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An operational radiation safety intervention: Minimizing dose in lab spaces due to photon sources in adjacent storage room

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Abstract The Nuclear Engineering Laboratory of NTUA operates a radiography installation incorporating a 200 kVp -x ray unit in a basement vault. During licensing characterization phase of the control, supervised and general public zone(s) by the Regulator, it was made obvious that there existed potentially harmful dose, greater than the background, within the control zone(s). At a limited number of points, easy to be avoided, dose reached $1.5 \mu\text{Sv h}^{-1}$. This dose was due to γ emitting sources stored in adjacent to the control zone(s) storage room. The situation was further investigated by dose measurements collected using a portable radiation monitor. The collection grid was set to about 0.5×0.7 m for approximately the following elevations: 0.00 m (floor), 1.00 m, 1.70 m and 2.20 m. Maps in 2D were then drawn numerically for these elevations using the kriging method. Results demonstrated that photons contributing to dose emerged at a height of about 1.00 m, from the NW wall of the vault, behind which the source storage room of the Laboratory is located. It was then realized that photon sources were placed behind this wall in drums without any particular shielding. It was consequently decided to move the sources away from this wall to the SW side of the storage room and shield them circumferentially with standard lead bricks. The result of this intervention was verified by remapping the dose rate in the control zone(s) for the worst case scenario of the 1.0 m elevation. New doses were found close to the background.

Keywords radiation safety, localized potentially hazardous dose, radiation protection intervention

INTRODUCTION

The as low as reasonably achievable (ALARA) principle has been described, with regard to dose optimization, in numerous publications (e.g. [1], [2]). The ALARA principle ensures that, subject to economic and practical factors, the total effective dose equivalent (TEDE) is minimized. In the Nuclear Engineering Laboratory of the National Technical University of Athens (NEL-NTUA), ALARA is implemented under the supervision of the Greek Radiation Protection Regulator, i.e. the EEAE. The implementation considers all the well recognized factors of time, distance, shielding and planning. Planning, a factor, which is not usually mentioned, is a radiation protection component that combines appropriately all others time, distance and shielding and provides the means of their integration in an optimal way. During the planning phase, each ALARA factor should be considered in defining the particulars of a practice. It could be said that planning may be divided in the design of the practice activities, the practice implementation and the post-practice review. At about 2010 and after a careful design, it was decided that the industrial radiography installation of NEL-NTUA could be located in an available underground abundant space, the external walls and roof of which had been constructed using reinforced concrete to a thickness of 60cm. This shielding thickness had been sufficiently calculated, so that, during the operation of a 200 kV -x ray unit, any area outside or above the radiography installation could be considered as public zone. Before the actual practice implementation, there were briefings and mock-up trainings by knowledgeable personnel of NEL-NTUA and the Greek Regulator, with emphasis to the identification of the controlled zone(s), the supervised zone(s), the public zone(s) and possibly anticipated problem areas. Alongside this investigation, it was established that there were areas within the controlled zone(s), in which there

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existed doses beyond the background (expected to be in the range of 50 to 100 nSv^h⁻¹), without any operation of the -x ray unit. The maximum of these doses were found to be very well localized in spots of the control zone(s), when the -x ray set-up was idle. Of course, when this set-up was operating these doses become unidentifiable due to the large -x ray flux. The reason for these doses was found to be dry storage boxes with old photon emitting radioactive sources, most of them Cs-137 in various configurations and low activities, kept in an underground room adjacent to the industrial radiography installation area. The maximum doses value was preliminary identified to be in the order of 1.5 μSv^h⁻¹, slightly greater than the accepted dose limit of the 1 μSv^h⁻¹, that is considered to be potentially hazardous in a public environment, both according to local and international regulations [3]. Addressing this dose issue could have been irrelevant in such an environment, where it is unlikely that members of the public would find themselves in the vicinity of the exposure spots. However, since the environment of NEL-NTUA is also academic, the general public, i.e., students, researchers etc., might spend time, when the -x ray set-up is idle, close or at the higher dose spots in ignorance. Therefore, it was deemed necessary that an operational radiation safety intervention should be applied.

