OCCUPATIONAL RADIATION DOSE EVALUATION IN X-RAY DIFFRACTION LABORATORY WORKING ENVIRONMENTS

by

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Banaras Hindu University and Bharathiar University conducted a study to assess occupational radiation doses among non-medical workers in X-ray diffraction analysis work environments at science departments. A total of five non-medical radiation workers were monitored to determine their average annual effective dose. Thermoluminescent dosimeters were issued to five X-ray diffraction analysis technologist to record their dose for a month. Dose rate measurements were recorded using survey meters. The average monthly dose for workers was 0.35 mSv. Average ambient dose rate values were 0.45 μSvh^{-1} for Bharathiar University, and 5.08 μSvh^{-1} for Banaras Hindu University. Conclusions dose levels are below the limits recommended by the International Commission on Radiological Protection. The study found the yearly average effective doses for five technologist workers to be 3197.4 μSv, 2847.0 μSv, 2978.4 μSv, 3328.8 μSv, and 3547.8 μSv. Importantly, these measured doses were significantly below the international recommended dose limit of 50 mSv.

Key words: X-ray, effective dose, International Commission on Radiological Protection

INTRODUCTION

In Banaras Hindu University and Bharathiar University, X-ray diffraction (XRD) analysis work environments in the science department stands as the primary field utilizing ionizing radiation. Despite joining the International Atomic Energy Agency (IAEA) in 2006 and enacting the Atomic Energy Act and Regulations in 2011 and 2012, respectively, the regulatory body responsible for ensuring compliance with radiation safety laws has not been established yet. The introduction to a discussion on occupational radiation dose evaluation in XRD laboratory work environments provides a contextual overview of the topic, setting the stage for further exploration. The XRD techniques play a pivotal role in various scientific and industrial applications, ranging from material characterization to pharmaceutical research [1, 2]. The ability to analyze the structure of crystalline materials using X-rays has revolutionized many fields, facilitating advancements in materials science, chemistry, biology, and beyond. However, the use of ionizing radiation in XRD experiments necessitates a comprehensive understanding and management of potential health risks, particularly for laboratory personnel [3-7].

Occupational exposure to ionizing radiation is a primary concern in XRD laboratory environments, where technologists and researchers routinely interact with X-ray equipment and samples. While XRD procedures offer invaluable insights into the properties of materials, they also entail inherent radiation hazards that must be carefully assessed and mitigated to ensure the safety and well-being of personnel. This discussion aims to delve into the evaluation of occupational radiation doses in XRD laboratory work environments, highlighting the importance of monitoring and managing radiation exposure levels. By examining current practices, regulatory guidelines, and emerging trends in radiation safety, we seek to enhance awareness and promote effective strategies for safeguarding the health of laboratory personnel [7-9]. Throughout this discussion, we will explore various aspects of occupational radiation dose evaluation, including measurement techniques, exposure limits, risk assessment methodologies, and best practices for radiation protection. By fostering a deeper understanding of these issues, we endeavor to empower XRD laboratory stakeholders to proactively address radiation safety

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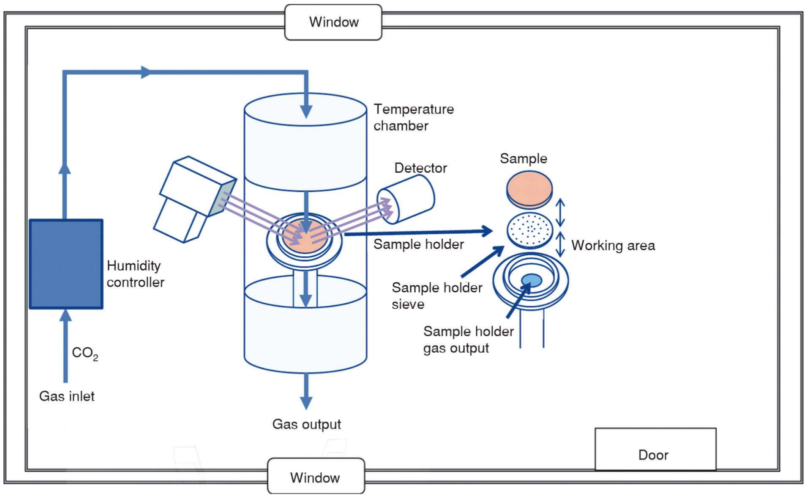

Figure 1. Layout of the XRD laboratory

challenges and cultivate a culture of safety and responsibility in their work environment.

