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Occupational radiation dose to workers in a cancer hospital

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ABSTRACT

Background: The amount of radiation absorbed and measured is called radiation dose. It is mandatory to monitor the radiation dose of the radiation worker, which should be less than the internationally allowed values. A cancer center has three radiation departments: diagnostic radiology, nuclear medicine, and radiotherapy. The workers in these departments are classified as radiation workers.

Methodology: The medical workers were monitored to determine their average annual effective dose using film badges for 4 years. The subdivision of Radiation Workers in a cancer center is medical Physicists, technicians, and nurses.

Results: The results are compared with national and international published data. The results of the measured Average Annual Effective dose were well below the international recommended dose limit of 20 mSv.

Conclusion: The results Suggested that the radiation safety standards are being practiced at Bannu Institute of NM, Oncology and Radiotherapy, Cancer hospital, Bannu, KPK, Pakistan.

Keywords: Occupational, radiation, exposure, cancer center.

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Introduction

Various natural and artificial ionizing radiation sources are being used in medical centers for both diagnostic and therapeutic purposes. These sources are X-rays, gamma rays, and beta particles [1]. These radiations are either produced by a radioactive element or by using high energy-charged particles. In either case, radiations are being used for medical purposes and for the betterment of mankind. In a nuclear medical center, there are three major radiation departments, which include nuclear medicine (NM), diagnostic radiology (DR), and radiotherapy (RT). The employees working in these departments are classified as radiation workers because they handle and interact with radiation sources [2]. The quantity of radiation absorbed by a worker is called radiation dose, and the International Commission on Radiological Protection (ICRP) has provided the radiation dose control limits for radiation workers as shown in Table 1. The radiation dose is measured in Sievert [3,4].

The dose estimation of radiation workers is an important factor in radiation-based institutes for the evaluation of radiation-related risks and protection of the workers. Several international and national bodies are providing guidelines for dose limits and radiation protection. The international bodies include the ICRP and the International Atomic Energy Commission (IAEA)[3,5]. A local body, Pakistan Nuclear Regularity Authority (PNRA), is ensuring the protection of Pakistan Atomic Energy Commission (PAEC) radiation workers by providing and monitoring the protection guidelines.

According to the ICRP (Report No. 60), occupational radiation dose is usually expressed as effective dose and equivalent dose. Nowadays, the internationally recommended quantity for dose evaluation is the personal dose equivalent $H_p(10)$. The personal dose equivalent $H_p(10)$ measures the dose in soft tissues at 10-mm depth. $H_p(10)$ is used for highly penetrating radiations and is measured by a detector. A worker wears this detector on the surface of body. Another quantity named $H_p(0.07)$ is used to measure the skin and lens doses of worker by weakly ionizing radiation that registers their dose at 0.07-mm depth [3,4].

The workers in NM are normally prone to higher radiation dose because of the direct handling of radioactive medicine and injected patients. On the other hand, the workers in the teletherapy unit and X-ray-based machines receive a lesser radiation dose because they are not interacting with radioactive elements directly [6].

The main objective of this study is to report and compare the radiation dose to workers of local centers with nationally and internationally reported data. Bannu Institute of NM, Oncology and Radiotherapy (BINOR) is a cancer hospital working under PAEC. The radiation sources that are being used in BINOR include iodine-131, Tc-99m generator, Co-57 sheet, and a Co-60 teletherapy unit. Other equipments are diagnostic X-ray, mammography, and Conventional simulator. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has reported the international data of many countries and provided a comparison between different centers around the world [7].

