ASSESSMENT OF RADIATION RISKS AND OCCUPATIONAL HEALTH AND SAFETY MEASURES TO BE TAKEN ABOUT THE HEALTH SECTOR EMPLOYEES OF THE CITY OF BABYLON

BY

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The Institute of Health Sciences
Occupational Health and Safety

The Degree of Master of Science

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2023

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ETHICS STATEMENT

The thesis entitled "Assessment of Radiation Risks and Occupational Health and Safety Measures to Be Taken About the Health Sector Employees of The City of Babylon," which was prepared and presented as a thesis, was written by myself and in accordance with the scientific, academic rules, and ethical conduct. The idea/hypothesis of my thesis solely belongs to my supervisor and to me. The research pertaining to the thesis was conducted by myself and therefore, all of the used sentences and interpretations within the work belongs to me.

I declare the aforementioned issues to be correct.

Qasim Arkan HAMZAH HAMZAH

ABSTRACT

ASSESSMENT OF RADIATION RISKS AND OCCUPATIONAL HEALTH AND SAFETY MEASURES TO BE TAKEN ABOUT THE HEALTH SECTOR EMPLOYEES OF THE CITY OF BABYLON

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Master of Science in Occupational Health and Safety

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June 2023

Radiation exposure among radiologists and radiographers has become a concern. The level of radiation safety knowledge influences them. If there is a lack of protection knowledge, their actions won't be safe and may have unfavorable consequences. The study aimed to assess and reduce radiation risks for health workers in the radiation fields. A cross-sectional study was conducted at the Morgan and Imam Sadiq hospitals. The sample size was 200 workers. They were selected using random sampling and then interviewed by the questionnaire elements. Age groups (31-35 years) and (41-45 years) show good assessment levels (1.511± 0.178) and (1.623±0.127), respectively. While workers who have postgraduate certificates with an evaluation (1.592±0.157).

As for career, the study found that radiologists have good scores (1.636±0.00) followed by radiologic technologists (1.500±0.186). The present study reveals that the mean of overall prevention and safety measures assessment was 16.33±2.24, which rested within poor levels (<17 scores). The results of this study indicate that the highest percentage (56.5%) of the participants have a poor assessment score for prevention and safety measures. In contrast, 43.5% of them with a good score.

The study found that workers in the radiation field who have served more than ten years show a good assessment score regarding occupational health and safety measures. This study also recommends training courses and ensuring the necessary radiation protection tools available for newly hired employees.

2023, 82 pages

Keywords: Radiation, Occupational Health and Safety, Hazards of Radiation, Health, Hospital, Radiology Worker, Disease, Protective Equipment, Protection from Radiation.

ÖZET

BABİL KENTİ SAĞLIK SEKTÖRÜ ÇALIŞANLARI HAKKINDA RADYASYON RİSKLERİNİN DEĞERLENDİRİLMESİ VE ALINMASI GEREKEN İŞ SAĞLIĞI VE GÜVENLİĞİ ÖNLEMLERİ

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Haziran 2023

Radyologlar ve radyograflar gibi sağlık çalışanları, radyasyonla doğrudan temas halinde oldukları için önemli sağlık riskleriyle karşı karşıyadır. Radyasyon, bu meslek gruplarındaki çalışanlar için birçok sağlık sorununa yol açabilir. Örneğin, kanser, katarakt, kalp hastalıkları, nörolojik sorunlar ve cilt problemleri gibi hastalıkların oluşumu, radyasyon maruziyetine bağlıdır.

Bu nedenle, radyasyon güvenliği konusu bu meslek grupları için hayati önem taşımaktadır. Radyasyonla çalışanlar, maruziyetlerini en aza indirmek için koruyucu önlemler almaları gerekmektedir. Bu önlemler arasında, kişisel koruyucu ekipmanların kullanımı, radyasyonu sınırlayan bariyerlerin kullanımı, maruziyet süresinin kısaltılması ve radyasyon kaynaklarının doğru bir şekilde kullanımı yer almaktadır.

Ayrıca, radyasyon güvenliği konusuyla ilgili eğitimler de bu meslek grupları için son derece önemlidir. Bu eğitimler sayesinde, çalışanlar radyasyon güvenliği konusunda bilinçli hale gelirler ve radyasyonla çalışırken kendilerini ve hastalarını koruma konusunda daha iyi bir farkındalığa sahip olurlar.

Yukarıda açıklanan nedenlerle, radyasyonla çalışan meslek grupları için radyasyon güvenliği konusu hayati önem taşımaktadır. Bu meslek gruplarının, kendilerini ve hastalarını korumak için gerekli önlemleri alması ve radyasyon güvenliği konusunda eğitim almaları gerekmektedir. Bu şekilde, radyasyon maruziyetiyle ilgili sağlık sorunlarının önüne geçilebilir ve sağlıklı bir çalışma ortamı sağlanabilir.

Bu çalışmada, Babil eyaletindeki sağlık çalışanları üzerindeki radyasyon riskleri ile risklerin azaltılması için alınan önlemlerin aşağıdaki hususlar göz önünde bulundurularak değerlendirilmesi amaçlanmıştır:

- Radyasyon ünitelerinde çalışanlar arasında güvenlik ve radyasyona karşı alınan önlemlerinin seviyesini değerlendirmek.
- Katılımcıların radyasyon alanındaki hizmet süreleri (yıl) ile sağlık sorunları arasındaki ilişkiyi belirlemek.
- Radyasyon önleme ve güvenlik önlemleri için toplam değerlendirme puanı ile katılımcıların sosyo-demografik özellikleri arasındaki ilişkiyi bulmak.

Bu kesitsel çalışma Babil valiliği yönetim alanında bulunan iki hastaneyi (Morgan hastanesi ve İmam Sadık Hastanesi) kapsamaktadır. Bu iki hastane, tüm Babil yönetim alanında en fazla personele sahip olan en büyük hastanelerdir.

Örneklem büyüklüğü, basit rastgele örnekleme tekniği kullanılarak belirlenmiş olup bu hastanelerde radyasyon alanında çalışan 200 sağlık personelini kapsamaktadır. Bu personelin demografik özelliklerini, alışkanlıklarını, güvenlik ve radyasyon önleme önlemlerinin değerlendirilmesini ve bu sağlık çalışanlarının sağlık sorunlarını kapsayacak şekilde dört eksen içeren anket öğeleri kullanılarak belirlenen çalışanlar ile sözlü mülakatlar yapılmıştır.

Çalışma bulguları, yaş gruplarının (31-35 yaş) ve (41-45 yaş) iş sağlığı ve güvenliği önlemleri açısından sırasıyla iyi bir değerlendirme düzeyine (1.511±0.178) ve (1.623±0.127) sahip olduğunu ortaya koymaktadır. Aynı zamanda, lisansüstü eğitime sahip çalışanlar iyi bir değerlendirme puanına sahiptir (1.592±0.157). Kariyer unvanları açısından bakıldığında bu çalışma, radyologların iyi puanlara (1.636±0.00) sahip olduğunu, bunu radyolojik teknoloji uzmanlarının (1.500±0.186) izlediğini bulmuştur.

Hizmet süreleri ile ilgili olarak bu çalışmada, radyasyon alanında on yıldan fazla hizmet vermiş olan çalışanların iş sağlığı ve güvenliği önlemleri konusunda iyi bir değerlendirme puanına sahip olduğu belirlenmiştir.

Çalışma sonuçları, önleme ve güvenlik önlemlerinin genel değerlendirme ortalamasının 16.33±2.24 olduğunu ve bunun zayıf düzeyde (<17 puan) olduğunu belirtmektedir. Çalışmaya katılan radyasyon alanında çalışan sağlık çalışanlarının büyük kısmının (%56,5) önleme ve güvenlik önlemleri anlamında zayıf bir değerlendirme puanına sahip

olduğu, buna karşılık, %43,5'inin bu anlamda iyi bir değerlendirme puana sahip olduğu belirlenmiştir.

Çalışma, radyasyon alanında on yıl ve daha fazla süre ile hizmet veren çalışanların iş sağlığı ve güvenliği önlemleri konusunda iyi bir değerlendirme puanına sahip olduğunu ortaya koymaktadır. Bu çalışma aynı zamanda yeni işe başlayan çalışanlar için eğitim kursları ve gerekli radyasyondan korunma araçlarının sağlanmasını önermektedir.

2023, 82 Sayfa

Anahtar Kelimeler: Radyasyon, İş Sağlığı ve Güvenliği, Radyasyonun Zararları, Sağlık, Hastane, Radyoloji Çalışanı, Hastalık, Koruyucu Ekipman, Radyasyondan Korunma.

PREFACE AND ACKNOWLEDGEMENTS

In my education life, my precious supervisor Assoc. Prof. Dr. Semih KUTER,
I want to thank the professor and the head of the department, who helped me a lot, special thanks to Assoc. Dr. Ercüment N. Dizdar
To my dear mother, father, and siblings, who are always by my side and whose rights I will never be able to repay,
To my colleagues whom I had the opportunity to get to know during the education process;
To the healthcare professionals who agreed to participate in my research;
To my dear wife and my dear son Adam, who always made us feel his love and support,
My respect and thanks.

Qasim Arkan HAMZAH HAMZAH
Çankırı-2023

CONTENTS

INDEX OF ABBREVIATIONS AND SYMBOLS

ALARA	As Low As Reasonably Achievable
CT	Computed Tomography
GY	Gray, Radiation Dose
OHS	Occupational Health and Safety
PET	Positron Emission Tomography
PI	Principal Investigator's
PPE	Personal Protective Equipment
RATYHA	Radiological Emergency Medical Assistance and Preparedness Network
RSC	Radiation Safety Committee
RSD	Radiation Safety Division
RSO	Radiation Safety Officer
SD	Standard Deviation
SOP	Standard Operating Procedure
WHO	World Health Organization

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1. INTRODUCTION

People are exposed to natural radiation every day. More than 60 naturally occurring radioactive substances can be found in soil, water, and the atmosphere. Radon is a naturally occurring gas that emits radiation from rocks and dirt. Breathing and swallowing air, food, and water exposes people to radionuclides daily (Mollamahmutoğlu 2004). Humans are also exposed to natural radiation from cosmic rays at high altitudes. They get it from naturally occurring terrestrial and cosmic rays from the Earth. Geological differences affect the radiation levels in the environment. In some regions, living people are exposed to 200 times more radiation than the global average (Gestal 1987).

There are also artificial radiation sources, from nuclear power plants to medical uses in diagnosing or treating patients. X-rays and other medical devices are today's most common artificial radiation sources (Korkmaz 2012).

The absorbed or radiation dose resulting in tissue and organ damage is determined by measuring it in a unit called Gray (Gy). The type of radiation and the sensitivity of different tissues or organs affect the damage that the absorbed dose can cause (Häusler *et al*. 2009).

Effective dose or weighted radiation dose is a unit of measurement and the way of measuring the extent to which those exposed to ionizing radiation are affected. Radiation type is taken into account by tissue and organ susceptibility. Smaller units such as millisieverts (mSv) or microsieverts (Sv) are more efficient due to the large sieve. A thousand microsievert sieves; contains a thousand millisieverts. Measuring a people's exposure to a specific radiation dose, such as microsievert per hour or millisievert per year, is an essential measure for the dose (Solmaz *et al.* 2017).

By giving the short-term doses they may have received (e.g., the effective amount over two to seven days and the quantity that causes damage to the thyroid gland), people should be protected from radiation exposure in the first few hours or days in the early stages of an emergency. While making these decisions, nuclear power plant conditions, the amount of radioactivity released into the atmosphere, current weather conditions, and other factors are considered. Emergency measures may include evacuation and, if necessary, obtaining non-radioactive iodine from local authorities (Rayner 1986).

Due to its constitution and international health regulations (2005), the World Health Organization (WHO) is responsible for assessing the public health risks associated with radiological events, including those from nuclear accidents, working with independent experts and other United Nations organizations, WHO aims to achieve this goal (Yarenoğlu 2018).

A global network of more than 40 institutions specializing in radiological emergency medicine assists the organization in this work. The Radiological Emergency Medical Assistance and Preparedness Network (RATYHA) is a network that provides the technical assistance needed to prepare for and respond to a radiological emergency (Rayner 1986).

The healing process is likely to take a long time. A risk-benefit analysis should be used to determine whether preventive measures should be stopped. Public health impacts and subsequent actions require establishing long-term programs with appropriate frameworks (Yarenoğlu 2018).

Occupational health and safety are the science that deals with eliminating hazards that can cause injury, illness, or death in the workplace, ensuring the safety of workers and the equipment they use, and maintaining health and well-being. In other words, it is a set of laws and regulations designed to protect people from the dangers of injury and property from damage or loss (Alli 2008).

1.1. Aims of the study

To evaluate the radiation risks on healthcare workers in the field of radiation in the province of Babylon. In addition, there are particular aims, including:

- To assess the level of safety and radiation prevention measures among those working in radiation units.
- To determine the relationship between the participants' years of practice in the radiation field and their health problems.
- To find the relationship between the total evaluation score for radiation prevention and safety measures and the socio-demographic characteristics of the participants.

1.2. Occupational health and safety definitions and concepts

Workplace safety can be defined as preventing injury to an employee due to his work. Occupational health definition is "the protection of the worker against any disease that may affect him or her as a result of exercising his profession" (Mollamahmutoğlu, 2004).

The primary purpose of Occupational Health and Safety (OHS) is to protect employees' physical and emotional health while at work and to ensure that the working environment is safe and conducive (Reese 2018).

OHS provides a healthy and productive working environment by reducing or eliminating workplace hazards. A Workplace should be well protected from injury and damage in all occupations and ensure that employees and equipment are protected against any dangers and diseases arising from their work (Alpsoy 2007).

It is undeniable because it encompasses the physical, emotional, and social well-being of those working there. Workers in all plants and sectors must be protected from accidents that can lead to death or severe injury and damage to facilities, machinery, and equipment (Küçük 2012). There is a direct relationship between a worker's job and his health.

Legislation, statutes, and regulations must be in place before a permit is issued to protect workers from occupational harm or illness (Logic *et al.* 2021).

As a scientific approach, OHS tries to instill a sense of safety and peace of mind while doing their jobs. In addition, it tries to reduce the anxiety and panic attacks experienced by employees when they have to share basic needs and tools, and sometimes they risk their lives in unsafe situations (Alpsoy 2007).

1.2.1. Security

Security personnel maintains protection from undesirable hazards and accidents. In addition, in parallel with rapid industrialization and technological developments, some problems have emerged regarding the safety of employees in the workplace. For this reason, occupational safety has gained importance since it is essential to make workplaces safe by taking certain precautions beforehand (Küçük 2012).

In addition, the general concept of safety and security can be considered a concept. Protecting human life and the institutions they operate is a primary focus. It is also essential to find the root causes of crimes that threaten people and property to help reduce the risk associated with them. (Mantık et al. 2021).

1.2.2. Health

When it comes to keeping people safe and healthy at work, occupational health ensures no accidents, injuries, or diseases. The term OHS refers to a set of regulations and procedures enacted by law to protect the health and safety of employees and assets related to their work (Odaman 2005).

It is important to remember that workplace safety permeates every aspect of our lives. Safety precautions must be present when dealing with anything potentially hazardous, such as electricity, driving, or even walking on the street (Oksay 2005).

Safety rules must be followed, and caution must be exercised. For example, overcrowding and high population density that characterizes many large institutions and educational institutions, such as pharmaceutical factories, will be on the general objectives, components, and examples of occupational health (Saygun 2012).

1.2.3. Hazard

Hazard is a term that refers to the possibility of communication or harm. Therefore, the focus is on the potential for injury. Because of the precision in defining these terms, it is clear that the concept of "occupational hazards" refers to a lack of safety in the workplace, so if there is a high probability of an accident or illness, there is a higher risk of injury or illness at work (Mantık *et al.* 2021). In this context, a hazard is defined as the potential to cause harm to people, the workplace, and the environment existing in the working environment and conditions (Quinlanv *et al*. 2010).

