YANGON UNIVERSITY OF ECONOMICS

DEPARTMENT OF APPLIED ECONOMICS

MASTER OF PUBLIC ADMINISTRATION PROGRAMME

A STUDY ON RADIATION PROTECTION AWARENESS AMONG RADIATION WORKERS (CASE STUDY: SELECTED HOSPITALS IN YANGON)

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EMPA - 37 (19^{th} BATCH)

JULY, 2024

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A STUDY ON RADIATION PROTECTION AWARENESS AMONG RADIATION WORKERS (CASE STUDY: SELECTED HOSPITALS IN YANGON)

A thesis submitted as partial fulfillment of the requirements for
the degree of Master of Public Administration

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This is to certify that this thesis titled "**A Study On Radiation Protection Awareness Among Radiation Workers (Case Study: Selected Hospitals in Yangon)"** submitted in partial fulfillment towards the requirements for the degree of Master of Public Administration (MPA) has been accepted by the Board of Examiners.

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ABSTRACT

This study assesses the awareness of radiation protection among healthcare workers operating in radiation environments at selected hospitals in Yangon. A cross-sectional study is conducted with 135 healthcare workers from five private hospitals and two Defence Services General Hospitals across various radiation application departments. Key findings show that most respondents have a high level of awareness, while the rest have a moderate level, with none displaying poor awareness. However, there are notable gaps in understanding radiation protection principles, differentiating between stochastic and deterministic effects, and recognizing the significance of dose in assessing radiation severity. The analysis of respondents' compliance with radiation protection practices reveals general adherence but identifies significant inconsistencies, underscoring the need for targeted education on the importance of these safety measures. By addressing these gaps and strengthening support systems, healthcare facilities can enhance radiation safety practices and ensure better protection for healthcare workers exposed to radiation. Continuous education through periodic training, updated guidelines, and accessible protective resources is essential for promoting safety and mitigating risks associated with radiation exposure.

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LIST OF ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
CT	Computed Tomography
DAE	Department of Atomic Energy (Myanmar)
Dexa	Dual-energy x-ray absorptiometry
DGSH	Defence General Service Hospital
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ISO	International Organization for Standardization
LMIC	Low-Middle Income Country
MOST	Ministry of Science and Technology
MRI	Magnetic Resonance Imaging
mSv	millisievert
NCRP	The National Council on Radiation Protection and Measurement (USA)
OSLD	Optically Stimulated luminescence detectors
PET CT	Positron Emission Tomography Computed Tomography
PET	Positron Emission Tomography
SI	International System of Units
TLD	Thermoluminescent detector
UV rays	Ultraviolet rays
WHO	World Health Organization

CHAPTER I
INTRODUCTION

Presently, radiation serves humanity across various domains, including medicine, academics, and industry, in addition to its role in electricity generation. Moreover, radiation has beneficial applications in fields such as agriculture, archaeology (carbon dating), geology (including mining), and numerous other areas, contributing to the betterment of society (Donya et al., 2014).

As the radiation application technologies are enhancing, the use of ionizing radiation for various applications has become increasingly accessible. However, this increased utilization has been linked to radiation exposure risks for those employed in radiation-related fields, known as radiation workers. Radiation poses potential risks and hazards to humans and the environment, especially when it is not used safely or properly. Radiation workers must possess and implement the principles of radiation safety in their professional activities. The extent of their awareness regarding radiation protection directly influences their behavior. In the absence of adequate information on radiation protection and safety, there is a risk of unsafe practices, posing a significant danger to both the radiation worker and the public (Holmberg et al., 2010).

1.1 Rationale of the Study

Among radiation workers of all sectors, radiation protection is a critical aspect of healthcare sector, particularly for those who are regularly exposed to ionizing radiation in their professional duties. Healthcare workers in the radiation sector play an essential role in public health by preventing, diagnosing, and treating various diseases using radiation technology. These workers perform crucial procedures like X-rays, CT scans, nuclear medicine tests, and radiotherapy for cancer patients. Given their regular exposure to radiation, it is essential that they ensure the safety and quality of radiation sources and devices, and protect themselves and others from harmful exposure (Griffiths, 2003).

As for exposure to ionizing radiation, even at low levels, can have negative effects on the health of healthcare workers. Severe exposure can lead to radiation sickness, while prolonged exposure increases the risk of various cancers, cataracts, and potential genetic mutations (Chew et al., 2021). These health risks underscore the necessity of stringent radiation protection measures in medical settings. By understanding and implementing effective radiation protection and safety protocols, healthcare workers can significantly reduce their exposure, thereby minimizing both short-term and long-term health risks associated with ionizing radiation. This not only ensures their immediate safety but also contributes to their overall well-being and longevity.

Given the critical issue of radiation protection and safety, international organizations such as the International Atomic Energy Agency (IAEA), the International Commission on Radiological Protection (ICRP) and the World Health Organization (WHO) provide guidelines, training, and resources aimed at enhancing radiation safety awareness and practices among healthcare workers. These organizations promote the adoption of best practices in radiation protection, encourage continuous education, and support the implementation of safety measures that comply with international standards. Their efforts help ensure that healthcare institutions maintain high levels of radiation protection and safety, thereby protecting both workers and patients (Holmberg et al., 2010).

The World Bank classifies Myanmar as a Low-Middle Income Country (LMIC) (World Bank, 2024). Since the beginning of the 21st century, like other LMICs, Myanmar has experienced accelerated development. This development has included significant improvements in healthcare for its population. Recent reforms in the health system have led to substantial enhancements in the delivery of radiotherapy services in both private and government sectors. Consequently, there is a growing utilization of ionizing radiation in public and private healthcare facilities as part of efforts to enhance healthcare services for the population. However, there may be unequal access to radiation protection and safety knowledge among healthcare workers. Given this trend, it is crucial to ensure that radiation workers in the health sector possess sufficient awareness and adherence to radiation protection protocols. Assessing the current level of radiation protection awareness among healthcare workers is essential for identifying gaps and areas needing improvement. By investigating radiation protection and safety awareness among radiation workers, occupational safety concerns can be proactively addressed, regulatory compliance can be promoted, risks can be mitigated, and the overall well-being of radiation workers can be enhanced.

The thesis focused to study the awareness level of radiation protection among healthcare workers in radiation environments (i.e., radiology, nuclear medicine, and radiotherapy) of selected private and public hospitals in Yangon. These hospitals offer a wide range of medical services to the public, including extensive use of radiation and advanced radiation equipment to serve the community

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1.2 Objective of the Study

The objective of this study is to assess the awareness level of radiation protection among healthcare workers in radiation environment of public and private hospitals in Yangon.

1.3 Method of Study

The research employs a cross-sectional study and survey-based design. The context of the study involves healthcare workers operating in radiation fields in both private and public hospitals in Yangon. The questionnaire used in this research was assembled after reviewing previous studies on comparable subjects and consulting with radiation protection officers from the Department of Atomic Energy (DAE).

In this study, primary data were collected from radiation workers of selected private and public hospitals in Yangon. A quantitative survey was conducted by using structured questionnaires, and data were gathered from the population, a total of 135 respondents from five private hospitals and two General Defence Service hospitals. The study employed a two-step analytical approach. First, descriptive statistics were used to analyze the frequency distribution of awareness levels. Second, the total score distribution was calculated to differentiate the score level.

Online sources such as Google, Science Direct, and PubMed were used as tools for searching the literature, including journals, articles, and research papers.

1.4 Scope and Limitation of the Study

The scope of this study is to analyze the awareness level of healthcare radiation workers on radiation hazard and protection. The population of the research is the healthcare radiation workers who are exposed to or use ionizing radiation in their work including medical doctors, technician and support staffs. The participants are healthcare radiation workers from public and private hospitals in Yangon. Seven hospitals were participated and the survey covers all healthcare workers exposed to radiation in those hospitals. The survey was conducted between March to April 2024.

For limitation, the survey could not be conducted in person, as healthcare workers' schedules are often busy and unpredictable due to their demanding duties and rotating shifts. This variability makes it challenging to capture their availability for assessment at a single fixed time. So, arrangements were made to coordinate with the relevant departments of hospitals.

1.5 Organization of Study

This study is organized into five chapters. Chapter (1) introduces the study covering the research's rationale, objectives, methods, scope and limitations and organizational framework. Chapter (2) provides a comprehensive literature review including nature of radiation and radiation protection, sources of the ionizing radiation exposure, uses of ionizing radiation in healthcare sectors, radiation dose and units of measurements, radiation effects on human health, factors contributing to unnecessary radiation exposure, radiation protection and safety measure, the economic impacts of radiation protection on healthcare workers and review of previous study. Chapter (3) discusses radiation protection functions in Myanmar, describing about the Department of Atomic Energy (DAE) as the responsible department for radiation protection and safety, radiation protection measures, current radiation safety and protection activities by DAE, personal radiation dosimetry services, recommended dose limits in Myanmar, radiation protection courses in the academic curricula of healthcare sectors and overview of radiation medical services of selected hospitals. Chapter (4) presents the analysis of the survey. Chapter (5) outlines the findings and offers suggestions for enhancing the awareness level of radiation protection and safety among healthcare radiation workers in hospital settings.

CHAPTER II
LITERATURE REVIEW

2.1 Nature of Radiation and Radiation Protection

Radiation is a type of energy that travels through space as particles or waves and it is a part of daily environment for us. There are many kinds of radiation including sunlight, radio waves, visible light, Ultra violet rays, X- rays and gamma rays, as well as electrons, protons, and alpha particles. There are two types of radiation depending on its energy as non-ionizing radiation and ionizing radiation. Non-ionizing radiation has low energy and cannot remove electrons from atoms or molecules. This kind of radiation includes radio waves, microwave and visible light. Most people are not harmed by non-ionizing radiation, but some workers who are exposed to it frequently may need extra protection (Galindo, 2023). On the other hand, ionizing radiation has high energy and it can remove electrons from atoms or molecules, altering them at the atomic level when they touch matter, including living things. High doses of ionizing radiation can harm cells and organs, potentially leading to severe damage or even death. However, with proper use and safety measures, ionizing radiation can be highly beneficial. It has many applications, including industry, research, energy production, and medical diagnostics and treatments, such as in the case of cancer (Galindo, 2023).

Ionizing radiation exists in two general types: particulate radiation and electromagnetic radiation. Particulate radiation consists of particles that have mass and carry energy. This kind of radiation includes alpha particles, beta particles, and neutrons. The second type of electromagnetic radiation comprises photons that propagate in waves at the speed of light. This kind of radiation include gamma rays and X-rays which have the potential to cause ionization in the materials they interact with, leading to potential biological effects.

Radiation Protection serves as a tool for the management of measures to protect health against the risks for people and environment arising from the utilization of ionizing radiation.

2.1.1 Sources of Ionizing Radiation Exposure

This ionizing radiation originates from both naturally occurring sources and artificially produced man-made sources. People are exposed to it through various way. The Earth's population is constantly exposed to ionizing radiation from natural sources, known as natural background radiation and it can vary greatly depending on geographical location. The sources of natural radiation are terrestrial radiation from Earth's crust, cosmic radiation from space and natural radioactivity in the body. Man-made radiations are coming from radionuclide radiation sources such as Co-60 source and radiation-generating machines such as particle accelerator and medical X-ray machines. Radiation-generating machines electronically produce ionizing radiation and cease emission when turned off. However, equipment containing radioactive material cannot be ceased as the radioactive source continually emits ionizing radiation. To mitigate radiation exposure, it is imperative to shield these sources by surrounding them with materials capable of blocking radiation.

According to National Council on Radiation Protection and Measurements (NRCP) report No.160, in the United State, 50% of ionizing radiation exposure of the population comes from natural background sources and 50% from man-made sources. 50% of man-made radiation exposure includes computed tomography, CT, (medical) 24%, nuclear medicine (medical) 12%, interventional fluoroscopy (medical) 7%, conventional radiography/ fluoroscopy (medical) 5%, consumer 2%, Occupational exposure less than 0.1% and industrial exposure less than 0.1%. Therefore 48% total radiation exposure comes from man-made medical radiation exposure. The imaging techniques of CT and nuclear medicine together account for 36% of the total radiation exposure and 75% of the medical radiation exposure in the U.S. population (Thurston).

2.1.2 Application of Ionizing Radiation

The application of ionizing radiation is widespread and covers various fields, including medicine, industry, research, and energy production. Here are some common applications of ionizing radiation:

1. *Medical Imaging*: Ionizing radiation is used in diagnostic imaging techniques like fluoroscopy, X-rays and CT scans to visualize internal structures of the body for diagnostic purposes.

