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Psychological Impact of Radiation Versus its Physiological Effects: Radiation Workers' Perspective in Medical Centers

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***Abstract*—**Radiation is a ghost causing unimaginable physical damage, but its harm is not inevitable. The panic created by previously reported worst-case scenarios i.e., Three Mile Island, Fukushima, Chernobyl, has adversely affected the attitude of radiation workers towards the profession. The psychological effect of radiation-related catastrophes creates an invisible barrier that reduces the efficiency of radiation workers. Careful handling and proper monitoring of radiation decreases the hazards of radiation and proves that the psychological impairment of radiation is myriad fold adverse than its physiological damage. Thermoluminescent Dosimeter (TLD) badges with unique identity numbers were provided to 36 radiation workers for a period of one year (2021). TLDs were read quarterly, and doses were recorded for every radiation worker. Annual doses were recorded and compared with national and international standards. Moreover, the period for which an individual worker is expected to reach one year limit of 20 mSv was also calculated. The highest radiation dose for the radiation worker in 2021 was found at 3.2 mSv, which was 16% of the permissible annual dose limit. The average occupational radiation doses ranged from 1.0 mSv to 3.20 mSv. 64% of the employees did not exceed the 10% of the annual limit, receiving less than 2 mSv. The least time for 20 mSv completion was found 6.25 years for the hot-lab technician. As a whole, the 20 mSv completion period ranged from 6.25 to 20 years. We concluded that the annual professional radiation doses were well within the permissible limits of Pakistan Nuclear Regulatory Authority (PNRA) and International Commission on Radiological Protection (ICRP). The fear of radiation is unnecessary and it creates reluctance towards performing their assigned duties and it is also not favorable for the institute. It must be abolished through education and training sessions.

***Keywords*—**TLD, thermoluminescent dosimeter, psychological impact, radiation dose, annual dose limit, PNRA, ICRP, IAEA.

I. Introduction

RADIATION is everywhere; there is a constant level of natural background radiation in the environment. This level of radiation exposure is further fortified by man-made radiation-generating equipment used mainly for medical purposes as well as industrial prospecting. An estimation of added exposure from X-ray modalities and nuclear medicine practices is 4% and 11% respectively [1]. Fig. 1 shows the daily-life sources of radiation for the general public as well as radiation workers. The yearly dose limit from background radiation i.e., ground radon gas and cosmic rays is set to 2.4 mSv by UNSCEAR [2].

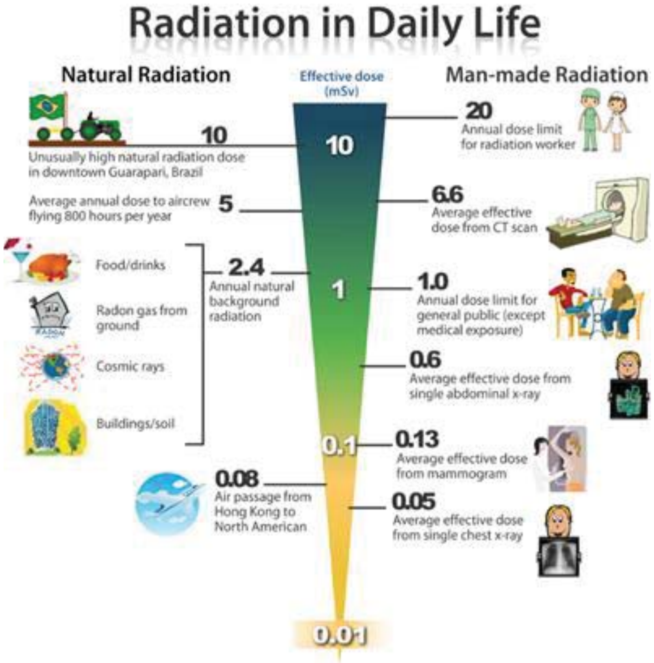

Fig. 1 Everyday sources of radiation [8]

