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DEPARTMENT OF ENVIRONMENTAL SCIENCE

Radiation safety protection knowledge and practice among hospital health workers working in radiation-emitting environments

By

Magadzire Fletcher (B241657A)

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DECLARATION FORM

The undersigned individual certifies that, they have read and agreed that Bindura University of Science Education to accept the dissertation entitled, Radiation safety protection knowledge and practice among hospital health workers working in radiation-emitting environments, in fulfilment of the MSc in Occupational Safety Health Environmental Management.

By Fletcher Magadzire

Student signature…………………………. Date…………………………

Supervisor signature……………………… Date…………………………

Chairman's signature……………………… Date…………………………...

ABSTRACT

Background: Radiation safety is a serious global concern, with low-and middle-income countries, including Zimbabwe, facing challenges in safeguarding adequate protection for hospital workers in radiation-emitting environments. Notwithstanding legal frameworks like Radiation Protection Act (Chapter 15:15) and SI 62 of 2011, compliance remains inconsistent due to knowledge gaps, infrastructural limitations and weak institutional support

Objective: This study aimed to assess radiation safety knowledge and practice levels among Zimbabwean hospital workers, identify compliance barriers, and develop an evidence-based framework for improving occupational radiation safety.

Methods and materials: A mixed methods sequential explanatory design was used. Quantitative data were collected through a structured questionnaire (n = 70), while qualitative insights were gathered utilizing key informant interviews (n = 7) and an observation checklist. Descriptive statistics and correlation analysis were conducted using SPSS.A thematic analysis was used on qualitative data. A critical review of existing frameworks guided the development of a new model-Integrated radiation safety knowledge and practice model (IRS-KPM).

Key findings: The average knowledge score was 66.8% and practice score was 63.4%, both indicating moderate levels. Training and education were significantly associated with higher scores. Compliance gaps were observed in use of personal protective equipment and safety briefings. Thematic analysis identified barriers such as equipment shortages, inadequate staffing, leadership gaps, and weak policy enforcement. Experts validated the IRS-KPM model as feasible, relevant and comprehensive.

Conclusions: Findings show a disconnect between knowledge and practice, indicating the need for structured training and leadership-driven safety culture. The IRS-KPM model offers a contextualized framework to augment radiation safety compliance. The study's insights are generalizable to similar low-resource healthcare settings. Further research is recommended to pilot the framework across diverse institutions

Key terms: Radiation protection, healthcare workers, knowledge and practice, compliance, Zimbabwe, framework development, IRS-KPM.

DEDICATION

This study is dedicated to my wife, Molina, for her love and patience during this study and the kindness and patience showed by my children, son Joshua Joel, my daughters Gracious, Precious Makanaka, and Ropafadzo Nicole Anita. To God we give all the Honor and Glory.

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CHAPTER 1: INTRODUCTION

1. Introduction

1.1 Background to the study

Current global evidence demonstrates significant variability in radiation protection knowledge and practices among healthcare workers. Systematic reviews indicate compliance rates ranging from 45-75% across different healthcare settings (Behzadmehr et al., 2021; Kyei et al., 2025). Despite established radiation safety frameworks, occupational exposure incidents persist due to knowledge gaps and procedural non-compliance (Adelodun & Anyanwu, 2024). Meta-analyses of international studies reveal that only 62% of radiation workers consistently implement ALARA (As low as reasonably achievable) principles, highlighting a critical gap between theoretical knowledge and practical application (Bryant, 2021; Mallia, 2025)

In Sub-Saharan Africa, radiation protection implementation faces distinct challenges, with only 55% of healthcare workers demonstrating adequate understanding of protection principles (Lewis et al., 2022). Zimbabwe specifically shows a 35% increase in radiological procedures without corresponding safety protocol enhancements, with compliance rates varying from 28-73% across institutions (Mpumelelo, 2022). These low compliance and safety protocols challenges are compounded by resource constraints, infrastructural limitations, and inadequate quality assurance programs, with equipment calibration compliance averaging only 47%. Bolowia (2025) highlighted that only 74% of healthcare workers in Libya consistently used personal protective equipment, citing training and equipment shortages as barriers. Khalilia (2025) found that in Palestine, while knowledge levels were relatively high (88%), compliance remained low due to poor policy enforcement and irregular monitoring. A study in India by Narendran et al., (2025) showed that only 59% of radiology staff practiced proper shielding protocols, attributing this to the absence of regular refresher training. Similarly, Elmorabit et al. (2025) in Morocco noted outdated equipment and limited institutional safety culture as key factors affecting radiation protection practice.

Recent global radiation safety protection frameworks have attempted to address these challenges, yet practical application remains problematic, particularly in low- and middle-income countries (Adelodun & Anyanwu, 2024). Studies indicate that practical experience often surpasses formal education in fostering effective safety practices (Martinucci, 2025), suggesting a need for targeted training programs and resource allocation. The persistently low compliance rates, often below 50% in some regions, emphasize the urgent need for contextually relevant frameworks that address unique challenges in radiation-emitting environments (Maina et al., 2020).

Radiation safety knowledge and practice studies show strong research interest in measuring knowledge and compliance among radiology staff, with consistent findings of good knowledge but poor practice and inconsistent attitudes (Wadood et al., 2025). However, there is a lack of research on behavioural drivers, institutional enforcement, and training effectiveness, highlighting a shift toward developing context-specific, practical frameworks that bridge the gap between knowing and doing.

1.2 Problem statement

Despite the increasing use of radiological procedures in Zimbabwean healthcare facilities, there is limited data on radiation protection knowledge and practices among hospital workers in radiation emitting environments (Chinene et al., 2023). Recent studies have highlighted significant gaps in radiation protection practices in low-income countries, with compliance rates as low as 45% (Frija et al., 2021). Specifically in Zimbabwe, inadequate documentation of occupational radiation exposure incidents, combined with a 35% increase in radiological procedures, pose significant radiation occupational health risks. Low knowledge levels in radiation safety knowledge in low-income countries (Kyei et al., 2025) combined with poor documentation practices significantly impact the safety of workers and quality of healthcare delivery (Shabani et al., 2024). Therefore, there is a need to assess radiation safety knowledge and practices among Zimbabwean hospital workers in radiation-emitting environments to ensure optimal protection for both healthcare workers and patients.

1.3.1 Aim

To assess radiation safety knowledge and practice, and identify barriers to compliance among Zimbabwean hospital workers in radiation-emitting environments

1.3.2 Objectives

1. To determine the level of radiation safety knowledge and practice among hospital workers in radiation-emitting environments in Zimbabwe.
2. To determine the level of compliance to radiation safety regulations in Zimbabwean hospitals.
3. To identify barriers to radiation safety compliance
4. To develop an evidence-based radiation safety framework to improve the protection of hospital workers working in radiation-emitting environments.

1.4 Research questions

1. What is the level of radiation safety knowledge of healthcare workers in radiation emitting environments?
2. To what extent do current radiation protection practices comply with international safety standards?
3. What are the main barriers affecting radiation safety compliance, and how do they impact protection measures?
4. What key components should be included in an evidence-based radiation safety framework to enhance the protection of hospital workers operating in radiation-emitting environments, and how can these components be effectively implemented within Zimbabwean healthcare settings?

1.5 Significance of the study

This study may contribute to occupational health and safety in Zimbabwe's healthcare sector by providing a comprehensive assessment of radiation safety knowledge and practices. It will give a critique of existing frameworks on radiation safety and then provide an evidence-based framework for radiation safety for hospital workers in radiation-emitting environments. The findings will inform radiation safety protection policy and practice by developing evidence-based training programmes for healthcare workers. The study 's recommendations may benefit hospital administrators, regulatory bodies such as RPAZ and healthcare workers by identifying practical solutions to enhance radiation safety compliance. The research outcomes will also contribute to the broader body of knowledge on radiation safety in low- and middle-income countries and serves as a reference for similar studies in the region.

1.6 Assumptions

- All participants will provide honest and accurate responses during data collection

- The selected hospitals are representative of typical radiation-emitting environments in Zimbabwean healthcare facilities
- Current international radiation safety standards are applicable and relevant to the Zimbabwean context
- The research instruments will effectively measure the intended variables

1.7 Limitations

- Access to some facilities may be restricted due to administrative procedures
- Some participants may be reluctant to disclose non-compliance with radiation safety protocols due to corporate image/governance issues.
- Resource constraints may limit the geographical scope of the study to major urban hospitals
- Time constraints may affect the depth of qualitative data collection

1.8 Delimitations

- The study will focus only on healthcare workers directly involved with radiation equipment or working in radiation-emitting environments
- The research will be conducted only in licenced healthcare facilities with radiation departments in Zimbabwe
- The study will assess only occupational radiation safety practices and not patient radiation protection measures
- Data collection will be limited to healthcare facilities in major cities and provincial hospitals

CHAPTER 2: REVIEW OF LITERATURE

2. Literature review

2.1 Introduction

This chapter presents a review of contemporary literature examining radiation safety knowledge and practice among healthcare workers in radiation-emitting environments. The review analyses sources of radiation in hospital facilities, the potential health risks associated with radiation emission, and critical evaluation of the existing radiation safety frameworks and proposal of new radiation safety framework.