2. *Radiation Therapy*: In oncology, ionizing radiation is used for cancer treatment through techniques such as external beam radiation therapy and brachytherapy to target and destroy cancerous cells.
3. *Industrial Applications*: Ionizing radiation is utilized in industrial radiography for non-destructive testing of materials, as well as in sterilization processes for medical equipment and food products.
4. *Research*: Ionizing radiation is employed in scientific research for various purposes, such as value-added materials modification and radiolabeling molecules for biological studies, inducing mutations in organisms, and conducting radiobiology experiments.
5. *Energy Production*: Ionizing radiation is utilized in nuclear power generation to produce steam for electricity through controlled nuclear fission reactions.
6. *Security and Detection*: Ionizing radiation is used in security applications such as cargo scanning and airport security to detect illicit materials and ensure public safety (Donya et al., 2014).

2.2 Uses of Ionizing Radiation in Healthcare Sectors

Ionizing radiation has been used for medical purposes since the discovery of X-ray in 1895 by Wilhelm Rontgen. The medical use of radiation encompasses both diagnostic and therapeutic applications, each playing a crucial role in modern healthcare.

2.2.1 Diagnostic Uses

Diagnostic procedures use relatively small amounts of radioactive materials or radiation to facilitate imaging of suspected medical issues. This includes radiology, which uses external sources of radiation such as x-ray machines, and nuclear medicine, which involves internal sources of radiation. As example for external source of radiation; X-ray imaging is widely used to visualize the internal structures of the body, such as bones and organs. It is commonly employed for detecting fractures, assessing lung conditions, and diagnosing various medical conditions. Dentists use X-rays to diagnose dental problems, such as cavities, impacted teeth, and jawbone issues. CT scans utilize a series of X-ray images taken from various angles to produce detailed cross-sectional images of the body. This method is valuable for detecting abnormalities, tumors, and injuries. X-rays are also used in mammography for the early detection of breast cancer by capturing detailed images of breast tissue.

In nuclear medicine, radioactive tracers are introduced into the body and detected by specialized cameras to create images of organ function, helping in diagnosis of various conditions. Some of Nuclear medicine procedures are the use of technetium-99m for bone or heart organ diagnostics and radioactive iodine for thyroid imaging. Positron emission tomography (PET) scanning, which involves injecting radioactive material into a person to visualize metabolic activity and circulation in the brain, has significantly contributed to the understanding and diagnosis of neurological diseases. PET studies have enabled scientists to precisely identify the location of brain tumors and better understand various neurological conditions.

2.2.2 Therapeutic Uses

Therapeutic uses of radiation aim to treat various medical conditions, particularly cancer. Teletherapy involves directing an intense beam of radiation from a high-activity external source onto the affected tissue of the patient. An example of this is the Gamma Knife, which focuses gamma rays from cobalt-60 sources to specific locations within brain tissue. Additionally, brachytherapy entails placing lower activity radioactive sources close to or within cancerous tissue, such as in breast, prostate, or cervical cancers, to effectively target and treat the affected areas (Donya et al., 2014).

While these medical applications are beneficial, it's crucial to carefully control and limit radiation exposure to minimize potential risks to patients and healthcare providers. So, it is very important for the healthcare workers who is working in radiation environment to follow the strict guidelines and safety protocols to ensure the responsible use of radiation in the medical field.

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2.3 Radiation Dose and Units of Measurements

In radiation protection, radiation dose refers to the amount of exposure ionizing radiation that an individual or biological system receives. There are three main types of radiation dose in radiation protection system: absorbed dose, equivalent dose and effective dose. Absorbed dose is a quantifiable physical quantity, whereas equivalent dose and effective dose are specifically designed for the purposes of radiological protection.

Absorbed dose is a measure of energy deposition in any medium by any type of ionizing radiation. In SI system of unit, the unit of absorbed dose is the gray (Gy), where 1 gray is equivalent to 1 joule of energy deposited per kilogram. Smaller units such as milligray (mGy) and microgray (µGy) are used for practical purposes to express smaller amounts of radiation.

Equivalent dose is a measure of dose that taking into account the different biological effects of various types of ionizing radiation. This type of dose can be calculated by multiplying the absorbed dose by a radiation weighting factor (W_R). The SI unit of equivalent dose is sievert (Sv) and smaller units such as millisievert (mSv) and microsievert (µSv), are used for practical purposes to express smaller amounts of radiation (Martin et al., 2019).

Equivalent dose = Absorbed dose x Radiation Weighting Factor (Source: Martin et al., 2019)

Table 2.1- Summary of values of radiation weighting factor

Type of radiation	Radiation weighting factor
X-rays, γ rays and electrons	1
Protons	5
Thermal neutrons	2.5
Fast neutrons	2.5-20[a]
A particles, fission fragments	20
[a] Depending on energy	

Source: Martin et al., 2019

The last one, effective dose is a concept that considers the different sensitivities of various tissues and organs to radiation. It is calculated for the whole body. The SI unit of effective dose is sievert (Sv) and smaller units such as millisievert (mSv) and microsievert (µSv) are used for practical purposes to express smaller amounts of radiation.

2.4 Radiation Effects on Human Health

Radiation and its interaction with living tissue have been the subject of scientific research for more than 100 years. By measuring radiation and understanding its health effects, radiation workers can work safely around it.

2.4.1 Biological Effects of Radiation

The biological effects of radiation can be divided into two categories: deterministic effects and stochastic effects.

1. **Deterministic effects**: These are short-term, adverse tissue reactions resulting from a dose that is significantly high enough to damage living tissues (Physics, 2021). Those effects have a threshold dose below which they do not occur, and their severity increases with the dose received. The typical threshold value is around 500 millisieverts (mSv). These effects result from massive cell death and the subsequent loss of function in the affected organs or tissues. Therefore, the ICRP has new adopted the more descriptive term harmful tissue reaction (Martin et al., 2019). In this study, the previous term of Deterministic effect is using. Examples of deterministic effects include skin burns, radiation sickness and cataracts. Deterministic radiation effects can be acute radiation injuries. These occur within days or weeks after high radiation exposures can include symptoms such as nausea, skin burn, hair loss, anemia.
2. **Stochastic effects**: These are those for which the probability of occurrence, rather than the severity, is dose-dependent. These effects are caused by low dose of ionizing radiation and the results of changes in the genetic material cells (DNA) include cancer and heritable effects. The risk of stochastic effects increases with the dose received, but there is no threshold dose below which they do not occur.

   Radiation protection aims to protect human health by reliably preventing deterministic radiation effects and minimizing the risk of stochastic effects to an achievable level (Federal Office for Radiation Protection).

   The comparison between deterministic and stochastic radiation effects are shown in table 2.2.

Table 2.2 – Comparing deterministic and stochastic radiation effects

	Deterministic Effects of Radiation Exposure	Stochastic Effects of Radiation Exposure
Description	Damage occurring after exceeding a threshold dose.	Delayed cellular damage arising from DNA (genetic material) alternations.
Cause of the Damage	Killing or dysfunction of numerous cells.	Mutations and subsequent replication of individual mutated cells (somatic cells or germ cells).
Dose Dependence	Higher radiation doses correlate with more severe damage.	Higher radiation doses increase the chance of damage occurring.
Dose Threshold Value	About 500 millisieverts (mSv); for the unborn child about 50 to 100 mSv.	Non-existent.
Examples	Skin reddening, hair loss, infertility, acute radiation syndrome, malformations and brain maldevelopments in the unborn child.	Cancer, hereditary effects.

Source: Federal Office for Radiation Protection

2.4.2 Response of Specific Organ Systems to Radiation Exposure

Radiation exposure can lead to different reactions in various organ systems:

- **Skin:** May experience redness (erythema), acute radiation dermatitis, and temporary hair loss.
- **Reproductive Organs:** Can result in temporary or permanent sterility.
- **Eyes:** Exposure can lead to cataracts, causing visual impairment.

The sensitivity to radiation also differs across organs:

- **High Sensitivity:** Lymphoid organs, bone marrow, testes, ovaries, and the small intestine are highly sensitive to radiation.

- **Moderate to High Sensitivity:** Skin, cornea, lens, oral cavity, esophagus, gastrointestinal organs, bladder, vagina, cervix, uterus, and rectum exhibit fairly high sensitivity.
- **Medium Sensitivity:** Growing cartilage, vascular system, and growing bones have medium sensitivity.
- **Low to Fair Sensitivity:** Mature cartilage, bone, lungs, kidneys, pancreas, adrenal glands, pituitary gland, thyroid, and salivary glands show fairly low sensitivity.
- **Very Low Sensitivity:** Muscle, brain, and spinal cord are among the least sensitive to radiation. (Yin Mar Hlaing, 2017)

This categorization helps in understanding the potential risks and necessary precautions during radiation exposure.

2.4.3 Health Risks Associated with Radiation Exposure

Exposure to ionizing radiation can increase the risk of developing various health problems, including cancer and non-cancer risks such as genetic effects and developmental abnormalities.

1. **Cancer risks:** Radiation exposure increases the risk of developing cancer, with the risk being proportional to the dose received. The types of cancer that are most commonly associated with radiation exposure include leukemia, thyroid cancer, breast cancer, and lung cancer.
2. **Non-cancer risks:** Exposure to ionizing radiation can also increase the risk of non-cancer health problems, such as genetic effects and developmental abnormalities. Genetic effects can be passed on to future generations and can include mutations in DNA that can lead to birth defects and other health problems. Developmental abnormalities can occur when radiation exposure occurs during pregnancy and can result in physical and mental disabilities in the child.

The severity of the health risks associated with radiation exposure depends on a range of factors, including the radiation type, the received dose, and the exposure duration. It is important to minimize exposure to ionizing radiation whenever possible and to implement appropriate radiation protection measures to reduce the risk of health problems.

Understanding these biological effects and health risks is essential for evaluating the potential impact of radiation exposure on human health and for implementing appropriate radiation protection measures.

2.5 Factors contributing to Unnecessary Radiation Exposure

There are several issues that can contribute to unnecessary radiation exposure in the healthcare sector. Some of them are:

1. **Issues related to device use**: There may be wide variations in the radiation doses associated with particular types of medical imaging exams, depending on how the imaging facilities administer them. There may also be a lack of regular inspection, maintenance, and calibration of medical radiation devices.
2. **Issues related to clinical decision making**: There may be inappropriate or overuse of medical imaging exams that use radiation, due to lack of awareness, guidelines, or evidence on the benefits and risks of different modalities. There may also be a lack of communication and coordination among healthcare providers, leading to duplication of exams.
3. **Issues related to occupational protection**: There may be inadequate training, supervision, and monitoring of health workers who use or work near sources of radiation. There may also be insufficient use of personal protective equipment, shielding, and safety measures to prevent accidental or unintended exposure.

To reduce unnecessary radiation exposure in the healthcare sector, the ICRP, IAEA, World Health Organization (WHO) and other international organizations have developed various initiatives, standards, and tools to enhance radiation safety and protection in healthcare settings.

2.6 Radiation Protection and Safety Measures

Radiation protection and safety measures in the health sector are important to prevent or minimize the harmful effects of exposure to ionizing radiation for both patients and healthcare workers. These measures encompass a range of strategies and protocols aimed at minimizing the potential harmful effects of ionizing radiation on individuals and the environment.

2.6.1 Fundamental Principles of Justification, Limitation and Optimization

The International Commission on Radiological Protection (ICRP) has formulated three radiation protection principles as follows:

1. **The Principle of Justification:** Any decision that alters the radiation exposure situation should do more good than harm (ICRP, 2007).
2. **The Principle of Optimization of Protection:** The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should be kept as low as reasonably achievable, taking into account economic and societal (ICRP, 2007).
3. **The Principle of Application of Dose Limits:** The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the Commission (ICRP, 2007).

Overall, these principles work together to ensure that radiation exposure is minimized and that the benefits of radiation use outweigh the potential risks.

These fundamental principles guide the approach to radiological protection in various exposure situations and are essential for ensuring the safety of individuals and the environment in the context of radiation exposure.

2.6.2 As Low As Reasonably Achievable (ALARA) Principle

ALARA, an acronym in radiation safety, stands for "As Low As Reasonably Achievable." This fundamental principle is centered on minimizing radiation doses and restricting the release of radioactive materials into the environment through the utilization of all "reasonable methods." The main idea is that there is no threshold in the relationship between dose and the probability of induced health effects. Even a small amount of radiation can cause health problems like cancer or genetic changes. The goal of zero risk cannot be achieved, because that would mean zero radiation, which is not realistic or affordable. Instead, a way to keep the radiation as low as possible is needed. ALARA is not only a robust radiation safety guideline but also a mandatory requirement for all "radiation protection programs." This concept plays a vital role in activities involving radiation or radioactive materials, aiding in averting unnecessary exposure and preventing overexposure.

In the medical field, diagnostic and therapeutic uses of ionizing radiation are carefully controlled to balance the benefits of the procedures with the associated risks.

Radiologists and medical professionals follow the principle of ALARA to minimize patient and staff exposure.

