APPLICATION OF RADIOLOGICAL CLEARANCE CRITERIA FOR THE DECOMMISSIONING OF NUCLEAR MEDICINE DEPARTMENT IN ALBANIA

BRIKENA VUÇAJ[1], KOZETA TUSHE[2], DRITAN PRIFTI[2],

ZELIHA MUÇO[1]

[1]University Hospital Centre "Mother Tereza", Tirana, Albania

[2]Institute of Applied Nuclear Physics, Tirana, Albania

e-mail: brikena_vucaj.fshnutdr@unitir.edu.al

Abstract

This paper presents the decommissioning process of a diagnostic and therapeutic nuclear medicine department located within "Mother Thresa" University Hospital Center. This department, operated for several years and served as the sole public provider of nuclear medicine services in the country, using radionuclides based on iodine-131 and technetium-99m. Following the relocation of all clinical services to a newly constructed Hospital, a comprehensive radiation monitoring was conducted as part of the clearance protocol. Gamma dose rate measurements, alpha and beta contamination checks and swipe tests were performed across all clinical and storage areas. The results indicated no presence of contamination above national and international clearance levels. This paper provides a practical case study on the safe closure and radiological assessment of a nuclear medicine facility and may serve as a guideline for similar future activities in diagnostic imaging and radionuclide therapy services.

Key words**:** *Decommissioning, nuclear medicine, radionuclides, clearance levels, radiological assessment.*

Përmbledhje

Ky punim paraqet procesin e çmontimit të një departamenti të mjekësisë bërthamore për diagnostikë dhe terapi, i vendosur në Qendrën Spitalore Universitare "Nënë Tereza". Ky departament ka funksionuar për disa vite si ofruesi i vetëm publik i shërbimeve të mjekësisë bërthamore në vend, duke përdorur radionuklide të bazuara në jod-131 dhe teknecium-99m. Pas zhvendosjes së shërbimeve klinike në një godinë të re spitalore, u krye një monitorim i plotë radiologjik si pjesë e protokollit të çlirimit të ambienteve. U *realizuan matje të dozës së rrezatimit gama, kontrolle të kontaminimit alpha dhe beta si dhe teste me fshirje në të gjitha ambientet klinike dhe të magazinimit. Rezultatet treguan se nuk u identifikua kontaminim mbi nivelet e lejuara sipas standardeve kombëtare dhe ndërkombëtare. Ky studim paraqet një rast praktik të mbylljes së sigurt dhe vlerësimit radiologjik të një njësie të mjekësisë bërthamore dhe mund të shërbejë si një udhëzues për aktivitete të ngjashme në të ardhmen në fushën e diagnostikës imazherike dhe terapive me radionuklide.*

Fjalë kyçe: *dekomisionim, mjekësi bërthamore, radiobërthama, nivele çlirimi, vlerësim radiologjik*.

Introduction

Decommissioning of nuclear medicine facilities is an essential phase in the life cycle of radiological installations, ensuring that areas previously used for handling unsealed radioactive materials are safe for unrestricted use. Unlike radiotherapy units that utilize high-activity sealed sources, nuclear medicine departments frequently deal with unsealed radionuclides, leading to potential surface and environmental contamination during routine clinical activities (IAEA, 2014; IAEA, 2019).

Iodine-131 (I-131) and technetium-99m (Tc-99m) are two of the most commonly used radionuclides in diagnostic and therapeutic nuclear medicine. I-131, a beta and gamma emitter with a half-life of 8 days, is widely used in the treatment of thyroid disorders, while Tc-99m, a gamma emitter with a short half-life of 6 hours, is commonly used for diagnostic nuclear imaging. The handling, administration, and disposal of these radionuclides require stringent radiation protection measures (Institute of Public Health, 2020).

While several publications detail the decommissioning of radiotherapy units or research facilities, few focus specifically on nuclear medicine departments using short- and medium-lived radioisotopes such as I-131 and Tc-99m (IAEA, 2014; IAEA, 2019). This paper aims to fill that gap by presenting the full decommissioning process, including radiological survey and clearance assessment, of a nuclear medicine unit that was relocated due to infrastructural redevelopment.