Material and Methods

This study was conducted in BINOR, where 33 employees are declared as radiation workers (employees working in RT, NM, and DR departments). The film badges are used for radiation monitoring, which are issued to each radiation worker with unique identification number. The films are calibrated in Secondary Standard Dosimetry Laboratory (SSDL) using an X-ray generator with gamma sources (Co-60 and Cs-137). This badge is worn near the chest or belt by the worker. A film badge consists of two films, a slow film and a fast film, to measure the true dose to the worker. A slow film is coated with radiation insensitive emulsion and a fast film is coated with sensitive emulsion. These films are packed inside a light-proof paper. This package is than enclosed in a plastic casing with one open portion, one lead shielding, and three different copper shieldings to provide the dose comparison of the different radioactive elements as shown in Figure 1. The comparison of these shieldings provides the information of the dose to the worker from a particular radioactive element [4]. The films can record the radiation dose of 0.1 mSv–18 Sv and can detect radiation exposure limit range of 0.10–0.20 mSv. The film badges are sent to report absorbed dose to the radiation dosimetry laboratory for processing and reading. The former department provides personal dosimetry and is responsible for ensuring the PNRA dose-recommended limits. The films are read using a densitometer and data are saved in a computer software of the "Radiation Lab. Software (RADLAB)" in both soft and hard copies. The absorbed dose is estimated by using a dose assessment algorithm. The data were collected for 2014–2018 (5 years) and compared with international and local centers.

Results and Discussion

Radiations are hazardous to humans; therefore, it is the responsibility of the institute to monitor the radiation dose of the workers [4]. A total of 43 radiation workers were monitored for 5 years (2014–2018) in BINOR. The institute uses the Film Badge Dosimetry (FBD) for dose monitoring. Approximately, 2,222 films were processed over the studied period and data were stored. However, the number of employees kept changing over the years because of the transfer of employees. This randomness is shown in Figure 2. The number of workers in RT, NM, and DR departments is plotted against the years. The staff

Figure 1. Film badge for radiation dose monitoring.

Table 1. ICRP 60 recommended dose limits.

APPLICATION	OCCUPATIONAL	PUBLIC
Whole body	20 mSv/years effective dose averaged over 5 years, maximum dose in any 1 year = 50 mSv	1 mv
Lens	20 mSv	1 mSv/year
Skin	500 mSv	15 mSv
Extremities	500 mSv	50 mSv

Adapted from [3].