CONTROL ZONE(S) LAYOUT AND CROSS SECTIONS

Figure 1 (left) presents the -x ray vault layout in top view. The controlled zone(s) are depicted in pink. Controlled zone(s) include the -x ray vault itself, as well as a maze-like entrance seen at the top of this figure. The supervised zone(s) are depicted in blue and comprise of a small space before the maze entrance. The general public zone is depicted in green, while, in gray, East and South of the vault, there exists bulk-soil shielding. The roof and the walls interfacing the vault to the public zone or to the bulk soil are made of 60 cm thick reinforced concrete. Figure 2 presents the North side view of cross-section "T6". The color code of Fig. 1 (left) applies. Figure 3 presents the East side view of cross-section "T3". The color code of Fig. 1 (left) and Fig. 2 applies. The radioactive sources storage room, from which the harmful doses emerge is clearly seen in Figs 1 (left) and 2. Figures 1 (LEFT) to 3 clearly show the initial location of these sources before any radiation safety intervention.

DOSE SITUATION MAPPING BEFORE INTERVENTION AND INTERVENTION

The dose situation mapping was made possible using grid measurements with the BD01 gas detector of a Polimaster PM1402M set [4] as in Fig. 4. According to [4], this particular set up has a sensitivity of 200 cps / (μSv^h⁻¹), its measurement range is 0.05 to 40 μSv^h⁻¹, its photon energy detection range is 0.06 to 1.5 MeV and its measurement uncertainty for dose rates around 1 μSv^h⁻¹ and measurement time around 30 s is estimated to about 20%, as usual for gas detectors of similar volume. The set up has been calibrated at the construction factory; no further check of this calibration was made locally. All measurements were performed taking into account the location of the detector effective center as described in [4]. Figure 1 (right-top) demonstrates the worst case dose mapping for the -x ray vault ramp at 1.70 m elevation from the vault floor level, while Fig. 1 (right-bottom) is the worst case dose mapping for the -x ray vault at 1.00 m elevation from the vault floor level. All mappings were produced using a contemporary version of the "Surfer" mapping software by Golden Software [5]. Figure 5 presents the new sources location at the Southern wall of the source storage room. All sources have been shielded by a lead brick wall.

DISCUSSION

Dose grid measurements and mapping after the intervention indicate that the dose field shown in Fig. 1 (right-top) at the Western wall of the -x ray vault is no longer detrimental or significant. Dose at the ramp area has been significantly reduced as well. However, records show that in the ramp area

there is still detectable dose, but very close to the background and far below the $1 \mu\text{Sv h}^{-1}$ limit, most probably due to Uranium photons coming from a Uranium storage kept in the adjacent room west of the source storage room. These photons penetrate into the ramp space and scatter on its walls, floor and roof. The aftermath of this intervention is that using simple equipment, suitable software and affordable shielding means, dose coming from sources could be easily controlled and detained.

