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Determination of Annual Effective Doses from Background Ionizing Radiation to Nuclear Medicine Professionals in Medical Centre

Muhammad Waqar[1*], *Touqir Ahmad Afridi*[1], *Quratulain Soomror*[2], *Jameela Khatoon*[2], *Jahangeer Dahri*[3]

[1]Medical Physics Division, Nuclear Medicine Oncology & Radiotherapy Institute Nawabshah (NORIN), Pakistan.
[2]NM & Allied Division, Nuclear Medicine Oncology & Radiotherapy Institute Nawabshah (NORIN), Pakistan.
[3]Administration Division, Nuclear Medicine Oncology & Radiotherapy Institute Nawabshah (NORIN), Pakistan.

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Abstract: Background: Nuclear medicine departments of medical centers deal with sealed as well as unsealed radioactive source for multiple purposes. This potentially rises the background dose rates and consequently, radiation exposure to nuclear medicine professionals. This study targeted to determine the background radiation levels in the nuclear medicine department of NORIN cancer hospital Nawabshah, Pakistan. **Materials & Methods**: Background dose rates of ten work stations of nuclear medicine department were recorded using a pre-calibrated radiation survey meter RM1001-RD LAMSE for one year periodically and Annual Effective Dose Rates (AEDRs) were determined with the help of standard notations. The organ doses were also calculated using recommended conversion and occupancy factors. **Results & Discussion**: The highest AEDR of 1.073 ± 0.056 mSv/yr was found at the door of radioactive waste room while the lowest was found 0.580 ± 0.013 mSv/yr in the stress room of nuclear medicine department. The standard error ranged between 0.020-0.056. Maximum organ dose of 0.880 mSv/yr was found to testes at the door of radioactive waste room and the lowest organ dose of 0.336 mSv/yr was found to ovaries in the stress room. These results show the T-test values in a level of significance of 5% ($P<0.05$). **Conclusions:** The radiation levels calculated in this study are well within the permissible radiation limit of 1.0 mSv/yr recommended by the ICRP and hardly 45% of UNSCEAR limit of 2.4 mSv/yr. The organ-specific doses are also in safe zone. Therefore, the nuclear medicine professionals of this medical Centre are safe from hazards of background radiation. Strict compliance with radiation protection and regulatory protocols eliminates the undue anxiety about the hazards of background radiation in the nuclear medicine professionals.

Keywords: Nuclear Medicine, Background Radiation, Effective Dose, SSDL, Survey Monitor, AEDR, Organ Specific Dose.

1 Introduction

Nuclear Medicine (NM) is a reputable branch of medicine which uses tracer amounts of radioactive isotopes for diagnostic as well as therapeutic purposes. These procedures involve suitable doses of radiation emitters for diagnosis and therapy of various types of cancers. Principle of justification and optimization is used for quantification of radioisotope administration. Use of radioactivity in the nuclear medicine department gives rise to elevated background exposures to the professionals working in these areas, hence increasing the probability of stochastic effects. Therefore, standard operating procedures are designed for the professionals' safe working in the nuclear medicine departments. Doses are kept as low as possible in order to abide by ALARA principle [1]. The radiation monitoring in the nuclear medicine is of extreme importance because the workers are at a greater risk of getting exposed to radiation. After having administered a dose of radiopharmaceutical, the patient also becomes a mobile source of radiation and exposes the workers around him [2]. According to policy of Pakistan Nuclear Regulatory Authority (PNRA), the annual dose limit for a radiation worker should not be more than 20 milli Sieverts [3]. In order to minimize radiation dose, three basic strategies are followed i.e., time, distance and shielding. But in congested places filled with radioactive patients, it is rather difficult to follow these strategies [4].