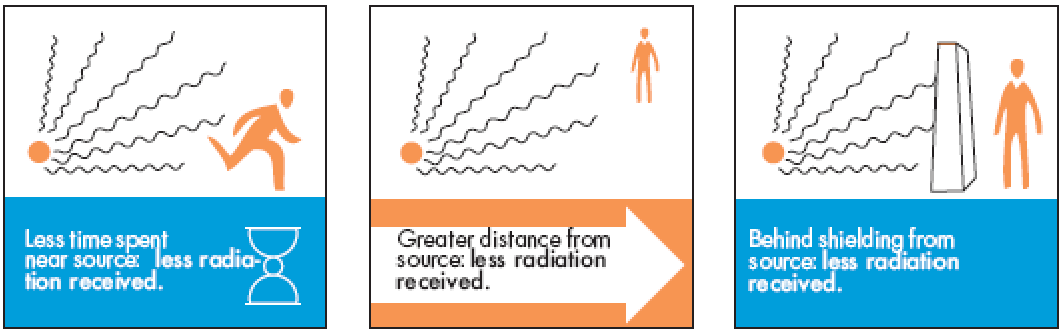
The three key principles to aid in keeping doses "As Low As Reasonably Achievable" are time, distance, and shielding.

2.6.3 Methods for Radiation Exposure Control

The external radiation exposure can be minimized by applying the three principles as shown in figure 2.1.

1. **Time:** Minimizing the time spent in areas with high levels of radiation can reduce the overall dose received.
2. **Distance:** Increasing the distance between the source of radiation and individuals can reduce the dose received.
3. **Shielding:** Using appropriate shielding materials, such as lead or concrete, can reduce the amount of radiation that reaches individuals. Lead shielding is an important protective measure against radiation exposure (El-Feky et al., 2017). For personal protective equipment as shielding include lead aprons, thyroid shields, gonad shields, lead gloves and eye goggles. Regular use of lead aprons gives an average of 75-80% protection to bone marrow (Salah Eldeen, N.G., & Farouk, S.A., 2020).

Figure 2.1 Demonstration for three principles for Radiation Exposure Control.



Source: United States Nuclear Regulatory Commission, 2019

2.6.4 Collimation of Xray beams

Collimation of X-ray beams refer to the process of narrowing the beam to a specific area. This restriction of the radiation field size serves multiple purposes. Primarily, it minimizes the amount of tissue exposed to radiation, thereby reducing unnecessary radiation exposure to healthy tissues. Additionally, collimation reduces the production of scatter radiation, which can otherwise affect the surrounding environment and compromise image quality. By focusing the X-ray beam precisely, collimation enhances both patient safety and the accuracy of diagnostic imaging. (Yin Mar Hlaing, 2017)

2.6.5 Dose Limits

ICRP recommends dose limits to manage ionizing radiation exposure and to protect people from adverse effects. These limits aim to prevent acute and chronic radiation- induced tissue reactions, deterministic effects, and to decrease the probability of cancer, stochastic effect, while still allowing the use of ionizing radiation for beneficial purposes. Recommended dose limits Occupational and public are shown in table 2.3.

Table 2.3 - ICRP Dose Recommendations

Type of Dose Limit	Limit on Dose from Occupational Exposure	Limit on Dose from Public Exposure
Effective Dose	20 mSv/yr, averaged over defined five-year periods, with no single year exceeding 50 mSv	1 mSv/yr
Effective Dose	Once employee declares pregnancy, the dose to embryo/fetus should not exceed 1 mSv during remainder of pregnancy	-
Equivalent Dose: Lens of the Eye	20 mSv/yr, averaged over defined five-year periods, with no single year exceeding 50 mSy	15 mSy/yr
Equivalent Dose: Skin	500 mSv/yr	50 mSv/yr
Equivalent Dose: Hands and Feet	500 mSv/yr	-

Source: Frane & Bitterman, 2023

2.6.6 Radiation Monitoring Instruments

Radiation monitoring instruments are essential for radiation workers, as radiation is not detectable by human senses. These instruments are used for individual monitoring and area monitoring. The devices employed to measure radiation levels are commonly known as area survey meters or area monitor. The instruments utilized to record the dose equivalents received by individuals who work with radiation are referred to as personal dosimeters or individual dosimeters.

(i) Survey Meters

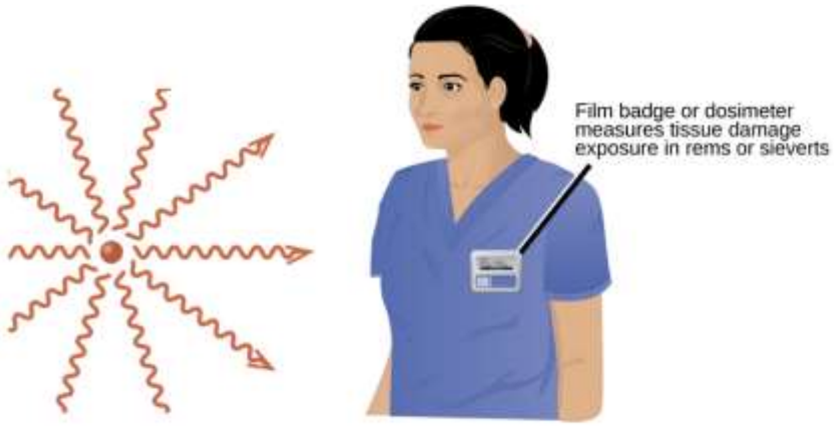
Survey meters are portable equipment designed to enable one to evaluate a particular radiation hazard. In and around laboratories containing radioactive materials or other radiation sources, survey meters are used to track radiation levels. Survey meters commonly used for radiation protection level measurements include ionization chambers, proportional counter and GM counter.

(ii) Personal Dosimetry

Since the radiation workers are exposed to ionizing radiation from various sources, such as x-ray, or radioactive materials, it is vital to monitor and limit the radiation dose received by the workers, and to follow the principle of ALARA.

Personal dosimetry is a key component of occupational radiation protection, and it is required for any person entering a restricted zone where radiation sources are present. Personal dosimetry is the measurement of the radiation dose received by an individual worker, using devices such as radiation badges, rings, or electronic dosimeters. These devices can detect and record the type, energy, and intensity of the radiation that the worker is exposed to. Personal dosimetry help to ensure that workers are not exposed to radiation levels exceeding their radiation protection plan or maximum permissible dose limits. If a worker exceeds 0.5 mSv for the E dose, 5 mSv for the lens dosage, or 15 mSv in a month, the WHO recommends that the Radiation Protection Officer (RPO) should contact them directly to address the unusual exposure and any related difficulties. It also helps to identify area where exposure levels are higher than expected, that can lead to improved safety procedures and equipment. The dosimetry service laboratory should notify the occupational workers without delay if the exposure limit values are exceeded. There are several types of personal radiation dosimeters including: Film badges, Thermoluminesent dosimeters (TLD), Optically Stimulated luminescence dosimeters (OSLD). Dosimeters are normally worn outside of clothing. A "whole body" dosimeter is worn on the chest or torso to represent the dose to the entire body. (Dosimeter, 2023). It is shown in figure 2.2.

Figure 2.2 Example of whole-body dosimeter positioning



Source: Dosimeter, 2023

2.6.7 Radiation Warning Sign

A radiation warning sign is a symbol that indicates the presence of dangerous levels of ionizing radiation, such as from radioactive materials or devices. The most common radiation warning sign is the trefoil, which consists of three blades in a circle around a dot. Basic ionizing radiation symbol of ISO 361 is shown in Figure 2.3, which is adopted in Myanmar as radiation warning sign. Where there are certain amounts of radioactive materials are present or where certain doses of radiation could be received, a yellow sign with a three-bladed symbol in black must be displayed.

In 2007, a new supplementary radiation warning sign was introduced by the IAEA and the ISO to warn the public about the dangers of large sources of ionizing radiation, such as food irradiators or medical equipment. The new sign, as shown in figure 2.4, shows skull and crossbones, radiating waves, and a running figure with and arrow pointing away from the scene. The new sign is intended to be more intuitive and recognizable than the trefoil, and to be placed on the device housing the source, not on the building or the container.

Figure 2.3 ISO 361 International ionizing radiation trefoil symbol

Source: International Atomic Energy

Figure 2.4 ISO 21482 high-level sealed-source ionizing radiation

Source: International Atomic Energy

2.6.7 Radiation Protection Training

To get the safety awareness, all workers handling ionizing radiation must possess a foundational understanding of general radiation protection to ensure the implementation of safe operational procedures. With rapid technological advances in the healthcare sector and a growing demand for diagnostic and treatment services, the utilization of ionizing radiation is on the rise. In light of these developments, healthcare professionals working in radiation environments is more needful for radiation protection training. This training is crucial not only for safeguarding the well-being of healthcare workers themselves but also for the protection of patients, the general public, and the surrounding environment. As the use of ionizing radiation becomes increasingly integral to medical practices, comprehensive training ensures that healthcare professionals are well-equipped to navigate the complexities of their roles responsibly and safely.

2.7 The Economic Impacts of Radiation Protection on Healthcare Workers

Healthcare workers, particularly those in radiology, nuclear medicine, and radiation oncology, are exposed to ionizing radiation regularly. Healthcare workers' exposure to different radiology waves leads to acute effects like dermatitis, mucositis, and hair loss, as well as long term complications such as cataracts, skin issues, genetic problems, and cancer due to disruptions in normal DNA functioning. Specifically, the healthcare workers exposed to ionizing radiation develop cancer by approximately more than 40% compared to patients and other groups of radiation workers (Behzadmehr et al.). Implementation of effective radiation protection measures, such as proper shielding, personal protective equipment (PPE), and safety protocols, reduces the incidence of occupational illnesses. This, in turn, lowers healthcare costs related to the treatment, rehabilitation, and potential disability of affected healthcare workers. The healthcare workers can enhance their professional competence and confidence by ensuring that they follow the principles of justification, optimization and limitation of radiation exposure. They can also protect their reproductive health and the health of their generation by avoiding unnecessary or excessive radiation exposure. Therefore, radiation protection for healthcare workers is not only a matter of occupational health and safety, but also a matter of economic health and social welfare. By investing in radiation protection measures, such as personal protective equipment, dosimetry, quality assurance, and education, healthcare facilities can enhance the well-being and performance of their staff, and ultimately, the quality and safety of patient care.

2.8 Review on Previous Studies

While extensive research has been conducted internationally to assess the awareness levels of radiation protection and safety, a noticeable scarcity exists in the context of Myanmar. Below are summaries of notable studies:

Yinn Mar Hlaing (2017) conducted a study on radiation safety awareness among medical doctors at North Okkalapa General and Teaching Hospital. The study aimed to assess the radiation safety awareness level among medical doctors at the mentioned hospital. The work was designed as cross-sectional study to assess the radiation safety awareness among 128 medical doctors who were not specialized in radiation environment at North Okkalapa General and Teaching Hospital. The survey was assessed by 4 sections of questionaries. The study revealed that there is a lack of awareness among medical doctors regarding radiation safety. More than half of the doctors incorrectly believed that there is a safe daily dose of X-ray radiation. Only half of the doctors were aware that mammography uses ionizing radiation, and MRI does not use ionizing radiation. Additionally, most of the doctors had limited knowledge about the stochastic effects of radiation, including the risk of cancer in the future. Furthermore, most of the doctors were not aware that bone has low radio-sensitivity, and only a few participants knew that cataracts can result from radiation exposure. These findings highlighted the need for improved radiation safety education and training programs for medical professionals to ensure the safe and effective use of radiation in medical practice.

Erkan et al. (2019) conducted the research on the investigation of radiation safety awareness among healthcare workers in an education and research hospital. The aim of this research is to determine the knowledge, attitude, and behaviors of healthcare personnel regarding radiation safety in an education and research hospital in Istanbul, Turkey. The study utilized a descriptive research design and employed a questionnaire consisting of 20 questions. The google form survey questionnaire was administered to 101 healthcare personnel working with radiation sources in operating rooms, endoscopy, and radiology units. The participants include doctors, nurse, auxiliary staff and radiological technicians. The obtained data was analyzed using the Statistical Package for the Social Sciences (SPSS) 22.0 program, and the chi-square test was applied to the results. The study found that the healthcare personnel lacked adequate knowledge about radiation safety, highlighting the need for improved training and infrastructure to ensure radiation safety in the healthcare setting.