Materials and methods

Description of the nuclear medicine unit

- The decommissioned facility was the only public nuclear medicine center in the country and had been operational for several decades within the University Hospital Center "Mother Teresa" as presented in Figure 1. It functioned for both diagnostic and therapeutic purposes, offering outpatient, inpatient, and emergency nuclear medicine services. The unit was equipped with three imaging systems:
- SPECT system (Mediso, AnyScan S, Serial No. AS-101040-S)
- Hybrid SPECT-CT system (Mediso, AnyScan SC, Serial No. AS-605208-SC)
- Planar gamma camera (Mediso, Planar Line, Serial No. TH-22)

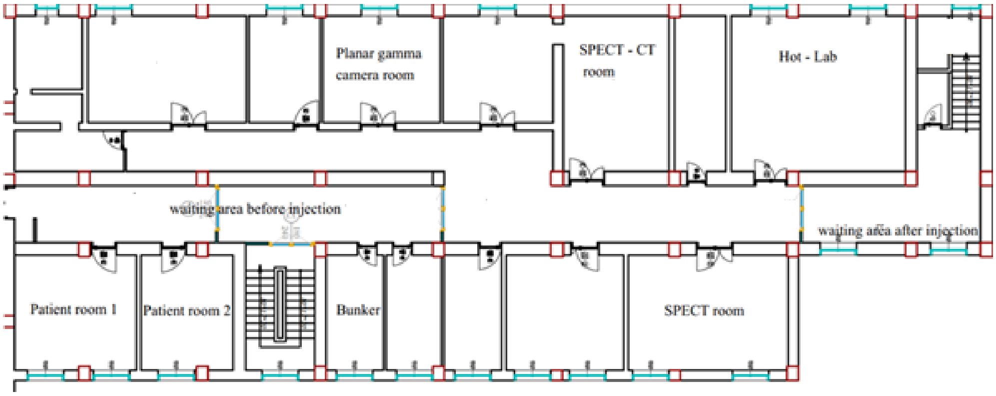

Figure 1. Floor plan of the nuclear medicine department.

Figure 1 presents the floor plan of the nuclear medicine department, where clinical services were performed, including thyroid imaging and functional assessment, renal scintigraphy, bone metabolism and metastasis imaging, cardiac perfusion imaging, parathyroid adenoma localization, pulmonary ventilation/perfusion studies, and I-131 therapy for thyroid cancer and hyperthyroidism.

The radioisotopes used in the unit were delivered once every two weeks, including Tc-99m generators (with an activity of approximately 20 GBq) and I-131 capsules in various activities.

These radioisotopes were procured through suppliers supported by the International Atomic Energy Agency (IAEA). Additionally, a Cs-137 calibration source (250 µCi), manufactured by Eckert & Ziegler, was used for quality assurance of the medical equipment.

The relocation of services was carried out due to the deteriorating structural conditions of the existing facility, which prompted the construction of a new medical building, including a new nuclear medicine department. As part of this transition, a comprehensive radiological assessment was required to ensure that the former unit met the clearance criteria for unrestricted reuse.

2.2. Radionuclides and Clinical Activity

The decommissioned nuclear medicine unit operated with regular biweekly deliveries of radionuclides, primarily technetium-99m (Tc-99m) and iodine-131 (I-131). These were used for a wide range of diagnostic and therapeutic applications, including thyroid imaging and treatment, renal and bone scintigraphy, cardiac perfusion studies, pulmonary function assessment, parathyroid adenoma localization, and whole-body metastasis detection.

Annual patient volumes exceeded 1,500 for thyroid scintigraphy, with over 600 patients undergoing bone imaging and approximately 400 renal scans. Therapeutic administrations of I-131 were performed for both hyperthyroidism and differentiated thyroid cancer, with administered activities ranging from 185 MBq to 3,700 MBq. The department received biweekly deliveries of these radionuclides to support its clinical workload:

- 2 capsules of I-131 at 3700 MBq
- 3 capsules at 740 MBq
- 2 capsules at 370 MBq
- 10 capsules at 185 MBq
- Tc-99m generators with an activity of 20 GBq

A Cs-137 calibration source (250 µCi) has been used for daily quality control.

