International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Review of Occupational Radiation Monitoring in Bangladesh: Insights from Selected Studies

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Abstract

Monitoring occupational radiation exposure is crucial to ensuring the safety of workers handling ionizing radiation. This review consolidates findings from multiple studies conducted in Bangladesh, focusing on occupational radiation exposure in industrial radiography, diagnostic radiology, radiotherapy, and nuclear medicine. The analysis examines key trends, methodologies, and regulatory compliance to assess the effectiveness of radiation protection practices. The reviewed studies indicate that the average annual effective dose among occupationally exposed workers ranged from 0.017 to 0.74 mSv, with sector-specific variations: diagnostic radiology (0.07–0.1702 mSv), interventional cardiology (0.03 - 0.74 mSv), radiotherapy (0.017-0.1112 mSv), nuclear medicine (0.13–0.27 mSv), and industrial radiography (0.2-0.4 mSv) which are well below than the annual average dose limit prescribed by national regulation and international organizations like the International Commission on Radiological Protection (ICRP). This review highlights notable improvements in radiation protection practices over the years, as reflected in the declining trends of average annual effective dose across various occupational groups. Improvements in monitoring systems, strengthened regulatory frameworks and enhanced safety training have contributed to a declining trend in annual radiation doses. However, some occupational groups, particularly in industrial radiography and interventional cardiology, have recorded occasional high-dose exposures, emphasizing the need for continued improvements in safety training, equipment handling, and regulatory enforcement. This review underscores the importance of maintaining robust radiation safety measures in Bangladesh and provides recommendations for future enhancements in occupational radiation protection.

Keywords: monitoring, occupational exposure, radiation dose assessment, TLD, radiation worker, regulatory requirement.

1. Introduction

Radiation has many beneficial applications, ranging from power generation to medicine, industry, agriculture, education, and research and development. Work associated with these applications can expose workers to ionizing radiation, which is regarded as occupational exposure [1]. According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) Report on Evaluation of Occupational Exposure to Ionizing Radiation, around 24 million workers worldwide are monitored for exposure to natural and artificial ionizing radiation; among these, about 11.4 million (48%) are employed in sectors that involve exposure to artificial ionizing radiation [2]. Occupational exposure is usually measured by individual monitoring; when this is not feasible, data from workplace monitoring are used to assign individual doses, which are typically assessed and recorded for radiation protection purposes [2].

The International Commission on Radiological Protection (ICRP) recommends a concise system of radiological protection, including dose limits for radiation workers. ICRP, in a publication ICRP publication 103 [3], recommends considering societal and socio-economic factors in keeping radiation exposure and the number of exposed individuals as low as reasonably achievable (ALARA). This is one of the fundamental principles of radiation protection. This system has formed the basis for safety standards of international organizations such as the International Atomic Energy Agency (IAEA). The Radiation Protection and the Safety of Radiation Sources: International Basic Safety Standards (GSR Part 3) of IAEA addresses all situations involving radiation exposure that are amenable to control and requirements on exemption and clearance [4].

In Bangladesh, radiation has also been used for a long time, immensely benefiting the national economy. At the same time, there is a growing need to evaluate radiation safety practices. The occupational radiation monitoring program for radiation workers is available in the country. However, with updated information on occupational radiation monitoring of radiation workers, few studies conducted in Bangladesh have been found. This review has been done to summarise existing information on monitoring external radiation exposure doses for the whole body, using data from different radiation sectors like Industrial Radiography (IR), Radiotherapy (RT), Diagnostic Radiology (DR), and Nuclear Medicine (NM) in the country. This review consolidates findings from previous analyses that have been done to check for any trends or changes in the levels of radiation doses received by these monitored groups and their alignment with national and international guidelines. The study findings could help strengthen the country's future radiation safety and monitoring infrastructure.

2. Occupational Radiation Monitoring Framework in Bangladesh

2.1. Legal Framework

The government of Bangladesh has established and maintained a legal and regulatory framework specific to occupational radiation monitoring. This setup includes the Bangladesh Atomic Energy Regulatory (BAER) Act 2012 [5] and Nuclear Safety and Radiation Control Rules (NSRC)-1997 [6] This ensures that all radiation workers have the necessary monitoring and safety measures. Regulatory guides with detailed instructions specific to Diagnostic X-ray, Radiotherapy, and Nuclear Medicine practices are also in place to implement the regulatory requirement. The legal framework provides the statutory basis for establishing requirements for protection and safety specific to occupational exposure. [5, 6].

2.2. Individual Radiation Monitoring Service

Bangladesh has infrastructure and services for individual radiation monitoring to fulfill the regulatory requirements. The Health Physics Division (HPD) of the Bangladesh Atomic Energy Commission (BAEC) is the one and only provider of an Individual Monitoring Service (IMS) for occupational radiation workers throughout Bangladesh. [7]. The dose report is always provided regarding personal dose equivalent, Hp (10), considered a whole-body effective dose. This service meets the IAEA International Basic Safety Standards and the ICRP recommendations. The calibration of dosimeters is performed in the Secondary Standard Dosimetry Laboratory (SSDL) of the BAEC. SSDL has been available at BAEC since 1991, and it is traceable to the Primary Standard Dosimetry Laboratory (PSDL) of the National Physical Laboratory (NPL), UK. The performance of SSDL is maintained according to the requirements of IAEA/World Health Organization (WHO) network of SSDLs. Therefore, the evaluated doses are traceable to the international measurement system. [8].