1.2.4. Risk

Regarding OHS, risk refers to the possibility of potential hazards. Uncertainty and Probability are the concepts of risk in this context. OHS risk refers to illness or loss, injury, and discomfort resulting from workplace hazards. However, risk and danger are often confused and are two separate concepts (Gazete 2012).

1.2.5. Occupational accident

A person can have spine, hands, head, and lung injuries. Workplace hazards (physical, chemical, biological, or psychosocial) such as heat, noise, insect or animal stings and bites, blood-borne diseases, aerosols, hazardous materials, radiation, and occupational fatigue exist in the work environment. However, many preventive measures have been developed. Heavy loads, equipment failure, exposure to common hazards, and inadequate safety training all contribute to injuries (Odaman 2005).

1.2.6. Occupational disease

For example, if someone has a long-term health problem due to his job, he may have an occupational disease. A disease in an occupation is generally considered an occupational disease if it appears more prevalent in a particular group of workers than in the general population or other workers. For example, falling from the top of a building is not an occupational disease because it is traumatic (Reese 2018).

Under workers' compensation laws in many countries, it is the responsibility of the employer or insurance company to prove that a particular illness was not caused by the worker's presence at the workplace. The term "occupational diseases" is often used to describe diseases for which workers' compensation authorities pay (Çetin *et al.* 2021).

Some countries do not cover work-related musculoskeletal disorders, while others (for example, Norway) are in the occupational disease category. For this reason, occupational diseases are called work-related diseases. This term includes compensated and uncompensated occupational diseases (Quinlanv *et al.* 2010).

In the narrowest sense, health problems that arise directly from one's workplace only occur in a particular sector. Occupational factors can generally cause or worsen many diseases, including existing ones (Oksay 2005). Occupational diseases are related to working standards and conditions requiring medical intervention (Korkmaz 2012).

1.2.7. Measures

Everyone in the workplace is responsible for preventing occupational accidents related to interactions with others, such as machines, tools, materials, working methods, and others (Odaman 2005). OHS is a set of procedures that protect workers, reduce the risk of equipment and machinery to workers and the facility, provide a professional atmosphere that helps workers work, and aim to prevent or minimize the occurrence of accidents. Its purpose is to prevent workplace injuries and illnesses. As a result, occupational safety has become a set of rules and laws that employers and employees must comply with (Küçük 2012). Hazard prevention is the main factor in protecting the human element from exposure to workplace hazards such as accidents, injuries, and diseases in the working environment (Çetin et al. 2021).

It should prevent damage and loss of devices and equipment, which are material elements in the components of organizations (Ergüt 2015). Providing and implementing all necessary OHS requirements should give a risk-free working environment for people and materials (Oksay 2005). As a scientific approach, OHS aims to establish safety and tranquillity while doing their jobs and reduce the anxiety and panic attacks they experience while living together with the necessities of life. Among the deadly hazards are tools, equipment, and machines that sometimes endanger people's lives in unsafe conditions (Korkmaz 2012).

1.2.8. Protectors

Personal Protective Equipment (PPE) prevents work-related injuries and illnesses, protects workers from health and safety hazards, and improves workplace health and safety. PPE is designed and tested by workers to protect them from one or more hazards. It is used when collective protection technical measures or work organization and methods cannot eliminate or reduce risks (Ergüt 2015).

The history of personal protective equipment started with a dust bag worn on the head. Throughout history, protective equipment has evolved to focus on specific work areas and parts of the body and has become an integral part of our daily lives. The primary function of this equipment is to protect workers from harm, especially in an occupational accident (Quinlanv *et al*. 2010).

CE marking is required for all personal protective equipment. Following the requirements of the regulations, manufacturers need to CE mark PPE. In addition, the CE mark serves as a visual indication that the product complies with EU regulations. It would be best if someone also inquired whether a user manual is available when purchasing products that are not CE-marked. They can learn how to use it with the help of this guide (Öcal 2010).

1.3. The importance of occupational health and safety

OSH is the cornerstone of long-term economic progress as it helps keep workers healthy and productive. Work and the environment in which it is performed are considered important factors in determining a person's health (Reese, 2018).

Many health problems can result from unsafe working conditions. Health and work are linked in a two-way reciprocal relationship. Employees who are well cared for and have access to healthcare are more productive and contribute more to the overall quality of their work. According to recent studies, events related to job losses, occupational diseases, and injuries cause 4% of the total income of the country's population to be used (Mollamahmutoğlu 2004).

1.3.1. Importance of OHS for employees

The importance of OHS and the steps to be taken in this regard were discussed. It benefits employees, employers, and society as a whole. A worker injured or killed in the workplace will also leave a significant financial and moral burden on his family. If occupational safety and health are not kept in the foreground, it can increase occupational accidents and diseases and experience injuries and psychological problems in these cases (Shikdar *et al.* 2003).

As a result, workers and society will suffer. In addition, the state and employers are legally required to prevent work-related injuries and illnesses that cause significant economic and social harm (Öcal 2010).

Because employers are responsible for the well-being of their employees, they should take these safety precautions and ensure that their employees are protected from hazards.

To achieve this, managers and employers must consult OHS experts, develop business plans and initiate business processes (Nasab *et al.* 2009).

1.3.2. Importance of OHS for the employer

As a business owner, someone is responsible for providing a safe workplace for their employees for financial and humanitarian reasons. Adequate investment in OHS results in lower accident rates, lower unit production costs, and higher profits. According to the accident cost calculation models used in developed countries, the cost of an accident is generally much higher than the cost of avoiding that accident (Kılkış 2013).

In the case of OHS, toxic effects may occur if businesses act carefully or err in their workplaces (microeconomic units). It can result in a significant drop in output. Therefore, in modern societies, states have created OHS regulations, various programs and training activities, taken legal measures, and developed new technologies to ensure the safety of workers (Korkmaz 2012).

Spending on OHS in the United States is always based on the social benefit-social cost ratio. No matter how much money you spend, the long-term social benefit always outweighs the short-term social cost. However, while the investment in OHS is a current expense in the short run, it becomes an investment with high efficiency and profitability in the long run (Shikdar *et al.* 2003).

This way, national wealth, workforce productivity, public health, and, most importantly, the ability to produce goods and services can be protected. Employees should meet with their managers to discuss their concerns, make requests, and ensure their rights are covered in the event of a security threat (Quinlanv et al. 2010).

Of course, managers and employers cooperate with OHS experts in this way and make the necessary arrangements. At this point, it is very important to meet with experts and determine how to run an efficient business (Reese 2018).

The measures to be taken concerning OHS have positive consequences for employees, employers, and society. In particular, it is essential to protect workers from the hazards of industrialization and threats to their lives, bodies, and health (Kılkış 2013).

Because the workers may lose their income due to a occupational accident or occupational disease, a worker injured or killed in the workplace will also leave a significant financial and moral burden on his family. If occupational safety and health aren't kept in the foreground, occupational accidents and diseases may increase, and people in this situation may be injured and experience psychological problems (Mollamahmutoğlu 2004). As a result, workers and society will suffer. In addition, the state and employers are obliged by law to prevent work-related injuries and diseases that cause significant economic and social harm (Korkmaz 2012).

1.3.3. Importance of OHS for the government

Economic losses can be substantial when workers are injured at work. According to the law, states must protect workers' health and safety and their ability to benefit from their work. When dealing with labor relations, the state's primary responsibility is to ensure they are adequately regulated and monitored. The importance of support propaganda for today's modern conditions OHS has increased (Shikdar *et al.* 2003).

In some European countries, government incentives and awards are given to companies that have survived a specific time without accident and exhibited exemplary behavior. OHS is supported by various initiatives, especially in small and medium-sized enterprises (European Agency for Occupational Health and Safety). Turkey's OHS legislation needs to be revised, and as a result, there are many new regulations in Law No. 6331. The problem here is that the solution is challenging to implement. Accordingly, while labor inspection capacity and efficiency should be increased, only 10% of the workplaces can be inspected (Küçük 2012).

2. OCCUPATIONAL HEALTH AND SAFETY BASIC RISK FACTORS AND RADIATION

2.1. Introduction

Technical development witnessed by the world has led to the emergence of many risks that people should be aware of and avoid falling. Workplace workshops, factories, and laboratories were accepted as working environments where many professional activities occur (Karaca 2013).

Annual statistics published by international organizations show that 110 million workers suffer various injuries, including four work injuries every second, a severe accident every 3 minutes, and 180,000 fatalities. For this reason, providing a safe working environment from the risks of various industries and increasing the effectiveness of prevention tools will undoubtedly decrease injuries and occupational diseases and protect employees from accidents (Güler 2006).

In addition, various risk factors can be encountered in the workplace. While chemical, physical, biological, and ergonomic risks may cause occupational diseases, structural elements, or incorrect operations, and maneuvers may cause accidents (Kaya *et al.* 2019).

2.2. Occupational health and safety risk factors

The danger is a general and abstract concept. "Risky" situations in an environment or workplace create danger. There are a variety of health hazards in the workplace, but these pose risks to those working in specific jobs: Risks are expressed as "likelihood." (Helvacı, 2011)

WHO defines an accident as "an unplanned and unexpected event" Another feature is that it can risk physically, spiritually, and financially harming people. It damages the person and the workplace. Occupational accidents are health and safety issues concerning working life (Helvacı, 2011).

2.2.1. Biological factors

Modern technology, such as laser systems and other electromagnetic sources, has not eliminated traditional workplace risks like biological agents. Biological risk is central to evaluating and treating modern Occupational Medicine (Kaya *et al.* 2019).

Skin and mucous membrane contact with various matrices may result in biological agent exposure. Natural or organic materials (such as soil and plant) and organic dust (such as flour or paper) are among the things workers encounter daily. Biological risk affects a wide variety of business functions. Workers in traditional industries, such as farming, and modern workplaces, such as the biotechnology industry, are at risk of exposure to biological agents (Güler 2006).

2.2.2. Psychological factors

Technological, political, and social developments have significantly affected the nature of work and how people do it over the last few decades. As a result of demographic and social changes, new risks to health in the workplace have emerged. In this scenario, OHS researchers, policymakers, and practitioners paid special attention to psychosocial risks (Che Huei *et al.* 2020).

The design, content, and management of the job and the social context in which it takes place all create psychosocial risks to workers' health. Because of their close connection with workplace stress, they are seen as a contemporary health issue. Workers' health and safety are adversely affected by work-related stress, especially concerning cardiovascular disease and mental, musculoskeletal, and chronic degenerative disorders (Akbulut 1996).

Many people are familiar with the term "stress," but it is difficult to define what it is and how it affects people. Workers' health, absenteeism, and productivity suffer from work-related stress, which is now widely accepted. Acute and chronic stress, although not a disease, can cause long-term damage to the body's systems and organs. If the body is constantly under pressure, stress can cause these changes, which is the first sign of a problem. Employee stress results from the employee's response to the structure, environment, and potentially harmful or embarrassing aspects of the workplace (Che Huei *et al.* 2020).

It shows that chronic stress can lead to memory loss and other health problems such as ulcers, gastrointestinal inflammation, musculoskeletal disorders, and hypertension, all of which can lead to heart and cardiovascular diseases. It can also affect the body's immune system, which can lead to the development of cancer. Together, these disorders are responsible for the vast majority of diseases, deaths, disabilities, and medical expenses in most developed countries. They are also the leading causes of death in developing countries (Çam *et al.* 2017).

2.2.3. Chemical factors

Most health risks result from breathing in chemicals in the form of fumes, gases, dust, fumes, or skin contact with these materials. The degree of risk of exposure to chemicals depends on the concentration and duration of the substance. Chemicals enter the human body in four ways (Che Huei *et al.* 2020):

- Inhalation is the fastest way for harmful chemicals to enter the human body.
- Absorption through the skin and eyes.
- Swallowing.
- Incorrect injection.

2.2.4. Ergonomic factors

To ensure maximum safety and productivity in the workplace, the physical and cognitive characteristics of people, work environments, and systems are examined in terms of ergonomics. Human behavior and biology are studied to design environments conducive to human life. In ergonomics, the relationship between people and any equipment or environment is scientifically examined (Niu 2010).

Ergonomic risk factors are work-related conditions that increase the likelihood of musculoskeletal disorders. Many things can affect the onset of the disease, both directly and through the body's natural healing processes (Kanten 2012).

2.2.5. Physical factors

Working conditions such as air conditioning, radiation, lighting, noise, vibration, and pressure significantly affect people's health. The most important thing is to protect workers from physical negativities in every business and eliminate them at the source (Schulte *et al.* 2012).

2.3. Radiation

X-rays and gamma rays, which can form ion pairs, interact with radiation as they travel through the material medium. Radiation in the form of particles, including charged particles, heavy ions, and free neutrons with kinetic energy, is known as particle-characterized radiation (Schulte *et al.* 2012).

Unstable nuclei can spontaneously lose mass by emitting particles or electromagnetic radiation. All living things are constantly exposed to radiation from space and the sun. In other words, it is the emission of energy from waves or particles from natural or artificial sources (Guden *et al.* 2012).

We can consider nuclear tests in the atmosphere and underground as one of the most important sources of radiation pollution. Accidents at nuclear power plants are another potential source. An underground radioactive waste container leaking radioactive elements can contaminate food sources for plants and animals (Schulte *et al.* 2012).

Another possible factor is the release of radiation from nuclear fuel-powered vehicles. Radiation contamination can also occur around radiation treatment units and in laboratory wastes produced using radioactive methods (Çam *et al.* 2017). Naturel sources were divided into the following types (Çolak 2014):

- Cosmic rays: come from the sun and the space between the stars.
- Soil rays: it remitted from the earth's surface due to the presence of radioactive substances in rocks, such as potassium, uranium, and radioactive radon gas leaking from all over the world due to the breakdown of some radioactive metals such as uranium (Bozbıyık et al. 2002).

Industrial Sources are divided into the following types:

- X-ray machines.
- In education and scientific research: nuclear physics laboratories, radiopharmaceutical research, and agricultural applications (Çolak 2014).
- Medical resources:
- Diagnostic and interventional radiological applications.
- Radiotherapy.
- Nuclear medicine.
- Nuclear reactors and explosions.
- Accelerators.
- Radiation applications in industrial and agricultural areas.
- Industrial radiography.
- Nuclear indicators.
- Hygrometers.

3. RADIATION FACTORS AND RADIATION HAZARDS

In the case of medicine and health professionals who are regularly exposed to high radiation levels, acute radiation syndrome may develop. In contrast, others may suffer from cataracts and skin cancers but are assumed to have no safe radiation exposure levels. According to a new study, radiation threatens health workers (Atomic Energy Licensing 2010).

Radiation is energy in motion that moves along invisible waves or rays. People are exposed to radiation every day. Radiation has always been a part of everyday life on Earth (Cotran RS *et al.* 2010). Radiation is the energy released from waves or small particles of a substance and radiated in space. Radiation is present throughout the universe. It has many forms, including X-rays, gamma rays, radiation from nuclear reactors, and ordinary sunlight, the most prominent structures. If we exclude regular light, most types of rays are invisible, such as ultraviolet, infrared, X-rays, and others (Balsak 2014).

Stars (and the sun, including them) are the primary radiation sources, so the sun produces electromagnetic radiation from nuclear reactions (composed of electrical and magnetic energy) occurring at its center. The sun and stars have all kinds of rays, from light to high-energy gamma rays from space to Earth and other nearby objects. Of course, astrophysics deals with everything that reaches Earth from radiation (Cotran RS *et al.* 2010). The energy moves in the form of particles or waves. Radio waves, microwave radiation, and other common forms of radiation are examples of radiation known to most people. The most active type of electromagnetic radiation is ionizing radiation (Zeyrek 2013).