In spite of all advantages, radiation has certain disadvantages too. We deal with many types of radiation with varying intensities in daily activities. Most common and well known acute hazards of radiation include cancer,

*Corresponding author e-mail: Muhammad Waqar (phy.waqar@gmail.com)

genetic mutation, cataract, degradation of bones and blood cells. If somebody somehow imparts radiation in the quantity large enough, it could prove fatal as reported by [5]. The major contributors to increased background radiation are the materials used in construction of buildings. They also transfer radionuclides into the environment, raising background radiation levels. Radon gas, formed in earth crust, is the biggest culprit of natural background radiation. 238Uranium produces 222Rn after radioactive decay, with half-life of 3.82 days as reported by [6]. It's inhalation entails absorption and penetration into the lung tissues. This absorption damages lung tissues and causes a mutation which finally results in lung cancer [7]. Internationally recommended annual safe exposure limit set by International Commission on Radiation Protection (ICRP) for Ionizing radiation is 1mSv/yr as reported by [8]. United Nation Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) sets the effective dose rate limit of 2.4mSv/yr, which is higher than that of ICRP. These safe limits are recommended for indoor modalities including research labs, offices, conference rooms, lecture halls, etc. Many a study has been reported previously which show that areas with elevated background radiation are found in Kerale, India; Yangjiang, China; and Ramsar, Iran as in [9] etc. Highest levels of outdoor background radiation have been reported in Malaysia and the highest indoor levels have been reported in Hong Kong and Iran by [10].

The Nuclear Medicine Oncology and Radiotherapy Institute Nawabshah (NORIN) is a comprehensive healthcare facility for diagnosis, treatment, and research on malignant tumors [11]. This institute was established with the objective to adopt the latest research approaches for cancer management. Nuclear Medicine & Allied Division is the core department that deals with the diagnoses as well as treatment of cancers of various types. This department is equipped with two SPECT dual head gamma cameras (Siemens and Infinia) [12]. Thyroid scans, bone scans, renal scans, lung perfusion, MUGA, myocardial perfusion with tetrofosmin and iodine-131 (I-131) whole body diagnostic and post-ablative imaging are routinely performed here. This is arguably the area with highest dose rate in the NORIN cancer hospital Nawabshah. The radiation protection protocols are implemented in such a way that the nuclear medicine professionals are safe from the acute hazards of radiation during work flow [13]. Figure 1 shows the map of Nuclear Medicine & Allied Division NORIN, Nawabshah.

2 Methods & Materials

NORIN Cancer Hospital Nawabshah located in the rural area of Sindh, Pakistan. On average, its Nuclear Medicine department entertains around 120 cancer patients a week. Following ten stations were selected for measurement of radiation levels: Hot-Lab, RIA-Lab, Injected Washroom

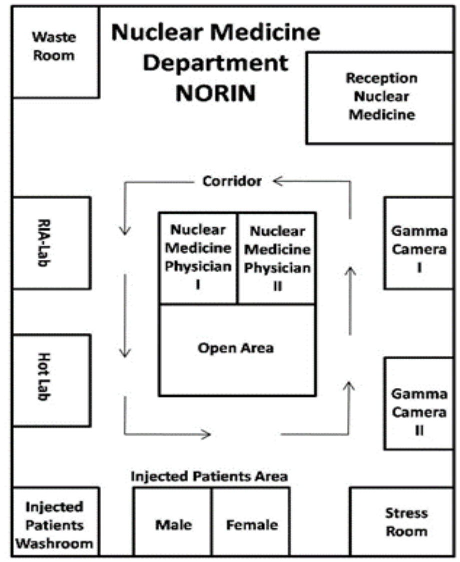

Fig.1: Map of Nuclear Medicine & Allied Division, NORIN Nawabshah.

Door, Patient Waiting Area (Female), Patient Waiting Area (Male), Corridor, Waste Room Door, Stress Room, Gamma Camera-I, and Gamma Camera-II. The data was collected on daily basis over the span of one year (2021) and was further analyzed for calculation of AEDR and organ specific radiation doses.

The study was carried out by using RM1001-RD LAMSE survey meter calibrated from Secondary Standard Dosimetry Laboratory PINSTECH Islamabad as shown in Figure 2. This model of survey meters is well-suited for the survey of background radiation in hospitals. The readings were taken in the morning before injecting the radiopharmaceuticals to patients. The equivalent dose readings were recorded in µSv/hr directly from the display screen of the radiation meter. The results were then converted into micro-Sievert per year (µSv/yr) and then finally to milli-Sievert per year (mSv/yr). An occupancy factor of 0.8 was used as recommended by the UNSCEAR (2000). The Annual Effective Dose Rates (AEDR) were calculated by using the following expression:

$$\text{Annual Effective Dose Rate}\left(\frac{\mu Sv}{yr}\right) = \text{Exposure}\left(\frac{\mu Sv}{yr}\right) \times T \times OF$$

$$\text{Annual Effective Dose Rate}\left(\frac{\mu Sv}{yr}\right) = \text{Esposure}\left(\frac{\mu Sv}{yr}\right) \times 8760 \times 0.8 \times 10^{-3}$$

Where T=total number of hours in a year (8760 hrs) and OF=occupancy factor (indoor = 0.8). Based on 24 hours a day and 365 days in a year; the number of hours in a year was 24 x 365 = 8760 hours [14]. AEDR is the total annual effective dose rate (mSv/yr).