2.3 Dosimeter

The dosimeter used to carry out the individual monitoring service in Bangladesh is the Thermoluminescence dosimeter (TLD). The specification of the TLD used is LiF-100 (Lithium Fluoride-100), manufactured by Harshaw Co., USA. Two LiF chips are embedded in a card, and the card is loaded in the black color holder. The dimensions of the crystals are 3.2 mm × 3.2 mm × 0.89 mm. A Teflon foil covers the chips with a thickness of about 13 mg/cm^2. The filter materials of the holder are 1000 mg/cm^2 ABS plastic and Teflon for deep dose estimation [7]. The TLD cards are read out by Harshaw TLD Reader Model 4500 & 6600.

3. Research Method

This review paper follows a systematic approach to identify and analyze existing literature on occupational radiation exposure in Bangladesh. The methodology includes a structured literature search, inclusion and exclusion criteria, data extraction, and thematic analysis.

3.1.Literature Search Strategy

The literature search was conducted exclusively using Google Scholar due to its extensive repository of academic articles, conference papers, and theses. Keywords used included "occupational radiation exposure Bangladesh," "thermoluminescent dosimeter (TLD) monitoring," "radiation dose assessment in industrial radiography," and "nuclear medicine radiation exposure." The search was restricted to studies published between 2010 and 2024 to ensure the inclusion of recent findings.

3.2.Inclusion and Exclusion Criteria

To ensure the relevance and reliability of the selected literature, studies published in English between 2010 and 2024 were searched. The research focused on occupational radiation exposure monitoring in Bangladesh, papers using thermoluminescent dosimeters (TLDs) for dose measurement, and studies providing quantitative radiation dose assessments, which were the criteria applied in the search process During the search, we excluded non-peer-reviewed articles, news reports, opinion pieces, studies unrelated to occupational radiation exposure, research on general radiation exposure without specific workplace data, and duplicates of previously selected studies

3.3.Data Extraction and Categorization

After identifying relevant studies, key information was extracted, including:

- Study objectives
- Methodologies used for radiation dose assessment
- Findings on Occupational Exposure Levels
- Regulatory compliance and safety recommendations

The extracted data were categorized into two main research areas: Industrial Radiography and Medical practices. The studies were again subdivided into three groups in medical practices: Radiotherapy, Diagnostic Radiology, and Nuclear Medicine.

3.4.Data Analysis Approach

A comparative thematic analysis was conducted to identify trends and common findings across studies. The selected studies were analyzed based on the radiation dose levels of the monitored workers, monitoring methods, compliance with safety standards, and risk assessment. Findings were then synthesized to present the current occupational radiation exposure monitoring trend in Bangladesh.

3.5.Limitations

This review is limited to sources available on Google Scholar, which may exclude some relevant research in other databases like PubMed or IEEE Xplore. Additionally, this review is limited by the availability of studies focused on Bangladesh.

4. Discussions on the Studies on Radiation Monitoring in Bangladesh

This review included six studies conducted in Bangladesh from 2010 to 2024 that published the results of dosimetric monitoring. The included studies involved radiation fields like Industrial Radiography (IR), Diagnostic Radiology (DR)-both conventional X-ray and interventional cardiology—radiotherapy (RT), and Nuclear Medicine (NM). Collectively, these studies provide insights into individual radiation monitoring practices, exposure trends, and areas for improvement in Bangladesh. The summary has been discussed category-wise in the following sections of this review.

4.1 Occupational Radiation Monitoring in Industrial Radiography (IR)

Industrial radiography (IR) uses nondestructive testing to inspect material and components and locate and quantify defects and degradation in material properties that could lead to the failure of engineering structures. In general, industrial radiography uses X-rays or gamma emitters. The most commonly used gamma emitter is ^{192}Ir [2]. In Bangladesh, the situation is the same; Iridium-192 is mainly used as the source of gamma rays, and the number of organizations and workers in this practice has increased in the last few years. [9]. In this category of IR, two (02) studies were conducted between 2010-14 and 2015-2018.

The study "Assessment of whole-body Occupational Radiation Exposure in Industrial Radiography Practices in Bangladesh during 2010-2014" by Rahman et al. [8] assessed occupational radiation exposure among industrial radiography workers in Bangladesh over five years (2010-2014). Using thermoluminescent dosimeters (TLDs), the study monitored workers from 7 to 14 industrial radiography facilities, with radiation workers ranging from 72 to 133. Approximately 75% of workers received doses below 1 mSv annually, while a small percentage (1%; 4 workers) exceeded the permissible annual dose limit of 20 mSv. No workers exceeded 100 mSv in 5 consecutive years. The average annual effective dose during the study period was 1.40 mSv. The findings revealed satisfactory radiation protection measures but highlighted high doses due to improper handling and inadequate training.

