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DISMANTLING OF THERATRON EQUINOX HEAD WITH Co-60 RADIOACTIVE SOURCE AND PERSONAL DOSE ASSESSMENT

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Abstract. *In this paper are presented some technical aspects from the decommissioning process of a Teletherapy machine model "Theratron Equinox" that contained category one Cobalt-60 radioactive source. This study includes some technical aspects of dismantling, security, transport and personal doses assessment during the dismantling procedure of teletherapy machine based on the Albanian Laws. During the dismantling process were used thermoluminescence dosimeters and Electronic Portable Dosimeters for personal doses received. The dismantled teletherapy head was transported securely to the National Radioactive Waste Storage Facility. This study highlights safety and security measures taken during the decommissioning process of Cobalt-60 sources while minimizing occupational exposure.*

Keywords: *radioactive source, dismantling process, radiation safety, occupation exposure decommissioning*

1. INTRODUCTION

The safety and security require continued vigilance at a time when increasing use of radioactive materials and sealed sources in industrial, medical and research applications increase the demand of establishing a procedure for removal and control of spent radioactive sealed sources from its devices such as a head of teletherapy unit that contains Co-60 [1], [4].

These activities have determined the necessity to formulate and apply an institutional strategy to assure harmless and ecologically rational management of spent sealed sources and radioactive waste conform national safety as well as security with international re-commendations [5][7].

The Co-60 radioactive source emits gamma rays which allows for more precise targeting of tumors during radiation therapy. This precision minimizes damage to surrounding healthy tissues, leading to better treatment outcomes and reduced side effects for patients [2].

Cancer treatment in Albania improved at the time when theletherapy machine with Co-60 came in use because many people had opportunities to follow radiation therapy. Co-60 source has longer half-life compared to other isotopes commonly used in radiation therapy, which means they require less frequent replacement. This reduces downtime for maintenance and replacement procedures, allowing healthcare facilities to operate more efficiently and treat more patients [3].

However, the dose rate of Co-60 source is relatively lower compared to linear accelerators, which means that the treatment may take longer, also the gamma radiation emitted by Co-60 source, can be suitable for many tumors, but not optimal for all the cases, especially those cases requiring higher energy level for deeper penetration or specific tissue types. That's why many old Co-60 sources all over the world are being decommissioned [6]. Linear accelerators have largely replaced Co-60 sources in teletherapy due to their superior precision and shorter treatment times. However, Co-60 remains essential for calibration purposes and is still used in resource-limited settings.

The same situation is in Albania with the Theratron Equinox Co-60 teletherapy machine. This machine was firstly introduced at University Hospital Centre "Mother Tereza" around 2007 and was used for several years until it was decided to decommission.

This study describes some technical aspects of dismantling, security, transport and personal doses assessment during the dismantling and removal procedure of teletherapy machine based on the Albanian Laws.

2. MATERIALS AND METHODS

2.1. Removal of the head assembly

Cobalt-60 was incorporated at the head of Theratron Equinox machine, and was located at Radiotherapy Department of University Hospital Centre "Mother Theresa".

In order to decommission a radioactive source, according to the Albanian laws needs to be obtained permission by the National Regulatory Body. The process of dismantling of Theratron Equinox head with Co-60 was carried out by International Atomic Energy

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Agency (IAEA) experts in collaboration with Institute of Applied Nuclear Physics experts (IANP).

The general information on the teletherapy source is presented in Table 1.

Table 1. The information on Teletherapy source

Device name:	Theratron Equinox unit
Source:	Co-60
Physical half –life:	5.26 years
Serial number:	S - 6070
Initial Activity:	8844Ci on 01/05/2013
Current Activity:	2303Ci on 25/07/2023

For the security of the radioactive source at Co-60 treatment room was installed an alarm system, ambient dose rate monitor, moving sensors, cameras, acoustic sensors, locked doors with a two-man rule for entry-exit at the treatment room. The position of the treatment room is presented in Figure 1.