2.3 Radiological Monitoring and Contamination Assessment

The primary objective of the decommissioning process was to verify the absence of radioactive contamination within the facility, ensuring that all rooms could be safely released for unrestricted use. The scope of the assessment included all clinical, preparation, injection, imaging, and storage areas. The evaluation was conducted in accordance with IAEA safety guidance and national regulatory criteria for clearance levels. (IAEA, 2014; IAEA, 2019; IAEA 2003)

A systematic radiological survey was conducted using a RadEye B20-ER multipurpose survey meter. (Thermo Fisher Scientific, Germany; PN 42506/8510, SN 35098) shown in figure no.2.

Figure 2. The RadEye B20-ER multipurpose survey meter

The RadEye B20-ER instrument was calibrated in June 2022 by an accredited laboratory in accordance with ISO 9001 standards. Reference levels for dose rates and removable surface contamination were based on IAEA guidance documents, including Safety Standards Series RS-G-1.7 and WS-G-2.1, as well as national clearance criteria (IEC, 2009; Eckert & Ziegler Isotope Products, n.d.).

The device was used with two dedicated filter modules:

- **Alpha Blocker Filter (PN 42506/8581):** used to block alpha particles and detect only beta and gamma radiation during surface contamination scans.
- _H(10) Filter (PN 42506/8582):_* used for the measurement of ambient dose equivalent H*(10) in µSv/h, representing exposure at a depth of 10 mm in tissue, in accordance with IEC 60846-1:2009, for photon energies between 17 keV and 3 MeV.

The assessment included:

• Ambient gamma dose rate measurements, performed at approximately 5 cm above the floor, at multiple predefined points within each room.
• Beta contamination monitoring, recorded in counts per second (CPS), using

the same RadEye B20-ER instrument with the alpha blocker filter to isolate beta signals.

Swipe tests were analyzed using a portable wipe counter (Model 2224), equipped with a 0.25 mm thick ZnS scintillator and a Mylar® window of 0.4 mg/cm², as shown in Figure 3.

Figure 3. Ludlum Scaler/Ratemeter Portable Wipe Counter Model 2224

Measurement points were selected to represent both high-use and low-use areas, including radionuclide preparation benches, injection chairs, gamma camera gantries, patient waiting areas, as well as floor corners, door handles, and waste container lids.

In this study, swipe tests consisted of wiping a defined surface area (typically 100 cm²) using absorbent paper or filter material. The collected samples were then analyzed using a portable wipe counter (Ludlum Model 2224), capable of detecting alpha, beta, and gamma radiation, depending on the radionuclides involved. For Tc-99m and I-131, both beta and gamma emissions are relevant; however, removable contamination is primarily evaluated via beta counting, in accordance with IAEA safety reports and ISO 7503-1 (ISO, 2017).

2.4. Radiation Protection Measures

All measurements were performed under strict radiation protection protocols. Personnel involved in the decommissioning survey used personal protective equipment and personal dosimeters and adhered to the ALARA (As Low As Reasonably Achievable) principle. Access to rooms previously used for I-131 therapy was delayed until sufficient radioactive decay had occurred. Handling was performed using long-reach tools and appropriate protective shielding.

Environmental and occupational safety procedures included:

- Use of PPE (gloves, aprons, personal dosimeters);
- Dedicated contamination control zones;
- Waste collection and isolation procedures;
- Survey meter cross-verification in suspect areas.

2.5. Statistical Analysis

To enhance the radiological evaluation and ensure objective interpretation of the measured data, descriptive statistical analysis was performed on the results obtained from gamma dose rate measurements, beta surface contamination scans, and swipe tests. While individual point measurements are important for identifying localized contamination, statistical parameters provide an overall assessment of the radiological condition of the entire facility. The use of statistical indicators enables:

- Detection of outliers that may suggest localized contamination requiring re-evaluation.
- Quantification of variability across different rooms and functional zones.
- Comparison with clearance criteria not only at single-point level but across the full distribution of values.
- Compliance assessment with national and international safety standards in a standardized and reproducible format.

2.6. Interpretation of Analytical Parameters

To ensure a comprehensive evaluation of removable radioactive contamination, each set of swipe test data was analyzed using a standardized statistical and radiological framework. The following indicators were calculated and interpreted:

Maximum Value – Beta / Alpha: The Maximum Value – Beta represents the highest gross count per minute (CPM) measured among all swipe samples at a given location for beta-emitting contamination. The Maximum Value –

Alpha corresponds to the same measure for alpha-emitting radionuclides. These values provide a conservative estimate of localized contamination hotspots and are critical for identifying areas requiring further attention. While mean values reflect general conditions, maximum values often dictate compliance decisions during regulatory inspections.