2.2 Sources of radiation in healthcare and potential health risks

Table 2.1 below details various radiation sources in healthcare and their associated health risks for exposed workers. It identifies key sources such as X-rays, CT scans, fluoroscopy, and radiotherapy, highlighting the professionals at risk, including radiologists, nurses, and nuclear medicine technologists. The table emphasizes significant health concerns, including increased cancer risk, cataracts, and genetic mutations, underscoring the necessity for effective radiation safety measures in clinical practice. This information is crucial for informing training and policy development in radiation protection.

Table 2.1 Sources of radiation and potential health risks

Radiation source	Description	Exposed healthcare workers	Potential health risks	Reference
X-rays (Diagnostic Radiology)	Ionizing radiation used for imaging internal body structures (e.g., chest X-rays, CT scans).	Radiologists, radiographers, nurses, dentists	Cancer (especially thyroid and breast), cataracts, skin burns	Karavas et al. (2022)
Computed Tomography (CT)	High-dose X-ray imaging producing detailed cross-sectional images of the body.	Radiologists, CT technologists, nurses	Increased cancer risk, especially leukaemia and brain tumours	Abuelhia & Alghamdi (2020)
Fluoroscopy	Real-time imaging technique using continuous X-ray beams during diagnostic and surgical procedures.	Interventional radiologists, surgeons, nurses	Skin injuries, cataracts, solid tumours, cardiovascular issues	Wan et al. (2021)
Nuclear medicine	Use of radioactive isotopes (e.g., Iodine-131) for diagnosis and treatment.	Nuclear medicine technologists, nurses	Thyroid dysfunction, leukaemia, genetic mutations	Alkhorayef et al. (2020)

Radiotherapy	High-energy radiation used to treat cancer, targeting malignant cells.	Radiation oncologists, medical physicists	Secondary cancers, infertility, tissue damage, cataracts	Cioffi et al. (2020)
Mammography	Low-dose X-ray imaging of breast tissue for cancer screening.	Radiographers, nurses	Localized radiation exposure, skin erythema, breast cancer	Çobanoğlu & Çayır, 2024
Interventional cardiology	Use of fluoroscopy for cardiac catheterization and angioplasty procedures.	Cardiologists, Cath lab technicians, nurses	Eye lens opacities, increased risk of brain tumours	Young (2020)
Positron Emission Tomography (PET)	Combines nuclear medicine and CT for imaging metabolic processes.	PET technologists, nuclear medicine staff	Whole-body radiation exposure, increased cancer risks	Mosima et al. (2023)
Gamma Cameras	Imaging device for nuclear medicine, detecting gamma rays from radiopharmaceuticals.	Nuclear medicine technologists	Internal organ radiation exposure, genetic damage	Martínez et al. (2019)
Portable X-ray Machines	Mobile imaging units used in intensive care units and operating rooms.	Radiographers, ICU nurses, surgeons	High scatter radiation, bone marrow suppression, leukaemia	Shbeer (2024)

2.3 Radiation safety knowledge

The findings from earlier studies as shown in Table 2.2 indicates that in high-income settings, such as Saudi Arabia and Morocco, the knowledge scores are high, above 90%, often linked to structured training programs and better resources. In contrast, low- and middle-income countries like Nigeria and Ghana show significantly lower scores, reflecting challenges such as limited access to training and outdated equipment. This disparity highlights the need for targeted educational interventions, especially in African contexts, including Zimbabwe, where advanced training and awareness programs are crucial for improving radiation safety knowledge among health workers.

2.4 Radiation safety practice

Earlier studies on radiation safety practice compliance rates as shown in table 2.2 reveals a concerning trend across both high- and low-income settings. While compliance rates are relatively high in countries like Saudi Arabia (88%) and Morocco (83%), they drop significantly in low-income environments, such as Nigeria (58%) and Ghana (59%). Common challenges identified include insufficient protective equipment, inadequate training, and poor maintenance of safety protocols. In the African context, including Zimbabwe, these findings underscore the urgent need for comprehensive safety audits and the establishment of standardized protocols to enhance compliance and protect healthcare workers from radiation exposure. The literature suggests that improving practice is as critical as boosting knowledge, with a focus on resource allocation and training in lower-income regions.

Table 2.2 Earlier studies on radiation safety knowledge and practice among hospital workers in radiation emitting environment

Country (hospital)	Description of the study	Key findings	Reference
Palestine (Private and public hospitals)	Mixed-methods study of 312 healthcare workers; focused on radiation protection training and implementation.	89% knowledge score; 78% compliance rate; Challenge: Lack of structured training programs.	Khalilia (2025)
Morocco (University Hospital centre of Rabat)	Cohort study of 280 hospital staff; evaluated long-term adherence to radiation protection protocols.	92% knowledge score; 83% compliance rate; Challenge: Insufficient protective gear availability.	Ridzwan et al. (2023)
Saudi Arabia (various hospitals)	Cross-sectional survey of 400 radiology personnel; examined compliance with international radiation safety guidelines.	96% knowledge score; 88% compliance rate; Challenge: Inconsistent enforcement of safety protocols.	Kanbayti (2025)
Nigeria (University Teaching Hospital, Zaria)	Cross-sectional study of 168 healthcare workers; assessed radiation protection knowledge and practices through structured questionnaires	Knowledge score: 65%; Practice compliance: 58%; Challenges: Limited PPE availability, inadequate training programs, poor maintenance of radiation protection equipment	Lawal et al. (2019)
Kenya (Bungoma County Referral Health Facilities)	Mixed-method study involving 195 radiation workers; evaluated knowledge, attitudes, and practices through surveys and observations	Knowledge score: 71%; Practice score: 63%; Challenges: Resource constraints, lack of regular quality assurance programs	Macharia (2021)

Egypt (Cairo University Hospitals)	Descriptive cross-sectional study of 276 healthcare workers; assessed radiation safety protocols and implementation	Knowledge score: 82%; Practice compliance: 75%; Challenges: Need for standardized protocols, gaps in continuous professional development	Ghallab et al. (2024)
Ghana (Korle Bu Teaching Hospital)	Quantitative study of 143 radiography staff; evaluated radiation protection practices and monitoring systems	Knowledge score: 68%; Practice score: 59%; Challenges: Outdated equipment, insufficient radiation monitoring devices	Akrobortu (2023)
Turkey (Research and Teaching Hospital)	Prospective study of 234 healthcare workers; assessed radiation protection awareness and compliance	Knowledge score: 77%; Practice compliance: 72%; Challenges: Inconsistent use of dosimeters, need for regular safety audits	Erkan et al. (2019)
Portugal (various health centres)	Multi-centre survey of 312 radiation workers; evaluated knowledge and adherence to ALARA principles	Knowledge score: 88%; Practice score: 83%; Challenges: Implementation of digital monitoring systems, standardization across centres	Rodrigues et al. (2024)
Trinidad (Two public hospitals)	Cross-sectional study of 156 healthcare workers; assessed radiation safety knowledge and protective measures	Knowledge score: 69%; Practice compliance: 61%; Challenges: Limited access to training resources, inconsistent safety protocols	Rodrigues et al. (2024b)

Thailand (Quaternary care academic centre in Bangkok)	Observational study of 189 healthcare staff; evaluated radiation protection practices and knowledge	Knowledge score: 76%; Practice score: 70%; Challenges: Language barriers in international guidelines, need for localized protocols	Khamtuikrua & Suksompong (2020)
Iran (various Hospitals)	Multi-centre cross-sectional study of 423 radiation workers; assessed knowledge and compliance with safety standards	Knowledge score: 73%; Practice compliance: 67%; Challenges: Need for standardized training programs, equipment maintenance issues	Moshfegh et al. (2018)

2.5 Zimbabwean radiation safety legislation

Zimbabwe's radiation safety landscape is guided primarily by the Radiation Protection Act [Chapter 15:15] of 2004 and Statutory Instrument SI 62 of 2011. These regulations mandate the licensing of radiation sources, appointment of radiation safety officers (RSOs), worker training, occupational exposure limits, and the enforcement of safety protocols across all medical facilities using radiation-emitting equipment. The Act establishes the Radiation Protection Authority of Zimbabwe (RPAZ), which oversees the regulation, inspection, and monitoring of radiation practices nationwide. SI 62 of 2011 further operationalizes these mandates by setting out detailed provisions on safety culture, equipment calibration, personal protective equipment, individual monitoring, and justification of medical radiation exposures (Ruhukwa, 2021), which are key principles aligned with international radiation frameworks like those of the IAEA and WHO.

Notwithstanding this robust legal framework, implementation challenges persist, especially in public health institutions with limited resources (Shem et al., 2022). Studies from similar low- and middle-income countries show that even where legislation exists, compliance gaps remain due to poor enforcement, lack of awareness, and inconsistent training (Maina et al., 2020). These concerns are echoed in Zimbabwe, where compliance rates remain highly variable and radiation protection practices are often underreported (Adelodun & Anyanwu, 2024). This study, as a result, is informed by the need to assess whether healthcare workers across Zimbabwean hospitals possess adequate knowledge of, and comply with, the provisions outlined in these legislative frameworks, ultimately highlighting where practical support and localized interventions may be needed to strengthen radiation safety culture.

2.6 Barriers to radiation safety compliance

Recent studies have identified multiple barriers to effective radiation protection, with economic constraints and equipment availability emerging as primary challenges. A comprehensive survey across 54 African countries (Mallum et al., 2024), revealed that 68% of facilities cited inadequate protective equipment as a major barrier to compliance. This study utilized a mixed-methods approach to assess both quantitative compliance rates and qualitative insights from healthcare workers regarding the challenges they face.