Fig.2: Pre-calibrated RM1001-RD LAMSE survey meter used in NORIN.

Inhalation in such an environment imparts doses to internal organs like lungs, kidneys, ovaries, testes, bone marrow, and whole body also. These doses are calculated using equation given below.

$$\text{Organ Specfic Dose}\left(\frac{mSv}{yr}\right) = \text{AEDR} \times CF$$

Where CF is the conversion factor for organ doses from air. The conversion factor for lung is 0.64, 0.62 for kidneys, 0.69 for bone-marrow, 0.58 for ovaries, 0.82 for testes, and 0.68 for whole-body [15]. In order to assess this data statistically, the independent T-test on SPSS 17 [16] statistical software (SPSS Inc. USA) was used at a level of significance of 5% (P<0.05).

3 Results and Discussion

Ten stations of the Nuclear Medicine and Allied Division are assessed for the radiation risks associated with the scanning examinations and treatment of patients in the cancer hospital NORIN Nawabshah, Pakistan. Annual Effective Dose Rates (AEDRs) and organ specific doses have been calculated and the results are shown in Table 1 with average values of AEDRs (mSv/yr), standard errors and P values. Results are lower due to the strict compliance with radiation protection protocols and PNRA & IAEA guidelines observed in nuclear medicine department. Moreover, the radiation burden of this hospital is within the permissible limits of UNSCEAR.

Table 1: Mean AEDRs with standard errors and P-Values.

Stations	Mean (µSv/hr)	Mean (mSv/yr)	AEDR (mSv/yr)	P-Value ($P < 0.05$)
Hot-Lab	0.121	1.06	0.848 ± 0.03	0.0250
RIA-Lab	0.113	0.986	0.789 ± 0.007	0.0330
Injected Washroom Door	0.148	1.292	1.034 ± 0.02	0.0116
Waiting Area (Female)	0.126	1.103	0.882 ± 0.015	0.0314
Waiting Area (Male)	0.118	1.029	0.824 ± 0.018	0.0225
Corridor	0.095	0.828	0.663 ± 0.05	0.0263
Waste Room Door	0.153	1.342	1.073 ± 0.056	0.0111
Stress Room	0.083	0.725	0.580 ± 0.013	0.0200
Gamma Camera-I	0.126	1.105	0.884 ± 0.031	0.0253
Gamma Camera-II	0.126	1.103	0.882 ± 0.029	0.0330

Figure 3 graphically shows the AEDR values of ten selected stations in the nuclear medicine department along with their comparison with universally accepted dose limits of ICRP and UNSCEAR. Every bar is associated with a certain location inside NM department and AEDR values are shown accordingly. The maximum yearly dose rate was found at the door of radioactive waste room with value of 1.073 ± 0.056 mSv/yr while the minimum does rate was observed in the stress room with AEDR of 0.580 ± 0.013 mSv/yr.

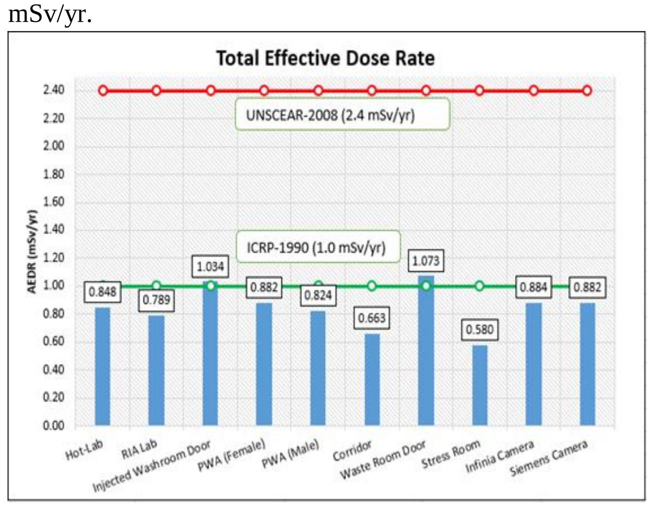

Fig.3: Total Annual Effective Dose Rates at selected stations in Nuclear Medicine Department.