Zervides et al (2019) conducted the research on assessing radiation protection knowledge in diagnostic radiography in the Republic of Cyprus. This research was the first of this type of research in the Republic of Cyprus. The aim of this research was to evaluate the level of knowledge on radiation protection in diagnostic radiography among radiographer. This study, conducted among radiographers in Cyprus through the Cyprus Society of Registered Radiologic Technologists & Radiation Therapy Technologists, employed a quantitative descriptive analysis using a questionnaire comprising 22 multiple-choice questions to gather data. The results indicated that the radiographers possess good levels of knowledge in radiation protection but there were some areas of confusion, particularly regarding dose limits and national radiation protection legislation. The workplace, type of work license, and years of clinical experience of the participants displayed statistically significant differences in mean knowledge scores. Additionally, there were no statistically significant differences in mean scores between genders, and the distribution of mean scores across different age groups was not statistically significant. The study also highlighted the influence of workplace and work license on radiation protection knowledge, emphasizing the importance of consistent radiation training across all types of workplaces. Overall, the study demonstrated a very good level of knowledge on radiation protection among healthcare workers and underscored the necessity of education for radiographers in relation to national radiation protection legislation.

Khamtuikrua, C., & Suksompong, S. (2020) studied awareness about radiation protection among healthcare personnel. The study aimed to assess the level of awareness and knowledge about radiation hazards among anesthesia personnel and surgical subspecialists in Thailand and this study focused on anesthesia personnel and surgical subspecialists in a specific academic center in Bangkok, Thailand. This study consisted for a total of 270 participants. This research was questionnaire-based cross-sectional study and the Google form online- questionnaire was distributed by email to participants. The research utilized a questionnaire consisting of three sections: demographic information, awareness about radiation protection practices, and knowledge about radiation hazard. Predictive Analytics Software Statistics 18.0.0 was used for data analysis. The findings revealed a high level of awareness about radiation hazards among the participants, with most reporting the habitual use of protective equipment except lead googles. However, the study also highlighted inadequate knowledge about radiation hazards, particularly concerning radiation doses, use of lead goggles, and safe distances from radiation machines. This research underscored the necessity to improve awareness and knowledge about radiation hazards among anesthesia personnel and surgical subspecialists.

Indukuri, S., & Easwaramoorthy, V. (2021) conducted research to find awareness of Radiation Protection Safety and Hazards among Healthcare Workers and Paramedical Students in a hospital setting. The study's objectives include comparing and evaluating the participants' knowledge about radiation protection, safety, and identification of radiation sources, assessing their awareness of radiation hazards, and evaluating the necessity for training sessions on radiation protection, safety, and hazards. The research utilized an online questionnaire consisting of 20 questions to gather data on the participants' knowledge and awareness of radiation protection and safety. This study consisted of 74 participants covering healthcare workers and paramedical students from various department such as Radiology, Nuclear Medicine and Urology and Anaesthesia Technology from various hospitals and diagnostic centers from Chennai, Kerala and Madurai. The findings indicated that there was a need for effective and frequent trainings for healthcare workers and paramedical students to progress their knowledge of radiation protection, safety, and hazards. This study underscored the importance of assessing and improving the knowledge and awareness of radiation protection and safety among healthcare personnel and paramedical students to ensure the safety of both workers and patients in healthcare settings.

Ud Din Malik et al. (2022) conducted a study on radiation hazards and protection among medical and imaging technology students using a questionnaire survey. The study aimed to assess the knowledge and perception of radiation hazards and protection involved in radiological examinations among students in the field of Medical and Imaging technology. The sample size was 216 participants. The authors used a questionnaire survey with 19 multiple-choice questions which were shared to participants by Google Form. The results showed that the participants had a good knowledge level about ionizing radiation hazards and protection in radiological examinations. However, the study also found that the participants had less knowledge about the use of TLD and equivalent dosage during X-ray examination. The authors concluded that there is a requirement for regular training and ongoing monitoring of occupationally exposed healthcare workers as well as students to ensure compliance with radiation safety regulations.

CHAPTER III
RADIATION PROTECTION FUNCTIONS IN MYANMAR

The radiation protection functions in Myanmar are primarily overseen by the Department of Atomic Energy (DAE), established under the Ministry of Science and Technology. The DAE is responsible for a range of activities aimed at ensuring the safe use of nuclear technology and protecting individuals and the environment from radiation hazards.

3.1 History of Department of Atomic Energy

Myanmar has had a longstanding interest in nuclear energy for peaceful purposes. In the Union of Burma Applied Research Institute (UBARI), an Atomic Energy Division was established in 1956. UBARI began as the Central Research Organization (CRO) and eventually became the Myanmar Scientific and Technological Research Department (MSTRD). Until 1997, the Atomic Energy Commission (AEC) was a branch of UBARI, CRO, and MSTRD. In 1997, the DAE was established as an independent government department, incorporating the Atomic Energy Research Department and the Research Policy Direction Board (DAE Myanmar).

Myanmar joined the International Atomic Energy Agency (IAEA) as a member country in 1957 and has actively participated in its programs since then, benefiting from scholarships and training initiatives. Recognizing the importance of embracing modern technology in all fields, including maritime, aerospace, medical and nuclear, the Myanmar Government established the Ministry of Science and Technology (MOST) in October 1996 (DAE Myanmar).

The DAE was formed under the MOST to conduct research, development, and training in the field of atomic energy as well as to ensure the safety of the radiation source and the protection against nuclear radiation hazards. The DAE, with the help of IAEA, has been actively working towards the development and promotion of peaceful nuclear technology applications (DAE Myanmar).

The main objectives of DAE are:

- To carry out research works for the development of nuclear technology in the country
- To carry out research, development and training in the field of atomic energy
- To protect radiation hazards or to implement nuclear radiation protection
- To coordinate with government and private sectors for their nuclear technology applications and promotion

The DAE is composed of 7 Divisions including Radiation and Nuclear Safety Division.

Radiation and Nuclear Safety Division is composed with 6 sections as:

(1) Registration and Licensing Section
(2) Inspection Section
(3) Food and Environmental Monitoring Section
(4) Occupational and Medical Exposure Control Section
(5) Secondary Standard Dosimetry Laboratory
(6) Waste Management and Transportation Section

Objectives of Radiation and Nuclear Safety Division are

(1) Carrying out measures for protection of radiation workers, people and the environment from harmful effects of nuclear and ionization radiation
(2) Issuing Licenses after verifying compliance with the safety requirements of Radioactive Materials and Radiation Apparatus for safe use of radiation hazards carried out by the Inspectors of the Department
(3) Dissemination of radiation knowledge to the public
(4) Coordination with relevant institutions in radiation emergency programs

Regarding the responsibilities of DAE, the Atomic Energy Law, enacted on 8 June 1998 in Myanmar, delegates the Department of Atomic Energy (DAE) with two primary responsibilities. The first is to promote the use of nuclear technology for the benefit of Myanmar's people, and the second is to implement regulatory controls to protect workers who work with radiation and radioisotopes, as well as the general public, from the harmful effects of ionizing radiation.

3.2 Radiation Protection Measures

The Republic of the Union of Myanmar National Report for the 7th review meeting of the convention on nuclear safety stated that the Atomic Energy Law governs the management of ionizing radiation within workplaces, encompassing all activities posing a risk of ionizing radiation exposure. Under this regulation, the Department of Atomic Energy (DAE) holds the responsibility for licensing and overseeing sources of ionizing radiation. Adhering to the fundamental safety standards outlined by the International Atomic Energy Agency (IAEA), the DAE prioritizes safeguarding the health of workers and the public from the hazards associated with ionizing radiation.

Operationalizing this framework falls under the purview of the Radiation and Nuclear Safety Division within the DAE. This division oversees the implementation of legal mandates and ensures day-to-day compliance with established safety protocols. Inspections conducted by the division aim to verify adherence to legislative requirements and license conditions. It is also an objective of the programme to assess the level of radiation protection in place at each licensed practice and to encourage licensees to strive to attain the best practice in relation to radiation protection.

To prevent exceeding individual dose limits as recommended by the ICRP, each radiation worker in hospitals, departments, companies, and clinics is mandated to wear personal monitoring dosimeters. These dosimeters measure ionizing radiation exposure over a two-month monitoring period, contributing to effective radiation safety management.

3.3 Current Radiation Safety and Protection Activities by DAE

The Radiation and Nuclear Safety Division within the Department of Atomic Energy is currently working to issue licenses for the import and export of radioactive materials and radiation apparatus. This process involves thorough inspections in accordance with guidelines set by the IAEA. The department's inspectors visit sites where radioactive materials and radiation apparatus are used to ensure compliance with licensing, registration, and renewal procedures, following the Code of Practices of the IAEA's Basic Safety Standards (DAE Myanmar).

Additionally, the department is tasked with educating individuals on radiation protection and the safe handling of radioactive materials. Undergraduate and postgraduate students are delivered practical lessons on subjects related to radiation protection. This includes providing lectures to trainees in Imaging, such as those in their fourth year at the Military Institute of Nursing and Paramedical Science (MINPS), as well as first-year M.Sc. trainees in Imaging. Furthermore, the department regularly conducts lectures on radiation protection for government and private radiation workers, as well as staff members from the Customs Department and the Myanmar Police Force (DAE Myanmar).

Moreover, as for personal radiation monitoring devices, DAE is expanding personal dosimetry services to the radiation workers on national level (DAE Myanmar).

3.3.1 Personal Radiation Dosimetry Service

In 1991, the Personnel Radiation Monitoring service was introduced using Thermoluminescent Detectors (TLD), established through an IAEA-assisted project. The IAEA provided satisfactory training and appropriate equipment. In early 1997, a fundamental radiation protection course was conducted by the Myanmar Atomic Energy Committee (MAEC) for hospital radiation workers in Mandalay. Then the personal radiation monitoring service expanded nationwide (DAE Myanmar).

The personnel radiation monitoring service's goal is to ensure that workers who are exposed to ionizing radiation, whether directly or indirectly, stay below the dosage limits specified by the ICRP, and that no one is exposed to the maximum permissible dose.

The personnel radiation monitoring service is concerned to control radiation hazards by monitoring the radiation exposure of workers involved in the use of ionizing radiations and isotopes across various fields such as medicine, research, industry, and agriculture. Individual monitoring is conducted using equipment carried by the worker. Currently, optically stimulated luminescence detectors (OSLD) are being used for personnel radiation monitoring. These detectors are utilized by workers exposed directly or indirectly to radiation in their workplaces. Each monitoring period for a service spans two months.

The Department of Atomic Energy (DAE) provides OSLD dosimeters free of charge to radiation healthcare workers in public hospitals. However, for healthcare workers in private hospitals, this service is available for a fee (DAE Myanmar).

3.3.2 Recommended Dose Limits in Myanmar

For radiation protection, the Department of Atomic Energy (DAE) adheres to the recommended dose limits by the International Commission on Radiological Protection (ICRP). The recommended dose equivalent limits are as follows:

Table 3.1 - Recommended Dose Limits in Myanmar

Occupational Exposure	20 mSv/year (averaged over 5 years, with no more than 50 mSv in a single year)
Public Exposure	1 mSv/year
Skin (Extremity) Exposure	500 mSv/year (e.g., wrist, ankle, feet)
Lens of the Eye	150 mSv/year

Source: (DAE Myanmar).

3.4 Radiation Protection Course in Academic Curricula of Healthcare Sectors

Radiation protection is an integral part of the curriculum for radiation-related programs in Myanmar. This critical subject is essential for ensuring the safety and efficacy of medical procedures involving radiation. At the University of Medical Technology, radiation protection is included in the curriculum for second-year and third-year students majoring in medical imaging technology and radiotherapy technology. These courses provide students with the knowledge and skills necessary to handle radiation safely, understand the principles of radiation physics, and apply protective measures in clinical settings.

Similarly, the Military Institute of Nursing and Paramedical Science (MINPS) incorporates a radiation protection course into its curriculum. This inclusion underscores the importance of radiation safety across various medical disciplines, ensuring that future healthcare professionals are well-equipped to protect themselves and their patients from the potential hazards of radiation exposure.

3.5 Overview of Radiation Medical Services of Selected Hospitals

In Myanmar, the public hospitals facilitated with extensive uses of radiation including radiotherapy centres exit in Yangon, Mandalay, Nay Pyi Taw and Taunggyi. In addition, radiation therapy treatment is available at Defence Services Hospitals and private hospitals in Yangon and Nay Pyi Taw. Yangon has the largest numbers of hospitals which have the extensive uses radiation for radiological imaging and nuclear medicine and radiotherapy. According to 2022 Myanmar Statistical Year Book, Yangon Regions have 67 Private Hospitals and 83 Public Hospitals. Among them 5 Private hospitals and 2 defence hospitals with extensive medical services were selected in this research.