The follow-up study, "Study of whole-body Occupational Radiation Exposure in Industrial Radiography in Bangladesh" by Yeasmin et al. [9] monitored 472 industrial radiography workers across Bangladesh between 2015 and 2018. The average annual effective dose decreased significantly compared to the earlier study, ranging between 0.2 and 0.4 mSv. The collective effective dose varied annually, peaking at 40.7 man·mSv in 2016. Most workers (80%) received doses below the minimum detection level (MDL) of 0.05 mSv, and only a few (2 workers) exceeded 10 mSv. A maximum dose of 19.9 mSv was recorded in 2018. The study attributed dose reductions to improved radiation safety practices and better adherence to protection guidelines. It also emphasized the importance of training and workload management.

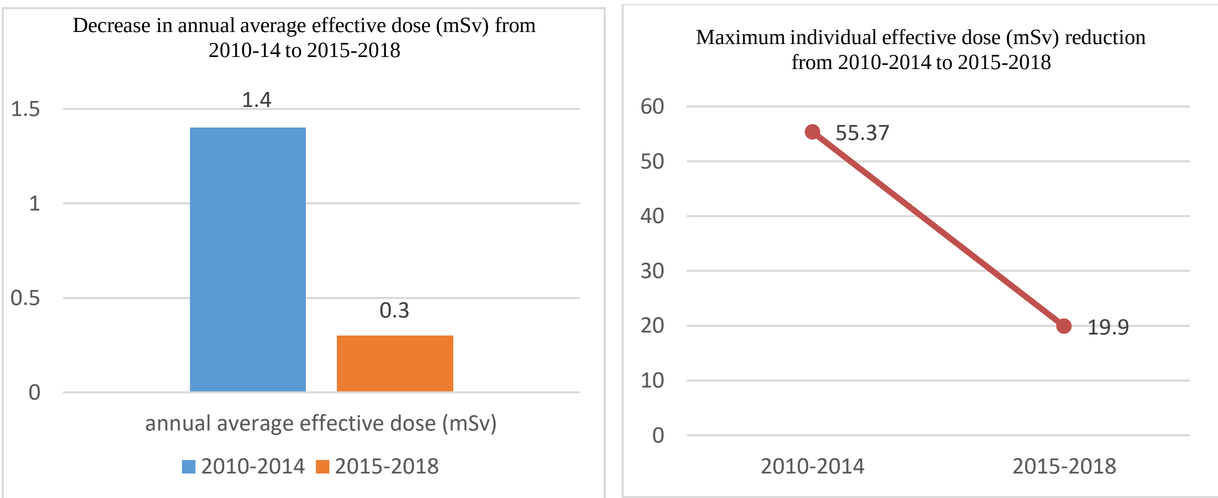
Table 1: Comparative Analysis of the two studies on IR.

Aspect	IR 2010-2014 Study [8]	IR 2015-2018 Study [9]
Period	2010-2014	2015-2018
Number of Workers Monitored	72 to 133 annually	472 total
Average Annual Dose (mSv)	1.40	0.2 to 0.4
Maximum Dose	55.37 in 2013	19.9 in 2018

Aspect	IR 2010-2014 Study [8]	IR 2015-2018 Study [9]
Recorded (mSv)		
Percentage Below 1 mSv	75%	~80%
Collective Effective Dose (man·mSv)	Not specified annually; collective dose noted	28.8 to 40.7 annually
Number of workers with dose >20 mSv during the study period	04	00
Number of workers with dose >50 mSv during the study period	02	00
Key Findings	Instances of high doses due to improper handling and lack of training. Regulatory improvements in 2013 contributed to dose reductions.	Significant dose reductions are achieved through better safety practices and training—improved adherence to radiation safety guidelines.
Recommendations	Focus on training, proper equipment handling, and adherence to protection protocols.	Continued emphasis on training, workload management, and national database development.

The average annual effective dose has decreased from 1.4 mSv to 0.3 mSv, and we can also find that the maximum individual effective dose from the previous study to the next one has also reduced significantly. The following graphical presentations show the improvements over the last nine years from these two studies:

Figure 1: (a) Decrease in annual average effective dose (mSv) from 2010-14 to 2015-2018; (b) Maximum individual effective dose (mSv) reduction from 2010-2014 to 2015-2018 [8, 9]



(a) **(b)**

The two studies demonstrate progress in radiation protection practices in industrial radiography in Bangladesh, with significant reductions in average annual doses, an increase in the number of monitored workers, and better compliance with safety protocols observed from 2015 to 2018. However, isolated cases of high exposure highlight the need for continuous training and stricter enforcement of safety measures. Establishing a national database and further technological improvements are recommended to sustain and enhance radiation safety practices.