As far as the radiation generated from man-made sources is concerned, a single abdominal X-ray and CT-scan contribute 0.03-0.11 mSv and 6.8 mSv respectively [3], [4]. For occupational exposures, the annual dose limit is set 20 mSv according to regulatory guidelines. The damaging behavior of radiation toward living cells is proven from the early experiments performed with X-rays. In order to reduce the harms of radiation, the first strategy which must be followed is the principle of Time, Distance, and Shielding (TDS) [5]. The principle dictates that one can minimize the effects of radiation by spending lesser time in the vicinity of the radiation source, ensuring an appropriate distance from source, and using proper shielding for protection [6]. Different tools for shielding are used at this medical center including source containers, protective lead glass shields, lead bricks, sliding lead shields, thick concrete walls constructed around sources, lead doors,

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and lead aprons [7]. The use of these tools reduces the personnel exposure and health risks of radiation workers and general public as well. The education available on the internet and print media no doubt spreads awareness about radiation safety but at the same time, it causes undue anxiety and fear which causes psychological damage to individuals and needs to be addressed.

Nuclear Medicine Oncology and Radiotherapy Institute Nawabshah (NORIN) is a cancer treatment facility in interior Sindh. Different radiation-generating machines along with sealed as well as unsealed radiative materials are used in cancer hospital [9]. The man-made radiation sources at the center include X-Ray units, Computed Tomography, Mammography, and DEXA. On the other hand, radiopharmaceuticals used for different nuclear medicine procedures include Tc-99m and I-131 [10]. Moreover, different radiation sources are also used for Quality Assurance and Quality Control of equipment. For radiotherapy, one Co-60 Teletherapy Machine and one Co-60 HDR Brachytherapy Unit are used at this facility. Working in such an environment requires proper radiation protection measures. Therefore, the radiation protection protocols are implemented in such a way that the radiation professionals remain safe from the acute impacts of radiation. For personnel dose monitoring, use of TLD badges is considered one of the highly recommended methods. A TLD is a thermo-luminescent dosimeter that measures the radiation dose a person receives during the workflow. A TLD dosimeter can measure a radiation dose from 0.1 mGy to 100 Gy. It contains 02 lithium fluoride chips doped with Magnesium and Titanium (LiF-Mg-Ti) encased in a plastic holder as shown in Fig. 2 [12]. The TLDs monitoring Programme has been used by all departments at NORIN for the collection of staff's occupational radiation exposures. Personal doses are evaluated at a centralized measuring dosimetry laboratory at KIRAN Karachi Pakistan.

Fig. 2 TLDs used in NORIN

According to guidelines issued by International Atomic Energy Agency (IAEA) and ICRP, the PNRA has established a dose limit of 20 mSv averaged over 5 years for radiation professionals for 1 year, averaged over five years with the provision that the dose should not exceed 50 mSv in any single year for radiation workers in Pakistan [11]. This study was conducted to measure the radiation doses received by radiation workers of NORIN, Nawabshah, and evaluate these doses conferring to permissible limits approved by national as well as international regulatory watchdogs and also to address psychological fear of radiation exposures among the professionals [12]

II. Methods and Materials

This study was performed in a rural area cancer hospital of Nawabshah to keep track of occupational radiation doses to workers who handle radioactive materials. The workers were issued TLD badges of unique identity numbers to monitor radiation doses. To measure occupational doses of professionals, TLD badges are used due to their good sensitivity in the mixed radiation fields along with high precision and fine accuracy. A TLD dosimeter can measure a radiation dose from 0.1 mGy to 100 Gy [13]. Karachi Institute of Radiotherapy & Nuclear Medicine (KIRAN) is the institute that provides the services of reading and annealing TLD badges. The TLDs were sent to the service provider every quarter for dose reading and processing. The results were mailed back and received by NORIN Radiation Protection Officer for maintaining the dose record. The reports were reviewed to identify any individual who may have received a relatively higher dose in this duration.

Amongst 36 occupationally exposed workers of NORIN, 9 (25%) worked in Nuclear Medicine and Allied Division, 4 (11%) in Radiology, 2 (6%) in Radio-Immune-Assay, 3 (8%) Repair and Maintenance section, whereas 9 (25%) worked in Radiotherapy section including 6 (13%) and 3 (8%) radiation oncologists and health physicists respectively. The distribution of workers in different departments is shown in Fig. 3.