This study aims to gauge the radiation doses received by occupationally exposed workers in radiology departments and compare them against the International Commission on Radiological Protection (ICRP) recommended limits. Exposure to ionizing radiation leads to two main effects on humans: deterministic and stochastic. Deterministic effects, such as acute radiation syndrome, skin burns, sterility, and cataracts, result from high doses over a short period. Conversely, stochastic effects, including radiation-induced cancer and hereditary effects, occur without a threshold dose and are proportional to dose levels over prolonged exposure periods. Optimization, central to radiation protection, involves minimizing the number of individuals exposed, the likelihood of exposure, and the magnitude of exposure, keeping them as low as reasonably achievable (ALARA) [10]. Dose assessment plays a crucial role in adhering to the dose limitation principle of radiation protection. Monitoring the doses received by exposed individuals ensures they remain within recommended limits [11-15]. This study evaluates ALARA practices and adherence to dose limitation principles in select universities across India.

MATERIALS AND METHODS

The study utilized thermoluminescent dosimeters (TLD) comprised of cards housing Harshaw detector crystals of LiF: Ti, Mg (TLD-100) to measure both skin and deep doses. Workers wore these badges appropriately during their tasks, with emphasis on placement over the upper-left side of the chest, as this area typically experiences the highest radiation exposure. Calibration and quality control were conducted using a ^{90}Sr/^{90}Y internal irradiator 18.5 MBq. The calibration process was fully automated in the reader to streamline efficiency and reduce costs [1-3]. Subsequently, the dosimeters were returned to the dosimeter company for evaluation using a Model 6600 TLD Reader with accompanying computer software [16, 17]. The dosimeter readings for the period of 2023 to 2024 were obtained from the dosimeter company database, focusing on whole-body dose (effective dose) Hp (10) and skin dose Hp (0.07). The International Commission on Radiation Units and Measurements' 1993 report guided the reporting of whole-body doses in terms of personal dose equivalent, Hp (10), which provides a conservative estimate of effective dose for incidents involving radiation exposure to the front of the body.

The TLD assigned to personnel were collected quarterly for the assessment of personnel dose equivalents, with background radiation doses measured using five non-irradiated TLD of the same type. The measured background radiation dose was subtracted from the measured dose values. Each TLD card featured a bar-coded number, wearer name, and institution. Calibration of the TLD took place at both dosimeter companies. Recommendations included the use of a single TLD badge for workers wearing lead aprons, except for nuclear medicine workers who were advised to use multiple badges. Pregnant workers were issued a supplementary badge to be worn inside the apron at waist level to monitor fetal dose.

RESULTS AND DISCUSSION

The XRD room layout and room survey

We can survey the radiation level of the XRD laboratory at different places like windows, doors, and working areas, fig. 1. In this measurement, we are using an ion chamber-based survey meter. From window 1 and window 2, the door, and working area radiation levels are 0.53 μSv, 0.61 μSv, 0. 41 μSv, and 0.81 μSv. The careful consideration of XRD room layout and regular room surveys are essential for ensuring the safety, efficiency, and regulatory compliance of laboratory environments. By implementing appropriate design principles, conducting thorough surveys, and fostering a culture of continuous improvement and

Table 1. Occupational workers' effective dose measurement using thermoluminescence

Occupational workers	Effective dose at 12 h [μSv]	Effective dose per week [μSv]	Effective dose per year [μSv]
Worker 1	0.73	5.11	3197.4
Worker 2	0.65	4.55	2847.0
Worker 3	0.68	4.76	2978.4
Worker 4	0.76	5.32	3328.8
Worker 5	0.81	5.67	3547.8

training, XRD facilities can effectively mitigate radiation exposure risks and create a safer working environment for all personnel involved in X-ray diffraction research and analysis.