4.2 Occupational Radiation Monitoring in Diagnostic Radiology (DR)

Diagnostic Radiology includes conventional diagnostic radiology and interventional radiology pooled together. Conventional Diagnostic Radiology involves static imaging, the various techniques applied (radiography, mammography, and bone densitometry), and computer tomography. Interventional radiology uses X-ray imaging techniques to facilitate the introduction and guidance of devices in the body for diagnostic or treatment purposes. [2]. Interventional radiology specialists used to receive individual effective doses notably higher than those observed in conventional diagnostic radiology. [2]. In Bangladesh, three (03) studies are found in the period of 2010-14 and 2015-2019 in both conventional radiology and interventional cardiology.

4.2.1. Interventional Cardiology

Interventional cardiology is a branch of cardiology that diagnoses and treats heart diseases using image-guided catheters. The most common imaging equipment used for this purpose is X-ray fluoroscopy.

The study titled "Occupational Exposure to Ionizing Radiation in Interventional Cardiology Practices in Bangladesh during 2010-2014" by Rahman et al. evaluated radiation exposure among healthcare workers performing fluoroscopy-guided procedures [10]. The study was conducted in major hospitals in Dhaka, and around 100 workers were monitored annually using TLDs, with quarterly assessments via Harshaw TLD Readers. The findings revealed that 80% of workers received an annual dose below 2 mSv, with no recorded exposures exceeding 50 mSv per year or 100 mSv over five years. The study concluded that occupational exposure to ionizing radiation of all workers in interventional cardiology practices is lower than the prescribed dose limit by ICRP 2007 and IAEA GSR part 3, 2014. Average annual effective doses in this period remain in the range of 1.04 to 2.18 mSv. However, slight fluctuations in maximum individual doses were observed (49.37 mSv in 2013), highlighting the need for further optimization of radiation protection measures. While radiation exposure levels were generally within safety limits, the study recommends enhanced radiation safety training, improved monitoring protocols, and stricter adherence to protection guidelines to minimize occupational risks for cardiologists and supporting medical staff.

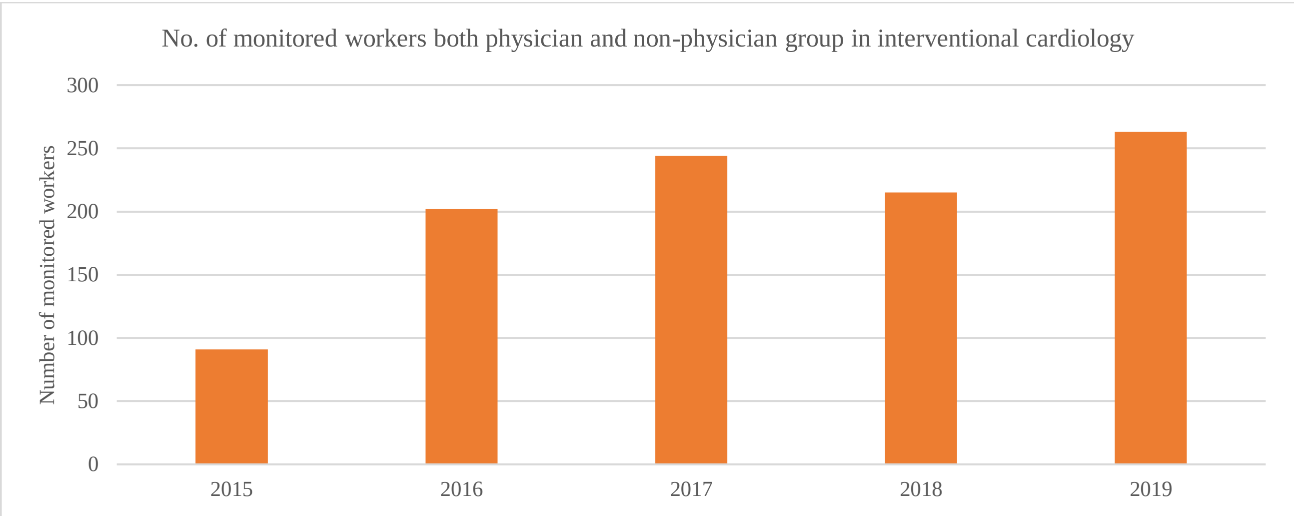
The second study, "Ionizing Radiation Exposure at Interventional Cardiology Practices in Bangladesh" by Shahadat Hossain et al. [11] expanded on these findings by monitoring 1,015 radiation workers and categorizing exposure levels into three groups: below detection level (<0.05 mSv), moderate exposure (<10 mSv), and high exposure (10–20 mSv). The study found that most workers had exposure levels below 0.05 mSv, with very few exceeding 10 mSv. Over time, the proportion of workers receiving moderate radiation exposure decreased, indicating improved radiation protection practices and monitoring systems.