Maximum Net Value – Beta / Alpha: The Maximum Net Value is obtained by subtracting the background count, determined from measurements in a clean reference area, from the gross maximum CPM:

$$\text{Net Maximum CPM} = \text{Gross Maximum CPM} - \text{Background CPM}$$

Any resulting negative values are rounded to zero to avoid reporting non-physical negative contamination. These net values form the basis for converting measured counts into surface activity, providing a quantitative assessment of removable contamination levels.

Removable contamination is calculated using the equation (1):

Following background subtraction, the net maximum CPM is converted to **Bq/cm²** using the equation:

$$\frac{\text{Bq}}{\text{cm}^2} = \frac{\text{NET CPM}}{60 \times \text{Efficiency} \times \text{Swipe Area (cm}^2)} \qquad (1)$$

Where:

- 60 = conversion from minutes to seconds
- Efficiency = detector-specific calibration factor (e.g., 0.374 for beta, 0.84 for alpha)
- Swipe Area = typically 100 cm^2

This conversion allows direct comparison with standardized regulatory thresholds for clearance. For these measurements, criteria levels were applied, representing the maximum allowable removable contamination on a surface for it to be considered radiologically clean. These levels are based on international and national regulations, including IAEA Safety Reports and ISO 7503-1.

- **Beta-emitting radionuclides:** ≤ 0.4 Bq/cm^2
- **Alpha-emitting radionuclides:** ≤ 0.04 Bq/cm^2

These limits ensure that residual contamination does not pose a risk to patients, staff, or the environment (IAEA, 2019; IAEA, 2003; IEC, 2009). Separate evaluations were conducted for both beta and alpha measurements. For alpha-emitting radionuclides, even low activity values are significant due to the higher radiotoxicity of alpha particles, necessitating stricter thresholds.

3. Results and discussion

3.1 Ambient Gamma Dose Rate Measurements

The measurements of gamma dose rate for each room are presented in tables as in the example of table 1. Throughout the old department of nuclear medicine were surveyed a total of 17 rooms with different purpose of use.

Table 1. Ambient Gamma Dose Rate Measurements

No.	1						
Location	**Patient room (1)**						
Dose (μSv/h)	0.150	0.160	0.140	0.100	0.110	0.120	0.130
Mean Value	0.130						
Standard Deviation	0.022						
Coeficient of Variation	0.166						
Maximum Value	0.160						
Criteria Levels	0.3						
Final Results	Pass						

In Table 1 are presented the data of gamma dose rate recorded in different functional zones for patient room no.1

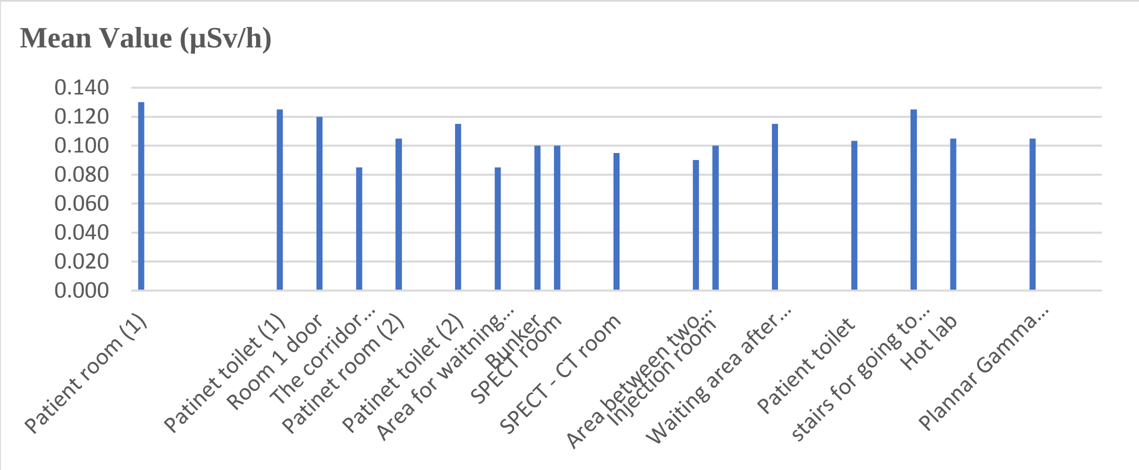

Figure 4. The mean gamma dose rate values

Figure 4 presents the mean gamma dose rate values measured in 17 different rooms of the former nuclear medicine department within the University Hospital Center "Mother Teresa." The graph illustrates that all average measurements are consistently below the established clearance level, confirming that residual radiation levels in the surveyed areas are within acceptable safety limits.