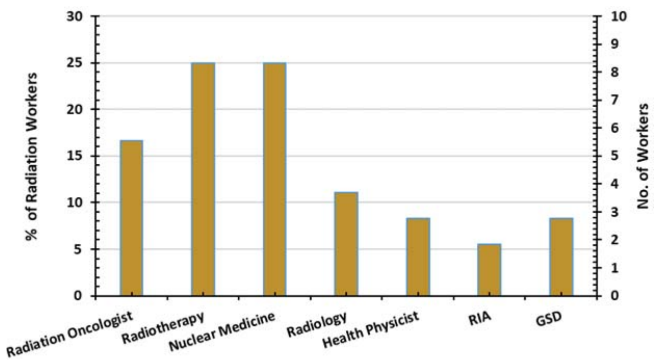

Fig. 3 Departmental Distribution of Radiation Workers in NORIN

All the workers were instructed to wear the TLD badges during working hours. Research of this type is usually conducted to find out the cause of the elevated doses. Based on results, recommendations for good practices are given to staff members on reduction of personnel doses and avoiding behaviors that may increase the received radiation doses. In this study, we calculated the radiation doses imparted to workers at this institute in 2021, the percentage-wise contribution of radiation workers' occupational doses, and the time required for achieving 20 mSv, i.e., dose limit for one year, for every radiation worker.

III. Results and Discussion

For individuals working in a radiation environment, dose monitoring and record maintaining are of extreme importance. It ensures that doses to staff members do not exceed the limit recommended by ICRP [12]. The annual doses of the radiation workers for 2021 and their percentages with respect to the annual dose limit are presented in Fig. 4. The data of radiation workers were recorded using TLDs assigned distinctly. The doses were found to range from 1.0 mSv to 3.20 mSv (5%-16% of annual dose) for 2021. The worker who served in the hot lab of the Nuclear Medicine and Allied Division received the highest dose of 3.2 mSv (16% of the 20 mSv limit). The reason for this dose inflation was the nature of work which involves handling Tc-99m and I-131 radionuclides along with other sources used for Quality Control Procedures. The highest dose recorded was still well below the permissible limits prescribed by PNRA, ICRP, and IAEA [14].

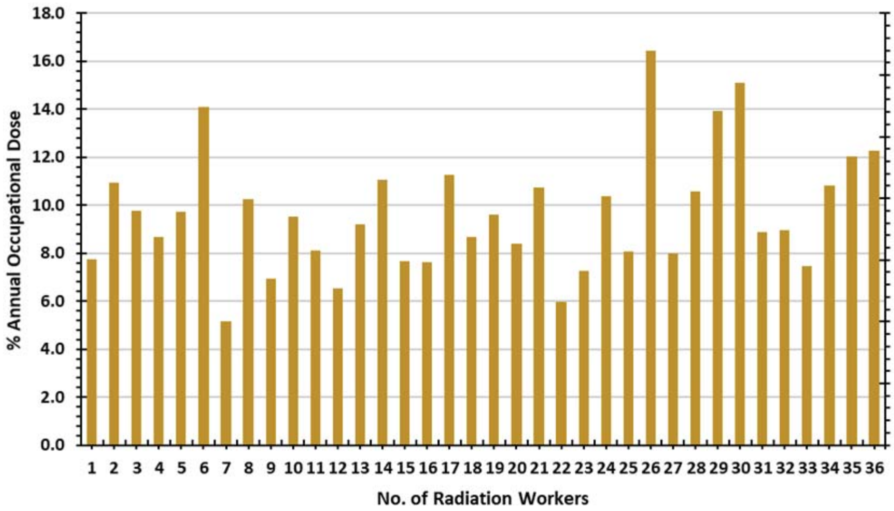

Fig. 4 Annual Effective Dose trend of radiation workers in NORIN

Moreover, 3% of the workers received radiation dose in the range of 0.1 mSv-1.0 mSv. 19% of the workers did not cross the 1.5 mSv upper bound and 42% of the workers were in the range of 1.6 mSv-2.0 mSv in the year under discussion (2021). Also, 25% of the workers were found in the range of 2.0 mSv-2.5 mSv while 8% of the workers went beyond 2.5 mSv and remained under 3.0 mSv. Only one worker crossed 3.0 mSv and received the maximum dose of 3.2 mSv among 36 employees. The percent dose distribution of radiation workers has been illustrated in Fig. 5. The chart shows that the maximum number of workers (42%) lies in the range of 1.6 mSv to 2.0 mSv and received minimal radiation dose. This is established from the above depiction that 64% of the workers at NORIN received less than 10% of the annual radiation exposure limit due to strict compliance with the radiation protection protocols and guidelines set by Health Physics Division.