Additionally, organizational culture and management support are critical factors influencing compliance rates. Facilities with strong safety cultures have shown that they have a better compliance, regardless of resource constraints (Umaru et al., 2024). Resources limitations, such as staff shortages leading to high workloads, further exacerbate non-compliance. A mixed-methods study done indicated that these factors significantly impact adherence to safety protocols, particularly in emergency settings (Yadav et al., 2024). Similarly, inadequate maintenance of radiation protection equipment and lack of quality assurance programs hinder effective safety practices, with 72% of surveyed facilities reporting challenges in maintaining protective equipment within recommended specifications (Adhikari et al., 2021)

2.7 Radiation safety frameworks

Radiation safety frameworks provide systematic approaches that guide healthcare professionals in implementing effective safety measures to minimize radiation exposure. These frameworks are essential in ensuring that healthcare workers are equipped with the knowledge and practices necessary to protect themselves and their patients in radiation-emitting environments.

Table 2.3 Existing radiation safety frameworks

Name of framework	Description/key information	Applications	References
Health Belief Model (HBM)	A psychological model explaining how individual beliefs about health risks and benefits influence behaviour, particularly in risk-prevention settings.	Applied to assess radiologic technologists' commitment to using radiation protective equipment in fluoroscopy units at Jazan University Hospital, Jazan, Saudi Arabia.	Shubayr (2024)
Protection Motivation Theory (PMT)	Explains behaviour through perceived threat severity and coping mechanisms, used to understand motivation for protective action.	Implemented in educational interventions to enhance protective behaviours among emergency ward nurses against occupational hazards in four educational hospitals in Tehran, Iran.	Nouri et al. (2024)
Theory of Planned Behaviour (TPB)	Explains behaviour as shaped by intention, attitude, subjective norms, and perceived behavioural control.	Used to determine radiographers' intentions and behaviours regarding radiation protection practices in various South African hospitals	Lewis et al. (2022)

Risk Communication Theory (RCT)	Focuses on how safety information is communicated, understood, and acted upon in health environments.	Applied to improve communication strategies regarding radiation risks in healthcare settings.	Hoti et al. (2020)
Behavioural Change Wheel (BCW)	A framework used to design and evaluate behaviour change interventions through capability, opportunity, and motivation models.	Used in designing of training programs for radiation safety in Malaysian teaching hospitals.	Kasim (2019)
Zimbabwe Radiation Protection Regulatory Framework	Based on the Radiation Protection Act [Chapter 15:15] and SI 62 of 2011; outlines legal duties, dose limits, training, equipment checks, and compliance mechanisms.	Used nationally by the Radiation Protection Authority of Zimbabwe (RPAZ) for monitoring and licensing.	Ruhukwa (2021)

2.8 Theoretical framework

This study is guided by the health belief model (HBM), protection motivation theory (PMT) and risk communication theory (RCT). HBM and PMT explains safety behaviour in terms of perceived risks, benefits, and self-efficacy. The HBM helps to explore how healthcare workers' beliefs about radiation risks influence their motivation to comply with safety protocols (Hwang et al., 2022). PMT supports the understanding of how fear of harm and belief in the effectiveness of protective actions drive compliance (Estebsari et al., 2023). RCT focuses on how radiation safety information is communicated especially from leadership, how it is understood, and acted upon resulting in improved knowledge and compliance. Together, these frameworks provide a foundation for assessing knowledge, behaviour, and barriers to radiation safety practices within Zimbabwean hospital settings.

2.9 Summary

The literature review highlights that there has been extensive research conducted on radiation safety knowledge and practices among healthcare workers in low-medium and high-income countries in the last six years with a focus on compliance on safety protocols, knowledge retention, and adherence to international standards. Studies show that while awareness of radiation risks is relatively high, there remains a critical gap between theoretical knowledge and practical implementation, particularly in low-resource settings. Research has predominantly centred on compliance rates, effectiveness of training programmes and barriers to adherence. However, there is limited investigation into long-term effectiveness of safety frameworks and their adaptation to specific healthcare environments. Current thinking emphasises the need for continuous training, improved institutional policies, and enhanced access to protective equipment to bridge these gaps. Further, gaps exist in assessing the role of hospital leadership in fostering a culture of radiation safety. The literature review guides this study by identifying critical radiation safety knowledge and practice, highlighting the necessity for an evidence-based radiation safety framework tailored to the Zimbabwean healthcare context.

CHAPTER 3: METHODS AND MATERIALS

3. Methods and materials

3.1 Description of the study area

The study was conducted across major healthcare facilities in Zimbabwe’s six main provinces: Harare, Bulawayo, Manicaland, Midlands, Mashonaland West and Mashonaland Central (Fig.3.1). These six provinces were selected because they have hospitals with radiation infrastructure, and they have representative number of healthcare workers working in radiation emitting environment. The selected facilities include six public hospitals and six private hospitals that operate radiation-emitting equipment (Table 3.1)

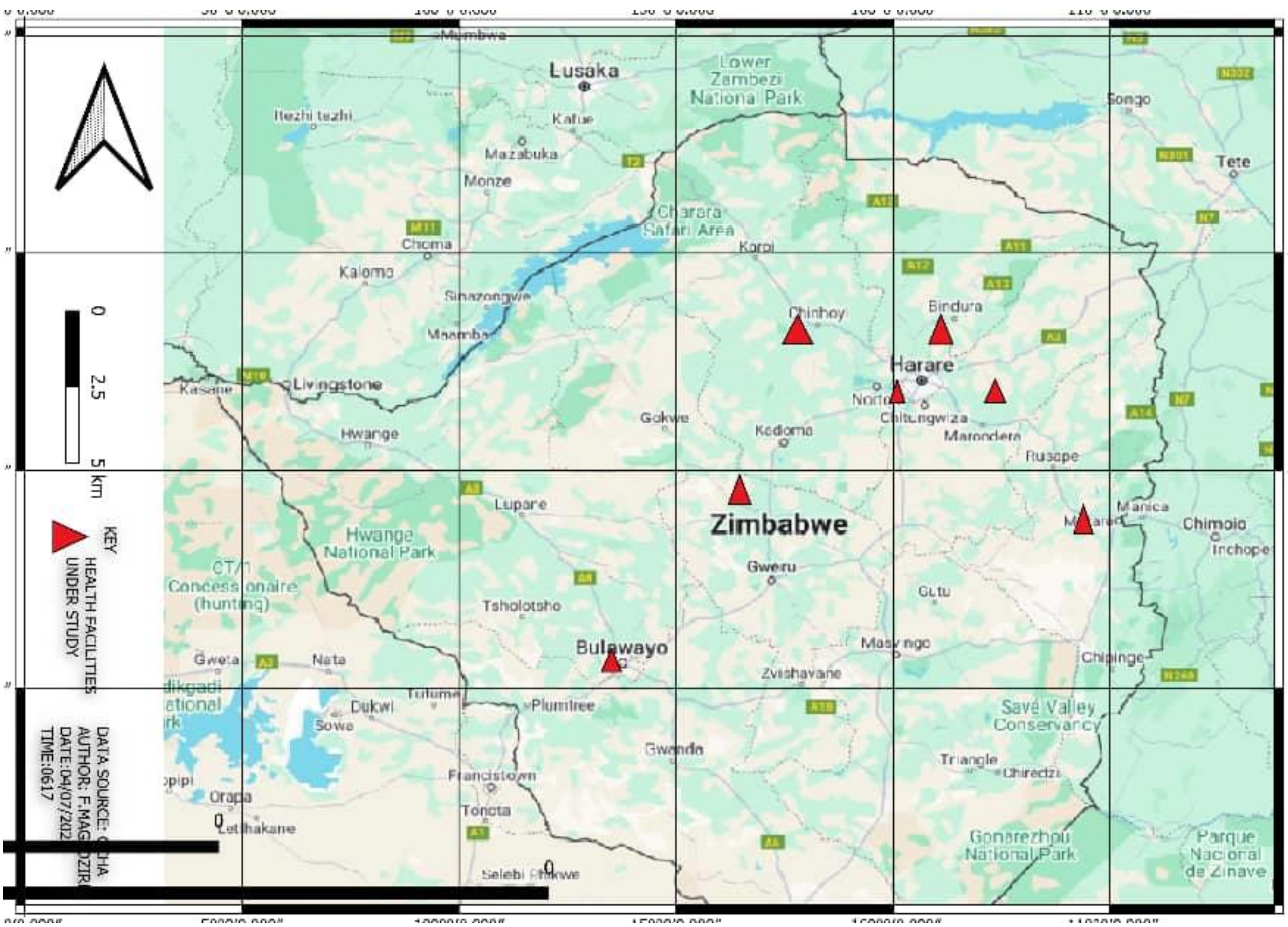

Fig. 3.1: Map of Zimbabwe showing health facilities under study

Table 3.1 Selected health facilities in Zimbabwean provinces and their radiation equipment

