

Insights from the analysis of the occupational exposure of personnel in the nuclear medicine department

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Abstract. This study focuses the retrospective analysis of the past 6 years of the occupational exposure at the Nuclear Medicine Department of the University Hospital Center “Mother Tereza” in Tirana (Albania). The effects of the relocating to a new building and the changes in the use of radiopharmaceuticals concerning radiological protection were analyzed. The personnel is monitored using chest badges equipped with TLD dosimeters, resulting in a total of 237 dose measurements. It was noted that the monitoring was not conducted systematically as expected by the legislation with a bimonthly cadence. The technicians and nurses were generally found to be the most exposed group of professionals, while occasionally the sanitary personnel received relatively high annual dose rates. Generally, the physicians received relatively low annual dose rates. The highest dose recorded was 1.32 mSv, reflecting a temporary increase in use of radiopharmaceuticals due to the management of increased demand. Particular cases of minor incidents and their impact on the recorded dose were examined. There were no cases of an exceeded dose limits, with the highest annual dose found to be 2.2 mSv. Nevertheless, careful focus is essential to optimize workflow and workload allocation and ensure continuous training of the personnel in response to an increase in procedures and changes in the radiopharmaceuticals utilized.

1 Introduction

Nuclear medicine is essential for diagnosing and treating different diseases through the use of radiopharmaceuticals emit ionizing radiation. At the Nuclear Medicine Service of "Mother Teresa" University Hospital Center in Tirana, Albania, a wide range of diagnostic and therapeutic procedures are conducted using commonly available radionuclides such as technetium-99m (^{99m}Tc) and iodine-131 (¹³¹I). Every two weeks, these isotopes are provided in the form of molybdenum-99/technetium-99m generators and sealed iodine capsules, respectively. Technetium-99m, with half-life of 6.02 hours and gamma emission energy of 140.5 keV, is the most frequently used isotope due to its favourable imaging characteristics and low radiation exposure. It is utilized in several organ-specific procedures, including renal scintigraphy (utilizing DMSA, DTPA, or MAG3), myocardial perfusion imaging, skeletal scintigraphy and pulmonary scintigraphy. Iodine-131 is mainly a beta emitter, but it also releases a significant gamma photon of 364 keV (about 10%

abundance), which makes it possible to image its biodistribution. The physical half-life is 197.72 hours. Given the nature of these radionuclides, radiation workers at the Nuclear Medicine Center are unavoidably exposed, which highlights the need for rigorous protection measures and continuous monitoring.

The evaluation of effective dose covered the annual effective doses of nuclear medicine personnel over a six-year period. Moreover, the evaluation of exposures by professional categories such as physicians, medical physicists, technologists, nurses, and support personnel is assessed, along with trends, anomalies, and factors affecting the radiation doses. At the end the cumulative dose, normalized to the number of nuclear medicine personnel, is also discussed.

2 Materials and Methods

This study is a retrospective analysis over a six-year period (2019–2025), of the occupational radiation exposure for healthcare personnel working in the Nuclear Medicine Service (NM) at the University Hospital Center “Mother Teresa” in Tirana, Albania. The monitored personnel comprised 2 physicians, 1 medical physicist, 4 technologists, 3 nurses, and 2 support personnel. The personnel are monitored using personal thermoluminescent dosimeters (TLDs) badges that contain two LiF:Mg,Ti detectors housed in a special holder, allowing simultaneous assessment of both skin and deep doses. Lithium fluoride is nearly tissue-equivalent and does not respond to light, ensuring reliable handling and accurate dose evaluation. The TLD badge is worn at the chest area (beneath the lead apron when utilized), and the dose rate required to be recorded every two months [1]. The Institute of Applied Nuclear Physics, in Tirana is the only institution that provides personnel dose-monitoring services to all radiation workers (workers exposed to ionizing radiation) in public and private hospitals in the country (including those in dentistry, medicine, industry and research facilities [2].

Dose reports provide evaluations of Hp (10) that are delivered to the Radiation Protection Office at the General Directorate of the hospital and assigned to the medical physicist in the NM service. The TLD badges are measured, analyzed, and calibrated according to standard procedures [1]. Quality control is performed with a Sr-90 irradiator, whereas calibration is done at the Secondary Standard Dosimetry Laboratory. The exposed TLDs are analyzed using the Harshaw 4500 Reader with a controlled hot nitrogen gas heating system (up to 300 °C), and the results are processed through the WinREMS software [1, 2]. From 2019 to 2025, a total of 237 occupational dose records were archived in the local database. The data underwent systematic review, and any anomalies relative to expected dose trends were investigated with corrective actions implemented when necessary.