Figure 4 shows Organ-specific annual effective doses to lungs, whole-body, ovaries, bone marrow, testes, and kidneys of nuclear medicine professionals. The most vulnerable organ prone to receiving maximum AEDR was testes with mean AEDR of 0.880 mSv/yr at radioactive waste-room door and least was found in the stress room with AEDR of 0.475 mSv/yr. Lungs received maximum 0.687 mSv/yr, whole-body 0.730 mSv/yr, Ovaries 0.623 mSv/yr, Bone Marrow 0.741 mSv/yr and kidneys 0.665 mSv/yr at the radioactive waste room door. Touqir et. al. reported maximum dose of 0.718 mSv/yr to testes at the operating console of Co-60 teletherapy machine [17]. All AEDRs were found well below the ICRP recommended limit of 1mSv/yr.

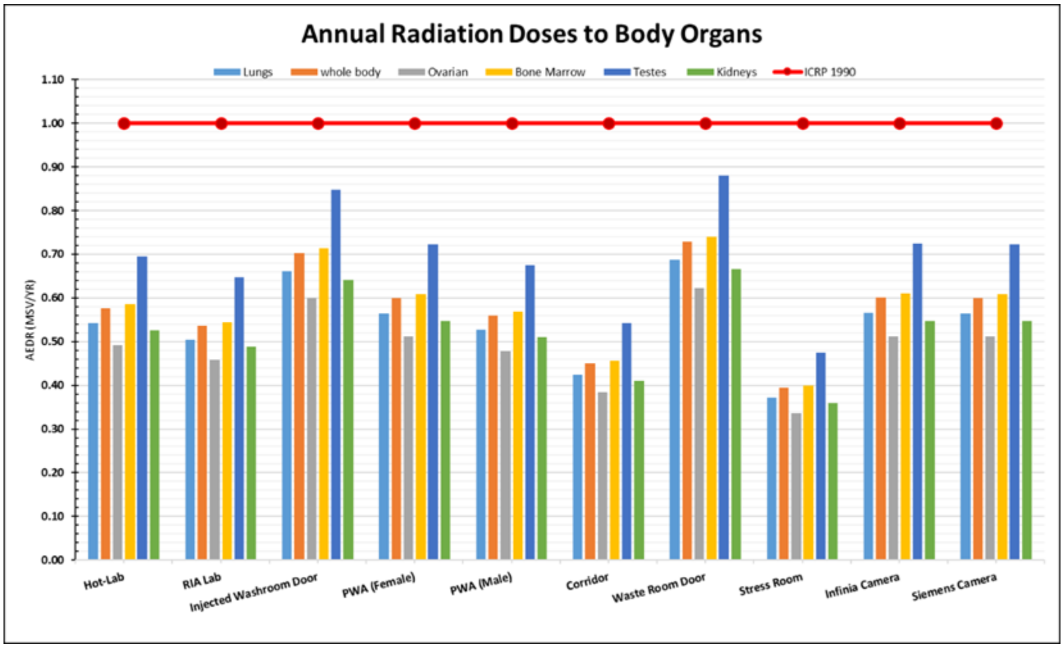

Fig. 4: Annual organ-specific doses in Nuclear Medicine department.