Name of hospital	Province	Nature of hospital	Nature of radiation equipment	Geo-references (X, Y)
Parirenyatwa Hospital	Harare	Referral, public	X-ray, CT scan, MRI, Radiotherapy	-17.8115º; 31.0426°
West End Hospital	Harare	Private, referral	X-ray, CT scan, Fluoroscopy	-17.8101°; 31.0422°
CIMAS Hospital	Harare	Private, Referral	X-ray, CT scan	-17.8273°; 31.0533°
Avenues Hospital	Harare	Private, Referral	X-ray, CT scan, MRI	-17.8186°; 31.0469°
Bindura Hospital	Mashonaland Central	Public, referral	X-ray	-17.2907°; 31.3293°
Chinhoyi Hospital	Mashonaland West	Public, referral	X-ray, CT scan	-17.3615°; 30.2084°
Zimplats Medical Centre	Mashonaland West	Private, general	X-ray	-18.8667°; 29.7833°
Kwekwe General Hospital	Midlands	Public, referral	X-ray, CT scan	-17.8101°; 31.0422°
Unki Mine Medical Centre	Midlands	Private, clinic	X-ray	-19.6833°; 29.8333°
Mutare General Hospital	Manicaland	Public, Referral	X-ray, CT scan	-17.81015°; 31.0422°
UBH	Bulawayo	Public, referral	X-ray, CT scan, Radiotherapy	-20.1664; 28.61694
Mate Dei Hospital	Bulawayo	Private, referral	X-ray, CT scan, Fluoroscopy	-20.1700°; 28.5800°

These healthcare facilities provide service to a combined population of approximately 10.2 million people (67.3% of national population (Zimstats, 2022) and employ above 240 employees working in radiation-emitting environments. These include radiologists, radiographers, specialist nurses, medical physicists, nuclear medicine technologists and support staff such as dosimetrists. The facilities vary in size, resource and technological advancement, providing a representative sample of radiation protection practices across different healthcare settings in Zimbabwe

3.2 Research design

A mixed-methods sequential explanatory design was employed in this study, combining a quantitative cross-sectional survey with qualitative key informant interviews (KIIs) (Tapera et al., 2019) and observation checklist. This approach has been shown to be effective in similar research contexts. It allows for the quantitative assessment of knowledge and compliance through surveys while also providing deeper insights into the factors influencing these metrics through KIIs (Qasem, 2022; Shih et al., 2025) and observation. The process typically begins with the collection and analysis of quantitative data, followed by the collection of qualitative data that helps to explain or contextualise the initial findings, leading to a more comprehensive understanding of the research topic (Toyon, 2021; Tanming et al., 2024). Additionally, the potential weakness of participant bias in self-reported surveys was addressed by employing data triangulation from multiple sources and validating findings through the insights gained from key informant interviews and observations (Bottiani et al., 2023).

3.3 Determination of sample size, recruitment and selection of participants

The study targeted healthcare workers regularly exposed to ionising radiation in their work environment. The sample size was determined using Yamane's formula as described by Chiaghanam (2022):

$$\boldsymbol{n} = \frac{\boldsymbol{N}}{(\boldsymbol{1}+\boldsymbol{N}(\boldsymbol{e})^{\boldsymbol{2}})} \quad \textit{Equation 1}$$

Where N = population size (240),

e = margin of error (0.05),

n = required sample size

This yielded sample size of 150 participants.

Adjusting the sample size (n) for non-response (assuming a response rate of 80%):

$$\text{n(adj)} = \frac{n}{r} \quad \textit{Equation 2}$$

To give 188 participants

Yamane's formula is particularly suitable for cross-sectional surveys with a finite population (Tuyishime et al., 2024). It has been successfully applied in similar healthcare-related studies assessing radiation protection practices, occupational health, and healthcare worker compliance (Edward et al., 2024).

Participants were categorised into four strata based on job category (Radiologists, radiographers, specialist nurses and support staff) following the procedure by Guo et al., (2025) as indicated in Table 3.2. Proportional allocation was used in stratified sampling. This is where the sample size for each sub-group (stratum) is proportional to the stratum's size in the population (Oyoo, 2021). This method ensures equal representation of different categories of healthcare workers:

$$\boldsymbol{n_i = \frac{N_i}{N} \times n} \qquad \textit{Equation 3}$$

Where:

n_i = Sample size for stratum *i*

N_i = Population size of stratum *i*

N = Total population (240)

n = Total sample size (188)

Table 3.2. Proportional allocation of participants based on job category

Job category	Total population (N_i)	Proportional sample (n_i)	Sampling intensity (%)
Radiologists	20	16	80.0
Physicians	20	16	80.0
Nuclear medicine technologists	13	10	76.9
Radiographers	110	86	78.2
Nurses	49	38	77.6
Support staff	28	22	78.6
Total	240	188	78.3

The adjusted sample size was further distributed across the six provinces and healthcare facilities (Table 3.3). The allocation follows the distribution of radiation professionals in public and private hospitals. Each province's sample was proportionally allocated among radiologists, radiographers, nurses, and support staff, ensuring representative participation across all healthcare workers (Table 3.4). First, Yamane's formula determined a sample of 188 from a population of 240, adjusted for a 20% non-response rate. Participants were stratified by job category (radiologists, physicians, nuclear medicine technologists, radiographers, nurses, and support staff), with each category receiving a sample proportional to its population size. The total sample was then distributed across six provinces according to the number of radiation professionals in public and private hospitals. Each province's sample was further allocated to health facilities proportionally, ensuring balanced representation of healthcare workers in different job categories across institutions.

Table 3.3. Distribution of the sample size among selected provinces and health facilities

Province	Number of health facilities	Sample size
Harare	4	161
Bulawayo	2	23
Midlands	2	15
Manicaland	1	10
Mashonaland West	2	15
Mashonaland Central	1	16

Table 3.4 Allocation of participants to health facilities based on job category

Province	Radiologists	Physicians	Nuclear Medicine technologists	Radiographers	Specialist Nurses	Support staff	Total
Harare	14	14	8	58	42	25	161
Bulawayo	2	1	1	9	6	4	23
Midlands	1	1	0	6	4	3	15
Manicaland	1	0	0	4	3	2	10
Mashonaland West	1	0	0	6	5	3	15
Mashonaland Central	1	0	1	3	4	2	16
Total	20	16	10	86	64	39	188

3.4 Research instruments

3.4.1 Semi-structured questionnaire

A semi-structured, self-administered coded questionnaire (Appendix 1) was developed by adapting the validated radiation safety knowledge assessment tool for healthcare workers (Ng et al., 2024). The questionnaire was used to collect demographic information (8 items), assess the level of radiation safety knowledge (12 items) and practices (10 items) among participants. The use of a standardised questionnaire allows for quantitative analysis, facilitating the comparison of results across different healthcare settings (Chaple & Luhariya, 2024). The tool is efficient and cost-effective and enables easy statistical analysis (Moore, 2021). However, its main limitations include potential for misunderstanding questions and is prone to response bias by relying on self-reported data (Woodhouse et al., 2018).

To minimise some of the identified limitations, clear instructions, and straightforward questions were used. The tool has been employed in similar studies (Rahimi et al., 2021; Sakafu et al., 2023). The questionnaire was pre-tested at West End Hospital (Harare) to six healthcare workers (3 radiographers and 2 nurses). The questionnaire was hand-delivered through their manager followed by discussions to gather feedback on clarity and relevance. This pre-test aimed to identify any issues in comprehension or structure. The revised questionnaire, A Cronbach's alpha of 0.85 was achieved (Appendix 7) which indicated high internal consistency and reliability (Samaila et al., 2022).

3.4.2 Key informant interviews

Key informant interviews (KIIs) were conducted using semi-structured, open-ended questions to explore in-depth insights into radiation protection knowledge, practices and compliance barriers. Seven key informants were purposively selected by snowballing. They encompassed radiation safety officers, nurses, and radiographers from selected hospitals. Interviews took place from 20th to 30th May 2025. Participants were chosen because of their expertise in radiation safety policies, training, safety culture, and compliance challenges. Each interview lasted 10 to 20 minutes. Questions in the interview guide (Appendix 4) were developed from literature review, survey findings and regulations. They were validated through review by an expert who is a renowned researcher. To address refusals and non-responses, additional participants were invited. Potential interviewer bias was mitigated through data triangulation and consistent interview procedures (Coetzee, 2024). Telephone and face-to-face interviews were recorded with permission from the interviewee.

3.4.3 Observation checklist

An observation checklist (Appendix 3) was deployed to seven health institutions to triangulate survey and KII data.

3.5 Ethical considerations

This study adhered to strict ethical guidelines as outlined in the World Medical Association (2018). Institutional approval was obtained from Bindura University of Science Education, through the Department of Environmental Science (Appendix 6), Radiation Protection Authority of Zimbabwe (Appendix 5). Additional ethical clearance was secured from participating health centre's institutional review boards (PSMI) (Appendix 8). Informed consent was obtained from all participants (included in the questionnaire) after providing detailed information about the study's purpose, potential risks, and benefits. Participants were assured of their voluntary participation in the study, with the right to withdraw at any time without any consequences. Confidentiality was assured through data anonymization and secure storage of information, ensuring that both institutional and personal identities would be protected in all publications. Participants would have access to the study findings upon completion. They were also assured that there would be zero exposure to additional radiation for research purposes, and anonymity was emphasized to encourage honest responses.