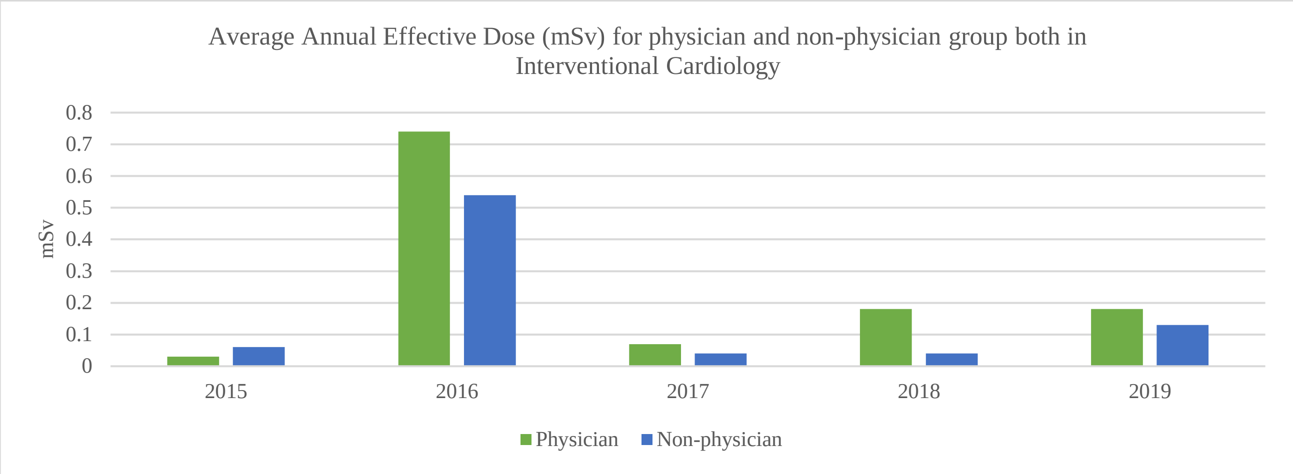
Table 2: Comparison of Occupational Radiation Exposure in Interventional Cardiology Practices in Bangladesh

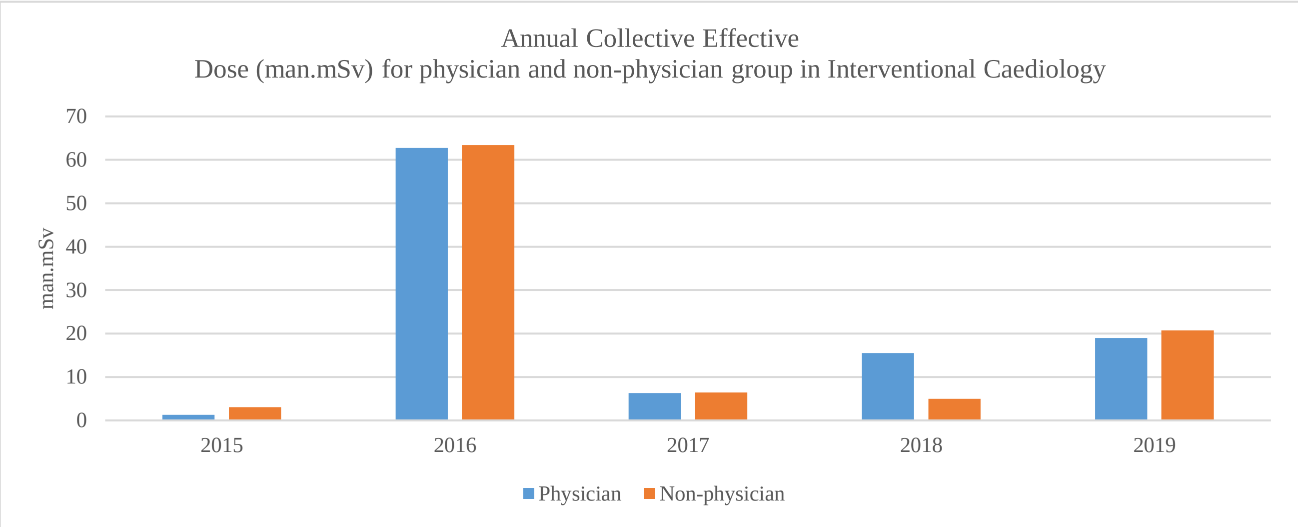
Aspect	Study: 2010-2014 [10]	Study: 2015-2018 [11]
Monitoring Method	Harshaw TLD Readers (Model 4500, 6600 Plus)	Harshaw TLD Reader (Model 4500)
Number of Monitored Workers	~100 per year	1015 total (417 physicians, rest non-physicians)
Average Annual Effective Dose	<2 mSv for 80% of workers	19.11% of workers are exposed (BDL-<10 mSv and 10-20 mSV, whereas 80.89% are non-exposed (fall under BDL)
Maximum Individual Dose	26.24 mSv (2011, physician)	15.21 mSv (2016, physician)
Regulatory Compliance	Below ICRP and IAEA limits	Below ICRP and IAEA limits
Trends Observed	Variation in individual doses requiring optimization	Decreasing trend in annual collective dose
Recommendations	Improve radiation safety practices	Continue monitoring and optimizing protection