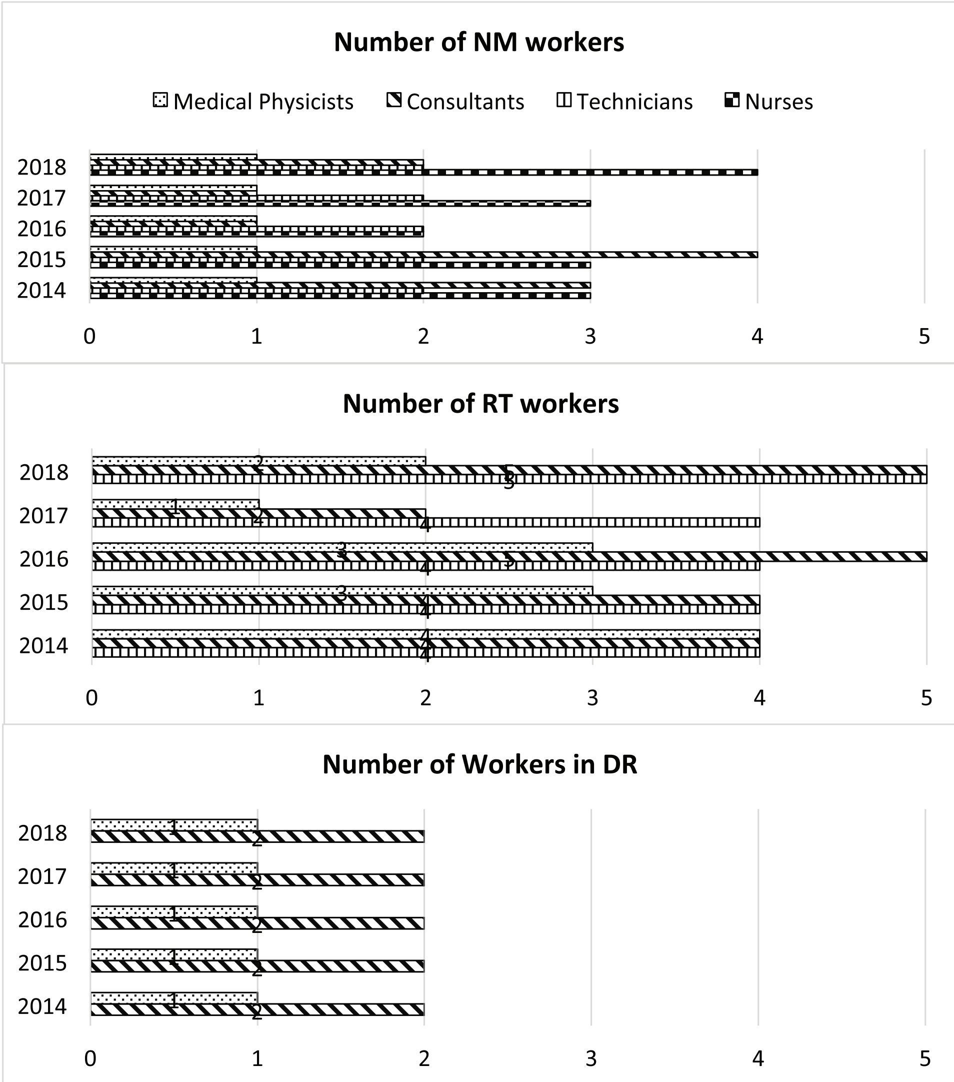

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Figure 2. *Number of radiation workers each year (2014–2018).*

are classified into four groups: medical physicists, oncologists, nuclear physicians and technicians, and nursing staff. The nursing staff are considered to be part of the NM department.

The workers in the NM medicine department received a higher radiation dose because of the direct contact of radioactive elements like technetium-99 m and iodine-131. Other radioactive sources, like Co-57 and Cs-137, are used for the calibration of gamma camera and dose calibrator, which are also directly handled by medical physicists and technicians. This is shown in Figure 3, where the dose of the NM workers is plotted against years. The dose of consultants in NM is 0.55–1.2 mSv, with an average annual effective dose (AAED) of 0.92 mSv and standard deviation of ±0.26 as shown in Table 2. The range of the absorbed dose by medical physicists and technicians is 0.7–1.29 mSv and 0.91–2.09 mSv, respectively. The AAED for medical physicists and technicians is 1.12 ± 0.24 mSv and 1.47 ± 0.42 mSv, respectively. Only one spike is higher than the others in 2017, where the dose of technicians is 2.09 mSv, which is way below the ICRP limit. On the other hand, the nursing staff receive the lowest dose because they take care of radioactive patients. The AAED for nursing staff is 0.81 ± 0.25 mSv as shown in Figure 3 and Table 2.

The source used by the teletherapy unit in BINOR is Co-60. The dose received by consultants was as low as 1.05 ± 0.26 mSv and above the range of 0.7–1.24 mSv, as shown in Figure 2 and Table 2. The dose to medical physicists was 1.08 ± 0.26 mSv and above the range of 0.65–1.36 mSv. The AAED for technicians is as high as 1.15 ± 0.34 and the range is 0.57–1.38 mSv.

The medical physicists and technicians in the radiology department had absorbed radiation doses of 1.2 ± 0.23 mSv and 1.06 ± 0.29 mSv, with the range of 0.8–1.36 mSv and 0.7–1.32 mSv, respectively, shown in Figure 2 and Table 2.