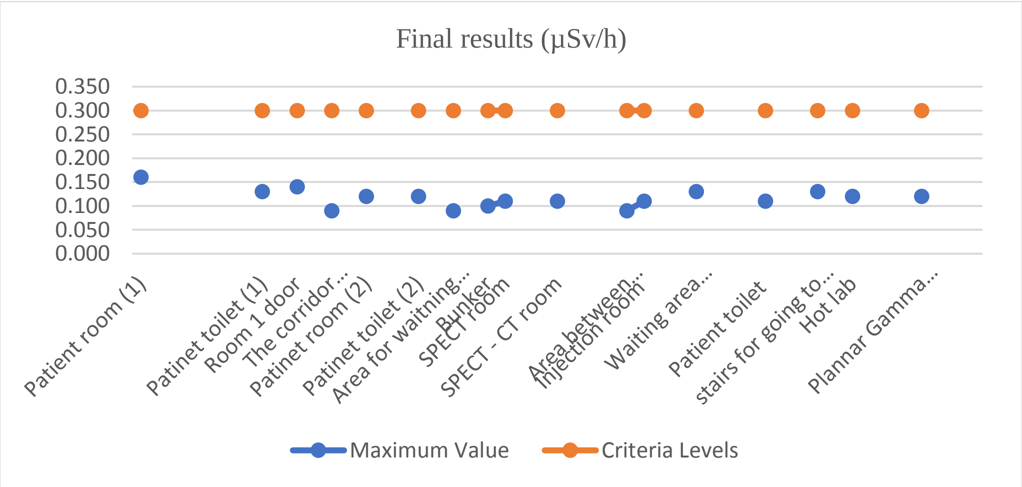

Figure 5. Maximum gamma dose rate values

Figure 5 shows the maximum gamma dose rate values recorded in each room, benchmarked against regulatory clearance levels. The results demonstrate full compliance with national and international radiological safety standards, confirming that all monitored areas are suitable for environmental clearance and unrestricted future use (Institute of Public Health, 2020; IAEA, 2003). All gamma dose rates were below the clearance threshold of 0.3 µSv/h.

No.	1						
Location	**Hot lab**						
	Door	Sink	Inside the room			Inside the room where the staff stays	
Dose (cps)	0.400	0.500	0.510	0.530	0.540	0.500	0.490
Mean Value Inside The Room	0.400	0.500	0.527			0.495	
Mean Value	0.476						
Standard Deviation	0.055						
Coeficient of Variation	0.115						
Maximum Value	0.527						
Criteria Levels	300						
Final Results	Pass						

3.2 Beta Surface Contamination Measurements

Measurements of beta surface contamination for each room are summarized in tables, as illustrated by Table 2. A total of eight rooms with different functions were surveyed throughout the former nuclear medicine department, focusing on areas where beta contamination could be present.

Table 2. Hot Lab Beta Contamination Results

Table 2 presents the beta surface contamination data recorded in the different functional zones of the Hot Lab.