Both studies indicate that occupational exposure to ionizing radiation in interventional cardiology practices in Bangladesh has remained within international safety limits. However, continued optimization and adherence to safety measures are necessary to minimize variations in exposure levels. The following figure illustrates the trend of occupational radiation exposure in Interventional Cardiology in Bangladesh:

Figure 2: Trend in Occupational Exposure for Interventional Cardiology in Bangladesh from 2015 to 2018 [11]





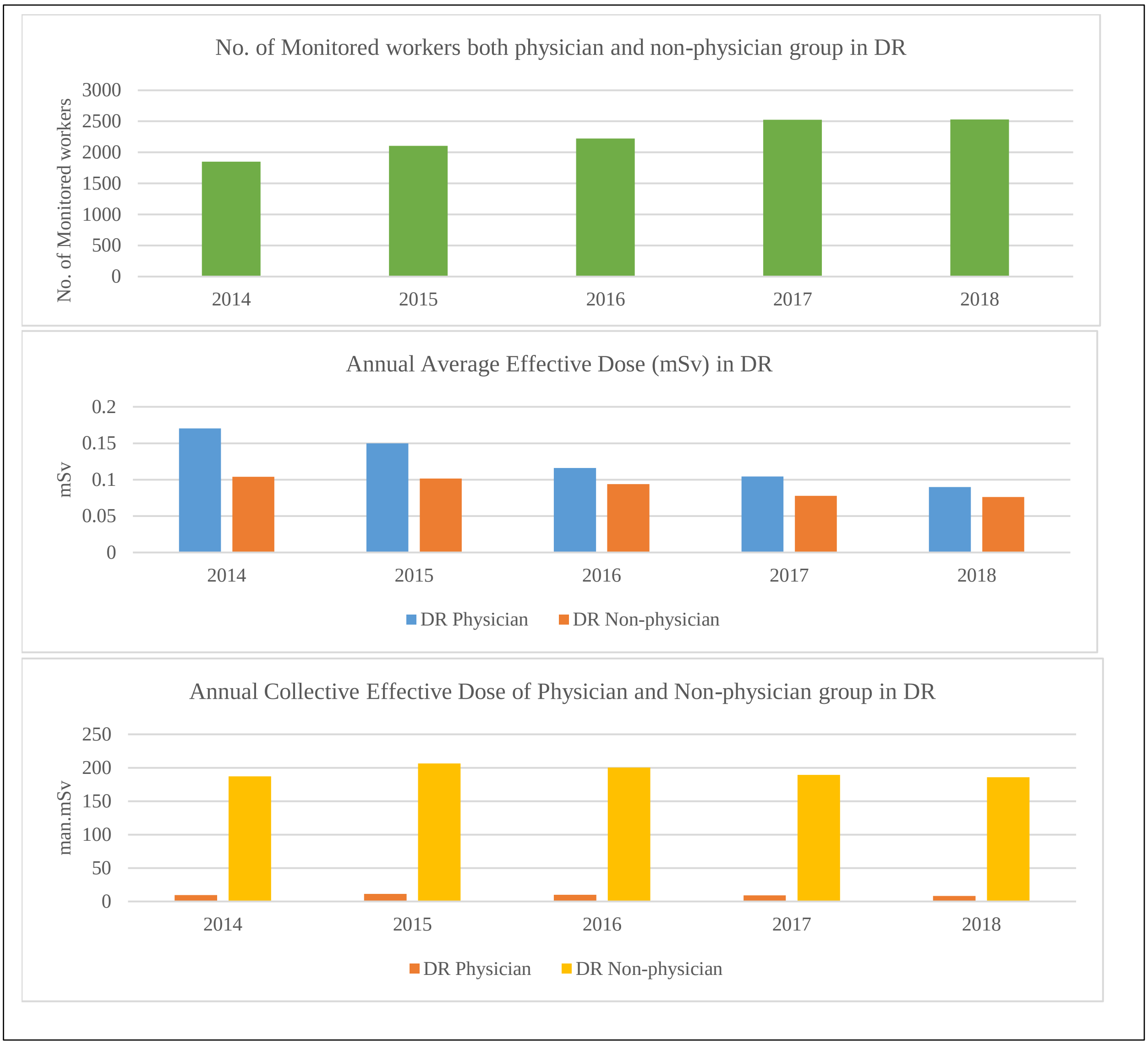


The highest annual collective effective dose was found for 2016; the values were 62.73 and 63.43 man.mSv for physicians and non-physicians, respectively. However, the lowest values were found for 2015 for both groups. Investigative work determined why 2016 had more excellent value than the other years. It was found that a few additional hospitals began offering interventional cardiology facilities in 2016, and these facilities were included in the individual monitoring services by HPD. One new hospital staff's failure to follow the ALARA principle was discovered to be the cause. They received proper guidance immediately, and the effects can be observed over the next few years [11].