Moe Kaung Treasure Private Hospital, particularly known for its Maternal and Child Hospital, is a reputable healthcare facility in Myanmar. This hospital was established in May 2021 offering a wide range of services. The hospital offers advanced imaging services PET CT Scan, CT and Digital X-ray. Moe Kaung Oncology Centre provides comprehensive services including radiation uses services of radiotherapy, concurrent chemo- radiotherapy. Brachy therapy. The centre is equipped with state-of-the-art technology, including a linear accelerator, PET CT, and a cyclotron. (Moe Kaung Treasure Women and Children Hospital)

SSC Hospitals, also known as Shwe Gon Daing Hospital, is a private hospital a capacity of 200-bedded multi-specialty facility. It was stablished in 2001. The hospital offers various medical services and specialties. Regarding medical radiation services, SSC Hospital does provide a range of diagnostic and treatment options, including radiology and imaging services including X-rays, CT scans, and other radiographic procedures. (Pro Clinic)

Victoria Hospital is a private healthcare facility with a capacity of 100 beds for in-patient care. It was established in 2011. The hospital offers a range of medical radiation services for patients, including radiation oncology, which uses high-energy radiation to shrink tumors and kill cancer cells. Additionally, Victoria Hospital provides advanced diagnostic imaging services such as MRI, CT scans, digital X-rays, and mammograms to support accurate diagnosis and treatment planning. (Victoria Hospital, 2024)

Pinlon Hospital is a private healthcare facility with a capacity of 200 beds and it was established in 2007. The hospital offers a medical service including radiation oncology and nuclear medicine (PET-CT & SPECT-CT), For cancer treatment, Pinlon Hospital's cancer center is notable for pioneering advanced radiotherapy techniques in Myanmar, such as 3D conformal radiation therapy and intensity-modulated radiation therapy (IMRT). In 2022, The center is equipped with the Varian TrueBeam LINAC Radiotherapy System, the first of its kind in Myanmar, providing state-of-the-art radiotherapy services. (Pinlon Group of Hospitals)

Grand Hantha International Hospital is one of Myanmar’s premier private healthcare facilities. It was established in 2017 and it boats a large capacity of 700 beds. The hospital provides a comprehensive range of medical services including medical radiation services for patients. Imaging department equipped with diagnostic tools such as MRI, CT scanners, digital X-rays, mammography, and DEXA scans. For cancer treatment, radiation oncology department offers service with Liner accelerator, Brachytherapy, CT Simulator, Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT). (Grand Hantha International Hospital).

Defence General Service Hospital 1 in Yangon is a significant medical facility operated by the Directorate of Medical Services of Myanmar's military. It is a 1000-bed hospital providing extensive healthcare services. The hospital is equipped with advanced diagnostic equipment including X-ray, CT scan, Fluoroscopy and C-Arm machines.

No. 2 Military Hospital is located at Dagon township. It has a capacity of 500 beds and it serves to patients with medical uses of radiation with radiological imaging procedures and radiotherapy. Imaging department equipped with three X-ray machines and one CT scan as diagnostic tools. Oncology Department offers radiation oncology services with Linear accelerator and Brachytherapy.

CHAPTER IV
SURVEY ANALYSIS

In order to fulfill the objective of this study, this chapter mainly describes the analysis on awareness level of radiation protection of healthcare workers from selected hospitals with extensive radiation facilities in Yangon.

4.1 Survey Profile

The study included healthcare workers working in radiation environments across various departments such as Oncology, Nuclear Medicine, Radiotherapy, Radiology, and other laboratories. This study encompassed healthcare workers from different hospitals with extensive radiation facilities in the Yangon Region.

Seven hospitals with extensive radiation facilities in Yangon participated in this study. The study population comprised healthcare workers working in radiation environments within these hospitals. Respondents were from two Defence Services General Hospitals and five private hospitals. The surveys were conducted from the last week of March to the last week of April 2024, with 135 participants fully responding out of the 145 who were initially surveyed. The final analysis covered these 135 respondents: 41 from No. 2 Military Hospital, 22 from Moe Kaung Treasure Hospital, 19 from Defence Service General Hospital (No,1, 1000 Bedded) DSGH (1/1000), 16 from Grand Hantha International Hospital, 13 from Pinlon Hospital, 13 from Victoria Hospital, and 11 from S.S.C. Hospitals. The survey population profile of this study is shown in Table 4.1.

Table 4.1- Survey Population Profile

Sr. No	Participated Hospitals	Department Name	Number of Respondents	Total no of Respondents	% of Respondents
1	DGSH (1/1000)	Radiology	19	19	14.1
2	Grand Hantha International	Radiology	15	16	11.9
		Nuclear Medicine	1		
3	Moe Kaung Treasure	Radiology	10	22	16.3
		Nuclear Medicine	4		
		Radiotherapy	5		
		Oncology	2		
		Other (Pharmacy)	1		
4	No.2 Military Hospital (500 Bedded)	Radiology	17	41	30.4
		Radiotherapy	12		
		Oncology	12		
5	Pinlon	Radiology	11	13	9.6
		Nuclear Medicine	2		
6	S. S. C	Radiology	11	11	8.1
7	Victoria Hospital	Radiology	12	13	9.6
		Lab	1		
	Total		135	135	100

Source: Survey Data, 2024, March-April

4.2 Survey Design

This study was designed to be included a wide range of participants, encompassing individuals with various educational backgrounds such as Bachelor's

Degrees, Master's Degrees, Ph.D. Degrees, Diplomas, Undergraduates, and high school. The participants' professions included medical doctors, radiological technicians, nurses, and auxiliary staff.

The questionnaire used in this research was developed after reviewing previous international and national studies on similar subjects and consulting with radiation protection officers from the DAE. The survey questionnaire is organized into five parts: Part A covers socio-demographic characteristics (e.g., gender, age, marital status, education, occupation) with 9 statements. Section B focuses on awareness of radiation, containing 14 statements. Section C explores radiation protection and safety awareness with 12 statements. Section D investigates biological hazards of radiation awareness, comprising 18 statements. Section B, C and D statements answered through multiple-choice and yes or no questions. Finally, Section E assesses compliance with radiation protection practices using a three-point Likert scale. The questionnaire was prepared in two versions—an English version and a native Myanmar version—to accommodate respondents with diverse educational backgrounds.

4.3 Survey Results and Discussions

This section presents data, analysis, and interpretation of survey findings obtained from responses provided by healthcare workers through the survey questionnaire.

4.3.1 Socio-Demographic Details of Respondents

Socio- Demographic data obtained in this survey conducted among healthcare workers exposed to radiation are presented in Table 4.2.

Table 4.2 - Socio-Demographic Characteristics of the healthcare workers

Sr. No.	Socio- Demographic Factors		Number of Respondents	Percentage (%)
1	Gender	Male	74	54.8
		Female	61	45.2
		Total	135	100
2	Age	18-30	40	29.6
		31-40	74	54.8
		41-50	14	10.4
		Over 50	7	5.2
		Total	135	100
3	Marital Status	Single	64	47.4
		Married	71	52.6
		Total	135	100
4	Education	Bachelor's Degree	92	68.2
		Master's Degree	28	20.7
		Ph.D Degree	2	1.5
		Under Graduate	6	4.4
		High School	7	5.2
		Total	135	100
5	Occupation	Medical Doctor	38	28.1
		Nurse	3	2.2
		Auxiliary Staff	9	6.7
		Radiological Technician	80	59.3
		Other	5	3.7
		Total	135	100

Source: Survey Data, 2024, March-April

The survey included respondents, with 74 males (54.8%) and 61 females (45.2%). The largest group of respondents falls withing the age range of 31-40 years (54.8%), followed by age group of 18-30 years (29.6%), 41-50 years (10.4%), and those over 50 years (5.2%). Marital status data showed that 71 respondents (52.6%) were married, while 64 (47.4%) were single. Regarding education, most respondents held a Bachelor's degree (68.2%), followed by those with Master's degrees (20.7%), high school education (5.2%), undergraduate degrees (4.4%), and Ph.D. degrees (1.5%). Respondents were from seven hospitals, with the highest numbers from No.2 Military Hospital (30.4%), Moe Kaung Treasure (16.3%), Defence General Service Hospital

(1/1000) (14.1%), and others from different hospitals. In terms of occupation, the majority (59.26%) were Radiological Technicians, followed by Medical Doctors (28.15%), Auxiliary Staff (6.67%), and other professionals (3.7%, including Medical Physicists, Pharmacists, and Medical Imaging Technologists). Nurses were the group with the lowest number of respondents (2.22%).

Table 4.3 presents distribution of radiation exposures of respondents.

Table 4.3- Distribution of Radiation Exposure of Respondents

Sr. No.	**Items**		**Number of Respondents**	**Percentage (%)**
1	Department (Field of Specialization)	Oncology	14	10.4
		Nuclear Medicine	7	5.2
		Radiotherapy	17	13.3
		Radiology	95	69.6
		Other (Pharmacy, Lab)	2	1.5
		Total	135	100
2	Working Experience (number of years working in radiation environment)	Less than 1 year	13	9.6
		1 to 5 years	36	26.7
		5 to 10 years	29	21.5
		10 to 15 years	33	24.4
		more than 15 years	24	17.8
		Total	135	100
3	Radiation Protection and Safety Training (Attended?)	Yes	55	40.7
		No	80	59.3
		Total	135	100

Source: Survey Data, 2024 March-April

Regarding specialization, a majority specialized in Radiology (69.6%), followed by Radiotherapy (13.3%), Oncology (10.4%), Nuclear Medicine (5.2%), and other fields (1.5%). It shows that high demand for Imaging Services in those hospitals.

The respondents' working experience in radiation environments varied, with 26.7% having 1-5 years, 24.4% having 10-15 years, 21.5% having 5-10 years, 17.8% having more than 15 years, and 9.6% having less than 1 year.

Concerning radiation protection training, a significant number of respondents (59.3%) indicated that they had not received previous training, while 40.7% had attended training courses.

4.3.2 Awareness for Radiation

The survey results on respondent's knowledge about radiation is shown by Table 4.4. The data provides insight into participants' understanding of various aspects of ionizing radiation and its applications. For radiation workers, it is crucial to acknowledge that ionizing radiation produces harmful effects on the human body. A strong majority, 96%, correctly identified that ionizing radiation produces harmful effects on the body, indicating a high level of awareness regarding the general risks associated with radiation exposure.

Similarly, nearly all participants (99.3%) correctly recognized that X-rays are a type of ionizing radiation, testing the respondents' knowledge about the types of ionizing radiation, reflecting a solid grasp of fundamental radiation concepts.

Concerning understanding of the nature of X-rays, when asked whether X-rays are electromagnetic radiations of high frequency, only 60% answered correctly, while 40% were incorrect. This indicates some confusion about the fundamental nature of X-rays.

When assessing the respondents' knowledge about the dual applications of X-rays in both diagnosis and therapy, 95% of participants correctly understood that X-rays can be used as dual purposes for both diagnostic and therapeutic, indicating strong awareness among the participants about the versatile applications of X-rays in the medical field.

Table 4.4 – Respondents' Knowledge about Radiation

No.	Items	Respondents with correct answer		Respondents with incorrect answer	
		Nos.	%	Nos.	%
1	Ionizing radiation produces harmful effects on the body.	129	96	6	4
2	X-ray is type of ionizing radiation	134	99.3	1	0.7
3	X-ray is Electromagnetic radiations of high frequency	81	60	54	40
4	X-ray can be used for both diagnostic and therapeutic purposes	128	95	7	5
5	Medical X-rays are a major source of man-made radiation exposure.	111	82.2	24	17.8
6	Radiation becomes a risk depending on the frequency of exposure.	127	94.1	8	5.9
7	Diagnostic procedure: CT scan uses ionizing radiation	132	97.8	3	2.2
8	Diagnostic procedure: Ultrasound uses ionizing radiation	127	94.1	8	5.9
9	Diagnostic procedure: Mammography uses ionizing radiation	120	88.9	15	11.1
10	Diagnostic procedure: MRI uses ionizing radiation	125	92.6	10	7.4
11	Diagnostic procedure: PET uses ionizing radiation	116	85.9	19	14.1
12	Diagnostic procedure: Barium swallow uses ionizing radiation	123	91.1	12	8.9
13	Diagnostic procedure: Dexa uses ionizing radiation	100	74.1	35	25.9
14	Both Gamma Camera and Radiopharmacy is source of radiation for nuclear medicine staff in Nuclear Medicine department	74	54.8	61	45.2

Source: Survey Data, 2024 March-April

Regarding the recognition of medical X-rays as a major source of man-made radiation exposure, 82.2% answered correctly, showing that most participants are aware of the significant contribution of medical imaging to radiation exposure. However, 17.8 %, a notable minority of respondents do not know that major source of man-made radiation exposure comes from medical X-rays.

The awareness of the concept of "Radiation becomes a risk depending on the frequency of exposure" is essential for individuals working in radiation environments to understand the cumulative effects of radiation exposure over time. 94.1% understood that radiation risk is dependent on the frequency of exposure, indicating a sound comprehension of exposure dynamics. A small percentage of 5.1 % incorrectly respond suggesting only a small percentage of respondents may not fully understand the relationship between frequency of exposure and the associated risks of radiation. This data reflects a strong overall awareness among the majority of respondents regarding the importance of managing and minimizing exposure to radiation to reduce potential health risks.