3.1. Radiation sources

Radiation comes from various sources, and we are constantly exposed to it. Radiation from natural background radiation shaped the ancestors of every species on Earth. Humans and other organisms have been exposed to synthetic sources in the last century. More than 80% of our radiation exposure comes from the natural world, and only 20%

comes from artificial sources, most of which come from radiation treatments used in medicine. This publication categorizes radiation exposure according to its source, emphasizing what the general public is exposed to (Daşdağ *et al.* 1990).

Regulatory considerations (e.g., radiation protection) address radiation exposure in various ways. As a result, this section contains information about patients exposed to radiation due to medical radiation use and employees in the workplace. Radiation exposure can also be classified according to the way it irradiates us. Our bodies can be exposed to radiation and radioactive substances from the environment. Alternatively, we can inhale, swallow or absorb substances through our skin and wounds, causing them to irradiate us from the inside out. Taken together, doses from both internal and external sources are comparable (Cotran RS *et al.* 2010).

3.1.1. Cosmic resources

Cosmic rays are a natural source of radiation. These rays come from interstellar space and solar flares. They directly irradiate the Earth and interact with the atmosphere to produce radiation and radioactive material. While Earth's atmosphere and magnetic field reduce cosmic radiation, some areas are more exposed. Due to the magnetic field, the North and South Poles receive more cosmic radiation than the equator. Altitude increases exposure because less air acts as a shield (Committee on the Biological Effects of Ionizing Radiations 1980).

On average, people at sea level receive 0.3 mSv per year from cosmic radiation sources, or 10-15% of their total dose from natural sources. Those over 2 000 meters get more. Air passengers' exposure to cosmic radiation depends on altitude and flight time. At cruise altitudes, a 10-hour flight averages 0.03-0.08 mSv. A round trip New York-Paris flight exposes a person to 0.05 mSv. That is approximately the same as the effective dose for a chest X-ray. Individual passenger doses are low, but collective doses may be high due to the many passengers and flights worldwide (Yarenoğlu 2018).

3.1.2. Medical applications

Radiation used to diagnose and treat diseases is the world's primary source of artificial exposure. It accounts for 98% of exposure to artificial radiation after natural sources and 20% of the global population exposure. Most of this exposure occurs in industrialized countries that have more medical resources and use radiology equipment. In some countries, medical use has resulted in an annual average effective dose similar to natural resources (Coşkun 2011).

As urbanization and living standards rise, more people can access healthcare. Medical exposure continues to increase the dose of the global population. UNSCEAR collects diagnostic and treatment information. The 1997-2007 survey shows that 3.6 billion medical radiation procedures were performed annually worldwide, up from 2.5 billion in 1991-1996 (Ward 1988).

Radiology (including interventional procedures), nuclear medicine, and radiotherapy use radiation. Health screening programs and voluntary participation in medical, biomedical, diagnostic, or therapeutic research are not evaluated by UNSCEAR (Daşdağ *et al.* 1990).

Diagnostic radiology analyzes X-ray images such as chest or dental X-rays, fluoroscopy, and CT scans (CT). UNSCEAR does not address non-ionizing imaging modalities such as ultrasound or MRI. In interventional radiology, image-guided minimally invasive procedures are used (for example, to guide a catheter in a blood vessel) (Cotran RS *et al.* 2010).

Interventional radiology (including interventional procedures), nuclear medicine, and radiotherapy use radiation. Health screening programs and voluntary participation in medical, biomedical, diagnostic, or therapeutic research are not evaluated by UNSCEAR (Canadian Center for Occupational Health and Safety 2016).

Nuclear medicine uses radioactive materials that are not sealed (i.e., dissolved and encapsulated) in the body to obtain images that provide information about organ structure or function. It is used less frequently to treat certain diseases, such as hyperthyroidism and thyroid cancer. It is common practice to convert a radionuclide into an intravenous or oral radiopharmaceutical. Scans are possible because they are distributed in the body by their physical or chemical properties, which makes this possible. Radionuclide radiation emitted by the body is analyzed to help diagnose and treat the disease (Balsak 2014).

Radiation therapy uses high-energy beams of radiation therapy (also known as radiotherapy) to treat various diseases, including cancer and benign tumors. External radiotherapy utilizes a radiation source outside the patient's body, known as teletherapy, for treatment. This procedure uses a highly radioactive source (cobalt-60) or a high-voltage machine that produces radiation (for example, a linear accelerator). Alternatively, radioactive sources, known as brachytherapy, can be implanted into the body temporarily or permanently (Coşkun 2011).

3.2. Biological effects (harms) of radiation

Research into the biological mechanisms by which radiation can harm human health has been ongoing for more than a century since the discovery of radioactivity. It has been shown that radiation affects cells at the cellular level, causing direct damage to DNA strands in a chromosome, causing them to die or change. If the number of damaged or killed cells is large enough, organ dysfunction and even death can occur. There may also be other types of DNA damage that do not kill the cell. If the damage is not completely repaired, the resulting change, known as a cell mutation, will be reflected in subsequent cell divisions and may eventually lead to cancer. Genetic disorders can occur if the cells that transmit genetic information to future generations are changed. Experiments in the laboratory are often used to gain insight into biological mechanisms and hereditary effects (Balsak 2014).

Here, health effects following radiation exposure are defined as either early or delayed health effects based on the observation of their occurrence. While clinical syndromes in individuals can often be used to diagnose early health effects, epidemiological studies can be used to observe the increase in the prevalence of a disease over time in a population to determine its later health effects, such as cancer. Here, special attention is paid to genetic effects and effects on children and embryos/fetuses (Committee on the Biological Effects of Ionizing Radiations 1980).

Cell death/damage causes early health effects. Burns, baldness, and infertility are examples. These health effects have a high threshold that must be crossed quickly. After the threshold, increasing doses intensify the impact. Acute doses above 50 Gy will damage the CNS so severely that death occurs within days. Radiation sickness symptoms include nausea, vomiting, diarrhea, intestinal cramps, salivation, dehydration, fatigue, apathy, weakness, sweating, fever, headache, and low blood pressure. Acute problems do not develop over time but soon after exposure. Survivors may die from gastrointestinal damage one to two weeks later. Lower doses may not cause gastrointestinal damage but still cause death after a few months, especially from bone marrow damage. Lower doses delay disease and reduce its severity. Half of the patients receiving 2 Gy vomit within three hours, which is rare below 1 Gy (Algüneş, 2002).

Radiotherapy uses the ability of radiation to damage cell DNA to kill malignant cells. Radiotherapy doses vary according to the type and stage of cancer. Solid tumor doses range from 20 to 80 Gy, which can be hazardous in a single amount. Repeated doses of radiation in 2 Gy fractions are administered to control the treatment. Normal tissue cells can recover, but tumor cells are killed after radiation because they cannot repair (Solmaz *et al.* 2017).

3.3. Radiation sources in hospitals

Radiation is used in medicine for both diagnosis and treatment. Radiology is the science that examines the use of radiant energy and radioactive materials in the field of diagnosis and treatment in medicine. The diagnostic branch of radiology is radio diagnostics. This branch of science deals with using radiant energy and radioactive materials in medical diagnosis. Radiotherapy is the branch of science related to using radioactive materials and ionizing radiation in medical treatment (Avci, 2016).

Radiological examinations include different methods such as plain X-rays of some anatomical regions, tests by administering contrast material to organs and systems (medicated films),15 ultrasonographic studies, angiography, computed tomography, and magnetic resonance imaging (Avci, 2016).

3.3.1. Radiology

Radiology is a medical specialty dedicated to the detection and treatment of diseases through the use of imaging techniques. Diagnostic radiology and interventional radiology are two branches of radiology. Radiologists are doctors who specialize in radiology (Balsak 2014).

3.3.2. Nuclear medicine

Nuclear medicine procedures help detect and treat diseases using small amounts of a radioactive substance called a radiopharmaceutical. Some radiopharmaceuticals are used with imaging equipment to detect diseases. Radiopharmaceuticals can also be placed inside the body near a cancerous tumor to shrink or destroy it (Daşdağ *et al.* 1990).

3.3.3. Radiotherapy

Radiopharmaceuticals also treat diseases by shrinking tumors and killing cancerous cells. During a brachytherapy procedure, doctors surgically place tiny radioactive "seeds" near or inside a cancerous tumor. Seed radiation helps destroy nearby cancer cells (Solmaz *et al.* 2017).

3.3.4. Medical x-ray

A positron emission tomography PET scan is an example of a nuclear medicine procedure used to diagnose disease. A PET scan uses a radioactive substance added to the bloodstream and travels to a specific organ. Doctors use a special camera to monitor how the tracker moves. The camera sends information to a computer that takes pictures as the viewer moves along the organ. Doctors use images to detect organ-related problems. When working with unsealed radioactive materials, there is a risk to anyone exposed. It must determine whether a domain should be designated as a "controlled " or a "managed" environment. Each controlled area should be evaluated for its potential hazards, and measures taken to limit exposure should be documented (Anjan 2018).

3.4. Radiation fields for hospital staff

When working with unsealed radioactive materials, there is a risk to anyone exposed. It must determine whether a domain should be designated as a "controlled " or a "managed" environment. Each controlled area should be evaluated for its potential hazards, and measures taken to limit exposure should be documented (Anjan 2018).

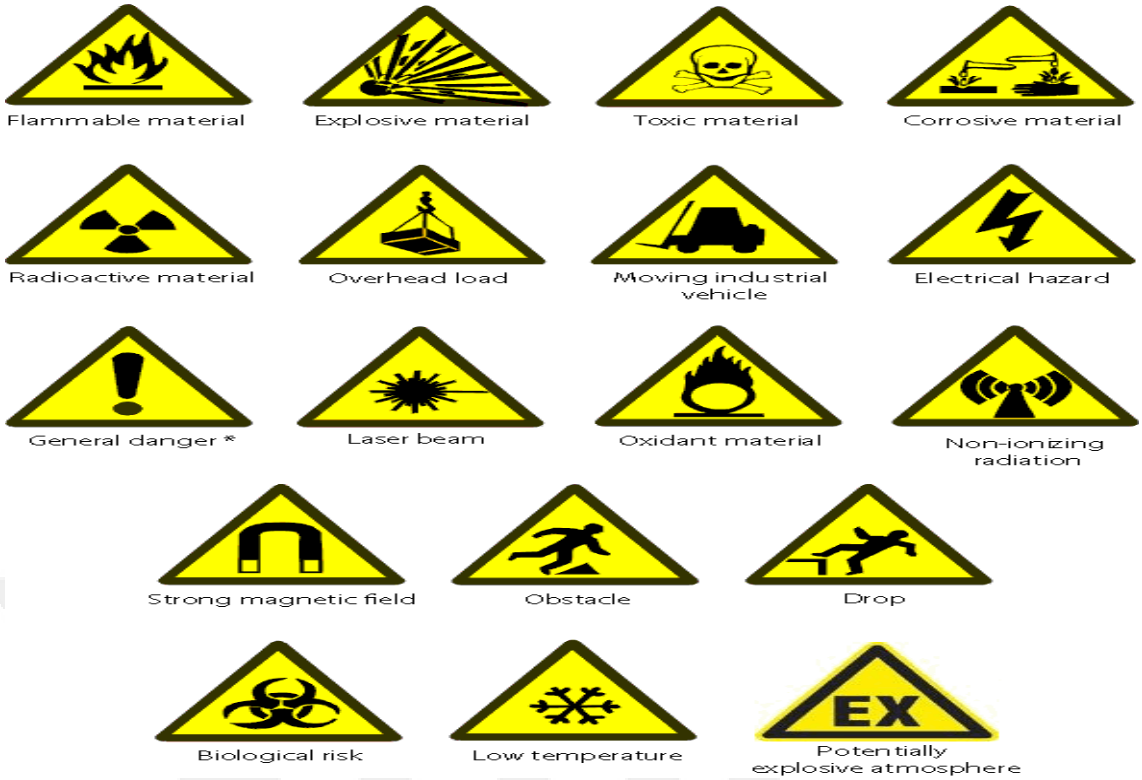

Figure 3.1 Signs with attention to identifying and protecting radiation areas (Göksel, 1973).

Working with radioactive material requires using designated areas mandated by the 2010 Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations. Controlling radiation exposure is the primary objective of this Standard Operating Procedure (SOP). That SOP identifies and separates high-risk and low-risk activities (Coşkun 2011).

3.5. Biological effects of ionizing radiation

A person's body contains various cell types with unique physical and radiation sensitivity properties. Immature cells with high mitotic activity are more sensitive (Anjan 2018). A cell's sensitivity decreases when it receives less blood and nutrients. The radiation effect will decrease if there is less oxygen in the tissue. The impact of radiation on the body is also affected by the size and shape of the irradiated area. A smaller space has less effect on the dose, while a more extensive site has a more significant impact. The cell is most vulnerable to radiation at the beginning of the resting phase and prophase (Coşkun 2011).

Radiation exposure can be reduced by having a high oxygen content in the surrounding environment. If the ambient temperature is low, the radiation effect will be reduced. Factors such as age, gender, health status, and innate biological differences all play a role in determining a person's risk (Amanda *et al.* 1993).

Radiation does not have an immediate effect on the body. A period known as the latent period occurs after a person is exposed to radiation. When it comes to this period, it can vary from a few days to a few weeks, as well as up to 20 years. High radiation doses shorten the well-known latent period (Alagoz 2017).

Somatic and genetic effects are two types of effects that occur when radiation interacts to a certain extent with atoms and molecules in the body. The irradiated person feels the biological effects of radiation. Somatic cells refer to all organ tissue cells except those in the reproductive system (performing body functions). There is no transmission of radiation damage to the next generations through these cells. Both acute (early) and chronic (late) somatic effects are possible (Bolus NE, 2001). The effects that may occur on the body after a single high dose of radiation are known as acute somatic effects and can vary significantly from person to person (Coşkun 2011).

Whole-body irradiation is usually responsible for this effect. It can manifest as anything from a mild illness to a life-threatening condition, and it can do so in minutes, hours, or even weeks. The clinical signs and laboratory findings resulting from short-term radiation exposure are defined as acute radiation syndrome. It can be seen in people whose whole body is irradiated and those who work with radiation daily (Committee on the Biological Effects of Ionizing Radiations 1980). In the long term, chronic (late) somatic effects may include cancer transformation, shortening of life and acceleration of physiological aging, increased leukemia, and development of benign and malignant tumors (Bolus NE 2001).

Damage can be repaired by prolonged exposure to radiation if the repair rate exceeds the rate at which the injury occurs. Permanent damage does not happen unless the threshold dose is exceeded. Radiation can damage the DNA of germ cells, which can have long-term effects on their reproductive ability. The larger the quantity, the higher the mutation probability (Daşdağ *et al.* 1990).

Extremely high doses of chemicals have been shown to cause genetic mutations in animal studies. Chromosomes can acquire new structural and chemical properties for various reasons. Mutations are the name given to these changes. Both reproductive and somatic cells can undergo genetic mutations. Tumors can result from somatic cell mutations. Mutations passed down through generations in reproductive cells have hereditary features (Balsak 2014).

3.6. Effect of ionizing radiation on some tissues and organs

The radiosensitivity of a tissue or organ is determined by how it responds to ionizing radiation. No clinical effect is seen if the number of missing cells is negligible. As the number of disappeared cells increases, clinical signs that everyone can see begin to appear (Bolus NE 2001). Depending on the dose and cell loss, this change can be severe. Deterministic (non-stochastic) effects describe these changes. Patients receiving radiotherapy for cancer may experience osteoradionecrosis, cataracts, and symptoms such as skin rash and dry mouth. Atrophic tissue hypoplasia (cell loss) has a deterministic effect. The doses must be taken to the cut-off point to see the decisive impact. A high threshold dose is required to observe harmful effects, and the latent period is concise (Cotran RS *et al.* 2010).