A review of annual effective dose rates reported previously and comparison with current AEDRs along with percentage with respect to UNSCEAR limit of 2.4 mSv/yr is tabulated in Table 2 & graphically represented in Figure 5. Fiona O. Robert et al. reported occupational annual effective dose rate of 2.00 mSv/yr (83.33%) in Department of Nuclear Medicine and Centre for PET Melbourne, Australia [18]. Another study done by M.M. Ahasan (2004) showed slightly higher values of 1.90 mSv/yr (79.17%) in hot-lab section of nuclear medicine department of Centre of Nuclear Medicine & Ultrasound Bangladesh [19]. According to Touqir et. al., the average AEDR in the operating consoles of radiology and radiotherapy departments in cancer hospitals was 0.86 mSv/yr (35.83%) [17]. Yearly cumulative dose rate in pharmaceuticals facilities in Nigeria [20] was reported 1.60 mSv/yr (66.67%) by Nwankwo et. al. (2014). In 2015, Felix B.M. Robert et. al. of Plateau University Bokos measured the background radiation levels of 1.54 mSv/yr (64.17%) [6]. Tikyaa et. al. reported the average effective dose rate per annum in the radiation labortries of Federal University KATSINA of 1.41 mSv/yr (58.75%) [21]. Jwanbot et. al. also documented slightly elevated values of ambient ionizing radiation of 2.11 mSv/yr (87.92%) in N.M departments of Jos Plateau state, Nigeria [22]. While the UNSCEAR (2008) recommends the yearly dose limit of 2.4 mSv/yr [23]. However, the AEDR calculated in this research has maximum value of 1.073 ± 0.056 mSv/yr in the nuclear medicine department of NORIN Nawabshah which is about 45% of the limit recommended by UNSCEAR 2008.

Table 2: Comparison of AEDRs with UNSCEAR limit.

Study	AEDR (mSv/yr)	Percentage with limit (2.4 mSv/yr)
Fiona O. Robert	2.00	83.33%
M.M. Ahsan	1.90	79.17%
Touqir et. al	0.86	35.83%
Nwankwo	1.60	66.67%
Felix, B. M. Robert	1.54	64.17%
Tersoo Atsue	1.41	58.75%
Jwanbot et. al	2.11	87.92%
Current Study	1.07	44.58%

The above comparison shows that the mean AEDRs in the nuclear medicine department are very well below the UNSCEAR recommended world average value of 2.4 mSv/yr. These results are higher than only one study i.e., Touqir et. al. [17] because they recorded AEDRs in the operating consoles of radiology department. This implies that the professionals working in the nuclear medicine department are radiologically safe from background radiation.

Better knowledge about background radiation is important for determining reasonable and appropriate precautions for radiation professionals working in nuclear medicine departments. Our results eliminate the fear among nuclear medicine professionals regarding exposure to background radiation.

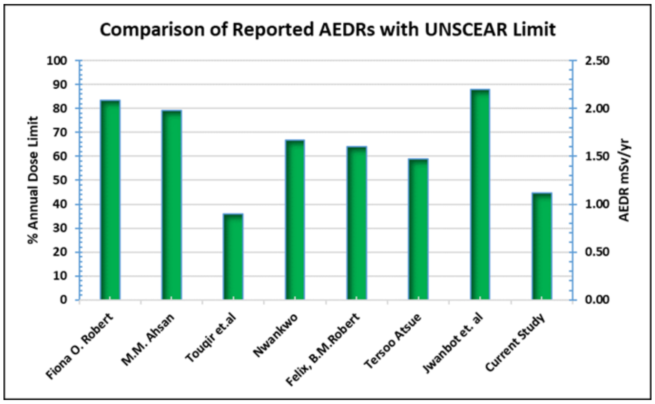

Fig. 5: Comparison of AEDRs as percentage of UNSCEAR recommendation.

4 Conclusions

The findings of this study showed that there were no significant health hazards to the nuclear medicine professionals from background radiation present in environment. The background exposure rate in different stations inside nuclear medicine department of this cancer hospital was well under the internationally recognized limits. Based on the aforementioned findings, it can be deduced that Annual Effective Dose Rates and organ-specific doses are within the permissible radiation limit as stipulated by the ICRP and UNSCEAR. The highest AEDR recorded in this study was at the door of radioactive waste room which is restricted area in the department and also, the waste inside the room contributes to the dose rates. Yet the AEDR calculated here was hardly 45% of the UNSCEAR recommended limit. This indicates that all radiation protection protocols are duly followed as per regulatory guidelines. This study reduces the undue fear of radiation hazards in the radiation workers of nuclear medicine department of cancer hospitals. Hence, all radiation workers in NM department of NORIN are radiologically safe in their work stations and also, this facility does not elevate the radiation levels of the surrounding environment. Public health around the center is not on stake and there is no significant impact on the radiation burden of the environment.

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