3 Results and discussions

The annual effective dose for all monitored personnel of nuclear medicine department from 2019 to 2025 is shown in Figure 1. The annual effective dose of supporting personnel was the highest among all the NM personnel. It reached 2.21 mSv/year in 2023, followed by a nurse with a peak reaching 1.95 mSv/year in 2023. Generally, the average doses for nurses are between 0.29 mSv/year and 1.95 mSv/year, related to the administration of radiopharmaceuticals, high radioactive doses of iodine for therapy and patient care activities. Technologists consistently showed the high exposure values, but lower than the nurses, ranging between 0.28 mSv/year in 2019 and 1.67 mSv/year in 2023, reflecting their

daily hands-on work with radiopharmaceuticals and patients. Medical physicist received average annual doses between 0.95 mSv/year and 1.45 mSv/year, consistent with their role in quality control and safety assurance. Physicians, who typically engage in diagnostic interpretation rather than hands-on radiopharmaceutical handling, recorded the lowest annual doses among workers, from 0.23 mSv/year in 2019 to 1.09 mSv/year in 2024. During the six-year period, the highest dose recorded in NM service was 2.21mSv/year, comparable to the maximum average annual effective dose registered in 2017 which was 2.44 mSv/year [2].

Technologist are the most exposed professional in nuclear medicine department not only in Tirana, also in Lithuania this group recorded the highest level among all other profession with 2.12 mSv [3].

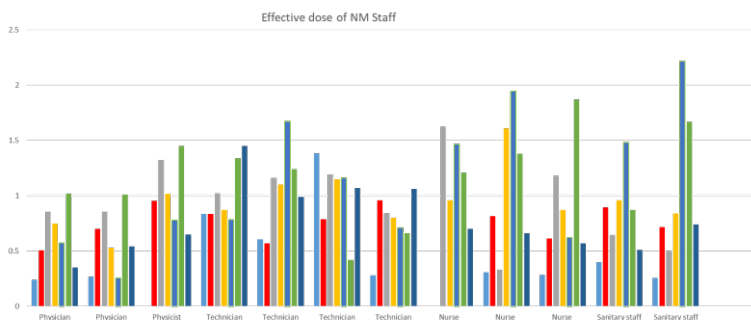


Fig. 1. The annual effective dose over any six consecutive years.

Figure 2 shows the six-year period dose across professional roles. From the graph it can be seen that physicians receive the lowest cumulative doses over 6 consecutive years, ranging from 4.2 to 4.3 mSv. The medical physicist has accumulated a total dose of approximately 6.0 mSv. Technicians recorded the highest total exposure dose among all radiation workers of NM department. For example, technician (1) and technician (2) recoded the total doses, at 7.2 and 7.3 mSv respectively. Nurses showed total dose values between 5.5 and 7.1 mSv, with nurse number 2 reaching the upper end of the range. Sanitary personnel demonstrated cumulative doses of 5.5 mSv and 6.6 mSv, respectively. All the radiation workers still have received doses well below the occupational dose limit [4].

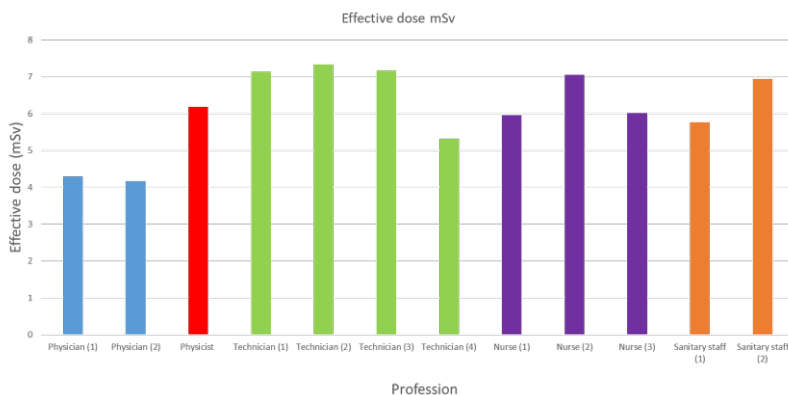


Fig. 2. The effective dose of nuclear medicine personnel over 6 consecutive years.

In addition to annual doses, the cumulative dose normalized per nuclear medicine (NM) staff member was analyzed for the period 2019–2025 (Figure 3). This metric provides an overview of occupational exposure trends over time, adjusted for variations in staffing levels. The data show a general upward trend in cumulative dose per person over the six-year period, reflecting increased workload and possible shifts in radiopharmaceutical usage. In 2019, the average dose per staff member was the lowest (approximately 0.48 mSv/year per personnel). From 2020 to 2021, there was a steady increase in cumulative dose per personnel, corresponding with an increase in the number of procedures. The dose remained stable from 2021 to 2022 (~0.92 mSv/year per personnel), before peaking in 2023 at approximately 1.12 mSv/year per personnel. This peak likely reflects both the increase in radiopharmaceutical use and a temporary mismatch between workload and protective infrastructure. In 2024, a slight decline in cumulative dose was noted (~1.08 mSv/year per personnel). Although still within safe limits, the upward trend over time highlights the need for continuous optimization of operational protocols, monitoring, and training to minimize occupational exposure.