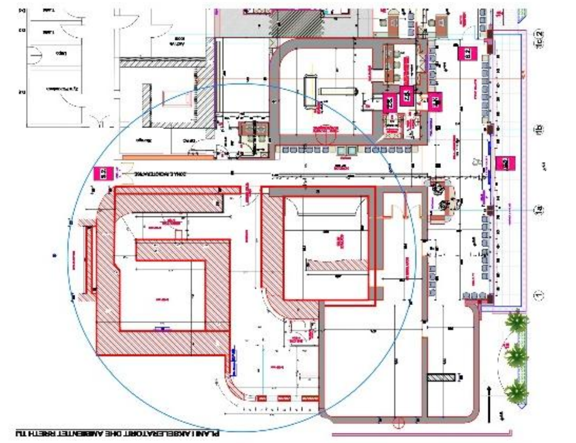

Figure 1. Floor Plan of Radiotherapy Department

Figure 2. Teletherapy unit before dismantling

Equipment containing radioactive sources has to be tested for removable radioactive contamination from time to time according to the institution procedure. The measurement of contamination levels inside the treatment room in different points of the room as well as leaking test was the first step of this process. The testing was performed with contamination monitor Berthold LB 124 which did not detected presence of contamination levels. In Fig. 2 is shown the Teletherapy unit before dismantling.

At the meantime initial dose rate measurements inside the treatment room and on the Teletherapy head was measured before removal of the Teletherapy head. The initial dose rate was as below:

Red dot: 33 μSv/h,

On the top of the collimator: 1.8 μSv/h,

Environmental dose rate: 0.8 μSv/h at 2 m distance from the source.

After all the measurements, the experts started with the process of dismantling which are presented in Figure 3 and Figure 4. The dismantling process lasted two working days (16 hours).

Figure 3. Dismantling process of collimator head

Figure 4. Dismantling process of collimator head

After the removal of the unit and Theratron head was completed, the head together with the Co-60 source was temporarily stored inside the treatment room ready for the transportation.

2.2. Personal dose measurements

During the procedure of the Co-60 source dismantling, workers were near the source for many hours. This exposure needed to be controlled and evaluated, during all the dismantling process as Co-60 source was always inside the head of Theratron Equinox machine. Two Thermoluminescence Dosemeters (TLD) were issued to Necsa's experts by UHC "Mother Tereza", RPO which at the end of the processes were measured at IANP and showed that the dose received during the dismantling process were less than 0.10 mSv. In the meantime, the Electronic Portable Dosimeters (EPD-s) used by the Necsa's team during the dismantling process measured a maximum dose of 8 μSv. Both TLDs and EPDs were used for individual monitoring. The EPD model used was the Thermo Scientific RadEye PRD. Comparative values for TLD and EPD measurements at different dismantling stages are presented.

2.3. Equipment and calibration

Both personal dosimeters and the area monitor were calibrated with traceability to Cs-137 standards. Energy-dependence corrections were applied to address Co-60 measurements. Specifically, calibration coefficients for Co-60 were derived by comparing Cs-137 calibration with Co-60 gamma-ray emissions (1.17 MeV and 1.33 MeV). A correction factor of 1.12, based on IAEA calibration protocols (IAEA Safety Standards No. RS-G-1.8), was applied to TLD measurements. This correction factor (1.12) is applied to raw TLD dose measurements to adjust for differences between Cs-137 calibration (used for TLDs) and the actual Co-60 gamma radiation energy. The raw TLD measurement is multiplied by the correction factor (1.12) to obtain the dose that more accurately reflects Co-60 exposure:

Adjusted Dose = Measured Dose × Correction Factor

This ensures that the dosimeter readings are accurate for Co-60 radiation.

Measured Dose: A TLD records a dose based on its calibration with Cs-137 (a commonly used calibration source with gamma energy of 662 keV).

Correction Factor: Co-60 emits gamma rays at higher energies (1.17 MeV and 1.33 MeV), which requires applying a correction factor to account for energy-dependent differences in detector response.

- Measured Dose: A TLD recorded a dose of less than 0.10 mSv based on Cs-137 calibration.
- Adjusted Dose: After applying the correction factor, the dose was adjusted to:

0.10mSv × 1.12=0.12 mSv.

This adjustment ensures that the dosimeter readings accurately reflect Co-60 exposure. Similarly, a TLD measurement of 0.08 mSv was corrected to 0.0896 mSv, and a reading of 0.07 mSv was adjusted to 0.0784 mSv. These corrections demonstrate consistency in applying the calibration factor across all measurements.