3.6 Data collection

A pre-tested semi-structured, self-administered questionnaire was distributed to 150 healthcare workers across six major hospitals in Zimbabwe from 8th to 11th May 2025 by the researcher through email, WhatsApp and hand-delivery. The participants were given maximum of 3 days to fully complete the questionnaires. Seven key informant interviews were conducted with selected healthcare professionals between 20th and 30th May 2025 over phone call. Each interview lasted average 15 minutes. The key informant interviews were audio-recorded and supplemented by transcribing. An observation checklist was also used to collect data on radiation safety protection knowledge, practice and barriers to compliance,

3.7. Data mmanagement

Data were checked for missing values and inconsistencies by cross-checking with original source for accuracy and using logical checks to ensure that all entries aligned with expected patterns and ranges. Data from questionnaires were captured into MS Excel software and exported to SPSS software for further statistical analysis. The data storage servers had data backup and regular system updates.

The levels of knowledge and practice were assessed following “number right” or “raw” scoring system described by (Shafiee et al., (2020). Responses from knowledge and practice were separately assigned a scale from 0 to 1. The total score for each participant was computed by summing the individual scores, allowing for classification into predefined knowledge and practice level ranges (Keshtkar & Masoumi, 2021).

Radiation safety knowledge was assessed using 12 questions on section B of the survey questionnaire, covering core radiation protection knowledge such as dose limits, inverse law, and ALARA principle. Each knowledge question was a multiple choice and was scored on a two-point scale (0-1) (Allam et al., 2024). A correct answer was scored as 1 point, and an incomplete or incorrect answer was given zero point. The total knowledge score was the sum of all scores (0-12, maximum being 12. When converted to percentages, these scores corresponded to specific fixed values (e.g., 41.7%, 50.0%, 58.3%, 66.7%, 75.0%, etc.). Intermediate percentages such as 43% or 49% could not occur under this binary scoring structure. Therefore, the classification into low (0–41.7%), moderate (50–66.7%), and high (75–100%) knowledge levels (Table 3.5) is based on these achievable percentage outcomes, ensuring that no scores fall outside the defined categories. This structured approach enhances interpretability and maintains consistency with standard KAP classification frameworks.(Partap et al., 2019)

Radiation safety practice was assessed using 10 questions on section C of the survey questionnaire, covering core radiation protection practices such safety monitoring, use of personal protective equipment (PPE), training and records keeping. Each knowledge question was a multiple choice and was scored on a two-point scale (0-1) (Kyaw, 2024). A fully correct answer was scored 1 point, and an incomplete or incorrect answer was given zero point. The total scores ranged from 0 to 10, producing a limited set of discrete percentage values when converted (e.g., 0%, 10%, 20%, ..., 100%). Due to this fixed structure, intermediate percentages such as 43% or 67% are not attainable within this scoring framework. Practice levels were therefore classified into three categories based on achievable percentages: Low (0–40%), moderate (50–60%), or high (70–100%) practice (Table.3.6).

Table 3.5 Radiation safety knowledge rating (Elzaki et al., 2025)

Scale	Scale range	% Range	Rating comment	Interpretation
0	0-5	0-41.7	Low knowledge	response is completely incorrect or don't know response
1	6-8	50-66.7	Moderate knowledge	answer shows incomplete understanding or partially correct response
2	9-12	75-100	High knowledge	Many or all answers are correct and/or complete

Table 3.6 Radiation safety practice rating

Scale	Scale range	% Range	Rating comment	Interpretation
0	0-4	0-40	Low practice	never or there is inappropriate radiation safety behaviour
1	5-6	50-60	Moderate practice	inconsistent or sub-optimal radiation safety behaviour
2	7-10	70-100	High Practice	This means the participant is consistently correct and practice safe behaviour

Descriptive statistics, including mean, standard deviation, and frequency distributions were used to summarise demographic variables on age, gender, job title, years of experience, department, and province, knowledge and practice on individual item responses and total scores. Associations between knowledge and practice scores (low, moderate, high) and demographic variables were analysed using Chi-square tests for categorical variables, point-biserial correlation for dichotomous variables, Cramer's V for nominal variables and Spearman's correlation coefficients for ordinal data variables (relationship between total knowledge and total practice scores; relationship between years of experience and knowledge/practice scores) (Alburayh et al., 2025). Qualitative data from KIIs was analysed using thematic analysis following the steps described by Braun & Clarke, (2023) as illustrated in Fig. 3.2 below.

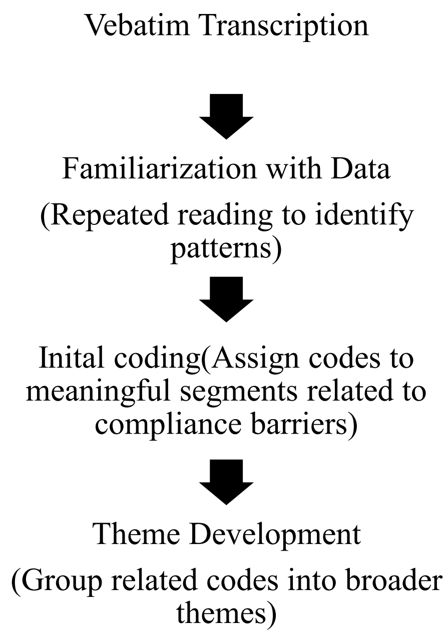

Fig. 3.2 KIIs Verbatim Transcription process (Shafiee et al., 2020)

3.8 Development of a radiation safety framework

A critical review method was chosen to review the current radiation safety protection frameworks as it allows for an in-depth, interpretive analysis of existing radiation safety frameworks, focusing not only on summarizing their content but also on evaluating their strengths, weaknesses, contextual relevance, and applicability to the Zimbabwean healthcare setting. Unlike scoping reviews, which broadly map available literature, or PRISMA approach which is best suited for systematic reviews with strict inclusion criteria, the critical review provides flexibility to critique, compare, and synthesize frameworks from diverse sources to inform a more context-sensitive model (Adelodun & Anyanwu, 2024).

3.8.1 Steps to conduct critical review

The review of current radiation safety frameworks was done utilizing a critical review approach to evaluate existing radiation safety protection frameworks. The methodology was structured into three key phases: Data collection, data analysis, and data presentation (Rodrigues et al., 2024).

3.8.1.1 Data collection

The data collection process for critical review was guided by a structure and rigorous approach to ensure that only relevant, credible, and high-quality literature on radiation safety protection frameworks was included in the analysis. The process began with the establishment of clear inclusion criteria to determine the eligibility of sources. These criteria focused on selected on selecting literature specifically related to radiation safety frameworks, ensuring that only peer-reviewed publications were considered, restricting the time frame to studies published withing the last six years, and limiting the review to English-language sources to ensure consistency and accessibility of interpretations.

A literature search was conducted using reputable academic databases such as PubMed, Scopus, and Google Scholar. The search employed carefully selected keywords including “radiation protection,” “healthcare workers,” “knowledge,” “attitude,” “practice,” and “radiation safety frameworks,” to capture a wide range of relevant literature across both theoretical and practical domains. Once the initial pool of studies was identified, a screening process was applied. Titles and abstracts were first reviewed to determine preliminary relevance. Full texts of potentially relevant studies were then assessed in detail to confirm they met all inclusion criteria. This step ensured that the final selection of literature directly contributed to answering the study’s research questions and aligned with the thematic focus of the review.

The final step in the data collection involved systematically extracting key information from each selected study. This included identifying the stated purpose of the framework, outlining its strengths and weaknesses, examining its practical application in healthcare or occupational settings, and noting any gaps or limitations highlighted by authors. This structured extraction of data provided a solid foundation for the subsequent phases of critical analysis and frameworks development