Stochastic effects are another type of radiation-induced biological effect; these are dose-dependent changes that may or may not be present, regardless of severity. Effects that are likely to occur even if a threshold dose is not reached. Examples of stochastic effects include leukemia, thyroid cancer, salivary gland tumors, and genetic disorders, as higher doses increase their occurrence but not severity. Radiation can cause tissue damage in two ways (Committee on the Biological Effects of Ionizing Radiations 1980):

- When rays damage cells directly, this is the primary effect.
- The primary cause of this secondary effect is a circulatory disturbance.

Chronic events cause swelling in the vascular endothelium, necrosis, thrombus formation, narrowing of the lumen, and ischemic damage to the tissue. Irradiated cells in various organs of the same person have varying response levels (Bergonie and Tribondeau). Cells with high mitotic activity, rapid division, and low differentiation are the most radiosensitive (Feinendegen 2005).

4. PROTECTION OF EMPLOYEES IN HOSPITALS FROM RADIATION

Protection against ionizing radiation beams is radiation safety. It protects ionizing radiation in applications where radioactive materials and similar sources are used. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) regularly reports to the UN General Assembly on radiation protection approaches and risks. According to the International Commission on Radiological Protection (ICRP), personal dose limits for irradiation should be set for personnel protection. Personal dose limits limit individuals' doses without irradiation (Dickson 2012).

The Atomic Energy Agency (TAEA) regulates, authorizes, and supervises the safe use of ionizing radioactive materials in Turkey. Exporting, importing, purchasing, selling, transporting, storing, maintaining, repairing, installing, disassembling, and using radiation sources requires a TAEA license. TAEA published the radiation safety regulation on the 24th of March, 2000, for the last time. This regulation sets effective dose limits for workers exposed to radiation from radiation sources. 96% of artificial radiation comes from medical applications. Interventional radiology, CT, mammography, and fluoroscopy can produce high radiation doses. Patients receive the most radiation, but radiologists and technicians are also exposed during diagnosis.

When the human body is exposed to radiation doses above 1 Sv, acute gastrointestinal, neurological, and hematological disorders occur, or due to long-term low-dose exposure, genetic effects such as cataracts, cancer, short life expectancy or transmission of genetic disorders to future generations can be seen. Employees working with ionizing radiation, those around them, and the community must be safe, as genetic damage can affect the next generation. It is important to make necessary measurements, to use radiation in a controlled manner, and to train people who work with radiation sources (Bora 2001).

All medical X-rays expose patients and staff to radiation. Although the doses used in diagnosis and examinations are low, the number of radiation patients and healthcare personnel should be minimized. Health personnel should be informed about radiation to protect themselves and their patients: precaution and lack of knowledge cause most mistakes. Radiation workers should receive training and update their knowledge regularly (Martin *et al.* 2018).

4.1. Radiation safety and the ALARA principle

This principle minimizes radiation doses and releases radioactive material by all reasonable means. The As Low As Reasonably Achievable (ALARA) is a regulatory requirement for all radiation safety programs. In other words, the ALARA principle states that every aspect of radiation protection must be considered to obtain the lowest possible dose (Bora 2001). It protects individuals or communities from the harmful effects of radiation. Most people were teleported to maximize the net benefit from the apps. In addition, while developing a safe dose, individual dose size and economic and social factors should be considered (Erdoğan 2017).

In the current radiation safety philosophy, the "Linear Hypothesis" is used to model the relationship between radiation dose and the biological effects of radiation on living tissues. According to this theory, even low doses of radiation can increase the risk of cancer and other genetic mutations and alterations. The NCSU Radiation Safety Program aims to reduce workers' radiation doses using practical and cost-effective measures (Avci 2016).

Successfully implementing the Radiation Safety Committee concept largely depends on the NCSU Radiation Safety Committee (RSC). The RSC must first review the proposed experimental protocols and verify the Principal Investigator's (PI) qualifications to allow the possession of radioactive materials or radiation-producing devices. To implement the ALARA concept, RSC authorized the Radiation Safety Division (RSD) and the Radiation Safety Officer (RSO). The RSO reviews all occupational radiation doses, especially to workers whose ALARA review level has been exceeded. RSC conducts an annual review of the radiation safety program in terms of operating procedures and dose records that demonstrate the success of ALARA (Dickson 2012).

RSO serves as the director and technical supervisor of the Radiation Safety Division, which oversees the ALARA program. It is expected that the RSD staff ALARA will contribute to the success of the program in the following ways (Çelik 2013):

- To provide technical support and guidance to PIs and their staff in implementing the ALARA concept.
- It inspected the lab regularly for signs of ALARA problems.
- It assigns dosimetry to workers and uses bioassays to monitor radiation doses.
- They monitor occupational doses and take action if research levels are exceeded.
- Provide training and counselling to workers to ensure doses are kept at an acceptable level of safety.

Emphasis should be placed on all laboratory operations ALARA performed by PIs and research staff with the support of RSDs. Protection, dosimetry, and contamination control techniques are part of this (Avci 2016).

For example, employees must be aware of the potential hazards of radiation, their workplace exposure levels, and safety precautions, and it is up to them to fulfil this duty (Erdoğan 2017). It is important to be aware of the practices that do not comply with the ALARA philosophy (Yarenoğlu 2018).

4.2. Radiation dose limits

When ionizing radiation enters the human body or an object, it accumulates energy. The energy absorbed from radiation exposure is called dose. Radiation dose amounts are defined in three ways: absorbed, equivalent, and effective. These are the annual dose limits that radiation workers or community members can take. There are two types of radiation dose limits (Bor *et al.* 1996).

The equivalent dose is the radiation weight factor multiplied by the quantity absorbed in the tissue and organ and is the unit (Coşkun, 2015). The effective dose for each tissue or organ is the effective dose is calculated by multiplying the equivalent quantity by the tissue weight factor for that tissue or organ. The unit of measure of the effective amount is millisievert (mSv). One sievert is equal to one hundred millisieverts (Çelik 2013).

Limits on the amount of radiation that the general public and nuclear energy workers may be exposed to are determined by the Radiation Protection Regulation. The annual dose limit for the general public is 1 mSv. Annual average effective doses of CNSC licensees to people are in the range of 0.001 to 0.1 mSv per year, according to regular reporting and monitoring (Coşkun 2015).

Effective dose limits for a nuclear power worker are set at 50 mSv per year and 100 mSv for five consecutive years. The dose limit for pregnant workers is 4 mSv from pregnancy announcement until delivery. Licensees must also ensure that all doses are as low as possible, considering social and economic factors ALARA. Average annual doses for the most exposed workers (e.g., industrial radiographers) are about 5 mSv per year based on regular reporting and monitoring (Bora 2001).

4.3. Personal protective equipment for radiation protection

When protecting workers working with ionizing radiation, radiation protection ensures that as few people as possible are exposed. As many as possible, avoid exposure in the first place, and ensure that the amount of radiation they are exposed to is protected (Çelik 2013). This equipment protects the user from injury, infection, and other hazards. In most hazardous occupations, personal protective equipment (PPE) must be used in a certain way to reduce the risk of injury. (Dökmeci *et al.* 2019)

The workplace licensee is responsible for ensuring appropriate safety measures to protect workers from exposure to ionizing radiation. Before starting any activities, the employees should be informed about the relevant radiological risks and the standard procedures for radiological protection. In addition, they need to be trained initially and regularly. Individual dosimetry records of workers exposed to hazardous substances for a long time are kept up-to-date and accessible. PPE for radiologists, radiographers, and other imaging department personnel may include (Ayan *et al.* 2016):

- Physical protection.
- Gloves.
- Eye protection.
- Masks.
- Face protective masks.
- Aprons or other items depending on the conditions and cases to be viewed.
- Protection from ionizing radiation (Larcos et al. 2014).
- Lead aprons.
- Thyroid shields.
- Personal radiation dosimeters.

Personal protective equipment should be put on and taken off in the prescribed order to maximize protection from communicable diseases, although these sequences may differ from institution to institution (Tetteh *et al.* 2020).

5. METHODOLOGY

This chapter describes the study's methodology, including permissions and approvals, study design, setting of the study, inclusion criteria, sample size, sample technique, selection criteria, data collection technique, research difficulties, scoring criteria, and statistical analysis. The primary focus of this study was the evaluation of PPE for healthcare workers in the radiation field.

5.1. Permissions and approvals

Necessary permissions were obtained from the Babylon health department (Appendix - 1). The researcher attached each questionnaire and explained it in Arabic langue, and all participants were informed about the aim and content of the study. The confidentiality of the participants was ensured. Ultimately, all the data collected was used for research purposes only.

5.2. The study design

A cross-sectional study was conducted at the Babylon hospitals.

5.3. The study setting and time

The data was collected from the 2nd of November 2022 till the 2nd of March 2023, 5 days a week and 5 hours daily (9.00 A.M- 2.00 P.M). This study was conducted in Babylon city, which included two hospitals (Morgan hospital and Imam Sadiq hospital) located within the geographical location of Babylon city.

5.4. Inclusion criteria

The study targets employees in hospitals who work in the field of radiation, and the job title was shared (radiographer, radiologic technologist, physicist, radiologist)

5.5. Sample size

Steven Thompson's formula was used to calculate the sample size. As a result, the minimum sample size for healthcare workers in the field of radiation is 188, while we have taken 200 to strengthen the study, as shown below:

$$n = \frac{N \times p(1-p)}{\left[\left[N-1 \times (d^2 \div z^2)\right] + p(1-p)\right]},$$

Where:

- N= The Study Population size (367 HCWs)
- n = sample size (188 for HCWs).
- Z= Confidence level at 95% (1.96)
- p = Probability (0.50)
- d = Error Proportion (0.05) (Thompson 2012)

The study samples were selected by simple random sampling

5.6. Data collection technique

The data was collected through questionnaires distributed based on four parts following are:

Part one includes socio-demographic characteristics through a direct interview regarding (age, gender, level of education, social status, job title, working hours, and experience years).

Part two includes the habits of the participants (smoking status, drinking alcohol, exposure to radiation, use of medication, etc.).

Part three includes health problems of HCW in the field of radiation (cardiovascular diseases, cancer, mental health problems, depression, migraine and anxiety, hypertension, stress, disruption in sleep patterns, eye condition, irritability, headache, eye discomfort, enlargement of lymph nodes, ear discomfort, hair loss, hair loss in areas exposed to radiation especially on the back of the hand, loss of sexual desire, bruises on the skin, frequent bleeding gums, Frequent gastrointestinal diseases, frequent respiratory illness).

Part four includes assessing the participant's answers about (occupational health and safety measures, training in radiation safety, dosimeters, and using PPE).

5.7. Research difficulties and limitations

Since participation in the research was voluntary, some HCWs in the radiation field refused to participate, so the entire limited universe could not be reached.

5.8. Scoring criteria

Regarding the assessment of occupational health and safety measures, the scale of the two levels was rated on the 2 points (Likert respondent scale). It was scored as a scoring of agreed by assigning a score of (1) for "No," (2) for "Yes." So, the Minimum mean Score= 1, the Maximum mean Score= 2, and the Median mean Score = 1.5. A score of equal to or more than 50% was considered good (≥1.5 MS), and less than 50% was taken as poor (<1.5 scores) (Shinde & Mohite 2014).

Regarding the assessment of occupational health and safety measures, the scale of the two levels was rated on the 2 points (Likert respondent scale). It was scored as a scoring of agreed by assigning a score of (2) for "Yes," (1) for "No." The overall assessment score for the assessment of occupational health and safety measures was 11, so the Minimum

Score= 11, Maximum Score= 22, and Median Score = 17. A score of equal or more than 50% was considered good (≥17 scores), and less than 50% was taken as poor (<17 scores) (Shinde & Mohite 2014).

Regarding the habits of the participants, the scale of the two levels was rated on the 2 points (Likert respondent scale). It was scored as a scoring of agreed by assigning a score of (1) for "Yes," (2) for "No." The overall assessment score for habit sub-domains was 7, so the Minimum Score= 7, Maximum Score= 14, and Median Score = 11. A score of equal or more than 50% was considered good (≥11 scores), and less than 50% was taken as poor (<11 scores) (Shinde & Mohite 2014).

5.9. Statistical analysis

The data from the questionnaire and the information for each question were transferred to code sheets, entered into the personal computer, and then analyzed by the statistical package available from SPSS for Windows 28.0 (SPSS-28 2021). Data were shown in simple measures of frequency, percentage, mean, standard deviation, and range (minimum and maximum values). The significance of the difference for different percentages (qualitative data) was tested using the Pearson Chi-square test ($\chi 2$-test). Statistical significance was considered when the *P*-value was equal to or less than 0.05. Two independent sample test analysis was used to study the difference in mean between the two groups. One-way ANOVA analysis was used to study the difference in mean between three or more groups, provided that the variable is normally distributed. Using Levene Statistic (equal variance is not assumed), Games-Howell is a post-hoc test in the present study. The *P*-value of <0.05 was considered significant (Field, 2018).

6. RESULTS

6.1. Socio-demographic variables of the participants

Table 6.1 demonstrates the distribution of the workers in the radiation field according to socio-demographic variables. The mean ± Standard deviation (SD) of the participant's age was 31.03±7.35 years, the age range was between 21-53 years, the highest percentage (32.0%) was in the age group (26-30) years, and the lowest rate (4.5%), was in the age group (>45) years. There was a distinct male preponderance of 64.0%. Regarding educational level, the results found that the highest percentage (47.5%) have Bachelor's certificates, followed by 40.0% of participants have Diploma certificates. The highest rate (61.5%) of the participants were married. Regarding job titles, the results found that the participants' highest percentage (49.0%) were radiologic technologists, followed by radiographers 39.5%. Also, these results found that most participants, 82.0%, have served in the radiation field for less than ten years. Finally, the results indicate that the highest percentage (69.5%) of participants worked 3-6 hours per day in the radiation field.

Table 6.1 Distribution of the workers in the radiation field according to socio-demographic variables

SOCIO-DEMOGRAPHICS		**NO.**	**%**
Age groups	≤ 25 years	52	26.0
	26-30 years	64	32.0
	31-35 years	37	18.5
	36-40 years	24	12.0
	41-45 years	14	7.0
	>45 years	9	4.5
	Mean± SD (Range)	**31.03±7.35 (21-53)**	
Gender	Male	128	64.0
	Female	72	36.0
Education level	Diploma	80	40.0
	Bachelor	95	47.5
	Postgraduate	25	12.5
Marital status	Single	77	38.5
	Married	123	61.5
Job title	Radiographer	79	39.5
	Radiologic technologist	98	49.0
	Physicist	21	10.5
	Radiologist	2	1.0

Table 6.1 Distribution of the workers in the radiation field according to socio-demographic variables (continued)

SOCIO-DEMOGRAPHICS		NO	%
How many years have you been working in the radiation field?	≤10 years	164	82.0
	>10 years	36	18.0
	Mean± SD (Range)	**6.82±6.15 (1-25)**	
How many hours do you work per day in the field of radiation?	<3 Hours	3	1.5
	3-6 Hours	139	69.5
	7-10 Hours	55	27.5
	>10 Hours	3	1.5
	Mean± SD (Range)	**6.07±1.58 (1-12)**	

6.2. Habits of the participants

Table 6.2 demonstrates that the highest percentage (100.0% and 85.0%) of the workers in the radiation field have no alcohol consumption and smoking, respectively. Most participants were not exposed to an accident in the field of radiation during working life, with a percentage of 96.0%. At the same time, the highest rate (62.5%, 66.0%, 60.5%, and 87.0%) of the workers in the radiation field have no exposure to (co-workers have been involved in a radiation-related accident, any additional work where you are exposed to radiation outside your organization, any children with congenital malformations, and using medication a daily, respectively).