The results of a radiation protection awareness survey highlight varying levels of understanding among respondents regarding the use of ionizing radiation in different diagnostic procedures. For CT scan, a vast majority of respondents 97.8% correctly identified y that CT scans use ionizing radiation, indication a high level of awareness about the radiation exposure associated with CT scans. Very few respondents answered incorrectly.

For ultrasound, most respondents 94.1% correctly recognized that ultrasound does not use ionizing radiation. Ultrasound uses sound waves, which are non-ionizing. A small percentage of 5. 9% incorrectly believed it uses ionizing radiation.

For Mammography, A high percentage 88.9% correctly understood that mammography uses ionizing radiation. Mammography is an X-ray technique used for breast imaging. The 11.1 % of incorrect responses suggest some room for improvement in awareness.

For MRI (Magnetic Resonance Imaging), most respondents (92.6%) correctly identified that ionizing radiation is not used in an MRI scan. MRI makes use of radio waves and magnetic fields. However, a small 7.4 % incorrectly believed it uses ionizing radiation. For Positron Emission Tomography (PET), A high percentage 85.9% correctly recognized that PET scans use ionizing radiation. PET scans involve radioactive tracers to visualize metabolic processes. The incorrect 14.1% responses indicate a need for better education on this modality.

For Barium Swallow, most respondents (91.1%) correctly identified that a barium swallow involves ionizing radiation. This procedure uses X-rays to visualize the esophagus and stomach after ingestion of barium contrast material. The incorrect 8.9 % responses suggest good overall awareness.

For DEXA (Dual-Energy X-ray Absorptiometry), a significant majority (74.1%) correctly recognize that DEXA uses ionizing radiation to measure bone density. However, a notable percentage, 25.9 % incorrectly respond indicating a need for improved knowledge on DEXA scans. The survey indicates varying levels of awareness among respondents regarding the use of ionizing radiation in different diagnostic procedures. Awareness is highest for CT scans, mammography, PET scans, and barium swallows. However, there are gaps in knowledge, particularly for DEXA scans, and a small percentage of respondents are consistently unsure or incorrect across the modalities

Interestingly, when analyzing the responses to the survey question about the sources of radiation for nuclear medicine staff, only 54.8% correctly identified both the gamma camera and radiopharmaceuticals as sources of radiation in nuclear medicine, with 45.2% being incorrect. While gamma cameras do emit radiation, the primary source of radiation exposure for staff is the radiopharmacy, where radioactive materials are handled and prepared for imaging procedures. It appears that knowledge in this area depends on respondents' specific responsibilities, which is reflected in the fact that the number of respondents from the nuclear medicine field is minimal.

The survey results on respondents' knowledge about radiation indicate that participants generally demonstrate strong knowledge of radiation and its use in medical procedures. However, specific knowledge gaps were identified in areas such as the nature of X-rays and certain diagnostic procedures.

4.3.3 Awareness for Radiation Protection and Safety

Table 4.5 displays the distribution of awareness level for radiation protection and safety.

Table 4.5- Respondents’ Knowledge about Radiation Protection and Safety Awareness

No.	Items	Respondents with correct answer		Respondents with incorrect answer	
		Nos.	%	Nos.	%
1	The principles for radiation protection is Justification, optimization, and dose limitation	44	32.6	91	67.4
2	"ALARA" represents: As low As Reasonably Achievable	129	95.6	6	4.4
3	To adhere to the “ALARA” process, it must be-Minimize time, maximize distance, and use shielding	90	66.7	45	33.3
4	OSLD is a personal monitoring device	125	92.6	10	7.4
5	0.25 mm to 0.5 mm is the range of common thickness of lead aprons used for radiation protection	89	65.9	46	34.1
6	In radiation exposure protection, collimation of the radiation beam is also important	134	99.3	1	0.7
7	During the radiological guided procedure, without any protection you should not stand within-1 meter	22	16.3	113	83.7
8	The effective dose limit (whole body) for radiation workers is 20 mSv per year	110	81.5	25	18.5
9	The equivalent dose limits (lens and skin) for public is " Lens 15 mSv, skin 50 mSv"	84	62.2	51	37.8
10	For pregnant radiation workers, after declaration of pregnancy, the dose on the embryo/fetus should not exceed 1 mSv	93	68.9	42	31.1
11	Survey meter is used for both area and contamination monitoring	104	77	31	23
12	Awareness for radiation sign	135	100	0	0

Source: Survey Data, 2024 March-April

This section of survey conducted among healthcare workers aimed to evaluate their awareness and understanding of radiation protection and safety principles. The findings from the survey reveal both strengths and areas needing improvement in their knowledge and practices related to radiation safety.

Firstly, only 32.6% of respondents correctly identified the principles of radiation protection—justification, optimization, and dose limitation—while a significant 67.4% answered incorrectly. This demonstrates that only nearly a third of the respondents have a correct understanding of the fundamental principles of radiation protection. A significant portion of respondents selected "Minimize time, maximize distance, and use shielding." This indicates a prevalent misconception among the respondents. Although minimizing time, maximizing distance, and using shielding are important aspects of radiation safety, they are not the fundamental principles of radiation protection. This indicates a considerable lack of understanding of the foundational principles of radiation protection, highlighting a need for enhanced training and education in this area.

On a positive note, 95.6% of respondents correctly identified "As low As Reasonably Achievable" as the meaning of the acronym "ALARA". The ALARA principle is a cornerstone of radiation protection, emphasizing the importance of keeping radiation exposure to the lowest possible level. This indicates a strong awareness and understanding of the ALARA principle among the respondents.

However, only 66.7% could accurately describe the methods to adhere to the ALARA process, such as minimizing time, maximizing distance, and using shielding, indicating that while the principle is well-known, its practical application might not be as well understood. It seems that most respondents confuse ALARA, a specific aspect of the optimization principle and comprehensive three principles of radiation protection.

Furthermore, 92.6% of respondents correctly identified the function of an OSLD (Optically Stimulated Luminescence Dosimeter) as a personal monitoring device, demonstrating strong knowledge in this area. However, only 65.9% were aware of the common thickness range of lead aprons used for radiation protection (0.25 mm to 0.5 mm), suggesting that knowledge about protective equipment could be improved. It seems some of the respondents believed that thicker lead apron offers better shielding. While thicker lead aprons might offer greater protection, they are not commonly used due to their weight and practicality.

An impressive 99.3% recognized the importance of collimation in radiation exposure protection, indicating a high awareness of technical practices that enhance safety. Collimation plays a crucial role in radiation safety by focusing the radiation beam to the specific area of interest, thereby reducing unnecessary exposure to surrounding healthy tissues and organs. This practice helps minimize radiation dose to the patient while maintaining image quality and optimizing radiation protection for both patients and healthcare workers. Conversely, only 16.3% of respondents knew that one should not stand within 1 meter without protection during radiological procedures, showing a critical gap in understanding safe distances. According to the survey results, it is indicating that a substantial number of respondents believed a greater distance is necessary without realizing the critical danger zone within 1 meter and highlights a lack of precise understanding of safe distances.

Regarding dose limits, 81.5% of respondents correctly identified the effective dose limit for radiation workers as 20 mSv per year. This indicates a strong understanding among the majority of respondents about the regulatory limits for occupational radiation exposure.

However, only 62.2% were aware of the equivalent dose limits for the public's lens and skin (15 mSv and 50 mSv, respectively). Additionally, 68.9% correctly answered the dose limit for the embryo/fetus of pregnant radiation workers (1 mSv), showing a need for clearer communication about dose limits for vulnerable populations. Lastly, while 77% knew that a survey meter is used for both area and contamination monitoring, the awareness of radiation signs was perfect, with 100% of respondents correctly identifying them.

The section of this survey results indicates a generally good awareness of radiation protection of respondents, particularly concerning key concepts like ALARA and the use of dosimeters. However, there are notable gaps in understanding the principles of radiation protection, practical applications of ALARA, safe distances during procedures, and specific dose limits.

4.3.4 Awareness for Biological Hazards of Radiation

The survey responses of the participants regarding their awareness of biological hazards associated with radiation exposure are presented in Table 4.6. The results highlight significant findings, revealing a mix of strong awareness in certain areas and notable misconceptions and knowledge gaps in others.

Table 4.6- Respondents' Knowledge about Biological Hazards of Radiation

No.	Items	Respondents with correct answer		Respondents with incorrect answer	
		Nos.	%	Nos.	%
1	A primary biological hazard associated with occupational radiation exposure for healthcare workers is "Ionizing Radiation Effect"	124	91.9	11	8.1
2	The most common source of radiation exposure for healthcare workers is "Medical Imaging Procedures"	123	91.1	12	8.9
3	The unit of measurement for radiation dose equivalent is Sievert (Sv)	116	85.9	19	14.1
4	Stochastic effects are probabilistic, deterministic effects are certain	68	50.4	67	49.6
5	Deterministic effects occurred due to receiving high dose in short span of time	72	53.3	63	46.7
6	The main factor that determines the severity of a deterministic effect of radiation is the dose of radiation	89	65.9	46	34.1
7	Cancer induction is caused due to Stochastic effects.	100	74.1	35	25.9
8	The main factor that determines the severity of a stochastic effect of radiation is the dose of radiation	57	42.2	78	57.8

Source: Survey Data, 2024 March-April

Firstly, a majority (91.9%) of respondents correctly identified ionizing radiation effects as the primary biological hazard associated with occupational radiation exposure, indicating a high level of awareness about the fundamental risks posed by radiation. Similarly, 91.1% accurately recognized medical imaging procedures as the most common source of radiation exposure for healthcare workers, reflecting a strong understanding of their work environment's primary radiation sources.

Regarding the measurement of radiation dose equivalents, 85.9% correctly identified the unit as Sievert (Sv), suggesting a good grasp of basic radiation measurement concepts.

However, awareness of the differences between stochastic and deterministic effects showed more variability. Only 50.4% of respondents correctly understood that stochastic effects are probabilistic while deterministic effects are certain, indicating that nearly half of the respondents (49.6%) have misconceptions about these critical concepts. Furthermore, just over half (53.3%) correctly identified that deterministic effects arise due to obtaining a high dose in a short period of time, leaving a significant 46.7% with incorrect understanding. This gap in knowledge underscores the need for clearer education on how acute radiation exposure leads to deterministic effects. Similarly, while 65.9% correctly noted that the dose of radiation determines the severity of deterministic effects, a significant portion (34.1%) did not, highlighting low knowledge. The awareness of cancer induction as a stochastic effect was relatively high, with 74.1% of respondents answering correctly. However, understanding the main factor determining the severity of stochastic effects was notably lower, with only 42.2% correctly identifying the dose of radiation, while a substantial 57.8% did not. It seems that most of the respondents have a lack or weak understanding of the complexity of concepts related to deterministic and stochastic effects. This indicates a critical area where knowledge is lacking and needs to be addressed to ensure comprehensive understanding among healthcare workers.

The results of this section indicate that while there is a high level of awareness among healthcare workers about some fundamental aspects of radiation exposure and its biological hazards, there are significant gaps in understanding the detailed mechanisms and differences between stochastic and deterministic effects.

Table 4.7 represents the results of a survey on awareness regarding tissues with high radiation sensitivity.

Table 4.7- Respondents' Knowledge about Radio- sensitivity of Tissues

No.	Tissues with high radiation sensitivity	Responds with Yes		Respondents with No		Respondents with No Idea	
		Nos.	%	Nos.	%	Nos.	%
1	Kidney	22	16.3	**105**	**77.8**	8	5.9
2	Gonads	**131**	97	2	1.5	2	1.5
3	Bone	12	8.9	**116**	**85.9**	7	5.2
4	Liver	28	20.7	**100**	**74.1**	7	5.2
5	Muscle	9	6.7	**118**	**87.4**	8	5.9

Source: Survey Data, 2024 March-April

According to above table, a minority of respondents (16.3%) incorrectly identified that kidneys are highly sensitive to radiation and (77.8%) correctly believe that kidneys have not high radiation sensitivity for kidney. For gonads almost all respondents (97%) correctly recognize that gonads (ovaries and testes) are highly sensitive to radiation. This high level of awareness is crucial since radiation exposure to gonads can lead to significant reproductive and genetic risks. For bone, most respondents (85.9%) correctly understand that bone is not highly sensitive to radiation. A small percentage (8.9%) incorrectly believe bones are highly radiosensitive, showing good overall awareness of bone tissue's relative resistance to radiation compared to more sensitive tissues. For Liver, a minority of respondents (20.7%) incorrectly believe that the liver has high radiation sensitivity. The majority (74.1%) correctly identify that the liver is not highly radiosensitive, indicating a reasonable level of awareness about the liver's actual radiation sensitivity. For muscle, most respondents (87.4%) correctly recognize that muscle tissue is not highly sensitive to radiation. The low percentage of incorrect responses (6.7%) and unsure responses (5.9%) demonstrates a good understanding of muscle tissue's relative insensitivity to radiation.