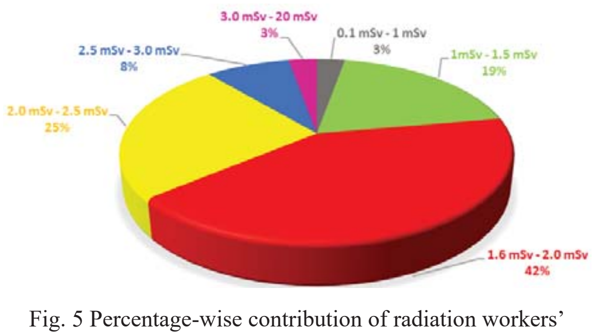

Fig. 5 Percentage-wise contribution of radiation workers' occupational doses

The periods for completion of the 20 mSv dose limit for radiation workers of different departments of NORIN are illustrated in Fig. 6. The graph depicts that 6 out of 36 (~17%) employees would attain 20 mSv in 11 years. Five radiation workers will receive the annual effective yearly dose limit of(20 mSv in 13 years and the other five workers in 10 years.

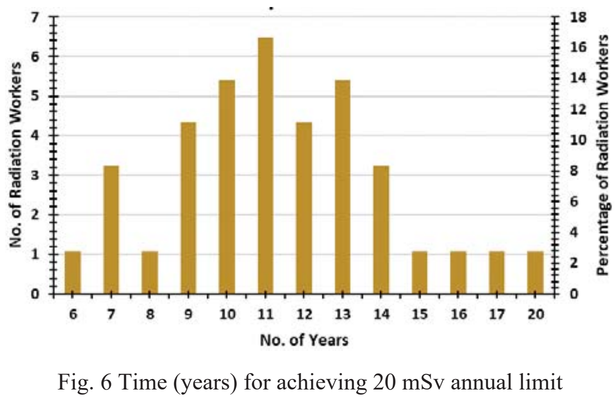

Fig. 6 Time (years) for achieving 20 mSv annual limit

The data show that there is one worker among a total of 36 who received just 1 mSv and will reach the annual limit in 20 working years. The maximum radiation dose is received by the hot-lab technician who handles sealed as well as unsealed radiation sources and requires least time of 6.25 years to reach the 20 mSv limit. Two employees from the nuclear medicine department and one from the radiotherapy department are expected to reach the limit in seven working years. One radiation oncologist is expected to receive 20 mSv in nine years whereas the Radiation Protection Officer, who is engaged in source handling and waste radioactive waste management, will attain the said limit in 11 years. A previous study conducted by Memon and Laghari concluded the shortest period of 6 years for the hot-lab technician at NIMRA Jamshoro [15].

TABLE I
SUMMARY OF PREVIOUSLY REPORTED RESULTS AND COMPARISON WITH CURRENT STUDY

Study	Highest Dose (mSv)	Percentage with 20 mSv
Memon et. al. [1]	< 3.7	19%
Korir et. al. [16]	< 7.5	38%
Weizhang et. al. [17]	< 3.0	15%
Carreiro and Avelar [18]	< 5.0	25%
Jabeen et. al. [19]	< 3.0	15%
S. A. Memon et. al. [20]	< 7.8	39%
Rahim et. al. [21]	< 4.42	23%
Mohib-ul Haq et. al. [22]	< 5.57	28%
Canadian Nuclear Safety Commission (for pregnant lady) [23]	< 4.0	20%
Current Study	< 3.2	16%
PNRA/ICRP/IAEA [24]	< 20	100%