4.2.2. Conventional Diagnostic Radiology

In diagnostic radiology (DX) departments, the study "Status and Trend of Occupational Radiation Exposure in Radiotherapy and Diagnostic X-ray Practices in Bangladesh" by Subrata Banil et al. [12] evaluated dose records for the radiation workers in the field of Diagnostic X-rays from 2014 to 2018. The total collective dose was 1016.894 man.mSv for the DR department in five years. The average annual effective dose in this field during 2014-2018 ranged from 0.076-0.172 mSv. The number of Physicians from DR who received doses below MDL was around 74-86%, and the highest number was in 2016. For non-physicians, the number of workers from DR was approximately 94-98%, and the highest was in 2018. The maximum individual dose a worker receives belongs to a non-physician, a more specific technician, of the DR department, which accounts for 19.90 mSv in 2016. The study mentioned that the number of cases in which maximum doses were received was very low. They could not impact the annual average effective dose, which leads to a decline in the doses as low as reasonably achievable (ALARA).

Figure 3: Trend in Annual Average Effective Dose (mSv) in Diagnostic X-ray Practice in Bangladesh from 2014-2018 [12]



4.3 Occupational Radiation Monitoring in Radiotherapy (RT)

Radiation therapy refers to using ionizing radiation produced by a sealed source or a radiation generator to treat various diseases (usually cancer). The study "Status and Trend of Occupational Radiation Exposure in Radiotherapy and Diagnostic X-ray Practices in Bangladesh" by Subrata Banil et al. [12] evaluated dose records for the radiation workers in the field of Radiotherapy from 2014 to 2018 in Bangladesh. The study is conducted by considering the employment category of the physician and non-physician group. The trend in occupational exposure at Radiotherapy in Bangladesh is illustrated in the following graphs from the outcomes of the study:

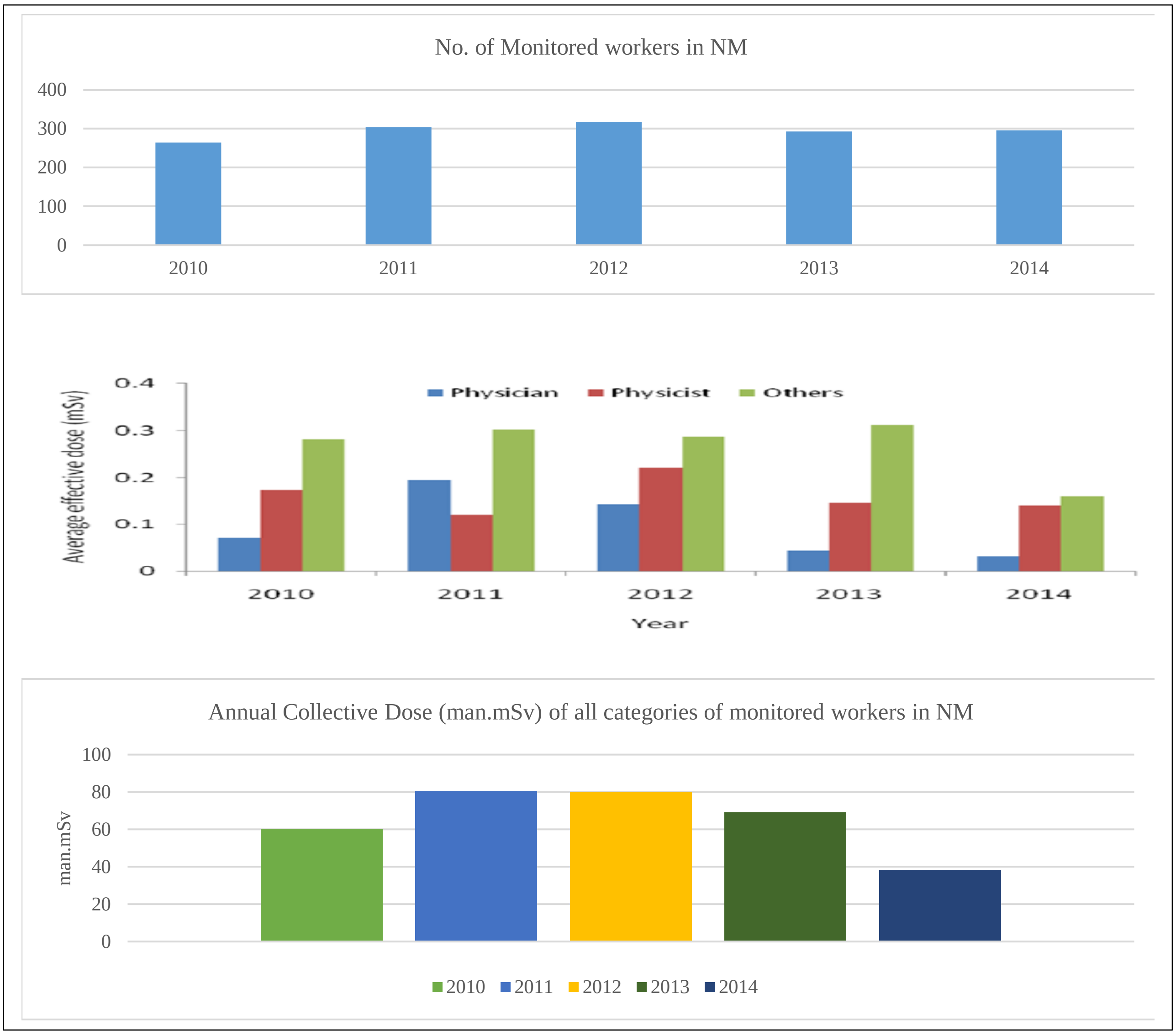
Figure 4: Trend in Occupational Exposure in Radiotherapy Practice in Bangladesh from 2014-2018 [12]

