by the ion beams and become active, targets used in various experiments which have long cooling times, system slits, etc.



a). b).

Fig. 1. a). Neutron source, b). Gamma and alpha sources. The black centered dot represents the radioactive material

All of these materials are treated as radioactive waste, are temporary deposited into the storage, and after a certain period of time they are transferred to the waste processing station from IFIN-HH [5].

The radioactive waste is usually of low activity (in the range of kBq) and is deposited in special boxes, in order to prevent any possible contamination when handling. Furthermore it is treated as gamma emitter when assessing the radiation field characteristics.

### 3. Storage design constrains

The storage of radioactive materials has been built in the basement of the T-9MV accelerator. It is placed in a low occupancy area with a restricted access. According to the radiation safety norms [4] only authorized personnel are able to manipulate the materials inside of the storage.

The existing basement walls have been completed with new ones in order to build the chicane of the storage. They are made of concrete bricks of 45 cm x 35 cm x 15 cm dimension which are bound in such way to eliminate the gaps between them. Thickness of these two walls is 35 cm. The other three remained walls, also made of concrete (see Table 1), are 40 cm thick. The roof of the storage is made out of a 5 mm thick steel plate.

A steel plate 5 mm thick door is used for access and is always kept locked with a padlock. Inside the storage, the small lead containers with the radioactive sources are placed in an iron closet, which is also locked. The storage was designed on the basis of numerical simulations of the doses from this work.

### 4. Simulation and measurements of radiation doses

The human body-related protection quantities, equivalent dose in an organ/tissue and effective dose, are not measurable. To overcome this difficulty for external irradiation, ICRU [6] has introduced and defined a set of operational quantities, which can be measured and which are intended to provide a reasonable estimate for the protection quantities. These quantities aim to provide a conservative estimate for the value of the protection quantity avoiding both underestimation and too much overestimation. The operational quantities are based on point doses determined at defined locations in defined phantoms.

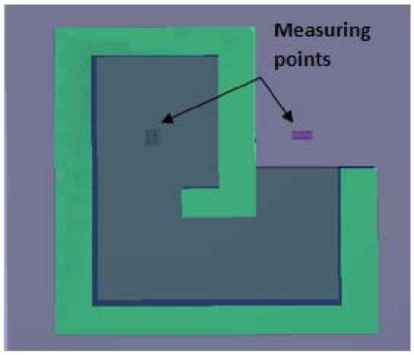
The ambient dose equivalent, $H^*(10)$, is the operational quantity for area monitoring. It is the dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned field in a 30-cm-diameter sphere of unit density tissue (ICRU-sphere) at a depth of 10 mm on the radius vector opposing the direction of the aligned field.

The following relation is used to calculate the ambient dose equivalent:

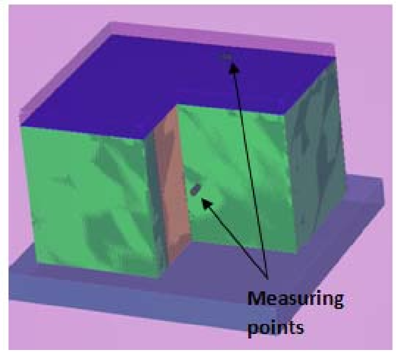
$$H = Q(L) \times D \quad [\mathrm{Sv}] \tag{1}$$

where $Q(L)$ is the quality factor dependent on the linear energy transfer ($L$) and $D$ is the absorbed dose in a point from the environment.

In order to estimate the radiation doses and to design the storage for radioactive materials, a Monte Carlo simulation code has been used [7, 8]. The code, MCNPX (Monte Carlo Neutral Particle Xtended), is a general purpose tool designed to simulate the transport of many particle types over broad ranges of energies through matter. It has been developed at Los Alamos National Laboratory (LANL), USA.




a). Top view




b). Side view

Fig. 2. The simulated storage geometry (3D) and location of scoring regions

The geometry of the storage has been modeled in the simulation by taking into account the configuration of the basement. The MCNPX input includes the geometry shown in Fig. 3. The door and the roof are made of 5 mm of iron plate. The height of the basement is 5 m and that of the storage 2 m including the roof. The floor, as well as the roof of the basement, are 40 cm thick and are also made of ordinary concrete (see Table 1).

*Table 1*

**Composition of the ordinary concrete (see e. g. MCNPX manual [6])**

| Element | Al | C | Ca | Fe | H | K | Mg | Na | O | Si |
|---|---|---|---|---|---|---|---|---|---|---|
| **Concrete composition (mass fraction)** | 1.995 | 0.248 | 4.295 | 0.644 | 2.210 | 1.005 | 0.127 | 1.521 | 57.493 | 30.463 |
| **Density** | 2.3 g/cm$^3$ | | | | | | | | | |

For the definition of the source term we took into consideration all the source types that will be deposited in the storage. The neutron source is neglected in the simulation due to the extremely low activity. Also, the alpha sources are neglected in the simulation due to the 2 cm thick container lead walls which are completely attenuating ionizing radiations coming from them.