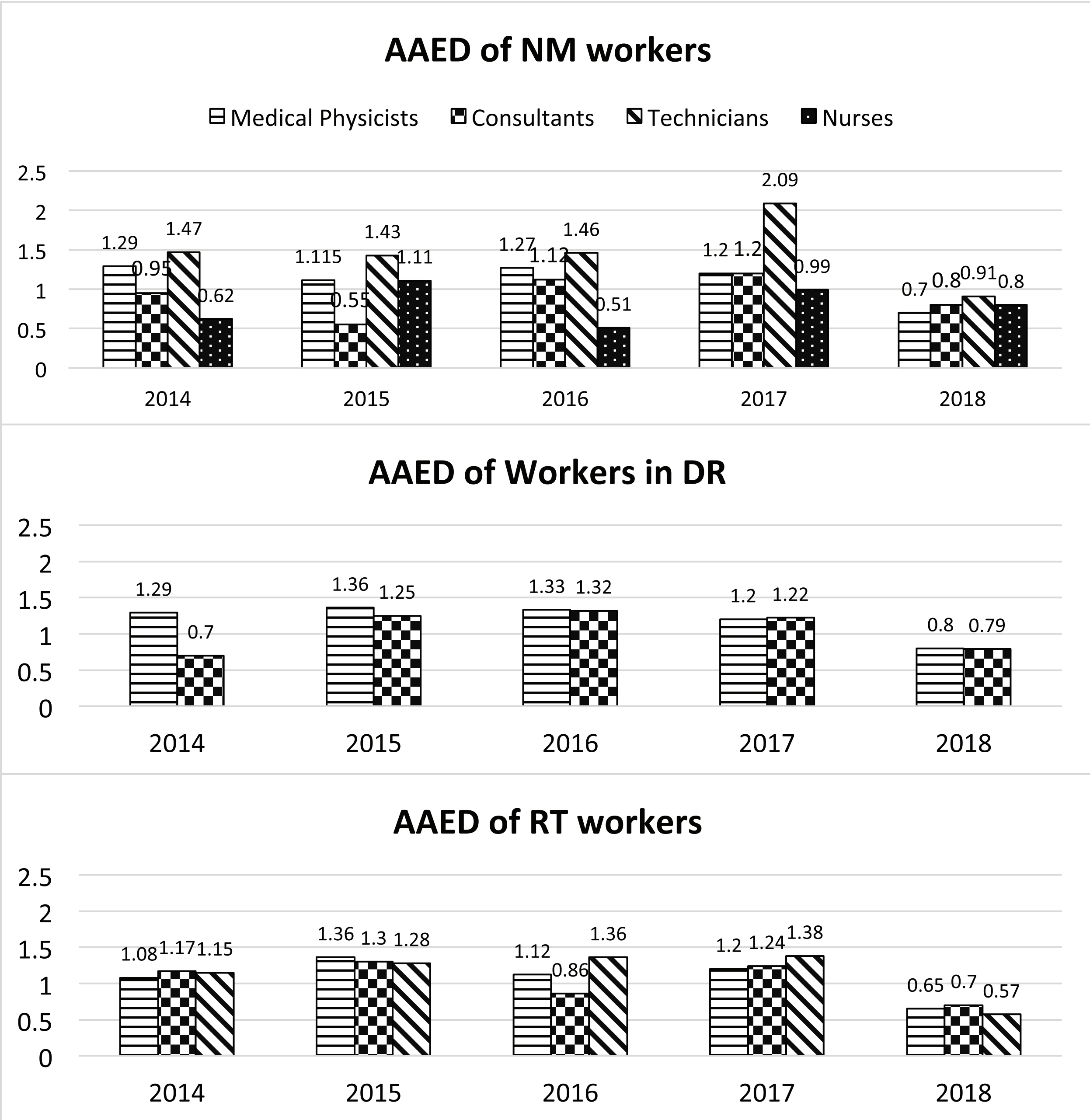

Figure 3. *AAED to radiation workers.*

Table 2. *AAED (mSv) of radiation workers.*

EMPLOYEE	NM			RT			DR		
	AVERAGE DOSE PER YEAR (mSv)	RANGE	SD	AVERAGE DOSE PER YEAR (mSv)	RANGE	SD	AVERAGE DOSE PER YEAR (mSv)	RANGE	SD
Consultants	0.92	0.88	0.26	1.05	0.79	0.26	–	–	–
Medical physicists	1.12	0.66	0.24	1.08	0.76	0.26	1.2	0.56	0.23
Technicians	1.47	1.40	0.42	1.15	1.08	0.34	1.06	0.83	0.29
Nurses	0.81	0.55	0.25	–	–	–	–	–	–

The comparison of annual average effective doses is shown in Figure 3, where the radiation dose received by staff in NM is as high as 1.15 mSv because of the direct interaction with the radioactive sources. The AAED is the lowest in DR (0.93 mSv) because extra care is taken for taking X-rays as shown in Figure 4.