Table 6.2 Distribution of the workers in the radiation field according to their habits

	RATING	NO.	%
Do you smoke?	Yes	30	15.0
	No	170	85.0
Do you drink alcohol?	Yes	-	-
	No	200	100.0
Have you been exposed to an accident in the radiation field during your working life?	Yes	8	4.0
	No	192	96.0
Have any of your co-workers been involved in a radiation-related accident?	Yes	75	37.5
	No	125	62.5
Do you have any additional work where you are exposed to radiation outside your organization?	Yes	68	34.0
	No	132	66.0
Do you have any children with congenital malformations?	Yes	2	1.0
	No	121	60.5
Is there a medication that you use daily?	Yes	26	13.0
	No	174	87.0

6.3. The health problems

Table 6.3 shows the distribution of the workers in the radiation field according to their health problems. The results of this study indicate that a high percentage of the workers have no health problems, as explained in the table below.

Table 6.3 Distribution of the workers in the radiation field according to their health problems

	RATING	NO.	%
Cardiovascular diseases	Found	7	3.5
	Not found	193	96.5
Cancer	Found	3	1.5
	Not found	197	98.5
Mental health problems	Found	5	2.5
	Not found	195	97.5
Migraine and anxiety	Found	67	33.5
	Not found	133	66.5
Depression	Found	76	38.0
	Not found	124	62.0
Allergic discomfort	Found	28	14.0
	Not found	172	86.0
Infertility	Found	5	2.5
	Not found	195	97.5
Hypertension	Found	36	18.0
	Not found	164	82.0
Stress	Found	125	62.5
	Not found	75	37.5
Disturbed by sleep patterns	Found	54	27.0
	Not found	146	73.0
Irritability	Found	23	11.5
	Not found	177	88.5
Eye discomfort	Found	76	38.0
	Not found	124	62.0
Ear discomfort	Found	47	23.5
	Not found	153	76.5

Table 6.3 Distribution of the workers in the radiation field according to their health problems (continued)

	RATING	NO	%
Headache	Found	93	46.5
	Not found	107	53.5
Bruises on the skin	Found	30	15.0
	Not found	170	85.0
Enlargement of lymph nodes	Found	14	7.0
	Not found	186	93.0
Hair loss	Found	119	59.5
	Not found	81	40.5
Hair loss in radiation-exposed areas, including on the back of the hand	Found	51	25.5
	Not found	149	74.5
Rash on the skin	Found	13	6.5
	Not found	187	93.5
Lack of sexual desire	Found	23	11.5
	Not found	177	88.5
Pallor of the skin	Found	36	18.0
	Not found	164	82.0
Frequent bleeding gums	Found	14	7.0
	Not found	186	93.0
Frequent gastrointestinal diseases	Found	44	22.0
	Not found	156	78.0
Frequent respiratory diseases	Found	15	7.5
	Not found	185	92.5

6.4. Assessment of occupational health and safety measures

Table 6.4, the current study found that all indicators have a good assessment score (mean score>1.5), except for the 4th, 5th, 8th, 10th, and 11th questions regarding (Are the measures taken by the hospital management to reduce the risks of ionizing radiation appropriate? Are the calibration and control of devices that emit ionizing radiation regularly carried out in the environment where you work? Lead neck brace (Protective thyroid apparatus), Lead gloves, and Lead glasses) have poor assessment scores (1.43±0.496, 1.43±0.496, 1.25±0.434, 1.17±0.377, and 1.18±0.381), respectively. While the first rank of occupational health and safety measures was enough knowledge of participants about radiation protection, and the last rank was for Lead gloves.

Table 6.4 Assessment of the participant's answers according to occupational health and safety measures

	RATING	NO.	%	MEAN± SD	ASSESSMENT	RANK
Are you trained in radiation safety?	No	50	25.0	1.75±0.434	Good	2
	Yes	150	75.0			
Do you know enough about radiation protection?	No	49	24.5	1.76±0.431	Good	1
	Yes	151	75.5			
Do you use a dosimeter?	No	64	32.0	1.68±0.468	Good	3
	Yes	136	68.0			
Does the hospital management take appropriate measures to reduce the risks of ionizing radiation?	No	115	57.5	1.43±0.496	Poor	7
	Yes	85	42.5			
Are the calibration and control of devices that emit ionizing radiation regularly carried out in the environment where you work?	No	115	57.5	1.43±0.496	Poor	7
	Yes	85	42.5			
Availability of an adequate amount of personal protective equipment	No	84	42.0	1.58±0.495	Good	5
	Yes	116	58.0			
Wear a lead apron (lead waistcoat)	No	96	48.0	1.52±0.501	Good	6
	Yes	104	52.0			
Wear a lead neck brace (Protective thyroid apparatus)	No	150	75.0	1.25±0.434	Poor	8
	Yes	50	25.0			
Use lead screen	No	81	40.5	1.60±0.492	Good	4
	Yes	119	59.5			
Wear lead gloves	No	166	83.0	1.17±0.377	Poor	10
	Yes	34	17.0			

Table 6.4 Assessment of the participant's answers according to occupational health and safety measures (continued)

	RATING	NO	%	MEAN± SD	ASSESSMENT	RANK
Wear lead glasses	No	165	82.5	1.18±0.381	Poor	9
	Yes	35	17.5			
Overall evaluation	**1.48±0.203 (Poor)**					

Mean (MS) less than 1.5 (Poor); MS ≥1.5 (good)

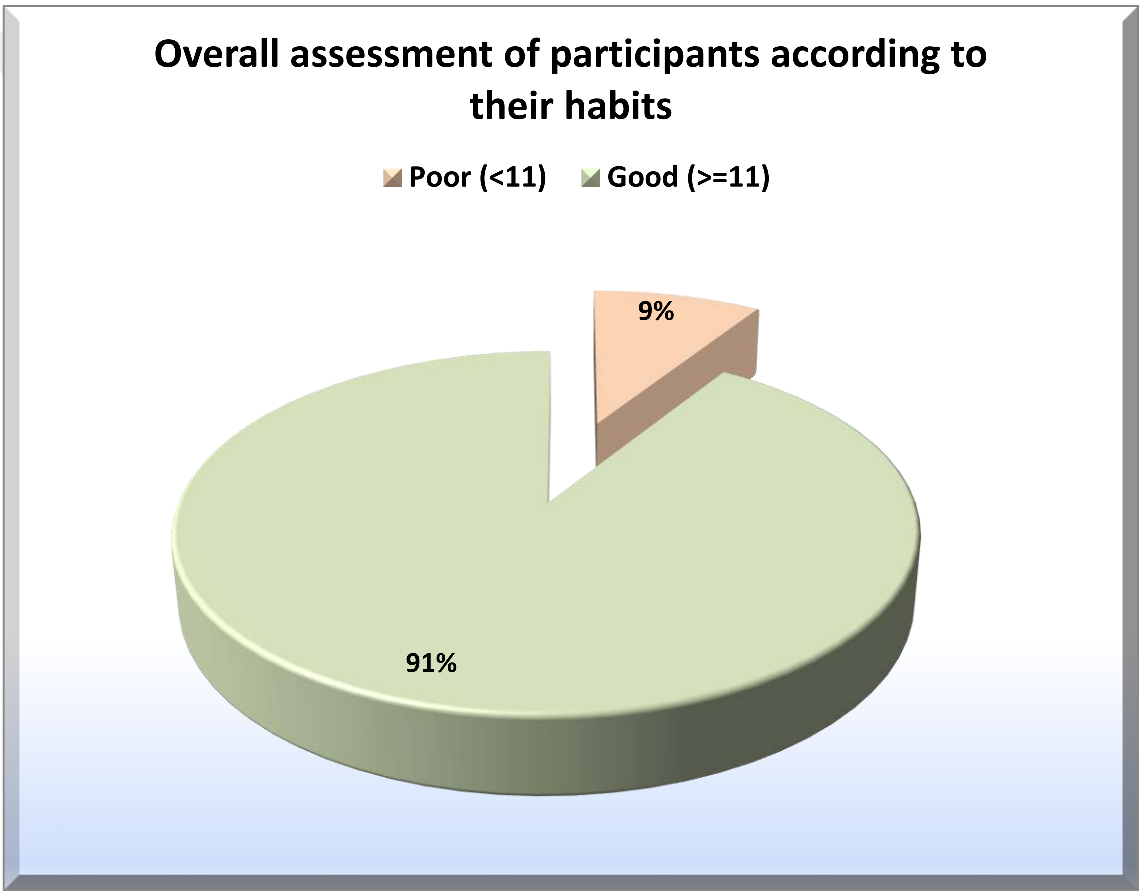

Figure 6.1 The overall assessment score of the participant's habit

Figure 6.1 shows the overall assessment score of the workers in the radiation according to their habits. The present study found that the highest percentage, 91.0%, of the workers in the radiation field has a good assessment score, while the lowest rate, 9.0%, has a poor assessment score.

Table 6.5 shows the association between service years and workers' health problems in the radiation field. This study's results indicate no significant association between service years and health problems (*P* value >0.05) except for depression, allergic discomfort, irritability, bruises on the skin, and hair loss in radiation-exposed areas, including on the back of the hand. The skin's pallor is significantly associated with service years (*P* value <0.05). The result explains that workers with service years equal to or less than ten years are more exposed to these health problems.

Table 6.5 Association between service years and the health problems of the participants

	RATING		SERVICE YEARS		X^2	P VALUE
			≤10 YEARS	>10 YEARS		
Cardiovascular diseases	Yes	No.	4	3	3.037	0.081
		%	57.1%	42.9%		
	No	No.	160	33		
		%	82.9%	17.1%		
Cancer	Yes	No.	3	0	0.669	0.414
		%	100.0%	0.0%		
	No	No.	161	36		
		%	81.7%	18.3%		
Mental health problems	Yes	No.	5	0	1.126	0.289
		%	100.0%	0.0%		
	No	No.	159	36		
		%	81.5%	18.5%		
Migraine and anxiety	Yes	No.	53	14	0.572	0.449
		%	79.1%	20.9%		
	No	No.	111	22		
		%	83.5%	16.5%		
Depression	Yes	No.	69	7	6.416	**0.011***
		%	90.8%	9.2%		
	No	No.	95	29		
		%	76.6%	23.4%		
Allergic discomfort	Yes	No.	17	11	9.994	**0.002***
		%	60.7%	39.3%		
	No	No.	147	25		
		%	85.5%	14.5%		

Table 6.5 Association between service years and the health problems of the participants (continued)

	RATING		SERVICE YEARS		X^2	*P* VALUE
			≤10 YEARS	**>10 YEARS**		
Infertility	Yes	No.	4	1	0.014	0.906
		%	80.0%	20.0%		
	No	No.	160	35		
		%	82.1%	17.9%		
Hypertension	Yes	No.	27	9	1.457	0.227
		%	75.0%	25.0%		
	No	No.	137	27		
		%	83.5%	16.5%		
Stress	Yes	No.	107	18	2.927	0.087
		%	85.6%	14.4%		
	No	No.	57	18		
		%	76.0%	24.0%		
Disturbed by sleep patterns	Yes	No.	42	12	0.893	0.345
		%	77.8%	22.2%		
	No	No.	122	24		
		%	83.6%	16.4%		
Irritability	Yes	No.	23	0	5.705	**0.017***
		%	100.0%	0.0%		
	No	No.	141	36		
		%	79.7%	20.3%		
Eye discomfort	Yes	No.	59	17	1.585	0.208
		%	77.6%	22.4%		
	No	No.	105	19		
		%	84.7%	15.3%		
Ear discomfort	Yes	No.	37	10	0.447	0.504
		%	78.7%	21.3%		
	No	No.	127	26		
		%	83.0%	17.0%		
Headache	Yes	No.	73	20	1.447	0.229
		%	78.5%	21.5%		
	No	No.	91	16		
		%	85.0%	15.0%		

Table 6.5 Association between service years and the health problems of the participants (continued)

	RATING		SERVICE YEARS		X^2	P VALUE
			≤10 YEARS	>10 YEARS		
Bruises on the skin	Yes	No.	20	10	5.622	**0.018***
		%	66.7%	33.3%		
	No	No.	144	26		
		%	84.7%	15.3%		
Enlargement of lymph nodes	Yes	No.	13	1	1.202	0.273
		%	92.9%	7.1%		
	No	No.	151	35		
		%	81.2%	18.8%		
Hair loss	Yes	No.	102	17	2.746	0.097
		%	85.7%	14.3%		
	No	No.	62	19		
		%	76.5%	23.5%		
Hair loss in radiation-exposed areas, including on the back of the hand	Yes	No.	49	2	9.193	**0.002***
		%	96.1%	3.9%		
	No	No.	115	34		
		%	77.2%	22.8%		
Rash on the skin	Yes	No.	13	0	3.052	0.081
		%	100.0%	0.0%		
	No	No.	151	36		
		%	80.7%	19.3%		
Lack of sexual desire	Yes	No.	22	1	3.282	0.070
		%	95.7%	4.3%		
	No	No.	142	35		
		%	80.2%	19.8%		
The pallor of the skin	Yes	No.	25	11	4.689	**0.030***
		%	69.4%	30.6%		
	No	No.	139	25		
		%	84.8%	15.2%		
Frequent bleeding gums	Yes	No.	14	0	3.304	0.069
		%	100.0%	0.0%		
	No	No.	150	36		
		%	80.6%	19.4%		

Table 6.5 Association between service years and the health problems of the participants (continued)

	RATING		SERVICE YEARS		X^2	*P* VALUE
			≤10 YEARS	>10 YEARS		
Frequent gastrointestinal diseases	Yes	No.	33	11	1.873	0.171
		%	75.0%	25.0%		
	No	No.	131	25		
		%	84.0%	16.0%		
Frequent respiratory diseases	Yes	No.	10	5	2.583	0.108
		%	66.7%	33.3%		
	No	No.	154	31		
		%	83.2%	16.8%		

Table 6.6 shows the assessment of occupational health and safety measures according to functional characteristics. The results reveal that radiologists have good scores (1.636±0.00), followed by radiologic technologists (1.500±0.186) regarding occupational health and safety measures. Regarding service years, the present study found that workers in the radiation field who have served more than ten years have a good assessment score regarding occupational health and safety measures. As for other variables, the study shows that all remaining variables have a poor assessment score (MS<1.5) for occupational health and safety measures.

Table 6.6 Assessment of occupational health and safety measures according to functional characteristics

		MEAN	SD	ASSESSMENT
Job title	Radiographer	1.484	0.231	Poor
	Radiologic technologist	1.500	0.186	Good
	Physicist	1.402	0.164	Poor
	Radiologist	1.636	0.00	Good
Service years	≤10 years	1.472	0.204	Poor
	>10 years	1.535	0.195	Good
How many hours do you work per day in the field of radiation?	<3 Hours	1.393	0.277	Poor
	3-6 Hours	1.493	0.206	Poor
	7-10 Hours	1.476	0.192	Poor
	>10 Hours	1.363	0.272	Poor

Mean (MS) less than 1.5 (Poor); MS ≥1.5 (good)

Table 6.7 demonstrates the assessment of occupational health and safety measures according to socio-demographic variables. The results found a significant difference between the studied variables and the score of occupational health and safety measures (*P*.value<0.05), except for marital status, have no significant differences regarding occupational health and safety measures (*P*.value>0.05).

Table 6.7 Association between occupational health and safety measures scores and some socio-demographic variables (By using analysis of variance "ANOVA" and "Independent samples test")

		MEAN	SD	F OR T-TEST	*P*.VALUE
Age groups	≤ 25 years	1.494 [a c]	0.239	2.394	0.039
	26-30 years	1.438 [a]	0.197		
	31-35 years	1.511 [a c]	0.178		
	36-40 years	1.458 [a]	0.203		
	41-45 years	1.630 [c]	0.126		
	>45 years	1.494 [a c]	0.129		
Education level	Diploma	1.483 [a]	0.230	4.442	0.013
	Bachelor	1.458 [a]	0.182		
	Postgraduate	1.592 [b]	0.157		
Gender	Male	1.506	0.194	1.996	0.047
	Female	1.447	0.217		
Marital status	Single	1.464	0.259	1.154	0.250
	Married	1.498	0.159		

Letter different denotes found significant differences <0.05

Table 6.8 demonstrates tests of homogeneity of variances for averages of prevention and safety measures regarding age groups. Using Levene statistic explains that the test was significantly at 0.002. This indicates that equal variance is not assumed.