In contrast, EPDs provided real-time monitoring during the dismantling process. The maximum dose recorded by the EPD was 8 μSv. The TLDs and EPDs were cross-compared, and the adjusted cumulative doses from the TLDs aligned well with real-time EPD readings. This comparison underscores the importance of combining real-time and cumulative dosimetry to ensure accuracy and safety.

Linearity of dosimeters was verified by exposing them to dose rates ranging from 1 μSv/h to 100 μSv/h. Linear regression analysis indicated proportionality between measured and expected values with deviations within 3%, satisfying international standards (ISO 4037).

A Berthold LB 124 monitor, utilized as both a contamination monitor and a dose-rate survey meter, was employed to measure ambient dose equivalent values. This dual functionality ensured reliable readings of both contamination and dose rates, critical for assessing radiation safety during the dismantling process.

2.4. The transportation processes

For security measures, it was decided that the transportation would take place at midnight, to avoid traffic jam and in that way, the transportation time will also be reduced.

The experts that did the dismantling together with the staff of IANP and also with the staff of UHC "Mother Tereza" came back at midnight to prepare for the transfer of the unit to the IANP storage facility. Transportation of the teletherapy head was performed at midnight to the IANP storage facility (See Fig. 5 and 6). The head was secured on the back of a suitable truck and transported to the IANP under the direct supervision of:

- Two Necsa experts,
- IANP Staff,
- Two Inspectors of the Radiation Protection Office (The Regulatory Body),
- Dedicated Police officers for traffic control and security purposes.

Figure 5. Head removed from unit.

Figure 6. Transportation of the head at midnight to the IANP storage facility.

3. RESULTS AND DISCUSSION

The dismantling of the Theratron Equinox containing Co-60 radioactive source was successfully completed, following all the procedures to ensure safety and security of the radioactive source and also minimizing radiation exposure to all the personnel involved in this process.

The head of Theratron Equinox together with Co-60 source was dismantled using specialized tools and handling techniques, ensuring that the personnel maintained a safe distance from the radioactive material. Following the source removal, final contamination measurements took place to make sure that the workplace was clean from contamination or not. After the measurements of the treatment room was not detected any contamination so no decontamination procedures were need to be carried out. Continuous environmental monitoring was conducted during the dismantling process to ensure that radiation levels in the surrounding areas remained safe. Ambient Dose Measurements Environmental dose rates at a starting distance of 2 m and all across the room remained consistent at 0.8 μSv/h.

Final dose rate, were also measured. After the dismantling of the head together with the Co-60 source inside, the results were as below:

In front of the head: 16.6 μSv/h,

The part of the head where the source was secured: 60 μSv/h,

In the back of the head: 1.8 μSv/h,

Environmental dose: 0.8 μSv/h at 2 m distance.

Measurements were made by Radiation Protection Officer of UHC "Mother Tereza" using a Berthold LB 124 radiation detector (survey meter). All the measurements were conducted at the points indicated in the above section. The Berthold LB124 provided precise and reliable reading of radiation levels, ensuring accurate data collection essential for the analysis and conclusions of this study. These measurements were critical for assessing the radiation exposure during dismantling process and for ensuring compliance with safety standards. Additionally, the environmental dose received from these measurements was carefully monitored to ensure it remained within permissible limits [7], [8]. Personal and Environmental Dosimetry TLD results indicated radiation doses received by personnel were less than 0.10 mSv. After applying the Co-60 correction factor of 1.12, the adjusted maximum dose was approximately 0.112 mSv. EPD measurements recorded a maximum dose of 8 μSv, which, after validation, aligned closely with TLD readings, confirming measurement consistency. This dual approach of environmental and personal dosimetry was vital in maintaining a safe working environment and protecting the health of all personnel involved in the project.

4. Conclusion

In conclusion, the dismantling of the Theratron Equinox head was conducted safely and efficiently, with personal doses well within regulatory limits, since dose limit for personal dosimetry for occupational workers is 20 mSv per year and also well within survived area dose limits of 6 mSv per year. This paper reinforces the critical role of a well-defined planning, effective training, and continuous monitoring in ensuring the safety of personnel and the environment during operations involving radioactive materials, we can say that this process was well within regulatory limits.

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