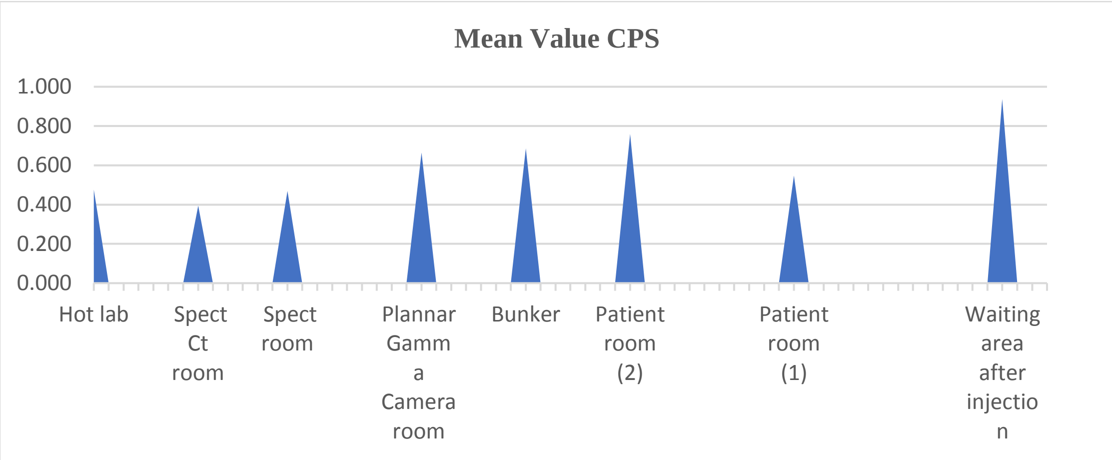

Figure 6. Mean beta surface contamination values

Figure 6 presents the mean beta surface contamination levels measured across the surveyed rooms. All average values remain well below the regulatory clearance limits, indicating that removable beta contamination is negligible and that the monitored areas comply with established radiological safety requirments.

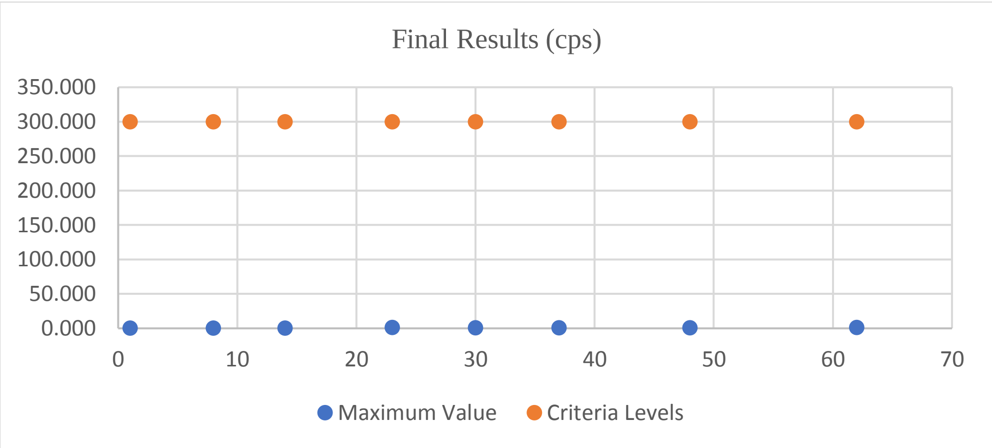

Figure 7. Maximum beta contamination values

Figure 7 presents the final results of the beta contamination survey, showing the maximum measured values in each room relative to the regulatory clearance levels. All maximum values were well below the threshold, confirming compliance with safety standards and supporting the radiological clearance of the facility. Furthermore, all beta contamination measurements were below the commonly applied intervention threshold of 300 counts per second (CPS).

3.3 Swipe Test Measurements

Swipe tests were performed by wiping a defined surface area of 100 cm² using filter paper, which was subsequently analyzed with a portable Ludlum wipe counter capable of detecting alpha- and beta-emitting radionuclides. The results of the swipe tests for each room are summarized in tables, as illustrated by Table 3. Swipe tests were conducted in eight rooms, covering a variety of surfaces including floors, toilets, walls, and doors.

Table 3. Swipe Test Measurements

Nr.	1			
Location	**Patient Room 1**			
	Door	Floor	Toilet	Wall
Beta (cps)	60	57	52	65
Alpha (cps)	0	0	0	0
Mean Value_Beta	58.50			
Mean Value_Alpha	0.00			
Standard Deviation_Beta	5.45			
Standard Deviation_Alpha	0.00			
Coeficient of Variation_Beta	0.09			
Coeficient of Variation_Alpha	-			
Maximum Value_Beta	65.00			
Maximum Value_Alpha	0.00			

Maximum Net Value_Beta	6.00
Maximum Net Value_Alpha	0.00
Beta (Bq/cm2)	0.003
Alpha (Bq/cm2)	0.000
Criteria Levels	0.4
Final Results_Beta	PASS
Final Results_Alpha	PASS