Table 6.8 Tests of homogeneity of variances for averages of prevention and safety measures regarding age groups

Tests of Homogeneity of Variances (age groups)					
		LEVENE STATISTIC	DF1	DF2	*P*.VALUE
Averages of prevention and safety measures	Based on Mean	3.972	5	194	0.002

Table 6.9 shows that the average age group (41-45 years) regarding prevention and safety measures assessment is significantly higher than other age groups.

Table 6.9 Post-hoc tests between averages of prevention and safety measures and age groups

Multiple comparisons						
Dependent Variable Averages of Prevention and Safety Measures						
Games-Howell						
(I) AGE GROUPS	**(J) AGE GROUPS**	**MEAN DIFFERENCE (I-J)**	**STD. ERROR**	***P*.VALUE**	**95% CONFIDENCE INTERVAL**	
					LOWER BOUND	**UPPER BOUND**
≤ 25 years	26-30 years	0.05592	0.0413	0.755	-0.0642-	0.1761
	31-35 years	-0.01621-	0.0442	0.999	-0.1452-	0.1128
	36-40 years	0.03651	0.0531	0.983	-0.1206-	0.1936
	41-45 years	-0.13600-	0.0472	0.065	-0.2773-	0.0053
	>45 years	-0.00011-	0.0544	1.000	-0.1719-	0.1717
26-30 years	<= 25 years	-0.05592-	0.0413	0.755	-0.1761-	0.0642
	31-35 years	-0.07214-	0.0383	0.421	-0.1840-	0.0397
	36-40 years	-0.01941-	0.0482	0.999	-0.1638-	0.1250
	41-45 years	-0.19192-*	0.0417	0.001	-0.3192-	-0.0647-
	>45 years	-0.05603-	0.0497	0.862	-0.2192-	0.1072
31-35 years	<= 25 years	0.01621	0.0442	0.999	-0.1128-	0.1452
	26-30 years	0.07214	0.0383	0.421	-0.0397-	0.1840
	36-40 years	0.05272	0.0508	0.903	-0.0985-	0.2040
	41-45 years	-0.11979-	0.0446	0.106	-0.2547-	0.0152
	>45 years	0.01611	0.0521	1.000	-0.1516-	0.1838

Table 6.9 Post-hoc tests between averages of prevention and safety measures and age groups (continued)

Multiple comparisons						
Dependent Variable Averages of Prevention and Safety Measures						
Games-Howell						
(I) AGE GROUPS	**(J) AGE GROUPS**	**MEAN DIFFERENCE (I-J)**	**STD. ERROR**	***P*.VALUE**	**95% CONFIDENCE INTERVAL**	
					LOWER BOUND	**UPPER BOUND**
36-40 years	<= 25 years	-0.03651-	0.0531	0.983	-0.1936-	0.1206
	26-30 years	0.01941	0.0482	0.999	-0.1250-	0.1638
	31-35 years	-0.05272-	0.0508	0.903	-0.2040-	0.0985
	41-45 years	-0.17251-*	0.0534	0.029	-0.3333-	-0.0117-
	>45 years	-0.03662-	0.0598	0.989	-0.2225-	0.1492
41-45 years	<= 25 years	0.13600	0.0472	0.065	-0.0053-	0.2773
	26-30 years	0.19192*	0.0417	0.001	0.0647	0.3192
	31-35 years	0.11979	0.0446	0.106	-0.0152-	0.2547
	36-40 years	0.17251*	0.0534	0.029	0.0117	0.3333
	>45 years	0.13589	0.0547	0.184	-0.0394-	0.3111
>45 years	<= 25 years	0.00011	0.0544	1.000	-0.1717-	0.1719
	26-30 years	0.05603	0.0497	0.862	-0.1072-	0.2192
	31-35 years	-0.01611-	0.0521	1.000	-0.1838-	0.1516
	36-40 years	0.03662	0.0598	0.989	-0.1492-	0.2225
	41-45 years	-0.13589-	0.0547	0.184	-0.3111-	0.0394

*. The mean difference is significant at the 0.05 level.

Table 6.10 demonstrates that tests of homogeneity of variances for averages of prevention and safety measures regarding education level. Using Levene statistic explains that the test was significantly at 0.001. This indicates that equal variance is not assumed.

Table 6.10 Tests of homogeneity of variances for averages of prevention and safety measures regarding education level

Tests of Homogeneity of Variances (Education level)					
		LEVENE STATISTIC	**DF1**	**DF2**	***P*.VALUE**
Averages of prevention and safety measures	Based on mean	7.135	2	197	0.001

Table 6.11, the present results reveal that the averages of postgraduate participants regarding prevention and safety measures assessment are significantly higher than other education levels.

Table 6.11 Post-hoc tests between averages of prevention and safety measures and education level

Multiple Comparisons						
Dependent Variable: Averages of Prevention and Safety Measures						
Games-Howell						
(I) EDUCATION LEVEL	**(J) EDUCATION LEVEL**	**MEAN DIFFERENCE (I-J)**	**STD. ERROR**	***P*.VALUE**	**95% CONFIDENCE INTERVAL**	
					LOWER BOUND	**UPPER BOUND**
Diploma	University\Bachelor	0.02481	0.0318	0.717	-0.0506-	0.1002
	Postgraduate	-0.10955-*	0.0407	0.025	-0.2075-	-0.0116-
University\Bachelor	Diploma	-0.02481-	0.0318	0.717	-0.1002-	0.0506
	Postgraduate	-0.13435-*	0.0367	0.002	-0.2235-	-0.0452-
Postgraduate	Diploma	0.10955*	0.0407	0.025	0.0116	0.2075
	University\Bachelor	0.13435*	0.0367	0.002	0.0452	0.2235

*. The mean difference is significant at the 0.05 level.

Table 6.12, the present study reveals that the overall prevention and safety measures assessment mean were 16.33±2.24, which rested within a poor level (<17 scores). The results of this study indicate that the highest percentage (56.5%) of the participants have a poor assessment score for prevention and safety measures. In contrast, 43.5% of them have a good score.

Table 6.12 The overall assessment of prevention and safety measures

	MEAN± SD	ASSESSMENT		NO.	%
Overall assessment of prevention and safety measures	16.33±2.24	Poor	Poor (<17 scores)	113	56.5
			Good (>=17 scores)	87	43.5

Table 6.13 shows the association between the overall assessment score of prevention and safety measures and the socio-demographic variables of the participants. The results found that there is a significant association between some socio-demographic variables (age groups, education level, career title, and work years) and the overall assessment score of prevention and safety measures (P value <0.05).

table 6.13 Association between the overall assessment score of prevention and safety measures and socio-demographic variables and the habits of the participants

			PREVENTION AND SAFETY MEASURES		*P* VALUE
			POOR (<17 SCORES)	GOOD (>=17 SCORES)	
Age groups	≤ 25 years	No.	27	25	0.049*
		%	51.9%	48.1%	
	26-30 years	No.	42	22	
		%	65.6%	34.4%	
	31-35 years	No.	20	17	
		%	54.1%	45.9%	
	36-40 years	No.	17	7	
		%	70.8%	29.2%	
	41-45 years	No.	4	10	
		%	28.6%	71.4%	
	>45 years	No.	3	6	
		%	33.3%	66.7%	
Gender	Male	No.	72	56	0.924
		%	56.3%	43.8%	
	Female	No.	41	31	
		%	56.9%	43.1%	
Education level	Diploma	No.	44	36	0.011*
		%	55.0%	45.0%	
	University\Bachelor	No.	64	31	
		%	67.4%	32.6%	
	Postgraduate	No.	13	12	
		%	52.0%	48.0%	

table 6.13 Association between the overall assessment score of prevention and safety measures and socio-demographic variables and the habits of the participants (continued)

			PREVENTION AND SAFETY MEASURES		*P* VALUE
			POOR (<17 SCORES)	GOOD (>=17 SCORES)	
Marital status	Single	No.	47	30	0.306
		%	61.0%	39.0%	
	Married	No.	66	57	
		%	53.7%	46.3%	
Job title	Radiographer	No.	35	44	0.008*
		%	44.3%	55.7%	
	Radiologic technologist	No.	63	35	
		%	64.3%	35.7%	
	physicist	No.	15	6	
		%	71.4%	28.6%	
	Radiologist	No.	0	2	
		%	0.0%	100.0%	
Work years	<5 years	No.	52	34	0.017*
		%	60.5%	39.5%	
	5-9 years	No.	40	24	
		%	62.5%	37.5%	
	10-14 years	No.	13	14	
		%	48.1%	51.9%	
	15-19 years	No.	4	1	
		%	80.0%	20.0%	
	≥20 years	No.	4	14	
		%	22.2%	77.8%	

Table 6.13 Association between the overall assessment score of prevention and safety measures and socio-demographic variables and the habits of the participants (continued)

			PREVENTION AND SAFETY MEASURES		*P* VALUE
			POOR (<17 SCORES)	**GOOD (>=17 SCORES)**	
Workday	<3 Hours	No.	2	1	0.071
		%	66.7%	33.3%	
	3-6 Hours	No.	70	69	
		%	50.4%	49.6%	
	7-10 Hours	No.	39	16	
		%	70.9%	29.1%	
	>10 Hours	No.	2	1	
		%	66.7%	33.3%	
Total habits score	Poor (<11)	No.	14	4	0.056
		%	77.8%	22.2%	
	Good (>=11)	No.	99	83	
		%	54.4%	45.6%	

Pearson Chi-Square

7. DISCUSSION

The present study found that the mean ± SD of the participant's age was 31.03±7.35 years, the age range was between 21-53 years, the highest percentage (32.0%) was in the age group (26-30) years, and the lowest rate (4.5%), was in the age group (>45) years. There was a distinct male preponderance of 64.0%. These results agreed with the study findings done in Erbil hospitals, Iraq (Hameed *et al.* 2017), which revealed that the employees 51 (46.4%) were mainly between the ages of 21 -30, and there 47 (42.7%) were female and 63 (57.3%) male. The possible explanation for the participation of males more than females may be due to health reasons that are more affected by women because they are subject to pregnancy, which requires, within the law of the Iraqi Ministry of Health, to exclude them during pregnancy.

Also, these results agreed with a study conducted by Khamtuikrua and Suksompong (2020), which found that the mean ± SD of the participant's age was 34.75±8.56 years, and the age range was between 25-66 years.

Regarding educational level, the results found that the highest percentage (47.5%) have Bachelor's certificates, followed by 40.0% of participants with diploma certificates. These results agreed with the findings of Goula *et al.* (2021), which revealed that 62.1% of participants have a university education.

In this study, the highest percentage (61.5%) of the participants were married. This result agrees with the study findings of Awosan *et al.* (2016), which revealed that 66.4% of the participants were married.

Also, these results found that most participants, 82.0%, have served in the radiation field for less than ten years. This result agrees with the study findings conducted in Northern Nigeria (Awosan *et al.* 2016), which reported that 95.5% of HCWs have practiced in the radiation field for 1-9 years.

The current study demonstrates that the mean in the radiation field was 6.82±6.15 years. This result work agrees with the findings of Khamtuikrua and Suksompong (2020), who reported that Work experience was 7.1±8.1 years.

The results of this study indicate that the highest percentage (100.0% and 85.0%) of the workers in the radiation field have no alcohol consumption and smoking, respectively. These results agreed with the study findings conducted by Ahmad *et al.* (2019), which found that a high percentage (100.0% and 85.0%) of participants, the workers in the radiation field, had no smoking and alcohol consumption, respectively. The possible explanation for the decrease in the proportion of smokers and alcohol may be due to social behavior on the one hand and health awareness on the other hand.

This study's results indicate no significant association between service years and health problems (*P* value >0.05) except for depression, allergic discomfort, irritability, Bruises on the skin, and hair loss in radiation-exposed areas, including on the back of the hand. The skin's pallor is significantly associated with service years (*P* value <0.05). The result explains that workers with service years equal to or less than ten years are more exposed to these health problems. These results disagreed with many studies which found that long-term exposure of HCWs to various rays leads to severe complications (dermatitis, irritability, and hair loss as well as cancer) (Alqahtani *et al.* 2018; Parikh *et al.* 2017; Shakeri *et al.* 2018; Daghighi *et al.* 2016). The possible explanation for the impact of the group that has served in the field of radiation (≥ ten years) is due to the lack of commitment of the majority of them to occupational health and safety measures, as shown in the results of this study.

On the other hand, the study shows that health problems do not have a statistical relationship with the length of practice in the radiation field, and this may be due to many explanations, including a study by Mettler (2012), who reported that the likelihood of stochastic effects depends on the levels of radiation received without a threshold. Cancer and genetic impacts like hereditary mutations make up most of these consequences, which can happen by accident. Years after exposure, stochastic effects frequently surface. Additionally, it is impossible to prove that a particular dose brought on the appearance of these symptoms because they might occur in people under background radiation levels without exposure.

These consequences, such as skin burns, cataracts, cardiovascular illness, intestinal damage, hemopoietic system failure, and central nervous system failure, do not exist below their threshold concentrations (Kadhim *et al.* 2013). Also, Nuclear Information and Resource Service (2005) reported that there is no safe level of ionizing radiation exposure despite the negative health effects of exposure, such as malignancies, skin erythema, and cataracts, among others, which are known to vary with dose and time.

The study's participants had a very low prevalence of abnormal clinical findings, which is comforting and highlights the significance of an effective occupational health service in preventing radiation hazards. It also provides baseline data for determining the development of diseases linked to occupational exposure to radiation in the affected workers later in life, even after retirement from service.

The present study disagreed with the previous studies, which reported that Ionizing radiation is one of the most important physical hazards which may lead to the development of radiation-induced cancer (e.g., leukemia and other circulatory diseases, skin, brain, thyroid, and breast cancer) or other non-communicable diseases of medical radiation workers (Bernier *et al.* 2018; Cardis *et al.* 2005; Azizova *et al.* 2018). A possible explanation for the difference might be the difference in study design.

While studies have shown that negative health consequences following ionizing radiation exposure have significantly increased during the past 20 years (Schauer and Linton 2009; Bury 2004), these studies have disagreed with the present results. The possible explanation for the difference may be due to the years of service between the studies, as the current research included that most of the participants had service in the radiation field for equal to or less than ten years, unlike previous studies.

The current study reveals a significant association between depression and the workers in the radiation field equal to or less than ten years with an of 90.8%. This result agrees with the study findings done by Adhikari *et al.* (2021), which reported the rise prevalence of anxiety and depression among healthcare workers in the radiation field.

The results of this study indicate that depression, allergic discomfort, irritability, Bruises on the skin, hair loss in radiation-exposed areas, including on the back of the hand, and pallor of the skin are higher significant in workers who have served in the field of radiation for equal or less than ten years compared those their service more than ten years. The possible explanation for these results may be due to the low level of knowledge of radiation protection procedures in workers who have service of less than or equal to 10 years compared to workers who have service of more than ten years, where they have a good level of knowledge of protection procedures. The explanation agreed with the previous studies (Shiralkar *et al.* 2003; Lee *et al.* 2004; Booshehri *et al.* 2012), which reported that the magnitude of the issue at hand is demonstrated by the recorded evidence of inadequate awareness of radiation safety among various cadres of health workers who are in danger of occupational exposure.

The present results found that 75.0% of the participants were trained in radiation safety. This result agrees with the study findings conducted in Egypt (Nanees and Salah, 2020), which found that 66.7% of the participants were trained in radiation safety. These results disagreed with the study findings done by Partap *et al.* (2019), who reported that 72% had never received formal training in radiation safety procedures.