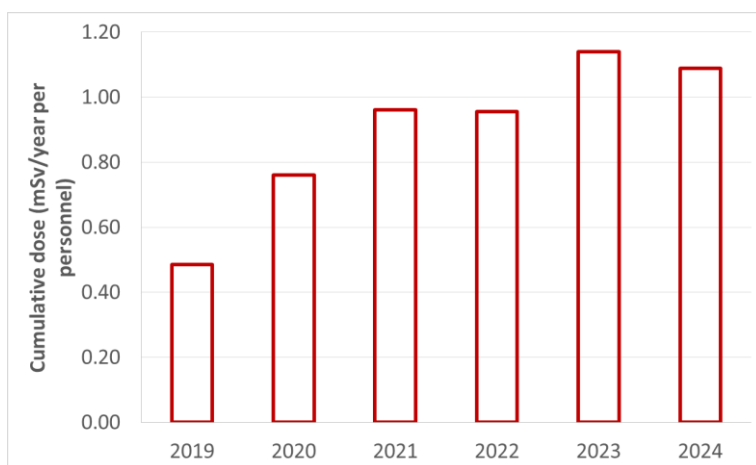


Fig. 3. Cumulative dose exposure normalized to the number of nuclear medicine staff.

Comparing the yearly averages with bimonthly records provided additional understanding. Nurses involved in administering radioisotopes and monitoring patients showed higher radiation exposure during these years, with one nurse nearing 1.87 mSv annually; although still under regulatory limits [4], these instances triggered an internal investigation. In 2019, effective doses recorded were lowest. This could probably be associated with delays exceeding bimonthly period (up to 6–7 months), which can cause fading effect on TLD dosimeters leading to underestimation of actual exposure. An irregular record (in 2023) for a sanitary personnel member was subsequently linked to her wearing the personal dosimeter while undergoing skeletal scintigraphy as a patient, resulting in a non-work-related high-dose artifact. In 2024, the addition of new personnel coincided with an increase in radiation exposure doses even though the total number of exams decreased. This trend was probably caused by the unfamiliarity with radiation safety protocols, increased errors during radiopharmaceutical administration, and the increase of supervisory demands from experienced personnel, resulting in longer times spent in high-exposure situations. These levels reached the department's internal reference limit and are consistent with their

routine, direct contact with patients and radiopharmaceuticals during preparation, injection, imaging, and post-procedure care [5].

Peak bimonthly values reached 1.32 mSv, higher than historical averages. This increase coincided with a higher clinical workload, which included an increase in high-activity I-131 therapies and a doubling of patients for diagnostics and therapy. The direct handling of unshielded I-131 capsules and close contact with isolated patients undergoing therapy likely contributed to these elevated radiation exposure doses. The personnel mostly affected consisted of technologists responsible for administration, as well as personnel managing the radioactive waste and patient isolation rooms, which require prolonged proximity to high-activity sources. The department utilizes a formal protocol for incident assessment when individual readings exceed those of other employees in the same department [4, 5]. Although all occupational exposures remained within both national and ICRP limits, the variability observed during high-demand clinical periods underscores the dynamic nature of radiation risk in nuclear medicine. Even when remaining significantly below regulatory limits, sustained attention on optimization is necessary to keep exposures as low as reasonably achievable (ALARA) [5, 6].

4 Conclusions

This study indicated that the Hp(10) levels of radiation workers over the 6-year period were significantly lower than the national limits. The technicians and nurses were typically identified as the most exposed group of professionals, while occasionally the sanitary personnel received relatively high annual dose rates. In general, the physicians received relatively low annual dose rates. It was observed that the monitoring was not performed systematically as required by the legislation on a bimonthly basis. Consequently, it is advisable to continuously assess occupational radiation dose exposure, particularly because of the increasing number of medical imaging procedures that are currently being performed.

Particular cases of minor incidents and their impact on the recorded dose were examined. There were no cases of an exceeded dose limits, with the highest annual dose found to be 2.2 mSv. Isolated incidents of minor occupational exposures and their influence on recorded dose values were investigated. Continuous training, strict adherence to monitoring protocols, and proactive adaptation of radiation protection strategies during peak demand periods are essential for sustaining low-dose environments in nuclear medicine practice. Findings confirm that radiation protection measures in the NM department were effectively implemented and that all staff remained within safe occupational exposure levels throughout the observation period.

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