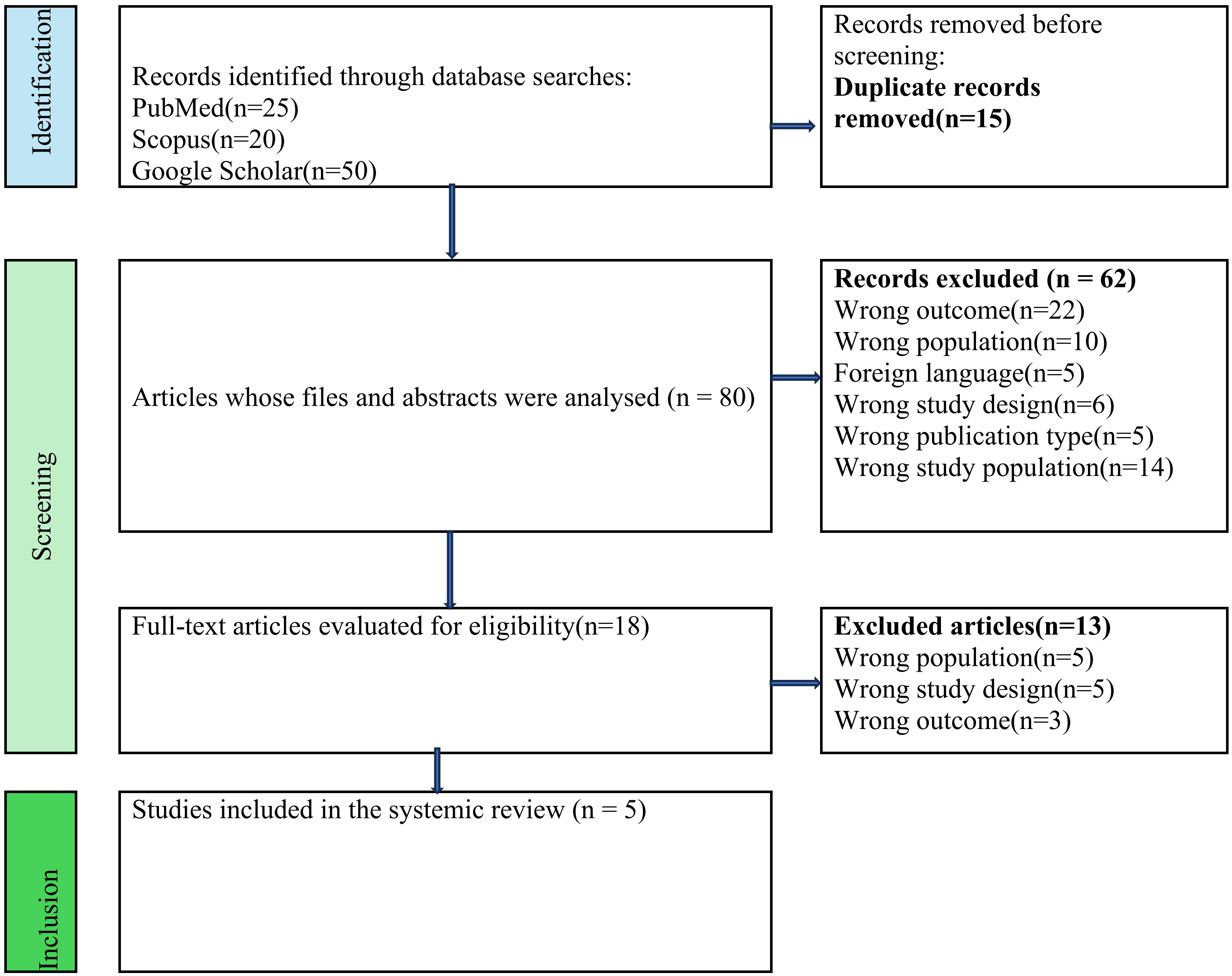

Fig. 3.3 Overview of article selection procedure according to PRISMA guidelines (Rodrigues,2024)

3.9 Data analysis

The data analysis process was designed to synthesize and critically appraise the selected literature with the aim of extracting meaningful patterns and insights relevant to radiation safety knowledge and practice. A thematic analysis was first conducted to identify common themes emerging across the reviewed studies. These included core aspects such as levels of radiation knowledge, compliance with radiation safety practices, structural features of existing radiation safety frameworks, risk assessment approaches used in various contexts, and occupational exposure guidelines outlined in different regulatory systems. The process involved carefully reviewing and grouping similar content to allow for deeper interpretation and categorization of the literature.

To enhance the depth of the analysis, a comparative approach was applied to assess the relative strengths and limitations of each identified framework. This involved examining how different models addressed radiation protection, identifying points of convergence or divergence in terms of objectives and application, and highlighting areas where evidence was limited or implementation appeared weak. Using this method, some gaps in policy integration, training coverage, and behavioural reinforcement mechanisms were uncovered and documented for further discussion in the development of the IRS-KPM framework.

3.10 Data presentation

The presentation of data was organized to provide both clarity and critical insight into the findings of the review. A structured tabulation method was used to present a side-by-side comparison of key characteristics of each identified radiation safety framework. This included attributes such as country of origin, stated objectives, documented, strengths, limitations, and areas where each framework had been applied in practice. The comparative table served as a visual summary to support the reader's understanding of how each framework functioned within its respective context.

In addition to the table, a narrative synthesis was developed to integrate and describe the thematic findings in more detail. This narrative placed the reviewed frameworks within a broader context and synthesized their contributions, challenges, and alignment with the Zimbabwean healthcare environment. The presentation concluded with a discussion of key implications arising from the findings, focusing on their relevance to improving radiation safety knowledge, enhancing compliance with protective practices, guiding policy development, supporting effective implementation in hospitals, and contributing to future academic research.

3.11 IRS-KPM testing

The new model was tested through a structured interview with radiation experts (Appendix 6) to collect detailed feedback on the framework's feasibility, relevance and comprehensiveness. The experts were given the framework 2 days before the interview for them to have time to review

CHAPTER 4: RESULTS

4. Results

4.1 Demographic characteristics of participants

Table 4.1 below shows the demographic characteristics of participants. Results show statistically significant relationships on both knowledge and practice scores for age, work experience, and education level. An interesting result was on staff with more than 10years of experience who showed better practice scores despite lower knowledge scores suggesting that practical skills improve with experience. Training came up as a crucial factor with significant differences in both knowledge and practice scores, where trained staff performed notably better

Table 4.1 Demographic characteristics of participants (n=70)

Characteristic	Category	n (%)	Knowledge score			Practice score		
			Score (%)	Chi-square	p-value	Score (%)	Chi-square	p-value
Gender	Male	36(51)	69.8	3.842	0.479	67.5	4.267	0.479
	Female	34(49)	64.2			58.5		
Age group(yrs)	18-25	9(13)	65.3	7.916	0.017	55.6	8.234	0.009
	26-35	34(49)	71.2			64.7		
	36-45	16(23)	63.4			61.3		
	46 and above	11(16)	62.7			71.8		
Work experience(yrs)	Less than 1 yr	6(9)	60.8	9.473	0.013	41.7	10.156	0.004
	1-5 yrs	30(43)	73.4			60.3		
	6-10yrs	7(10)	65.7			65.7		
	More than 10yrs	27(39)	64.5			69.6		
Level of education	Certificate	0(0)	0.0	12.845	0.006	0.0	11.932	0.020
	Diploma	5(7)	25.0			70.0		
	Undergraduate degree	36(51)	71.9			58.1		
	Post graduate diploma	6(9)	73.2			63.3		

	Post graduate degree	23(33)	68.7			71.3		
Type of healthcare	Public hospital	46(66)	67.8	5.673	0.198	62.4	6.124	0.233
	Private hospital	20(29)	65.5			64.5		
	Clinic	2(3)	58.5			55.0		
	Research institution	0(0)	0.0			0.0		
	Others	2(3)	46.0			70.0		
Profession	Radiologist	0(0)	0.0	8.932	0.112	0.0	9.456	0.092
	Radiographer	60(86)	67.3			61.7		
	Physician	0(0)	0.0			0.0		
	Nurse	1(1)	58.0			40.0		
	Radiation safety officer	6(9)	73.7			73.3		
	Other	3(4)	53.0			89.0		
Department	Radiology	58(83)	67.4	4.567	0.358	62.2	5.234	0.270
	Nuclear medicine	0(0)	0.0			0.0		
	Radiation oncology	8(11)	69.5			65.0		
	Other	4(6)	58.0			70.0		
Training	Yes	45(64)	70.8	6.234	0.008	65.3	7.123	0.014

	No	25(36)	61.2			59.2		
Province	Harare	45(64)	67.2	11.456	0.421	60.4	12.234	0.393
	Mashonaland west	4(6)	70.5			67.5		
	Mashonaland Central	2(3)	35.0			75.0		
	Midlands	6(9)	76.2			66.7		
	Manicaland	3(4)	66.7			60.0		
	Bulawayo	10(14)	65.7			66.0		

4.2 Determined the level of radiation knowledge and practice among hospital workers in radiation emitting environment

4.2.1 Results of radiation knowledge levels

Table 4.2 shows results of radiation protection knowledge of respondents. The results indicate that the mean score was 66.8% denoting a moderate knowledge. There were strong positive correlations found between education, training and radiation knowledge scores. No significant correlations were found with gender, department, type of healthcare and province.

Table 4.2: Respondents' level of radiation safety protection knowledge (n = 70)

No.	Question	Correct answer		Incorrect answer	
		Freq.	%	Freq.	%
11	What is the recommended annual dose limit for occupational radiation exposure (mSv)?	58	83	12	17
12	The ALARA principle stands for:	69	99	1	1
13	Which of the following is most sensitive to radioactive emission /material?	44	63	26	37
14	What is the inverse square law?	62	89	8	11
15	What is the recommended annual dose limit for the lens of the eye (in mSv)?	27	39	43	61
16	Which of the following is not a radiation protection measure?	62	89	8	11
17	Pregnant radiation workers should:	34	49	36	51
18	What is the correct placement of a Thermoluminescent Dosimeter (TLD) badge?	36	51	34	49
19	Which of the following is a short-term (deterministic) effect of high-dose radiation exposure?	53	76	17	24
20	What is the maximum annual radiation dose limit for the general public (in mSv) according to national guidelines?	32	46	38	54

21	What is the permissible radiation dose limit to the foetus during pregnancy (in mSv)?	23	33	47	67
22	Who is the '10-day rule' in radiation protection most relevant to?	61	87	9	13
	Average knowledge score	66.8			33.2

Table 4.3 Correlation analysis of radiation safety knowledge with demographic variables(n=70)

Variable	**Knowledge score**	
	r- value	**p-value**
Age	0.284	0.017*
Work experience	0.297	0.013*
Level of education[1]	0.326	0.006**
Training status[2]	0.315	0.008**
Gender[2]	-0.086	0.479
Deaprtment[3]	0.112	0.358
Type of healthcare[3]	0.156	0.198
Province[3]	0.098	0.421

Notes

**Significant at p <0.05*

***Significant at p = 0.01*

[1]*Spearman's correlation used for ordinal data*

[2]*Point-biserial correlation used for dichotomous variables*

[3]*Cramer's V used for nominal variables*

4.2.2 Results of radiation practice levels

Table 4.4 shows results of radiation protection practice of respondents. The results indicate that the mean score was 63.4% denoting a moderate practice level.