In Turkey, a study by Erkan *et al.* (2019) revealed that 77.2% of the participants claimed they had no training on radiation protection for employees. These results disagree with our results. This difference may be due to the difference between the countries of the study, where training courses in Iraq are continuous and free, and this may enhance workers' access to training courses regarding radiation safety.

In this study, 75.5% of participants have known enough about radiation protection. These results agree with the study findings in Northern Nigeria by Awosan *et al.* (2016), which found that 52.7% and 59.1% understood personal protective equipment and radiation hazards. At the same time, these results disagreed with the study findings done by Goula *et al.* (2021), who reported that the general level of information held by health professionals about the safety of radiation protection was bad.

The results of this study indicate that the mean of the calibration and control of devices that emit ionizing radiation regularly carried out in the environment where work was 1.43±0.496, which rested within a poor level. This result agrees with the study findings by Hameed *et al.* (2017), which revealed that the highest percentage (38.2%) of the participants never calibrated the X-ray machine.

Regarding the availability of an adequate amount of personal protective equipment, the present study found that 58.0% of participants reported the availability of an adequate amount of personal protective equipment. These results differ from the study findings by Khanal *et al.* 2020; Gupta *et al.* 2020), which revealed that most participants indicated a shortage of personal protective equipment. A possible explanation for this difference may be the difference in the time of the study since the previous studies were conducted during the Corona pandemic, and this increases the demand for personal protective equipment.

Regarding using a dosimeter, the study found that 68.0% of the participants used it. This result agrees with the study findings conducted in Turkey by Erkan *et al.* (2019), who reported that 50.5% of the subjects used dosimeters. Radiation is detected and measured to provide adequate radiation protection. One of the essential tools to assess the radiation dosage for personal dosimetry is monitoring employees working in radiation areas using film badges (Memon *et al.* 2012).

In this study, 52.0% of the workers in the field of radiation wear lead aprons (lead waistcoats). This result agrees with the study findings by Awosan *et al.* (2016), which revealed that 51.8% of HCWs wear lead aprons. Also, a study conducted in Taif, Saudi Arabia (Ahmed *et al.* 2015) found that most participants wore a lead apron.

The results of this study indicate that the highest percentage (83.0% and 82.5%) of the workers in the field of radiation do not wear lead gloves and lead glasses, respectively. These results agreed with the study findings by Sharma *et al.* (2016), which revealed that 70% and 76% of participants never used lead gloves and eyeglasses, respectively. Also, a study in Egypt (2020) reported that 88.7% of the subjects do not wear lead gloves.

Regarding wearing a lead neck brace (protective thyroid apparatus), the study reported that 75.0% of the subjects had not worn it. This result is lower than the findings of Nanees and Salah (2020), who reported that all participants (100.0%) do not wear thyroid shields. These results disagreed with Khamtuikrua and Suksompong (2020), who found that 78.5% of participants always wore a thyroid shield when working in the radiation field.

The present study reveals that the mean of the overall assessment of prevention and safety measures was 16.33±2.24, which rested within a poor level (<17 scores). The results of this study indicate that the highest percentage (56.5%) of the participants have a poor assessment score for prevention and safety measures. In contrast, 43.5% of them have a good score. These results disagree with the study findings conducted by Behzadmehr *et al.* (2021), who reported that practice regarding radiation protection was moderate (average).

The results found that there is a significant association between some socio-demographic variables (age groups and education level) and the overall assessment score of prevention and safety measures (*P* value <0.05). At the same time, these results indicate that old age and postgraduate are higher significant compared to other categories. These results agree with the findings of Briggs-Kamara *et al.* (2013), who reported that 58.7% of radiographers were aware of radiation hazards. Also, these results agreed with Nanees and Salah (2020), which stated higher educational attainment (74.3%).

8. CONCLUSIONS AND RECOMMENDATIONS

Radiation exposure is a significant occupational hazard for healthcare workers who handle radioactive materials or operate radiation-emitting equipment. Healthcare workers exposed to ionizing radiation are at an increased risk of developing cancer, genetic mutations, and other health problems. Therefore, healthcare facilities must take necessary precautions to protect workers from radiation risks. This paper will discuss the safeguards hospitals should take to prevent radiation risks for healthcare workers.

To achieve the aim of the study in 200 healthcare workers regarding evaluating the radiation risks to healthcare workers in the field of radiation in the province of Babylon, we concluded that the overall evaluation of safety and radiation prevention measures among workers was poor despite their possession of good social habits.

This study showed that workers who have practised in the radiation field for less or equal to 10 years are more exposed to health problems such as depression, allergic discomfort, irritability, the pillar on the skin, and hair loss. The study revealed that workers who have a long practice in the radiation field comply with safety and radiation protection measures well. At the same time, a high percentage of workers in the area of radiation who have higher degrees and a job title as a radiologist have good levels compared to other categories regarding prevention and safety measures.

The current study reported that older workers are more committed to prevention and safety measures, and these ages are considered an extension of long experience and good levels. The results found a significant difference between the studied variables and the score of occupational health and safety measures (*P*.Value$<$0.05), except for marital status, have no significant differences regarding occupational health and safety measures (*P*.Value$>$0.05). This explains that the averages of postgraduate participants regarding prevention and safety measures assessment are significantly higher than other education levels. At the same time, the averages of age groups (41-45 years) regarding prevention and safety measures assessment are significantly higher than other age groups.

Radiation protection should be implemented as the primary strategy for mitigating the risk of radiation exposure for healthcare workers. Healthcare workers who handle radioactive materials or operate radiation-emitting equipment are at increased risk of developing health problems due to radiation exposure. Hospitals must take necessary precautions to protect healthcare workers from these risks. One essential precaution is using personal protective equipment (PPE), such as lead aprons, gloves, and thyroid shields, which provides a physical barrier between the healthcare worker and the radiation source. Another precaution is to limit the time healthcare workers spend in areas where radiation is present. This involves reducing exposure time to the minimum amount necessary to complete tasks.

Healthcare workers should also maintain a safe distance from radiation to reduce exposure. Hospitals can install appropriate shieldings, such as lead-lined walls and floors, to reduce the amount of radiation that escapes from areas where radioactive materials are used or stored.

Training is also essential for healthcare workers to handle radioactive materials and radiation-emitting equipment safely. We highly recommend training courses, rigorous application of safety measures, and ensuring the availability of all the necessary radiation protection tools; training should show how radiation exposure can be minimized, keeping health professionals confident and feeling safe by significantly improving their working environment. Conduct continuous health education regarding health problems and how to prevent them through early examinations. Regular periodic in-service monitoring of occupationally exposed health workers is necessary to ensure compliance with radiation safety regulations. Risk prevention requires proper planning of human resources in the health institution. In addition, the appropriate implementation should be applied to risk analysis.

By providing appropriate PPE, limiting exposure time, maintaining safe distances, installing proper shielding, and providing appropriate training, hospitals can significantly reduce the risk of radiation exposure for healthcare workers. These precautions will ensure healthcare workers' safety and well-being while performing their duties.

REFERENCES

Adhikari, S. P., Rawal, N., Shrestha, D. B., Budhathoki, P., Banmala, S., Awal, S., Bhandari, G., Poudel, R., & Parajuli, A. R. (2021). Prevalence of anxiety, depression, and perceived stigma in healthcare workers in bghnepal during later phase of first wave of covid-19 pandemic: a web-based cross-sectional survey. Cureus, 13(6).

Ahmad, I. M., Abdalla, M. Y., Moore, T. A., Bartenhagen, L., Case, A. J., & Zimmerman, M. C. (2019). Healthcare workers occupationally exposed to ionizing radiation exhibit altered levels of inflammatory cytokines and redox parameters. Antioxidants, 8(1), 12.

Ahmed, R. M., Elamin, A. M. T., Elsamani, M., & Hassan, W. B. (2015). Knowledge and performance of radiographers towards radiation protection, Taif, Saudi Arabia. IOSR J Dent Med Sci, 14(3), 63–68.

Alagoz, E. (2017). Basic Concepts in Intervention of Nuclear, Radiological Injuries, Acute Radiation Syndrome and Its Treatment/Nukleer Radyolojik Acillere Mudahalede Temel Kavramlar, Akut Radyasyon Sendromu ve Tedavisi. In Nuclear Medicine Seminars (Vol. 3, No. 3, pp. 189-196).

Algüneş, Ç., (2002). Radyasyon Biyofiziği.1. Basım. Edirne: Trakya Üniversitesi Yayınları No: 51, 59-62.

Alli, B. O. (2008). Fundamental Principles of Occupational Health and Safety Second Edition. Geneva, International Labour Organization, 15, 2008.

Alpsoy, L. (2007). İş Sağlığı ve Güvenliği.Yerel İş Barışı Kongre Tebliğleri, Yerelsen, Eğitim Yayınları, (01)

Alqahtani, S. J. M., Welbourn, R., Meakin, J. R., Palfrey, R. M., Rimes, S. J., Thomson, K., & Knapp, K. M. (2018). Increased radiation dose and projected radiation-related lifetime cancer risk in patients with obesity due to projection radiography. Journal of Radiological Protection, 39(1), 38.

Amanda, L. Ogilvy-Stuart' & Stephen, M. S. (1993). Effect of radiation on the human reproductive system. Environmental Health Perspectives Supplements, 101(2), 109- 116

Anjan, D. (2018). Radiation Hazard and Radiation Protection. ISRRT, Tunisian Society of Radiographers.

Atomic Energy Licensing, (2010). (Basic Safety Radiation Protection) Regulations 2010.

Avci, R. (2016). Diyarbakır ilinde radyoloji çalışanlarının radyasyondan korunma durumları ve sağlık yakınmaları (Master's thesis, Sağlık Bilimleri Enstitüsü).

Awosan, K. J., Ibrahim, M. T. O., Saidu, S. A., Ma'Aji, S. M., Danfulani, M., Yunusa, E. U., Ikhuenbor, D. B., & Ige, T. A. (2016). Knowledge of radiation hazards, radiation protection practices and clinical profile of health workers in a teaching hospital in Northern Nigeria. Journal of Clinical and Diagnostic Research: JCDR, 10(8), LC07.

Ayan, A., Dönmez, S., Aras, F., Günalp, B., Kıraç, S., Özaslan, İ. A., ... & Yeyin, N. (2016). Radyoaktif madde veya radyonüklid tedavi uygulanmış hastanın tıbbi durumunda değişiklik olması halinde radyasyon güvenliği süreci: acil tıbbi müdahaleler. Nükleer Tıp Seminerleri, 3, 168-171.

Azizova, T. V, Bannikova, M. V, Grigoryeva, E. S., & Rybkina, V. L. (2018). Risk of malignant skin neoplasms in a cohort of workers occupationally exposed to ionizing radiation at low dose rates. PLoS One, 13(10).

Balsak, H. (2014). Radyoloji çalışanlarının tanı amaçlı kullanılan radyasyonun, zararlı etkileri hakkında bilgi, tutum ve davranışları (Master's thesis, Sağlık Bilimleri Enstitüsü).

Behzadmehr, R., Doostkami, M., Sarchahi, Z., Saleh, L. D., & Behzadmehr, R. (2021). Radiation protection among health care workers: knowledge, attitude, practice, and clinical recommendations: a systematic review. Reviews on Environmental Health, 36(2), 223–234.

Bernier, M. O., Doody, M. M., Van Dyke, M. E., Villoing, D., Alexander, B. H., Linet, M. S., & Kitahara, C. M. (2018). Work history and radioprotection practices in relation to cancer incidence and mortality in US radiologic technologists performing nuclear medicine procedures. Occupational and Environmental Medicine, 75(8), 533–561.

Bolus, N. E. (2001). Basic review of radiation biology and terminology. Journal of nuclear medicine technology, 29(2), 67-73.

Booshehri, M. Z., Ardakani, F. E., & Nozari, H. (2012). Evaluation of dentists' awareness about personnel and patients' national protection in Yazd dental office. Health, 4(8), 490–492.

Bor, D., Buyan, G., & Meriç, N. (1996). Tanısal radyolojide radyasyondan korunmada yeni kavramlar (2. Bölüm). Tanısal ve Girişimsel Radyoloji, 2(2), A10-A13.

Bora H., (2001). "Radyasyon Güvenliği", Ankara Üniversitesi Dikimevi Sağlık Hizmetleri Yüksekokulu Yıllığı, Cilt 2, Sayı 1

Bozbıyık, A., Özdemir, Ç., & Hancı, İ. H. (2002). Radyasyon yaralanmaları ve korunma yöntemleri. Sürekli Tıp Eğitimi Dergisi, 7(11), 274.

Briggs-Kamara, M. A., Okoye, P. C., & Omubo-Pepple, V. B. (2013). Radiation safety awareness among patients and radiographers in three hospitals in Port Harcourt. Am J Sci Ind Res, 4(1), 83–88.

Bury, B. (2004). X-ray dose training: are we exposed to enough? Clinical Radiology, 59(10), 926–927.

Çam, O., & Büyükbayram, A. (2017). Hemşirelerde psikolojik dayanıklılık ve etkileyen faktörler. Psikiyatri Hemşireliği Dergisi, 8(2), 118-126.

Canadian Centre for Occupational Health and Safety (2016). Hazard and risk. Canadian Centre for Occupational Health and Safety Publication.

Cardis, E., Vrijheid, M., Blettner, M., Gilbert, E., Hakama, M., Hill, C., Howe, G., Kaldor, J., Muirhead, C. R., & Schubauer-Berigan, M. (2005). Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. Bmj, 331(7508), 77.

Çelik, S. (2013). Ankara Üniversitesi nükleer bilimler enstitüsü radyasyondan korunma programı ve radyasyondan korunma optimizasyonu (Master's thesis, Nükleer Bilimler Enstitüsü).

Çetin, S., & Beğik, V. (2021). İş sağlığı ve güvenliği'nde sürdürülebilir kişisel koruyucu donanım politikalarının uygulanması. International Journal of Engineering Research and Development, 13(1), 202-211.

Che Huei, L., Ya-Wen, L., Chiu Ming, Y., Li Chen, H., Jong Yi, W., & Ming Hung, L. (2020). Occupational health and safety hazards faced by healthcare professionals in Taiwan: A systematic review of risk factors and control strategies. SAGE Open Medicine, 8, 2050312120918999.

Çolak, Ş. (2014). Fiziksel risk etmenleri. İş Sağlığı ve Güvenliği Haftası, 4(10).

Committee on the Biological Effects of Ionizing Radiations (1980). The effects on population of exposure to low levels of ionizing radiation. National Academic Press, Washington DC. Erişim adresi: https://www.osti.gov/etdeweb/biblio/20685306

Coşkun, A. (2015). Radyoloji birimlerinin ortam radyasyon doz dağılımlarının belirlenmesi (Master's thesis, Fen Bilimleri Enstitüsü).

Coşkun, Ö. (2011). İyonize radyasyonun biyolojik etkileri. Teknik Bilimler Dergisi, 1(2), 13-17.

Cotran RS, Kumar V, Collins T (2010). Robbins Pathologic Basis of Disease, 8th Edn. W.B. Saunders, Philadelphia

Daghighi, M. H., Poureisa, M., Safarpour, M., Behzadmehr, R., Fouladi, D. F., Meshkini, A., Varshochi, M., & Kiani Nazarlou, A. (2016). Diffusion-weighted magnetic resonance imaging in differentiating acute infectious spondylitis from degenerative Modic type 1 change; the role of b-value, apparent diffusion coefficient, claw sign and amorphous increased signal. The British Journal of Radiology, 89(1066), 20150152.

Daşdağ, S., Çelik, S., (1990). Mikrodalgaların biyolojik etkileri ve güvenlik standartları, Çevre Sorunlarının Boyutları "90" Sempozyumu, Diyarbakır. [3] Gençay, Ş., 1994. Nükleer Elektrik ve Çevre, Elektrik Enerjisi ve Teknolojileri Sempozyumu, İTÜ Yayınları, İstanbul.