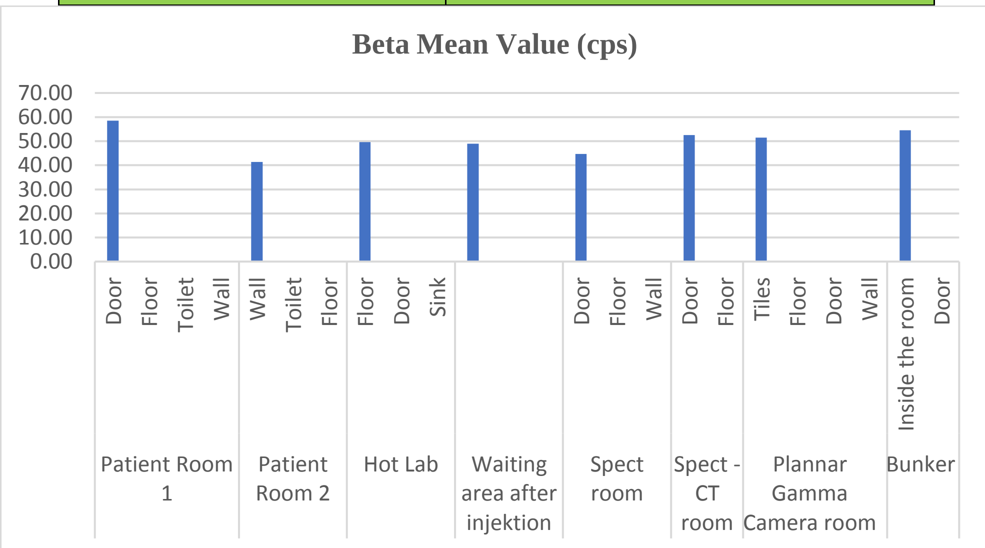

Figure 8. Beta mean values

Figure 8 presents the final evaluation of beta measurements, expressed in counts per second (CPS). All recorded values were at or near background levels, indicating that no significant beta contamination was present. All results remained well below the clearance thresholds, confirming the absence of residual beta-emitting radionuclides in the facility.

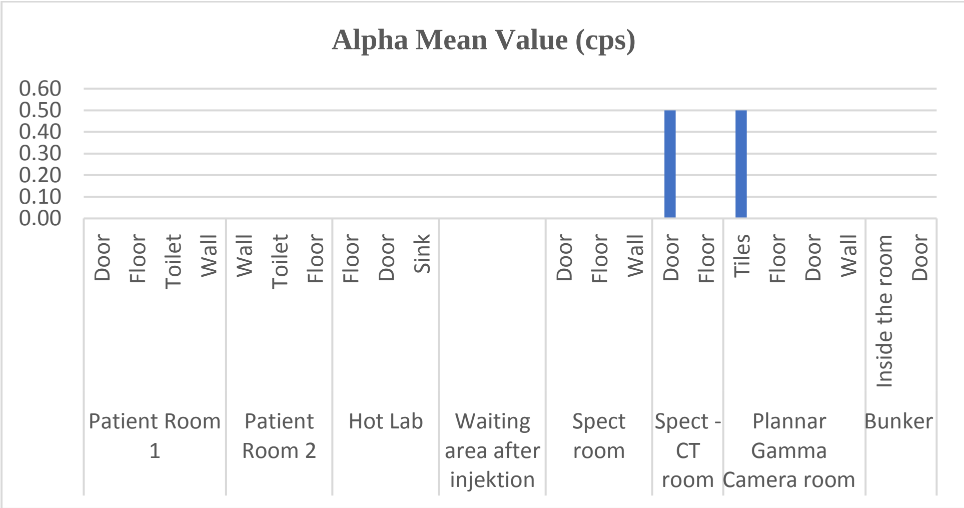

Figure 9. Alpha mean values

Figure 9 presents the final evaluation of alpha measurements, expressed in counts per second (CPS). All recorded values were at or near background levels, indicating that no significant alpha contamination was present. All results remained well below the clearance thresholds, confirming the absence of residual alpha-emitting radionuclides in the facility.

The final comparative evaluation of surface contamination levels indicates that both beta and alpha measurements remained below the established clearance limits (0.4 Bq/cm² for beta and 0.04 Bq/cm² for alpha, in accordance with ISO 7503-1 and IAEA guidelines). While low-level beta contamination was detectable in some areas, all results were well below regulatory thresholds, and alpha contamination was essentially at background levels. These findings confirm that all surveyed areas fully comply with radiological clearance requirements, with all swipe test measurements below the specified threshold.