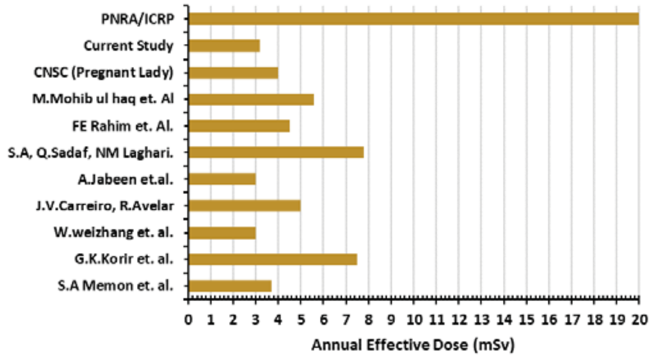

Fig. 7 Comparison of results with previous studies

A summary of annual radiation doses to radiation professionals reported previously and their comparison with current results is given in Table I and graphically represented in Fig. 7. Memon et al. reported a maximum yearly occupational effective dose of 3.70 mSv (18.5%) in NIMRA cancer hospital Jamshoro, Sindh [1]. Another study conducted by Korir et al. showed slightly elevated values of 7.5 mSv (37.5%) in Medical Institutions in Kenya [16]. According to Weizhang et al., the peak annual effective dose for Chinese professional radiation workers was 3.0 mSv (15% of the 20 mSv limit) [17]. Yearly peak cumulative radiation dose to medical and paramedical professionals in Portugal was reported as 5.0 mSv (25%) by Carreiro et al. [18]. Maximum occupational exposure from external radiation used in medical practices in Pakistan by film badge dosimetry was reported by Jabeen et al. and had a dose value of 2.0 mSv (10%) [19]. Memon et al. also reported the maximum annual effective dose of 7.8 mSv in cancer hospital radiation staff [20]. Rahim et al. documented the peak value of annual radiation dose of 4.42 mSv (23%) in Cancer Hospital IRNUM [21]. Mohib-ul Haq et al. reported a radiation dose of 5.57 mSv (28%) to workers of Sher-i-Kashmir Institute of Medical Sciences (SKIMS) Hospital [22]. It is pertinent to mention here that the Canadian Nuclear Safety Commission approved 4.0 mSv per year as the safe limit for pregnant ladies [23], while the PNRA, ICRP & IAEA recommend the yearly dose limit of 20 mSv [24]. However, the annual effective dose calculated in this research has a maximum value of 3.20 mSv which is about 16% of the acceptable limit recommended by regulatory bodies.

It has been observed that some radiation handling professionals are afraid of radiation doses. Due to unauthentic knowledge and literature available on radiation disasters like Three-Mile Island and Fukushima etc., the workers have developed a falsely over-careful attitude towards radiation. Therefore, with this phobia and scary picture of radiation in mind, they fear that they might get cancer or other fertility-related issues from radiation [25]. Safety is first, beyond doubt, but this unnecessary anxiety and fear from low-level occupational radiation exposures is falsely established and needs to be overthrown. While working in cancer treatment setups using radiation involvement, it is impossible to eliminate radiation. It is impossible to receive no dose in such an environment where direct dealing with radiation sources is involved. The mammoth hazard is inevitable; the discussion here is whether it is as harmful as it is portrayed or if there is something else that might support the counter-argument. The solution to this riddle is quite logical [7]. First, there are safe limits for radiation exposures which are seldom breached. Secondly, protective measures, like the TDS principle, are established and globally recognized that help minimize exposures to very lower dose values [20].

IV. CONCLUSION

This study was conducted to address the psychological and physiological impact of radiation among professionals by evaluating the occupational doses in medical practices and comparing them with the permissible dose limits recommended by PNRA and ICRP. The results were found in the acceptable range of international and national organizations, which validates the reasonability of radiation protection protocols at this institute. 64% of the workers did not even exceed the 10% of the annual limit of 20 mSv and attained a 20 mSv dose limit in more than 13 years. The highest occupational radiation dose of a worker was 3.2 mSv which is 16% of the limit and attained the limit of 20 mSv in the shortest period of 6.25 years. It is necessary to observe the radiation protection guidelines to minimize the exposure. On the other hand, being too much afraid from radiation is not a solution. Fear creates anxiety and reduces the working efficiency of employees, creating an invisible fence in the workflow. To become a useful professional, the worker has to eliminate the fear and psychological burden of radiation and eradicate reluctance to handle radiation. Through the right education and training, the attitude of fear towards radiation can be avoided. This is concluded that the psychological impact of radiation is much more dangerous than its physiological effect for the worker as well as the institution with its drawbacks and it needs to be abolished at every cost.

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