The results of survey on awareness regarding diseases caused by radiation hazards represents in Table 4.8.

Table 4.8- Respondents' Knowledge about diseases of radiation hazards

No.	Tissues with high radiation sensitivity	Responds with Yes		Respondents with No		Respondents with No Idea	
		Nos.	**%**	**Nos.**	**%**	**Nos.**	**Nos.**
1	Osteopenia	39	28.9	**81**	**60**	15	11.1
2	Leukemia	**106**	**78.5**	25	18.5	4	3
3	Skin cancer	**106**	**78.5**	22	16.3	7	5.2
4	Cataract	**84**	**62.2**	41	30.4	10	7.4
5	Infertility	**112**	**83**	14	10.4	9	6.7

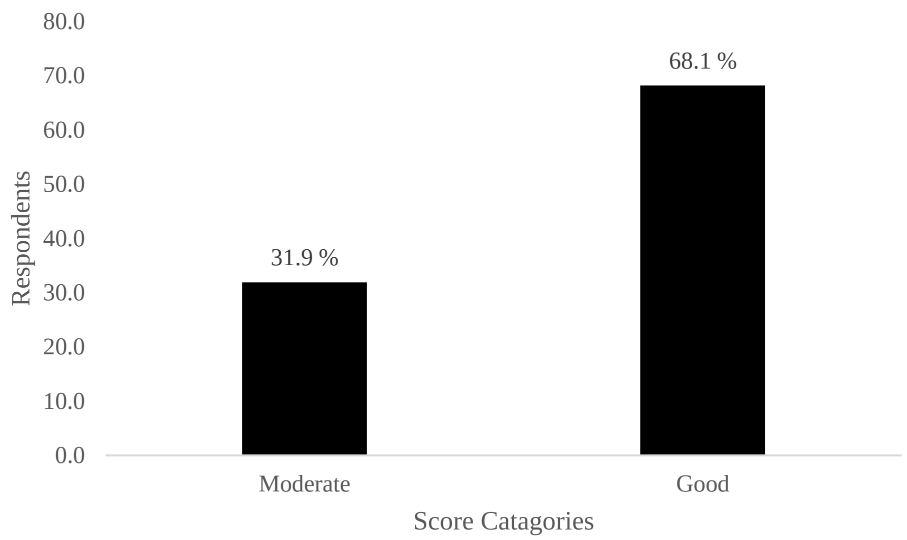
Source: Survey Data, 2024 March-April

For Osteopenia, a significant majority of respondents (60%) correctly believe that osteopenia is not associated with radiation exposure. Only 28.9% incorrectly recognize it as a potential consequence of radiation exposure, and 11.1% are unsure. For Leukemia, a large majority (78.5%) correctly identify leukemia as a disease that can be caused by radiation exposure. Leukemia is a well-known radiation-induced cancer, reflecting a high level of awareness among respondents. However, 18.5% of respondents are unaware, and 3% are unsure. For skin Cancer, most respondents (78.5%) correctly recognize skin cancer as a potential radiation-induced condition. This high awareness is important as radiation exposure is a known risk factor for skin cancer. The respondents of 16.3% incorrectly believe otherwise, with 5.2% who are unsure. For Cataract, a majority (62.2 %) correctly identify cataract a potential consequence of radiation exposure and 30.4 % of respondents incorrectly recognize and 7.4 % unknown. Cataracts can indeed result from radiation exposure, especially to the eyes. For Infertility, most respondents (83%) correctly identify infertility as a potential consequence of radiation exposure. This high level of awareness is crucial given the significant impact radiation can have on reproductive health. The 10.4% who are incorrectly believe otherwise and 6.7% who are unsure.

4.3.5 Investigation on Total Knowledge Score for Radiation Protection Awareness

To determine the knowledge score for radiation protection awareness, sections B, C, and D were assessed, encompassing a total of 44 questions. Each correct answer was awarded 1 point, while incorrect answers received 0 points. The total score for each respondent was converted into a percentage. Based on Ahmed et al. (2021), knowledge levels were categorized into poor, moderate, and good. In this study, a score of less than 40% was considered poor knowledge, 40-70% was considered moderate knowledge, and 70% and above was considered good knowledg**e.**

Figure 4.1 Distributions of Total Knowledge Score Categories of the Respondents



Source: Survey Data, 2024 March-April

Figure 4.1 illustrates the distributions of total knowledge score categories of the respondents. The bar graph presents the distribution of participants' total knowledge scores regarding radiation protection awareness, categorized into good, moderate, and poor levels. The analysis reveals that a substantial majority of participants, 92 out of 135 (68.1%), possess a good level of knowledge, indicating a strong understanding of radiation protection practices among this group. Meanwhile, 43 participants (31.9%) fall into the moderate knowledge category, suggesting that although they have a fair understanding, there is still room for improvement. Notably, there are no participants in the poor knowledge category, implying that all individuals surveyed have at least a basic awareness of radiation protection. This distribution reflects positively on this survey, as it shows that all participants have acquired at least a moderate level of knowledge, with the majority reaching a good level of comprehension.

4.3.6 Radiation Protection Compliance Awareness

This section assessed how well individuals adhere to established protocols and practices in environments with radiation exposure.

The distribution of radiation production practice is shown in Table 4.9.

Table 4.9- Responses to questions related to Radiation Protection Practice

No	Items	Never		Sometimes		Always	
		n	%	n	%	n	%
1	Do you use a dosimeter when working in radiation environment?	19	14.1	46	34.1	70	51.9
2	If you are using a dosimeter, is it routinely sent for measurement?	-	-	30	25.9	86	74.1
3	Do you use any protective shielding equipment to avoid the unnecessary exposure during you are working in radiation environment?	4	4.4	40	29.6	89	65.9
4	Do you use minimal exposure time?	1	0.7	30	22.2	104	77
5	Do you keep enough distance from the radiation source?	1	0.7	30	22.2	104	77
6	Do you provide lead aprons for all co-patients or staff in radiation environment?	4	3	35	25.9	96	71.1

Source: Survey Data, 2024 March-April

Table 4.5 presents the frequency of specific radiation protection practices among participants. A significant majority, 51.9%, consistently use a dosimeter while working in a radiation environment, reflecting a high level of awareness and adherence to safety protocols. However, 14.1% never use a dosimeter, indicating a gap that needs to be addressed through targeted awareness on the importance of personal radiation monitoring. Regarding the routine measurement of dosimeters, 74.1% of participants always send their dosimeters for measurement, ensuring accurate tracking of radiation exposure, which is crucial for long-term safety. Meanwhile, 25.9% do so only sometime, suggesting that consistent follow-up on this practice could improve overall safety.

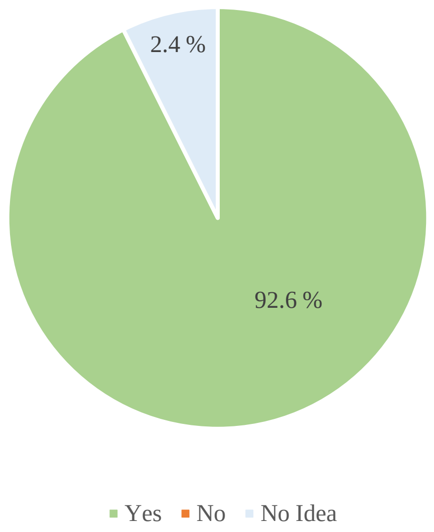
In terms of using protective shielding equipment, 65.9% always use such equipment, significantly reducing unnecessary exposure, while 4.4% never use it. This shows that while most participants are well-protected, a small portion may still be at risk due to a lack of protective measures. For minimizing exposure time, an impressive 77% of participants always use minimal exposure time, and the same percentage is noted for maintaining sufficient distance from the radiation source. These high percentages indicate strong adherence to these critical safety practices.

Lastly, 71.1% of participants always provide lead aprons for co-patients or staff in radiation environments, underscoring a strong commitment to protecting others. However, 3% never provide this protection. Overall, while the majority of participants demonstrate good practices in radiation protection, there are specific areas, such as the consistent use of dosimeters and protective equipment, where further education and reinforcement of safety protocols could enhance overall radiation safety.

4.3.7 Awareness of the Need for Periodic Radiation Protection Refresher Training

Figure 4.2 shows the pie chart illustrating the participants' responses for survey question regarding to refresher training of radiation protection. A majority (92.6%) indicated that periodic refresher training on radiation protection is needful. Remarkedly, there were no responses indicating that the training is unnecessary and only a small fraction of respondents, 2.4%, were unsure about the need for the training. This shows a strong recognition of the importance of ongoing education and training to ensure safety and compliance with radiation protection practices.

Figure 4.2 Pie Chart for Awareness of the Need for Periodic Radiation Protection Refresher Training (n=135)



Source: Survey Data, 2024 March-April

CHAPTER V
CONCLUSION

Radiation Protection is an important concern in daily practice of healthcare workers exposed to radiation. The survey of this thesis was designed to assess the awareness level of radiation protection among healthcare workers who are working in radiation environment of different hospitals in Yangon. The questionnaire used in the research was developed after consulting with radiation protection officers and covered five areas; characteristics of respondents, awareness of radiation, radiation protection and safety, biological hazards of radiation, and protection practices. Out of the 145 survey questionnaires initially distributed, 135 participants from seven hospitals provided complete responses.

5.1 Findings

As for radiation protection functions in Myanmar, it was found that the DAE, under the MOST, is responsible for ensuring the safe use of nuclear technology and protecting individuals and the environment from radiation hazards. The DAE oversees various activities related to radiation safety and regulation, implementing legal mandates and compliance checks to ensure adherence to safety protocols in radiation practices. This includes issuing licenses for radioactive materials and conducting inspections to verify compliance with safety standards. The DAE follows the ICRP recommended dose limits for radiation exposure, and each radiation worker is mandated to wear personal monitoring dosimeters to prevent exceeding individual dose limits. Additionally, the DAE provides Optically Stimulated Luminescence Dosimeter (OSLD) personal dosimetry services on a national level and conducts regular lectures on radiation protection for both government and private sector radiation workers. In the healthcare sector, radiation protection is included in the curricula of programs at the University of Medical Technology and the Military Institute of Nursing and Paramedical Science to ensure future healthcare professionals are equipped with necessary knowledge for safe radiation handling.

In Myanmar, public hospitals equipped with extensive radiation facilities, including radiotherapy centers, are located in Yangon, Mandalay, Nay Pyi Taw, and Taunggyi. Radiation therapy services are also available at Defence Services Hospitals and private hospitals in Yangon and Nay Pyi Taw. Yangon has the highest concentration of hospitals utilizing extensive radiation for radiological imaging, nuclear medicine, and radiotherapy. In this work, five private hospitals and two defence hospitals with extensive medical radiation services and advanced radiation equipment have been selected. The survey conducted among healthcare workers of these selected hospitals regarding their awareness and practices in radiation protection has yielded insightful results. The data highlights both strengths and areas for improvement in radiation safety practices.

Socio- Demographic data obtained in this survey revealed a balanced gender distribution, with slightly more male respondents than female. The age range was diverse, capturing views from both younger and middle-aged healthcare workers with primary age group falls in the range of 31-40 years. Most respondents were married. Most respondents had a bachelor's degree, followed by those with master's degrees, doctorates, high school level, and undergraduate education, indicating a generally well-educated group. The respondents were well-distributed across seven hospitals in Yangon and most respondents were from the No.2 Military Hospital. Professional roles included mainly radiological technicians, and then medical doctors, auxiliary staff, and others, with nurses being the lowest in number. The years of experience ranged widely, from less than 1 year to more than 15 years. While some had formal training in radiation protection, many had not, though those with relevant educational backgrounds had studied it in their curriculum.

The survey results of awareness for radiation revealed a high level of awareness among respondents about the harmful effects of ionizing radiation. Most respondents correctly identified the nature of X-rays and their dual diagnostic and therapeutic uses, though some confusion remained about X-rays being streams of electrons. A majority recognized medical X-rays as a major source of man-made radiation exposure and understood the importance of managing cumulative exposure. Knowledge about the use of ionizing radiation in specific diagnostic procedures, such as CT scans and mammography, was strong, though there were gaps regarding DEXA scans. Awareness of radiation sources in nuclear medicine was mixed.

The survey results of awareness for radiation protection and safety revealed a varied level of awareness regarding radiation protection among healthcare radiation workers, highlighting both strengths and areas needing improvement. A significant portion of respondents misunderstood fundamental principles, confusing practical measures with core principles such as justification, optimization, and dose limitation. However, the understanding of the ALARA principle was notably high, though there was confusion between theoretical knowledge and practical application. Awareness of personal monitoring tools like OSLDs was good, and knowledge about the thickness of lead aprons was relatively strong, despite some misconceptions about protective equipment standards. The importance of collimation in reducing radiation exposure was widely acknowledged. Nevertheless, knowledge about maintaining safe distances during radiological procedures was lacking, and there were misconceptions regarding effective dose limits for radiation workers and the public. While awareness of dose limits for the lens, skin, and embryo/fetus showed some strength, there was still lack of knowledge. Awareness of survey meters for area and contamination monitoring was strong. All respondents correctly identified the radiation warning sign, indicating a strong understanding of this critical safety indicator.