The average annual effective dose decreasing trend in both groups. This implies that proper safety measures were maintained, and under the BAER Act- 2012, the Bangladesh Atomic Energy Regulatory Authority (BAERA) regulation was followed correctly. Also, advanced devices in RT departments for treatment use an external beam from a highly protected Cobalt-60 source or linear accelerator (LINAC), and workers can operate the device from outside the treatment room. Based on occupational responsibility, the collective effective dose received by non-physicians is much higher than by physicians [12].

4.4 Occupational Radiation Monitoring in Nuclear Medicine (NM)

The study, Assessment of Whole-Body Occupational Radiation Exposures in Nuclear Medicine Practices of Bangladesh During 2010–2014 by Rahman et al. [13], evaluated radiation exposure among 300 nuclear medicine workers in Bangladesh using TLDs. The annual average effective dose ranged from 0.13 to 0.27 mSv, significantly below the ICRP recommended limit of 20 mSv. During the study period, 95% of workers received doses under 1 mSv, while only 0.33% exceeded 10 mSv. The study highlighted that the decrease in average annual effective dose after 2013 was probably due to the forming of an independent regulatory authority, BAERA, and proper regulatory control of the nuclear medicine facilities. There is a need for rigorous radiation safety protocols and continuous monitoring to ensure doses remain As Low as Reasonably Achievable (ALARA). Comparatively, doses for Bangladeshi workers were three times lower than the global average cited by UNSCEAR during 2000–2002. Emphasis is placed on regular training and improved safety protocols to minimize risks further. The trend in occupational exposure at Nuclear Medicine in Bangladesh is illustrated in the following graphs from the outcomes of the study:

Figure 5: Trend in Occupational Exposure in Nuclear Medicine in Bangladesh from 2010-2014 [13]



5. Summary

This review examines occupational radiation monitoring in Bangladesh by consolidating findings from studies conducted in various radiation-related sectors, including industrial radiography, diagnostic radiology, radiotherapy, and nuclear medicine. The analysis reveals that occupational radiation exposure levels in Bangladesh are generally within national and internationally accepted limits, with a declining trend in average annual effective dose observed over the years. Also, there is a trend in an increase in the number of monitored workers in all sectors, which indicates improvement in radiation safety culture and compliance with regulatory requirements. Implementing regulatory requirements, better adherence to protection protocols, and advancements in monitoring infrastructure have contributed to these positive trends.

However, some occupational groups, particularly in industrial radiography and interventional cardiology, have recorded occasional high-dose exposures, emphasizing the need for continued improvements in safety training, equipment handling, and regulatory enforcement. The study also highlights the role of the regulatory body in ensuring compliance with international radiation protection standards.

Future efforts should focus on continuous professional training, enhanced monitoring techniques, and a comprehensive national exposure database to strengthen radiation safety practices. By maintaining rigorous oversight and promoting the ALARA (As Low As Reasonably Achievable) principle, Bangladesh can ensure the sustained safety of radiation workers and align with global best practices in occupational radiation protection.

6. Conclusion

This review provides an overview of occupational radiation monitoring in Bangladesh, synthesizing findings from multiple studies across industrial radiography, diagnostic radiology, radiotherapy, and nuclear medicine. The analysis highlights notable improvements in radiation protection practices over the years, as reflected in the declining trends of average annual effective dose across various occupational groups. Regulatory frameworks, such as the BAER Act 2012 and NSRC Rules 1997, have played a significant role in enforcing radiation safety measures and monitoring compliance with international standards.

Despite these advancements, some challenges remain. Occasional high radiation exposure, particularly in industrial radiography and interventional cardiology, emphasizes the need for continuous training, stricter adherence to safety protocols, and improved workload management. The findings also indicate that while most radiation workers receive doses well below the regulatory limits, ongoing monitoring and optimization of personal dosimetry practices are essential to maintaining a robust radiation protection culture.

Future efforts should focus on enhancing radiation safety education and training, expanding individual monitoring services, and implementing a national database for occupational exposure tracking. Strengthening regulatory oversight, investing in advanced dosimetry technologies, and promoting adherence to the ALARA (As Low As Reasonably Achievable) principle will further ensure the safety of radiation workers in Bangladesh.

By addressing these challenges and leveraging existing progress, Bangladesh can continue to improve its occupational radiation protection framework, aligning with global best practices and ensuring long-term radiation safety for its workforce.

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