Table 4.4: Results of radiation safety practice (n = 70)

No.	Question	Correct answer		Incorrect answer	
		Freq.	%	Freq.	%
23	How often do you wear a radiation monitoring badge?	49	70%	21	30%
24	How frequently do you review your radiation dose records?	19	27%	51	73%
25	How often do you wear a lead apron when exposed to radiation during procedures?	47	67%	23	33%
26	What safety action is taken when performing radiological procedures on a potentially pregnant patient?	62	89%	8	11%
27	How often do you attend radiation safety training?	21	30%	49	70%
28	What action do you take if radiation exposure exceeds dose limits?	58	83%	12	17%
29	What is your practice for paediatric radiation protection?	62	89%	8	11%
30	How often is patient exposure information (e.g. dose, time, justification) recorded in medical or radiation logs?	26	37%	44	63%
31	How often is gonad shielding used when exposing patients to radiation?	36	51%	34	49%
32	How do you store radiation protection equipment?	64	91%	6	9%
	Average practice score level		63.4		36.6

Table 4.5 Correlation analysis of radiation safety knowledge with demographic variables(n=70)

Variable	**Practice score**	
	r- value	**p-value**
Age	0.312	0.009**
Work experience	0.345	0.004**
Level of education[1]	0.278	0.020*
Training status[2]	0.293	0.014*
Gender[2]	-0.092	0.449
Deaprtment[3]	0.134	0.270
Type of healthcare[3]	0.145	0.233
Province[3]	0.104	0.393

Notes

**Significant at p <0.05*

***Significant at p = 0.01*

[1]*Spearman's correlation used for ordinal data*

[2]*Point-biserial correlation used for dichotomous variables*

[3]*Cramer's V used for nominal variables*

4.3 Determined the level of compliance to radiation safety regulations among hospital workers working in radiation emitting environment in Zimbabwe

4.3.1 Observation checklist results

Table 4.6 shows practical results of radiation regulatory and best practice compliance. The results indicate inconsistencies in compliance especially in posting of emergency procedures in some departments, inadequate safety briefings, inadequate personal protective equipment such as lead aprons and gonad shields and personal monitoring devices such as TLDs, pointing to opportunities for improvement

Table 4.6 Observation results

Area	% Compliance
Personal protective equipment and basic safety practices	63.4%
Safety infrastructure and documentation	65%
Patient safety and professional oversight	71%
Safety briefings	28.6%

4.4 Identified barriers to radiation safety compliance among hospital workers working in radiation emitting environment in Zimbabwe

4.4.1 Results of thematic analysis of key informant interviews

The thematic analysis of the key informant interview transcripts produced the key themes, as in Table 4.7, in relation to the barriers to radiation safety compliance among hospital workers working in radiation emitting environment in Zimbabwe. The results indicate shortage of resources such as funding for equipment purchase and maintenance, staff shortage, training gaps and leadership inadequacy as negatively impacting on radiation safety protection compliance

Table 4.7 Identified barriers to radiation safety compliance from thematic analysis

Theme	Sub-themes	Illustrative quotes
Theme 1: Inadequate resources and equipment provision	• Inadequate personal protective equipment (PPE), e.g. lead aprons and TLDs • Lack of radiation monitoring devices such as survey meters • Failure to calibrate equipment on time and poor-quality service from contractors • Infrastructure limitations and CAPEX deficiencies	*"Lead aprons are inadequate, especially on theatre staff"* *"There are no survey meters available…servicing tales too long"* *"Building needs modification to comply with shielding standards"* *"When one dosimeter has gone to RPAZ as per legal requirement, we don't have anything to monitor us, we should have at least two dosimeters"*
Theme 2: Shortage of staff and resulting staff over-exposure	• Inadequate staffing especially radiographers and support staff • Extra workload causing prolonged exposure to radiation • Inexperienced or underqualified personnel are being assigned radiation jobs	*"Support staff and radiographers are affected the most"*
Theme 3: Training and knowledge gaps	• Provided training is generic and not customised to specific professions • There is limited training for nurses and support staff on radiation • There is lack of public and leadership radiation awareness	*"Training is too generic. It needs to be tailored to each profession."* *" We need awareness programs for both staff and the public."* *"Access to RPAZ training is limited due to funding."*

Theme 4: Gaps in leadership and policy enforcement	• Weak support from hospital leadership in promoting safety culture • Insufficient funding for training, licensing and equipment purchase or maintenance • Lack of policy enforcement and designated RSO support	*"leadership must provide funding and need to enforce radiation policy."* *"We need training for leadership to improve radiation safety culture."* *"Radiographers sometimes report to superiors who don't appreciate radiation safety."*
Theme 5: Suggested interventions	• Improve CAPEX provision and procure quality equipment • Recruit and retain skilled staff • Revise curriculum and include benchmarking and role specific training • Create public awareness campaigns and revise policy	

4.5 Developed evidence-based radiation framework

Table 4.8 shows results of critical review of relevant frameworks to radiation safety protection. The results show the applicability of the frameworks, their strengths and gaps which positively point to need for a robust radiation framework.

Table 4.8 Outcome of critical evaluation of relevant radiation frameworks

Relevant radiation safety framework	Literature review	Critique and how it will guide in the study	References
Health Belief Model (HBM)	Explains radiation safety behaviour based on perceived risk and benefits. Used in health interventions.	Strong in explaining knowledge-behaviour links but lacks real-time decision-making and environmental factors. Gaps in no focus on institutional policies, training, and compliance enforcement. The model guides the study by examining how healthcare workers' perceptions of radiation risk influence their compliance with safety practices.	Maier et al. (2023)
Protection Motivation Theory (PMT)	Predicts radiation safety behaviour based on fear and coping mechanisms. Used in risk prevention studies.	Addresses motivation but ignores external influences such as organizational culture and safety infrastructure. Gaps in no focus on system-wide safety policies and regulatory monitoring. It helps investigate how perceptions of radiation risks and the effectiveness of safety protocols affect adherence among hospital staff.	Balla & Hagger (2025)
Theory of Planned Behaviour (TPB)	Expands on TRA by including perceived control over behaviour.	Useful for explaining safety compliance but does not address external barriers like resource constraints. Gap in limited applicability in mandatory compliance settings like hospitals.	Lewis et al. (2022)
Risk Communication Theory (RCT)	Focuses on how safety information is conveyed to the public and workers.	Addresses communication but does not explain behavioural adherence. No emphasis on monitoring systems or compliance tracking.	Yoshida (2023)

Behavioural Change Wheel (BCW)	Provides a framework for designing behavioural interventions.	Comprehensive but lacks specificity for radiation safety. Not widely applied in radiation protection.	Fahim et al. (2020)
Zimbabwe radiation protection regulatory framework	The regulatory framework in Zimbabwe especially SI 61 of 2011 and the principal Act of radiation protection provides for registration, licencing, and dose limits requirements on hospital workers working in radiation emitting environment, licensing, and dose limits for workers. It also sets exposure limits and mandates workers safety	The radiation protection principal act provides a broad framework but lacks clear mechanisms for real-time radiation exposure monitoring while SI 62 of 2011 lacks specificity in enforcement measures. The principal act has no explicit requirement for continuous professional training on radiation safety for hospital staff.	Chinene et al. (2024)

4.5.1 Results of developed evidence-based radiation safety framework to enhance the protection of hospital workers operating in radiation-emitting environments

Table 4.9 IRS-KPM objectives

What	How	Who
Encourage knowledge	**1. By improving understanding of radiation safety principles among healthcare workers through:**	
	a. Training workshops Organize regular workshops focusing on radiation safety principles including ALARA (As low as reasonably achievable) principle, dose limits, and protective measures	Radiation safety officers External radiation experts
	b. E-Learning modules Develop interactive online courses that cover radiation safety topics, allowing healthcare workers to learn at their own pace. Make it accurate and engaging	Instructional designers in collaboration with radiation safety experts
	c. Resource materials Create easy to understand handbooks or infographics summarizing key radiation safety principles	Radiation safety committee Educational teams within healthcare institution
	d. Mentorship programs Pair less experienced healthcare workers with seasoned professionals to facilitate knowledge transfer and practical insights on radiation safety	Reviewed by radiation experts