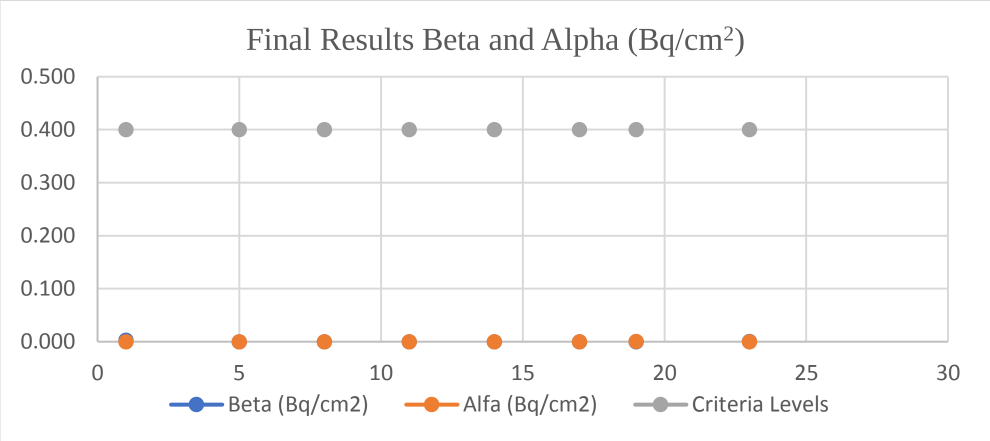

Figure 10. Beta and alpha mean values

The results of the radiological survey indicate that no residual contamination remained in any of the monitored areas of the decommissioned nuclear medicine unit. All gamma dose rates were well below the clearance threshold of 0.3 µSv/h, and all beta surface contamination measurements were below 300 counts per second (CPS), a commonly accepted operational limit for unrestricted use of medical premises.

Particular attention was given to high-risk areas, including the radionuclide preparation room, the I-131 therapy room, and the radioactive waste storage area. Although these locations historically handled relatively high activities of unsealed radionuclides such as routine Tc-99m administrations and multiple I-131 therapies no measurements exceeded the recommended clearance levels. For example, the highest recorded beta values (1.2–1.3 CPS) were detected on tiles in the planar gamma camera room and on the floor of the post-injection room; however, these values remained well below the intervention threshold.

No area required additional decontamination procedures, confirming that operational radiation protection practices—including routine cleaning protocols, appropriate shielding, safe handling of sources, and personnel training—were effective throughout the facility's lifetime. This outcome is further supported by the unit's strict adherence to radiation safety protocols, including controlled patient release criteria, internal contamination prevention, and environmental monitoring during therapeutic procedures.

These findings align with international experiences in the decommissioning of nuclear medicine facilities utilizing short- and medium-lived radioisotopes.

For instance, IAEA Safety Reports and case studies of I-131 therapy rooms have demonstrated that proper implementation of safety practices—particularly in the management of patient excreta and the use of shielding in storage and treatment areas—significantly reduces long-term contamination risks.

This case highlights the importance of a structured and well-documented decommissioning plan that includes comprehensive radiological assessment, staff protection measures, and compliance with clearance criteria. It also underscores the value of incorporating adequate infrastructure planning in future facility design to facilitate eventual decommissioning and repurposing.

Conclusion

The decommissioning process of the nuclear medicine unit described in this study represents a successful example of a systematic, evidence-based approach to facility closure following prolonged use of unsealed radioactive sources. Comprehensive radiological monitoring—including ambient gamma dose rate measurements, beta contamination assessments, and planned swipe testing—confirmed that the facility was free of residual contamination, with all values below national and international clearance criteria.

No additional decontamination actions were required, demonstrating the effectiveness of routine radiation safety practices and environmental hygiene maintained during the unit's operational phase. This emphasizes the critical role of preventive measures, such as staff training, proper shielding, waste segregation, and strict adherence to handling protocols, particularly in therapeutic applications involving Iodine-131.

The methods, results, and practices presented here may serve as a reference model for similar institutions planning the closure or relocation of nuclear medicine services. Early planning, clear documentation, and adherence to recognized safety standards are essential for minimizing radiological risks to staff, the public, and the environment during decommissioning activities.

"Data Availability Statement

Part of the data generated or analyzed during this study are included in this published article.

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