Measurements of the ambient dose rate equivalent were performed in three points located outside of the storage and shown in Figure 2. In each point 10 measurements were made. Their average values are presented in Table 2. The gamma sources were placed inside the storage before measuring, at 1 meter above the floor level. First measurement point (1) was located in front of the door at 1 m above the floor and 30 cm from the door. Second measurement point (2) was located at 30 cm above the storage roof in front of radiation sources location. The third point (3) was located on the same direction as the second one, but 1 cm below the roof of the basement.

For dose rate equivalent measurements, a Berthold UMo-LB123 monitor with a gamma type LB 1236 detector attached dosimeter was employed [9]. The gamma probe has an active energy range of 30 keV – 1.2 MeV and the measuring range for the ambient dose rate equivalent between 0.05 and 10000 μSv/h.

The 1 GBq gamma sources are the ones which compose the source term from simulation. The total activity of gamma sources is splitted to each individual source, as follows: $^{60}$Co – 0.4 MBq, $^{90}$Sr-$^{90}$Y - 973 MBq, $^{137}$Cs - 7.6 MBq, $^{147}$Pm - 3.6 MBq and $^{152}$Eu - 28.5 MBq. The source term was modeled as a point source having complex spectrum in order to include all source types.

The following two scenarios were considered in the simulations: (A) the existing radioactive sources were placed into the 2 cm lead containers, and (B), the "worst case scenario", to find the maximum activity of the sources that can be accommodated into the storage (with the containers from the (A) scenario) in order to meet the acceptance radiation protection criteria. The results of the dose rates measurements in case (A) are compared to the MCNPX simulations in Table 2.

*Table 2*

**Measured gamma ambient dose rates compared with simulated ones. All values are given in μSv/h. The measured reference background is 0.1 μSv/h. See text for details.**

| Measuring point (see text for details) | Measured values (case A) | Simulated values (case A) (see also Figure 4) | Simulated values (case B) |
|---|---|---|---|
| (1) | 0.2 (1) | 0.2 (1) | 1.5 (3) |
| (2) | 0.9 (1) | 1.1 (1) | 9.3 (2) |
| (3) | 0.2 (1) | 0.3 (1) | 1.9 (2) |

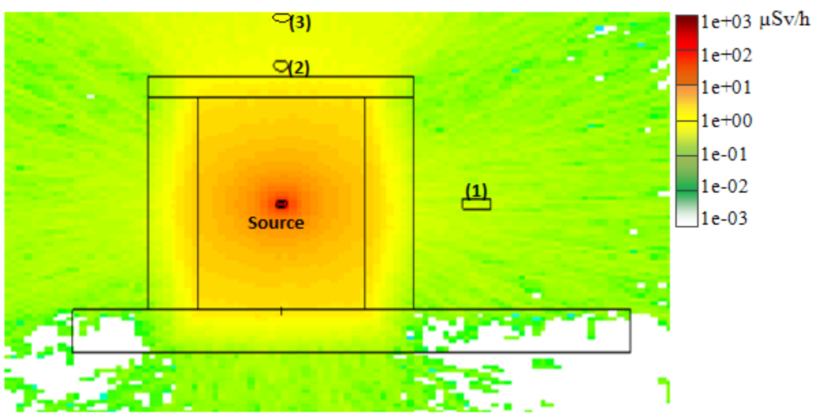



Fig. 4. a) Side view. Gamma dose rates simulated with MCNPX (case A). Source and measuring positions (1), (2) and (3) are indicated.

The main conclusion of the present part, as can be observed from the last column of Table 2 (case B), is that the maximum activity of the sources that can be accommodated into the storage is approximately 8 times bigger than the original one, in order to meet the acceptance criteria [4].

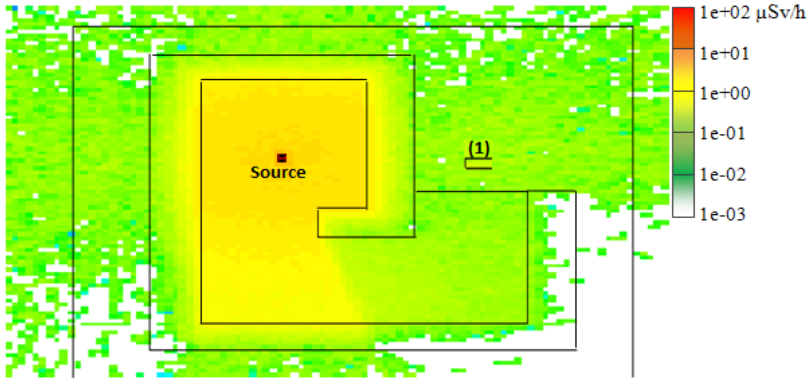



Fig. 4. b) Top view. Gamma dose rates simulated with MCNPX (case A). Source and measuring position (1) is indicated.

## 5. Conclusions

An assessment of the radiological protection has been made in order to design the new storage for radioactive materials according to safety norms and licensing. For this purpose, a Monte Carlo simulation code has been used to estimate the ambient dose equivalent levels produced by the radioactive materials located inside the storage. The results were compared with doses values obtained from the experimental measurements and a good agreement was obtained.

Also, the simulation results of the ambient dose equivalent obtained by using MCNPX for the "worst case scenario" for radiological protection indicate that shielding walls of the new storage are efficient for an 8 times larger amount of radioactive materials placed inside than they are in the present.

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