The survey results of awareness for biological hazards of radiation highlights varying levels of awareness among healthcare radiation workers concerning different aspects of radiation hazards. Most respondents demonstrated a good understanding of key concepts. There was widespread recognition of ionizing radiation effects as the primary biological hazard and medical imaging procedures as a common source of exposure. However, some misconceptions were evident, particularly regarding the unit of measurement for radiation dose equivalent and the radiosensitivity of certain tissues like kidneys, liver, bone, and muscle. Despite generally high awareness of diseases resulting from radiation exposure, some respondents incorrectly associated osteopenia with radiation. Additionally, there were notable gaps in understanding the differences between stochastic and deterministic effects and the factors influencing their severity.

By investigating the total knowledge score for radiation protection among the participants, the results reveal that all respondents possess at least a moderate level of knowledge. Moreover, the majority demonstrate a good level of understanding regarding radiation protection.

The analysis of respondents' compliance with radiation protection practices indicates that while a majority consistently use dosimeters, protective equipment, and adhere to minimal exposure times and safe distances, notable gaps in consistency remain. These inconsistencies highlight the need for targeted education on the importance of these safety measures. Additionally, the survey reveals strong agreement among respondents on the necessity of periodic refresher training for radiation protection. These findings underscore the critical need for enhanced training programs, stricter enforcement of safety protocols, and continuous monitoring to ensure optimal radiation protection practices across all participants.

5.2 Suggestions

Based on the survey assessing the awareness of radiation protection among healthcare workers in hospitals in Yangon, it was found that most respondents showed a good level of awareness, with the remaining at a moderate level and no one displaying a poor level of knowledge regarding radiation protection. However, there are some confusions in knowledge and notable gaps in practices. Radiation protection in the healthcare sector is crucial, especially as technological developments in medicine continue at a rapid pace, posing challenges in producing timely recommendations to address associated radiological protection issues. Therefore, it is essential to continuously raise awareness of radiation protection among healthcare workers exposed to radiation.

For ongoing awareness, periodic training programs are needed to cover the principles of radiation protection and safety protocols. It is also important to update healthcare workers about new techniques and developments to reduce radiation. Practical measures such as displaying guidelines and safety protocols in the form of posters within departments can serve as constant reminders for healthcare workers. Easy access to protective resources, such as lead aprons and shields, should be ensured to facilitate adherence to safety measures. Regular assessments and feedback mechanisms will help identify knowledge gaps and areas needing improvement. Encouraging inter-hospital collaboration and engagement with responsible organizations like the Department of Atomic Energy (DAE) can further standardize and enhance radiation safety practices. Establishing a culture of continuous improvement through recognition programs and ensuring easy access to protective resources are also essential steps.

Additionally, academic institutions should incorporate more extensive radiation protection curricula into relevant programs at universities. This would ensure that future healthcare professionals enter the workforce with a solid foundation in radiation protection and safety.

This approach will support enhancing the awareness level of radiation protection of healthcare workers exposed radiation, promote a safer and more efficient working environment within healthcare facilities and mitigate the risks associated with radiation exposure.

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APPENDICES

Questionnaire on Radiation Protection Awareness of Healthcare Workers Working in Radiation Environment

I am a candidate of Master of Public Administration at Yangon University of Economic. You have been invited to participate the survey on "Study on Radiation Protection Awareness Among Radiation Workers". In this survey, approximately 135 radiation workers will be asked to complete this survey that ask questions for their knowledge about radiation, radiation protection, safety and hazard and following protection practice.

Read the questions and mark your response off with a mark (✓) in the box provided as ☐. Your answers will be strictly confidential. Thanks for your participation in my thesis work as an integral part of the study to complete the Master's Program.

Section A. Demographic Details of Participants

((Please mark (✓) the most relevant response in the box ☐)

1	Gender	☐ Female	☐ Male	
2	Age (Completed age)	----------------------------yrs		
3	Marital Status			
	☐ Single	☐ Married		
4	Education			
	☐ Diploma (Please fill name of Diploma) -------------	☐ Bachelor's Degree (Please fill name of degree) ------------------	☐ Master's Degree (Please fill name of Master degree) ------------------	☐ Ph.D (Please fill name of Ph.D degree) ---------------
	☐ Under Graduate	☐ High School		
5	Hospital name			
	--			
6	Occupation			
	☐ Medical Doctor	☐ Nurse	☐ Auxiliary staff	☐ Radiological Technician
	☐ Other ---			

7 Department (Field of Specialization)

☐ Oncology ☐ Nuclear Medicine ☐ Radiotherapy ☐ Radiology

☐ Other -------------------

8 Working experience (Number of years working in radiation environment)

☐ Less than 1 year ☐ 1 to 5 years ☐ 5 to 10 years ☐ 10 to 15 years

☐ More than 15 years

9 Have you attended any training courses on radiation protection and safety?

☐ Yes ☐ No

If you have, please kindly fill the name of course and year of joined. (If you remember)

Course title---------------------

Attended year------------------

Section B. Awareness for Radiation

(Please mark (✓) the most relevant response in the box ☐)

1 Ionizing radiation produces harmful effects on the body.

☐ Yes ☐ No ☐ No Idea

2 Which of the following is ionizing radiation.

☐ Micro-wave ☐ Ultraviolet (UV) ☐ Radio wave ☐ X-ray

3 X- ray is

☐ Stream of electrons ☐ Stream of positively charged particles ☐ Electromagnetic radiations of high frequency ☐ Stream of uncharged particles

4 X-ray can be used for both diagnostic and therapeutic purposes.

☐ Yes ☐ No ☐ No Idea

5 Medical X-rays are a major source of man-made radiation exposure.

☐ Yes ☐ No ☐ No Idea

6 Radiation becomes a risk depending on the frequency of exposure.

☐ Yes ☐ No ☐ No Idea

7 Which of the following diagnostic procedures uses ionizing radiation?

(a) CT scan ☐ Yes ☐ No ☐ No Idea

(b)	Ultrasound	☐ Yes	☐ No	☐ No Idea
(c)	Mammography	☐ Yes	☐ No	☐ No Idea
(d)	MRI	☐ Yes	☐ No	☐ No Idea
(e)	Positron Emission Tomography (PET)	☐ Yes	☐ No	☐ No Idea
(f)	Barium swallow	☐ Yes	☐ No	☐ No Idea
(g)	Dexa	☐ Yes	☐ No	☐ No Idea

8 Which of the following is source of radiation for nuclear medicine staff in Nuclear Medicine Department?

☐ Gamma camera ☐ Radiopharmacy ☐ Both Gamma Camera and Radiopharmacy ☐ Console Room

Section C. Awareness for Radiation Protection and Safety
(Please mark (✓) the most relevant response in the box ☐)

1 The principle for radiation protection is -

☐ Maximize time, minimize distance, and use shielding

☐ Minimize time, maximize distance, and use shielding

☐ Justification, optimization, and dose limitation

☐ Measuring, recoding and reporting

2 Which one of the following represents the acronym “A L A R A”?

☐ As little As Relatively Achievable

☐ As less as Reasonably Achievable

☐ As low As Reasonably Achievable

☐ As low As Relatively Achievable

3 To adhere to the “A L A R A” process, it must be-

☐ Maximize time, minimize distance, and use shielding

☐ Minimize time, maximize distance, and use shielding

☐ Justification, optimization, and dose limitation

☐ Measuring, recoding and reporting

4 Which of the following is a personal monitoring device?

☐ OSLD ☐ Survey Meter ☐ Dose Calibrator ☐ Thyroid Probe

5 What is the range of common thickness of lead aprons used for radiation protection?

☐ 0.05mm to 0.1 mm ☐ 0.25 mm to 0.5 mm ☐ 1 mm to 2 mm ☐ 5 mm to 10mm

6 In radiation exposure protection, collimation of the radiation beam is also important.

☐ Yes ☐ No ☐ No idea

7 During the radiological guided procedure, without any protection you should not stand within

☐ 1 meter ☐ 2 meters ☐ 3 meters ☐ 5 meters

8 What is the effective dose limit (whole body) for radiation workers?

☐ 1 mSv per year ☐ 150 mSv per year ☐ 20 mSv per year ☐ 100 mSv per year

9 What is the equivalent dose limits (lens and skin) for public?

☐ Lens 50 mSv, skin 15 mSv ☐ Lens 20 mSv, skin 15 mSv ☐ Lens 15 mSv, skin 50 mSv ☐ Lens 15 mSv, skin 20 mSv

10 For pregnant radiation workers, after declaration of pregnancy, the dose on the embryo/fetus should not exceed

☐ 1 mSv ☐ 20 mSv ☐ 15mSv ☐ 50 mSv

11 Survey meter is used for which of the following?

☐ Personal monitoring ☐ Only for Area monitoring ☐ Only for contamination monitoring ☐ Both area and contamination monitoring

12 Which of the following is a radiation sign.

☐  ☐  ☐  ☐ 

Section D: Awareness for Biological Hazards of Radiation

(Please mark (✓) the most relevant response in the box ☐)

1 What is a primary biological hazard associated with occupational radiation exposure for healthcare workers?

☐ Thermal Burns ☐ Chemical Poisoning ☐ Respiratory Issues ☐ Ionizing Radiation Effects

2 What is the most common source of radiation exposure for healthcare workers?

☐ Natural background radiation ☐ Medical Imaging procedures ☐ Nuclear power plants ☐ Cosmic rays

3 What is the unit of measurement for radiation dose equivalent?

☐ Gray (Gy) ☐ Sievert (Sv) ☐ Becquerel (Bq) ☐ Curie (Ci)

4 Which of the following tissues are highly radiosensitive?

(a)	Kidney	☐ Yes	☐ No	☐ No Idea
(b)	Gonads	☐ Yes	☐ No	☐ No Idea
(c)	Bone	☐ Yes	☐ No	☐ No Idea
(d)	Liver	☐ Yes	☐ No	☐ No Idea
(e)	Muscle	☐ Yes	☐ No	☐ No Idea

5 Which of the following diseases may be a result of radiation hazard?

(a)	Osteopenia	☐ Yes	☐ No	☐ No Idea
(b)	Leukemia	☐ Yes	☐ No	☐ No Idea
(c)	Skin cancer	☐ Yes	☐ No	☐ No Idea
(d)	Cataract	☐ Yes	☐ No	☐ No Idea
(e)	Infertility	☐ Yes	☐ No	☐ No Idea

6 What is the difference between stochastic and deterministic effects of radiation?

☐ Stochastic effects have a threshold dose, deterministic effects do not
☐ Stochastic effects are probabilistic, deterministic effects and certain
☐ Stochastic effects are reversible, deterministic effects are irreversible
☐ Stochastic effects are acute, deterministic effects are chronic

7 Deterministic effects occurred due to

☐ Receiving high dose in short span of time
☐ Receiving low dose in short span of time
☐ Receiving high dose over a long period of time
☐ Receiving low dose over a long period of time

8 What is the main factor that determines the severity of a deterministic effect of radiation?

☐ The type of radiation
☐ The dose of radiation
☐ The age of the exposed person
☐ The latency period of the effect

9 Which of the following is caused due to stochastic effects.

☐ Skin Rashes ☐ Cancer induction ☐ Hair fall ☐ Nauseas

10 What is the main factor that determines the severity of a stochastic effect of radiation?

☐ The type of radiation ☐ The dose of radiation ☐ The age of the exposed person ☐ The latency period of the effect

Section E: Protection Practice

(Please mark (✓) the most relevant response in the box ☐)

1. Do you use a dosimeter when working in radiation environment?

   ☐ Never ☐ Sometimes ☐ Always

2 If you are using a dosimeter, is it routinely sent for measurement?

   ☐ Never ☐ Sometimes ☐ Always

3 Do you use any protective shielding equipment to avoid the unnecessary exposure during you are working in radiation environment?

   ☐ Never ☐ Sometimes ☐ Always

4. Do you use minimal exposure time?

   ☐ Never ☐ Sometimes ☐ Always

5. Do you keep enough distance from the radiation source?

   ☐ Never ☐ Sometimes ☐ Always

6 Do you provide lead aprons for all co-patients or staff in radiation environment?

   ☐ Never ☐ Sometimes ☐ Always

7 Do you think that the radiation protection refresher training should be launched periodically for workers who are exposed to ionizing radiation?

   ☐ Yes ☐ No ☐ No idea

Thank you so much for your kind cooperation and if you have any question about this survey, you can contact email address of kyawsusu2021@gmail.com.