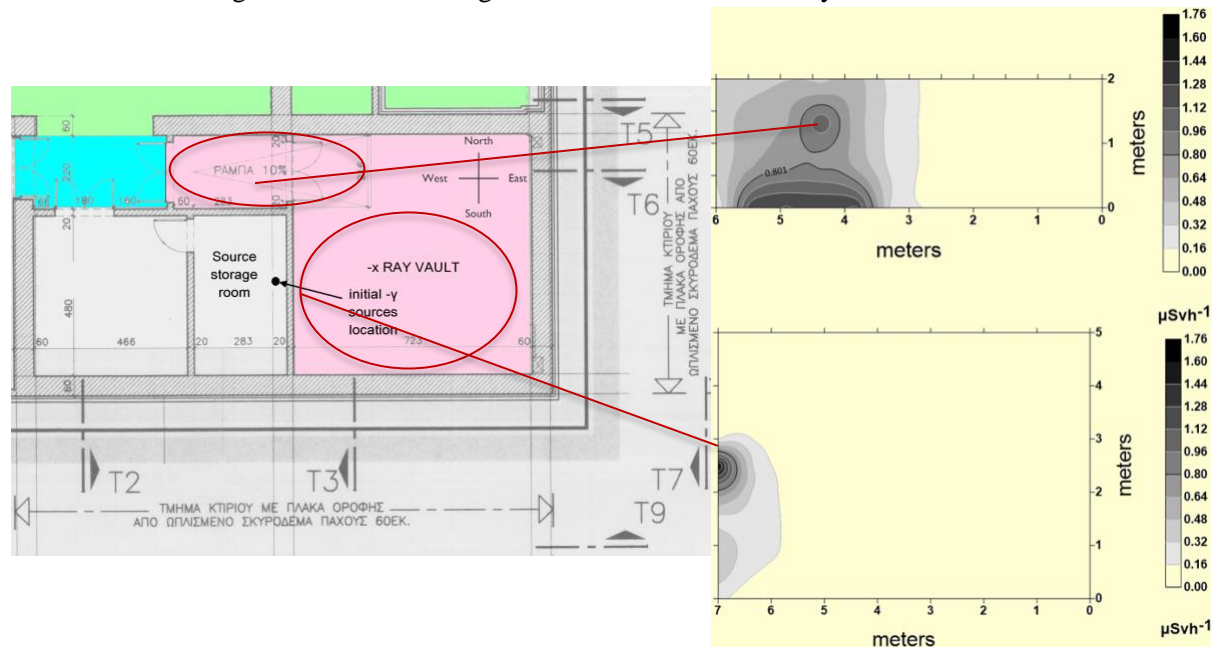


Figure 1. (left) -x ray vault layout; In pink: the control zone(s) in and around the vault; In blue: the supervised zone; In green: the public zone; In gray: not characterized; ROOF AND WALLS ARE OF 60 cm THICK CONCRETE (right top) Worst case dose mapping for the -x ray vault ramp at 1.70 m elevation from the vault floor level (right bottom) Worst case dose mapping for the -x ray vault at 1.00 m elevation from the vault floor level.

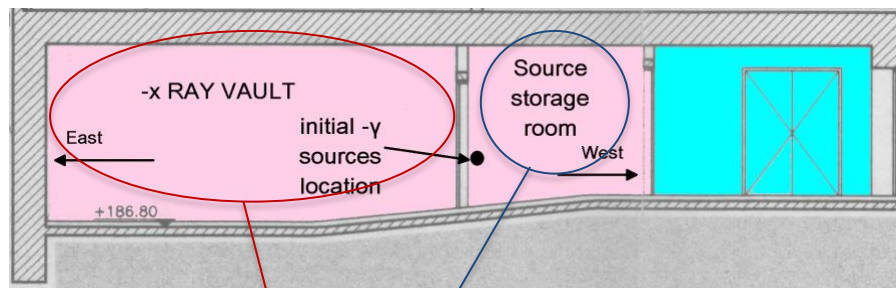


Figure 2. -x ray vault and surroundings cross-section "T6"; In pink: the control zone in and around the vault; In blue: the supervised zone

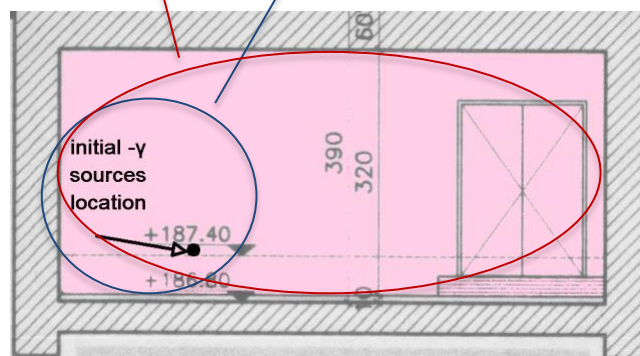


Figure 3. -x ray vault and surroundings cross-section "T3"



Figure 5. (left) Dose measurement instrumentation set Polimaster PM1402M, (right) Detector BD01 with telescopic branch and reading unit

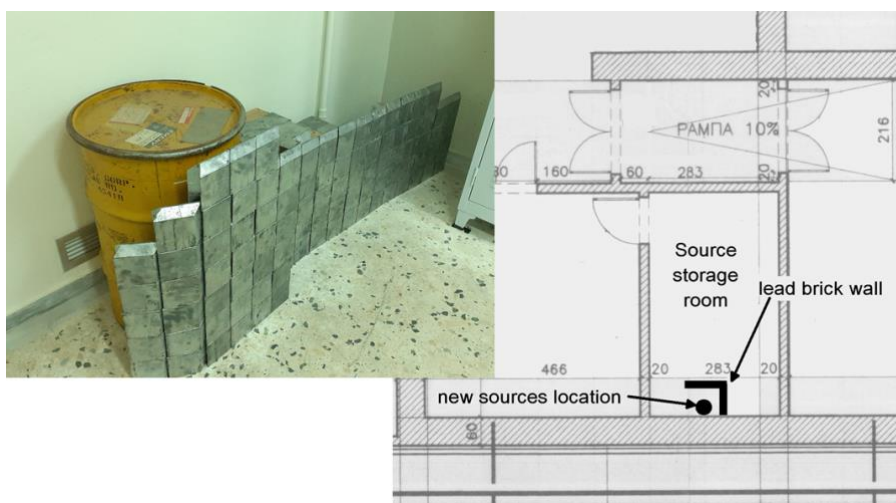


Figure 5. New sources location at the Southern wall of the source storage room.

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