Dauer, L. T., Ainsbury, E. A., Dynlacht, J., Hoel, D., Klein, B. E., Mayer, D., ... & Blakely, E. A. (2017). Guidance on radiation dose limits for the lens of the eye: overview of the recommendations in NCRP Commentary No. 26. International Journal of radiation biology,93(10), 1015-1023.

Dickson, E. F. G. (2012). Personal Protective Equipment For Chemical, Biological, And Radiological Hazards: Design, Evaluation, And Selection. John Wiley & Sons.

Dökmeci, A. H., & Aksan, Ö. (2019). Çorlu Devlet Hastanesindeki Elektromanyetik Alanların (EMA) Sağlık Çalışanlarına Olası Sağlık Etkileri. Karaelmas İş Sağlığı ve Güvenliği Dergisi, 3(1), 53-61.

Erdoğan, M. (2017). İyonlaştırıcı radyasyon ve korunma yöntemleri. Selçuk Üniversitesi Fen Fakültesi Fen Dergisi, 43(2), 139-147.

Ergüt, F. (2015). Beykent Üniversitesi Sosyal Bilimler Enstitüsü İşletmelerde iş sağlığı ve güvenliğinin sağlanmasında önleyici uygulamarın önemi (Master's thesis, Sosyal Bilimler Enstitüsü).

Erkan, I., Yarenoglu, A., Yukseloglu, E. H., & Ulutin, H. C. (2019). The investigation of radiation safety awareness among healthcare workers in an education and research hospital. International Journal of Radiation Research, 17(3), 447–453.

Feinendegen LE (2005). Low doses of ionizing radiation: relationship between biological benefit and damage induction. A synopsis. World J Nucl Med 4:21–34

Field, A. (2018). Discovering statistics using IBM SPSS statistics 5th ed. Sage.

Gazette, R. (2012). İş Sağlığı ve Güvenliği Risk Değerlendirmesi Yönetmeliği. Resmî Gazete Tarihi,285 12.

Gestal, J. J. (1987). Occupational hazards in hospitals: accidents, radiation, exposure to noxious chemicals, drug addiction and psychic problems, and assault. Occupational and Environmental Medicine, 44(8), 510-520.

Gökharman, D. F., Aydın, S., & Koşar, P. N. (2016). Radyasyon güvenliğinde mesleki olarak bilmemiz gerekenler. Süleyman Demirel Üniversitesi Sağlık Bilimleri Dergisi, 7(2), 35-40.

Göksel, S., (1973). Radyasyonun Biyolojik Etkileri ve Korunma, İ.T.Ü. Matbaası, İstanbul.

Goula, A., Chatzis, A., Stamouli, M.-A., Kelesi, M., Kaba, E., & Brilakis, E. (2021). Assessment of Health Professionals' Attitudes on Radiation Protection Measures. International Journal of Environmental Research and Public Health, 18(24), 13380.

Güden, E., Öksüzkaya, A., Balci, E., Rukiye, T. U. N. A., Borlu, A., & Çetinkara, K. (2012). Radyoloji çalışanlarının radyasyon güvenliğine ilişkin bilgi, tutum ve davranışı. Sağlıkta Performans ve Kalite Dergisi, 3(1), 29-45.

Güler, Ç., Akın, L(Ed.)., (2006). "Halk Sağlığı Temel Bilgiler". Ankara: Hacettepe Üniversitesi Hastaneleri Basımevi.

Gupta, A. K., Mehra, A., Niraula, A., Kafle, K., Deo, S. P., Singh, B., Sahoo, S., & Grover, S. (2020). Prevalence of anxiety and depression among the healthcare workers in Nepal during the COVID-19 pandemic. Asian Journal of Psychiatry, 54, 102260.

Hameed, S. M., Ali, Q. A., & Ess, R. T. A. (2017). Assessment of Ionizing Radiation Protection Awareness among Radiation Workers in Erbil Hospitals. The Journal of Medical and Pharmaceutical Sciences,1(3),19 –25

Hastanelerde radyasyona maruz kalan çalışanların çalışan güvenliği ve radyasyon güvenliği konusunda bilgi, tutum ve davranışları (Master's thesis, Sağlık Bilimleri Enstitüsü).

Häusler, U., Czarwinski, R., & Brix, G. (2009). Radiation exposure of medical staff from interventional x-ray procedures: a multicentre study. European Radiology, 19(8), 2000-2008.

Helvacı, M. (2011). Edirne'de iyonlaştırıcı radyasyon kaynakları ile çalışan sağlık personelinin radyasyon güvenliği konusunda bilgi düzeyleri ve tutumları Trakya Üniversitesi Sağlık Bilimleri Enstitüsü.

Holland, M. G., & Cawthon, D. (2015). Personal protective equipment and decontamination of adults and children. Emergency Medicine Clinics, 33(1), 51-68.

IBM Corp. Released (2021). IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp

Kadhim, M., Salomaa, S., Wright, E., Hildebrandt, G., Belyakov, O. V, Prise, K. M., & Little, M. P. (2013). Non-targeted effects of ionising radiation—implications for low dose risk. Mutation Research/Reviews in Mutation Research, 752(2), 84–98.

Kanten, S. (2012). Çalışma koşullarının fiziksel-psikolojik sağlık belirtileri ve iş kazaları ile ilişkisi: mermer çalışanları örneği-the relationships among working conditions physical/psychological symptoms and occupational accidents: marble workers' case. Mehmet Akif Ersoy Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 4(7), 155-167.

Kaplan, D. J., Patel, J. N., Liporace, F. A., & Yoon, R. S. (2016). Intraoperative radiation safety in orthopaedics: a review of the ALARA (As low as reasonably achievable) principle. Patient Safety İn Surgery, 10(1), 1-7.

Karaca, Y. (2013). Erzincan Üniversitesi Sosyal Bilimler Enstitüsü Sağlık çalışanlarında iş sağlığı ve güvenliği (Master's thesis, Sosyal Bilimler Enstitüsü).

Kaya, İ. E., & Ölçücü, H. (2019). Tehlikeli atık bertaraf tesislerinde meslek hastalığı ve biyolojik faktörler açısından risk değerlendirmesi. Avrupa Bilim ve Teknoloji Dergisi, (17), 1375-1382.

Khamtuikrua, C., & Suksompong, S. (2020). Awareness about radiation hazards and knowledge about radiation protection among healthcare personnel: A quaternary care academic center–based study. SAGE Open Medicine, 8, 1–8.

Khanal, P., Devkota, N., Dahal, M., Paudel, K., & Joshi, D. (2020). Mental health impacts among health workers during COVID-19 in a low resource setting: a cross-sectional survey from Nepal. Globalization and Health, 16(1), 1–12.

Korkmaz, A., Avsallı, H. (2012). "Çalışma hayatında yeni bir dönem: 6331 sayılı iş sağlığı ve güvenliği yasası", süleyman demirel üniversitesi fen edebiyat fakültesi Sosyal Bilimler Dergisi, 26, 153-167.

Küçük, S. (2012). İş Sağlığı ve Güvenliği Eğitim Notları, İstanbul: İstanbul Sanayi Odası Yayınları.

Larcos, G. S., Collins, L. T., Georgiou, A., & Westbrook, J. I. (2014). Maladministrations in nuclear medicine: revelations from the Australian Radiation Incident Register. Medical Journal of Australia,200(1), 37-40.

Lee, C. I., Haims, A. H., Monico, E. P., Brink, J. A., & Forman, H. P. (2004). Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. Radiology, 231(2), 393–398.

Mantık, S., Laboratuvarı, I., Devreleri, I., Haberleşme, I., Teorisi, D., Ve D., ... & Ve A. (2021). İş sağlığı ve güvenliği.

Marks, L. B., Bentzen, S. M., Deasy, J. O., Bradley, J. D., Vogelius, I. S., El Naqa, I., ... & Jackson, A. (2010). Radiation dose–volume effects in the lung. International Journal of Radiation Oncology Biology Physics, 76(3), S70-S76.

Martin, A., Harbison, S., Beach, K., & Cole, P. (2018). An İntroduction To Radiation Protection. CRC Press.

Memon, S. A., Laghari, N. A., & Cheema, A. A. (2012). Evaluation of radiation workers' occupational doses working at NIMRA Jamshoro. JLUMHS, 11(03), 190.

Mettler, F. A. (2012). Medical effects and risks of exposure to ionising radiation. Journal of Radiological Protection, 32(1), N9.

Mollamahmutoğlu, H. (2004). İş Hukuku. Ankara: Turhan Kitaevi.

Nanees, G & Salah, E. (2020). Assessment of awareness and practice of ionizing radiation protection procedures among exposed health care workers. Egyptian Journal of Occupational Medicine, 44(1), 529–544.

Nasab, H. S., Ghofranipour, F., Kazemnejad, A., Khavanin, A., & Tavakoli, R. (2009). Evaluation of knowledge, attitude and behavior of workers towards occupational health and safety. Iranian Journal Of Public Health, 38(2), 125-129.

Nikolaev, V. A. (1995). Application of SSNTDs to investigations of radiation accident after-effects. Radiation Measurements, 25(1-4), 337-345.

Niu, S. (2010). Ergonomics and occupational safety and health: An ILO perspective. Applied Ergonomics, 41(6), 744-753.

Nuclear Information and Resource Service. (2005). US radiation panel recognizes no safe radiation dose. Biological Effects of Ionizing Radiation Report VII (BEIR VII). NIRS/WISE. In (NIRS/WISE). https://www.nirs.org/wpcontent/uploads/radiation/radtech/nosafedose072005.pdf

Öcal, A. (2010). Beykent Üniversitesi Sosyal Bilimler Enstitüsü Sağlık çalışanlarında iş sağlığı ve güvenliği (Master's thesis, Sosyal Bilimler Enstitüsü).

Odaman, S. (2005) "4857 Sayılı Yeni İş Kanunu Sonrasında İş Sağlığı ve Güvenliği Hükümlerinin Önemi ve OHSAS 18001 Yönetim Sistemi", Human Resources, 22-28.

Oksay, A. (2005). Çalışanlarda İş Tatmini: Sağlık Sektörü Üzerine Bir Araştırma. (Yayımlanmamış Yüksek Lisans Tezi). Isparta: Süleyman Demirel Üniversitesi Sosyal Bilimler Enstitüsü.

Parikh, J. R., Geise, R. A., Bluth, E. I., Bender, C. E., Sze, G., Jones, A. K., & Radiology, H. R. C. of the A. C. of. (2017). Potential radiation-related effects on radiologists. American Journal of Roentgenology, 208(3), 595–602.

Parlak, Y., Uysal, B., Kıraç, F. S., Kovan, B., Demir, M., Ayan, A., ... & Dönmez, S. (2020). Radyasyon Güvenliği Kılavuzu: Genel Tanımlar ve Nükleer Tıp Uygulamalarında Radyasyondan Korunma Kuralları. Nucl Med Semin, 6, 71-89.

Partap, A., Raghunanan, R., White, K., & Seepaul, T. (2019). Knowledge and practice of radiation safety among health professionals in Trinidad. SAGE Open Medicine, 7, 2050312119848240.

Pedrosa, M. C., Farraye, F. A., Shergill, A. K., Banerjee, S., Desilets, D., Diehl, D. L., ... & ASGE Technology Committee. (2010). Minimizing occupational hazards in endoscopy: personal protective equipment, radiation safety, and ergonomics. Gastrointestinal Endoscopy, 72(2), 227-235.

Quinlan, M., Bohle, P., & Lamm, F. (2010). Managing Occupational Health And Safety. Palgrave Macmillan.

Radiation Protection in Nuclear Medicine, (2008). Radiation Protection Series Publication No. 14.2, ARPANSA 2008.

Rayner, S. (1986). Management of radiation hazards in hospitals: Plural rationalities in a single institution. Social Studies of Science, 16(4), 573-591.

Reese, C. D. (2018). Occupational Health And Safety Management: A Practical Approach. CRC Press.

Rodrigues, M. D. S. B., Oliveira, S. M., & de Sá, L. V. (2021). Development of a model for registration and notification of accidents and incidents in nuclear medicine. Journal of Radiological Protection, 41(1), 59.

Rose, A., & Rae, W. I. D. (2019). Personal protective equipment availability and utilization among interventionalists. Safety and Health at Work, 10(2), 166-171.

Saygun, M. (2012). Sağlık çalışanlarında iş sağlığı ve güvenliği sorunları. TAF Preventive Medicine Bulletin, 11(4), 373- 382.

Schauer, D. A., & Linton, O. W. (2009). National Council on Radiation Protection and Measurements report shows substantial medical exposure increase. Radiology, 253(2), 293-296.

Schulte, P. A., Pandalai, S., Wulsin, V., & Chun, H. (2012). Interaction of occupational and personal risk factors in workforce health and safety. American Journal Of Public Health, 102(3), 434-448.

Shakeri, A., Shakeri, M., Ojaghzadeh Behrooz, M., Behzadmehr, R., Ostadi, Z., & Fouladi, D. F. (2018). Infrarenal aortic diameter, aortoiliac bifurcation level and lumbar disc degenerative changes: a cross-sectional MR study. European Spine Journal, 27(5), 1096–1104.

Sharma, M., Singh, A., Goel, S., & Satani, S. (2016). An evaluation of knowledge and practice towards radiation protection among radiographers of Agra city. Sch J Appl Med Sci, 4(6), 2207–2210.

Shikdar, A. A., & Sawaqed, N. M. (2003). Worker productivity, and occupational health and safety issues in selected industries. Computers & İndustrial Engineering, 45(4), 563-572.

Shinde, M. B., & Mohite, V. R. (2014). A study to assess knowledge, attitude, and practices of five moments of hand hygiene among the nursing staff and students at a tertiary care hospital at Karad. Int J Sci Res, 3(2), 311-321.

Shiralkar, S., Rennie, A., Snow, M., Galland, R. B., Lewis, M. H., & Gower-Thomas, K. (2003). Doctors' knowledge of radiation exposure: questionnaire study. Bmj, 327(7411), 371–372.

Solmaz, M., & Solmaz, T. (2017). Hastanelerde iş sağlığı ve güvenliği. Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi, 6(3), 147-156.

Taner, A. C. (1983). Radyasyonun Biyolojik Etkileri.

Tetteh, E., Sarker, P., Radley, C., Hallbeck, M. S., & Mirka, G. A. (2020). Effect of surgical radiation personal protective equipment on EMG-based measures of back and shoulder muscle fatigue: A laboratory study of novices. Applied Ergonomics, 84, 103029.

Thompson, S. K. (1987). Sample size for estimating multinomial proportions. The American Statistician, 41(1), 42–46

Ward, J. F. (1988). DNA damage produced by ionizing radiation in mammalian cells: identities, mechanisms of formation, and reparability. Progress in nucleic acid research and molecular biology, 35, 95-125.

World Health Organization. (1988). Derived İntervention Levels For Radionuclides İn Food: Guidelines For Application After Widespread Radioactive Contamination Resulting From A Major Radiation Accident. World Health Organization.

Yarenoğlu, A. (2018). İstanbul Yeni Yüzyil Üniversitesi Sağlik Bilimleri Enstitüsü

Yilmaz, B. (2018). Acil Servis Hekimlerinin Radyasyondan Korunma Farkındalığı.

Young, J. Y., Rhee, T. K., Atassi, B., Gates, V. L., Kulik, L., Mulcahy, M. F., ... & Salem, R. (2007). Radiation dose limits and liver toxicities resulting from multiple yttrium-90 radioembolization treatments for hepatocellular carcinoma. Journal of Vascular and Interventional Radiology, 18(11), 13751

Zeyrek, C. (2013). İyonize radyasyon uygulamaları için güvenlik ve korunmaya yönelik genel kavramlar. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 17(3), 1-9.

APPENDICES

APPENDIX 1. Approval of the Babylon health department in Iraq

APPENDIX 2. Questionnaire

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