Occupational doses at the XRD lab technologist

The unit of measurement for X-ray intensity in IS is the Sievert corresponding to the absorption of one joule in one kilogram of biological matter, taking into account the quality factor and other modifying factors. The radiation monitors measure the radiation in terms of rate – μSvh^{-1}. The normal background radiation level in our XRD lab is on the order of 0.65-0.81 μSvh^{-1}. At this rate, one would expect to receive a maximum of 0.81 μSv of exposure per day or $0.81 \times 12 \times 365 = 3.55$ mSv per year shown in tab. 1.

Standard limits of effective dose are 20 mSv per year for occupational and 1 mSv per year for the general public. Although the standard prescribes limits on an annual basis, it is useful to ensure that doses received do not exceed 1 mSv per week. It should be noted that natural background radiation to which everybody is exposed from the environment is in an order of 2 mSv per year.

The XRD techniques involve the use of ionizing radiation, which can pose health hazards if proper precautions are not taken. Technologists working in XRD labs are exposed to radiation primarily through the operation of X-ray equipment and the handling of samples. The measurement of radiation intensity in micro-sieverts per hour helps quantify their exposure levels. Normal background radiation levels in XRD labs typically range from 0.65 to 0.81 μSvh^{-1}, resulting in annual exposure levels of approximately 3.55 mSv mentioned in fig. 2(a)-2(c).

However, it's essential to consider that occupational exposure limits are set to ensure the safety of workers. The standard effective dose limits, such as 20 mSv per year for occupational exposure, guide acceptable levels of radiation exposure. Additionally, the limit of 1 mSv per year for the general public serves as a benchmark for protecting individuals who may have incidental exposure to radiation from XRD activities. To manage occupational doses effectively, XRD lab technologists should undergo proper training on radiation safety protocols, including the use of personal protective equipment and adherence to exposure monitoring procedures. Regular monitoring of radiation doses and