This study is compared with other local centers as shown in Table 3. The data were published by several

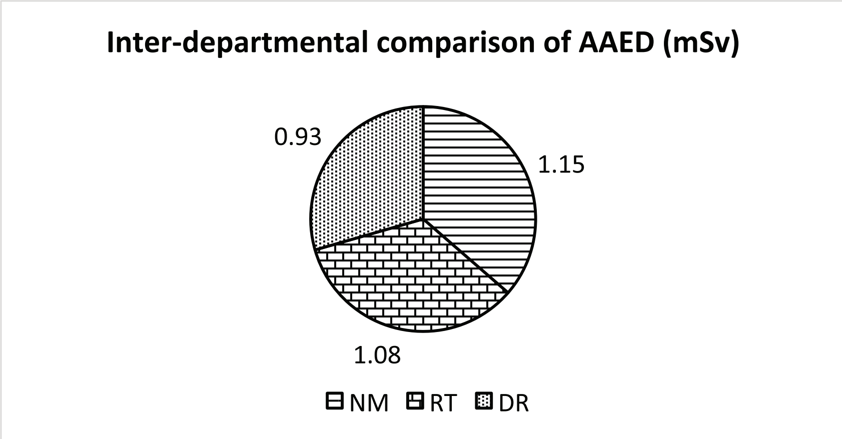

Figure 4. *Interdepartmental comparison of AAED.*

Table 3. *Comparison of AAED with local centers in Pakistan.*

INSTITUTE (DURATION)	DR (mSv)	NM (mSv)	RT (mSv)
NIMRA, Nawabshah (2007–2011)	2.2	1.6	1.5
BINO, Bahawalpur (2000–2013)	1.49	1.88	1.43
Institute of Nuclear Medicine and Oncology, Lahore (INMOL), Lahore (2007–2011)	1.55	1.17	1.47
Province Punjab (2003–2012)	0.68	0.63	0.7
Institute of Radiotherapy and Nuclear Medicine (IRNUM), Peshawar (2009–2016)	1.3	1.39	1.23
BINOR, Bannu (2014–2018)	0.93	1.15	1.08

Adapted from [8–12].

Table 4. *Comparison of AAED with international centers and UNSCEAR.*

COUNTRY (DURATION)	DR (mSv)	NM (mSv)	RADIOTHERAPY (mSv)
Australia (1990–1994)	0.19	0.75	0.35
Brazil (1990–1994)	2.58	3.5	3.95
Canada (1990–1994)	0.35	1.96	0.8
Greece (1990–1994)	3.86	2.27	2
Indonesia (1985–1989)	1.75	1.2	1.63
India (1990–1994)	0.42	1.36	1.34
Iran (2009–2011)	0.38	1.61	0.95
Syria (1990–1994)	4.4	3.16	1.37
Thailand (1990–1994)	0.58	2.89	1.05
China (1986–2000)	1.85	1.4	1.25
Lithuania (1996–2000)	1.48	1.14	1.51
Pakistan (2003–2018)	1.33	1.188	1.32
Kingdom of Saudi Arabia (2009–2010)	0.66	1.56	0.28
World UNSCEAR (1990–1994)	1.34	1.41	1.33

Adapted from [11,13–15].

centers in Pakistan, which are also using FBD. The AAED is way below the allowed annual limit of ICRP.

The data were also compared by the investigator of other countries and world data of UNSEAR and the results are similar, as shown in Table 4. This means that the workers in Pakistan took extra precaution to assess the radioactive environment. The individual dose received by workers is very low when compared to the limit set by the IAEA and the ICRP.

Conclusion

The presented analysis assesses the annual average effective dose to the radiation workers in NM department,RT department and DR department in BINOR. The radiation workers were monitored for 5 years (2014–2018). The assessment of the workers infers that the radiation protection services at BINOR, Bannu, are satisfactory and comparable with other national and international institutes.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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Consent for publication

Written consent was obtained from all the participants.

Ethical approval

Ethics approval was granted by Bannu Institute of Nuclear Medicine Oncology and Radiotherapy.

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