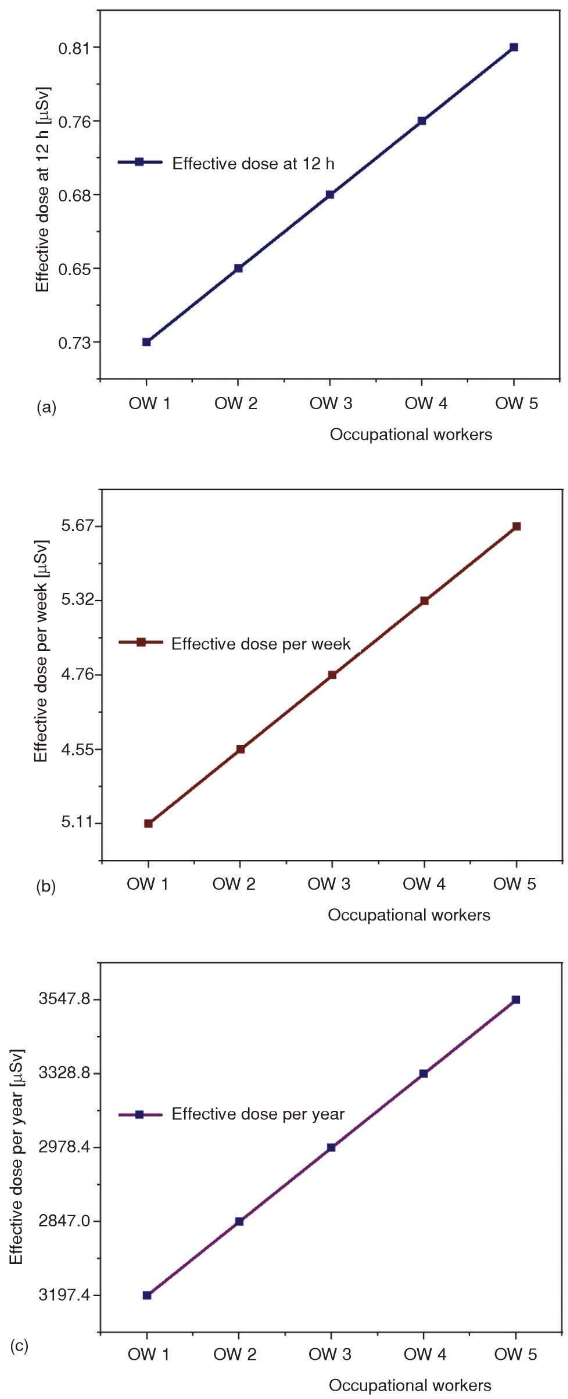

Figure 2. Occupational workers' effective dose measurement (in μSv) using thermoluminescence; 12 hour (a), per week (b), and per year (c)

implementing dose optimization strategies are essential to minimize the risk of adverse health effects.

Collaboration between radiation safety officers, health physicists, and XRD lab personnel is crucial for developing and implementing effective radiation protection programs. This collaboration can involve conducting regular risk assessments, implementing engineering controls to minimize exposure, and providing ongoing education and training on radiation safety practices. By actively addressing occupational doses in XRD lab environments, technologists can work confidently and safely while minimizing their risk of radiation-related health issues.

CONCLUSION

Normal background radiation levels in XRD labs typically range from 0.65 μSvh^{-1} to 0.81 μSvh^{-1}, resulting in a maximum expected daily exposure of 0.81 μSv and an annual exposure of 3.55 mSv. While these levels are generally within acceptable limits, it's essential to adhere to standard effective dose guidelines. The standard effective dose limits set at 20 mSv per year for occupational exposure and 1 mSv per year for the general public serve as important benchmarks. Additionally, monitoring weekly doses to ensure they do not exceed 1 mSv is prudent. It is worth noting that natural background radiation, which averages around 2 mSv per year, contributes to overall exposure levels. By actively monitoring radiation doses and adhering to safety protocols, XRD laboratory workers can minimize their risk of radiation-related health issues and ensure a safe working environment.

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AUTHORS' CONTRIBUTIONS

P. Venkatraman collected the data under C. S. Sureka and L. M. Aggarwal's supervision, while S. Choudhary, calculated the occupational dose based on the ICRP report, also under L. M. Aggarwal's supervision. S. Choudhary contributed to writing the manuscript. All authors discussed the results and participated in writing the manuscript.

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ПРОЦЕНА ДОЗЕ ПРОФЕСИОНАЛНОГ ЗРАЧЕЊА У РАДНОМ ОКРУЖЕЊУ ЛАБОРАТОРИЈЕ ЗА ДИФРАКЦИЈУ РЕНДГЕНСКИХ ЗРАКА

Банарас Хинду универзитет и Баратиар универзитет спровели су студију за процену професионалних доза зрачења међу немедицинским радницима у радним окружењима за анализу рендгенске дифракције на научним одељењима. Праћено је укупно пет немедицинских радијационих радника да би се утврдила њихова просечна годишња ефективна доза. Термолуминисцентни дозиметри издати су петорици технолога рендгенске дифракцијске анализе да би се забележиле њихове дозе током месец дана. Мерења јачина доза регистровано је коришћењем анкетних мерача. Просечна месечна доза за раднике била је 0.35 mSv. Просечне вредности јачине амбијенталне дозе биле су 0.45 $mSvh^{-1}$ за Баратиар универзитет и 5.08 $mSvh^{-1}$ за Банарас Хинду универзитет. Нивои доза су испод граница које препоручује Међународна комисија за радиолошку заштиту. Студија је показала да су годишње просечне ефективне дозе за пет радника технолога 3197.4 μSv, 2847.0 μSv, 2978.4 μSv, 3328.8 μSv, и 3547.8 μSv. Важно је да су ове измерене дозе биле значајно испод међународне препоручене границе дозе од 50 mSv.

Кључне речи: ефективна доза, Међународна комисија за радиолошку заштиту