	2. **Foster awareness of radiation risks and protective measures** through a. Awareness campaign Implement campaigns that highlight the importance of radiation safety, utilizing posters, newsletters, and digital displays within the workplace b. Simulation training Conduct practical simulation exercises that demonstrate safe practices and the consequences of unsafe behaviour regarding exposure c. Regular safety briefings Schedule briefings (radiation safety talks) at departmental meetings to discuss current radiation safety practices, recent incidents and updates on regulations. There must be portion of open dialogue among staff d. Feedback mechanism Establish anonymous surveys or suggestion boxes where staff can share concerns or ask questions about radiation safety. The committee must ensure feedback is reviewed and acted upon.	Heads of departments or radiation safety coordinators Led by hospital communication team Collaborate with radiation safety committee Facilitated by radiation safety officers Trained by educators to ensure hands-on learning experiences Departmental heads Safety officers Manged by radiation safety committee
2. Promote safe practices	1. **Encourage adherence to established radiation safety protocols through:** a. Regular training sessions Conduct mandatory training sessions that reinforce the importance of observing established radiation safety protocols, focusing on practical application in daily tasks. b. Standard operating procedures (SOPs). Develop clear, accessible SOPs detailing radiation safety protocols, including	Led by radiation safety officers and senior clinicians

procedures for patient handling, equipment uses, and emergency responses	
c. Monitoring compliance Implement regular audits to assess adherence to radiation safety protocols, providing feedback to departments on compliance rates and areas for improvement.	Radiation safety committee Review by clinical staff
d. Recognition programs Establish recognition programs that reward departments or individuals who consistently adhere to radiation safety protocols to foster a culture of safety.	Internal auditors or Radiation safety committee
2. Implement best practices for minimizing occupational exposure	
a. Personal protective equipment (PPE) usage Ensure the availability and proper use of PPE, such as lead aprons, thyroid shields, and dosimeters, to minimize exposure during procedures	Hospital administrators Radiation safety committee
b. Radiation safety signage Install clear and adequate signage in both English and local language in areas where radiation is present, reminding the staff of safety practices and exposure limits.	Radiation safety officers Training-Clinical educators
c. Optimized workflows Review and optimize workflows in radiology and other departments to minimize unnecessary radiation exposure, including patient positioning and equipment settings	Facilities management Radiation safety officers
d. Regular safety drills Organize safety drills that simulate scenarios involving radiation exposure,	Department managers

	allowing staff to practice responses and reinforce best practices for real situations.	Radiation safety officers
3. Facilitate continuous training	1. **Establish ongoing training and education programs on radiation safety** a. Annual training workshops Organize annual workshops that cover updated radiation safety guidelines, new technologies and best practice b. Certification programs Develop certification programs that healthcare workers can complete to enhance their qualifications in radiation safety. c. Onboarding training for new staff Implement a structured onboarding program for new hires that includes comprehensive training on radiation safety protocols and practices to ensure new staff are adequately prepared from day one. d. Webinars and online courses Offer regular webinars and online courses that allow staff to engage with radiation safety topics in a flexible and convenient manner.	Radiation safety officers External experts Education department Radiation safety officers Department heads Mentors Training department Radiation safety experts
	2. Provide resources for skill development related to radiation protection a. Access to educational materials Create a centralized repository of educational materials, including manuals, guidelines and articles on radiation safety and protection b. Simulation training facilities Develop simulation training facilities where staff can practice radiation safety skills in a controlled environment, using realistic scenarios	Training department Radiation safety officers Clinical educators

	c. Peer learning opportunities Establish peer learning groups where staff can share experiences, challenges and strategies related to radiation safety practices. Participation from staff from all levels must be encouraged d. Continuous feedback and assessment Implement a system for ongoing feedback and assessment of staff skills related to radiation safety, identifying areas for improvement and additional training needs utilizing performance metrics and staff surveys	Radiation safety committee Clinical educators Facilities management Department managers All staff
4. Strengthen policy and compliance	**1. Align radiation safety practices with national and international guidelines** a**.** Regular review guidelines Establish a schedule for regularly reviewing and updating radiation safety practices to ensure alignment with the latest national and international guidelines (such as ICRP or IAEA) b. Policy development workshops Organize workshops to educate staff about the relevant guidelines and how they apply to local practices, fostering understanding and implementation c. Integration into institutional policies Embed national and international guidelines into the institution's radiation safety policies, making them a standard part of operational procedures. d. External audits Engage independent auditors to assess compliance with national and	Radiation safety committee External experts Radiation safety officers Regulatory representatives Hospital administrators Radiation safety committee Third party radiation safety auditors

	international standards, providing recommendations for improvement to management for action	
	2. Ensure compliance with regulatory requirements and institutional policies	
	a. Compliance training programs Develop training sessions focused specifically on regulatory requirements and institutional policies related to radiation safety ensuring clarity on expectations and responsibilities.	Regulatory compliance officers Radiation safety experts
	b. Monitoring and reporting systems Implement systems to track compliance with radiation safety policies and regulatory requirements, including incidental reporting to departmental heads and senior management for corrective actions	Safety committee Radiation safety officers
	c. Regular compliance audits Conduct internal audits to assess adherence to regulatory requirements and institutional policies, identifying areas for enhancement. Share results with relevant stakeholders for transparency.	Designated compliance officers Internal auditors
	d. Feedback and improvement mechanisms Create channels for staff to provide feedback on compliance Issus, ensuring that concerns are addressed promptly and effectively	Radiation safety committee
5. Monitor and evaluate	**1. Develop mechanisms for continuous monitoring of radiation practices**	
	a**.** Radiation dose tracking systems Implement electronic systems to track individual radiation doses received by healthcare workers, ensuring real-time monitoring of exposure levels.	Radiation safety officers IT department

b. Routine compliance checks Establish a schedule for regular compliance checks on radiation safety practices in various departments, including equipment usage and PPE protocols	Radiation safety auditors Designated compliance officers
c. Incident reporting systems Create user-friendly system for reporting radiation safety incidents, near misses, and breaches of protocol to facilitate immediate corrective actions	Radiation safety committee
d. Regular feedback sessions Hold periodic meetings to discuss monitoring results, share best practices and address any concerns related to radiation safety in the workplace.	Departmental managers Radiation safety officers
2. Evaluate the effectiveness of radiation safety interventions over time	
a. Performance metrics Establish clear performance metrics to assess the impact of radiation safety interventions such as reduction in dose levels and compliance rate	Radiation safety committee Data analysts
b. Longitudinal studies Conduct longitudinal studies to track changes in knowledge, attitudes, and practices related to radiation safety among healthcare workers over time	Researchers Radiation safety committee
c. Regular review of safety outcomes Analyse data from monitoring system and compliance checks to evaluate the effectiveness of implemented radiation safety interventions and make necessary adjustments. The reports must be shared with staff and senior management for transparency	Radiation safety committee
d. Stakeholder feedback	

	Gather feedback from healthcare workers on the effectiveness of radiation safety training and interventions through surveys and focus groups to inform future initiatives	Training department Radiation safety committee
6.Encourage organizational support	**1. Foster a culture of safety within healthcare institutions** a. Safety awareness programs Implement programs that promote awareness of radiation safety as a core value within the organization, highlighting the importance of safety in daily operations	Radiation safety committee
	b. Open communication channels Establish clear channels for communication regarding safety concerns, encouraging staff to report issues without fear of reprisal	Heads of departments Human resources
	c. Recognition and reward system Create a recognition program that rewards departments or individuals who demonstrate exceptional commitment to radiation safety practices	Hospital administration
	d. Regular safety meetings Schedule regular safety meetings to discuss radiation safety topics, share updates and reinforce the importance of a safety -first mindset	Safety committee Departmental heads Safety officers
	2. Engage leadership in promoting radiation safety initiatives a. Leadership training Provide training for leadership on the importance of radiation safety and their role in fostering a culture of safety within the organization	Radiation safety experts
	b. Involvement in safety committees Encourage leaders to actively participate in radiation safety committees, providing oversight and support for safety initiatives	Safety committee

c. Strategic planning Involve leadership in strategic planning sessions focused on integrating radiation safety into organizational goals and objectives	Senior management Radiation safety committee
d. Public commitment to safety Have organizational leaders publicly commit to radiation safety through statements, policies, and participation in safety events	Hospital executives Communication department

Table 4.10 Components of IRS-KPM

Component	**Description**	**Implementation mechanics**	**Responsibility**
Educational strategies	Consist of workshops, e-learning modules, and resource materials to enhance knowledge	Conduct regular training sessions and resource distribution	Radiation safety officers Educational teams
Behavioural motivation	Consist of risk communication and feedback mechanisms to encourage adherence	Hold regular feedback sessions and risk awareness campaigns	Departmental heads Radiation safety officers
Policy framework	Development of guidelines and protocols aligned with regulations and international standards	Establish clear documentation and integration into practices	Radiation safety committee Policy makers
Monitoring systems	Consist of systems to track radiation exposure and compliance with safety protocols	Implement tracking and reporting systems	Radiation safety officers IT departments
Organizational support	Engagement of leadership and fostering a culture of safety	Establish reward and recognition programs and hold consistent safety meetings	Hospital leadership Radiation safety committee
Peer learning and collaboration	Give staff opportunities to learn through sharing knowledge and experiences	Establish peer review sessions and collaborative workshops	Department managers Safety officers

Evaluation framework	Develop metrics to assess the effectiveness of radiation safety interventions	Establish regular reviews and longitudinal studies	Radiation safety committee Researchers

4.5.2 Demographic characteristics of radiation experts

Table 4.11 shows results of demographic characteristics of experts who evaluated the new radiation safety protection model. The results show a balanced input from industry, regulatory and academia fields.

Table 4.11 Results of demographic characteristics of radiation experts

Variable	Category	n	%
Gender	Male	2	66.7
	Female	1	33.3
Educational qualification	Master’s Degree	1	33.3
	PHD	2	66.7
Work experience(yrs)	6-10	1	33.3
	Above 10	2	66.7
Affiliation	Regulatory	1	33.3
	Industry	1	33.3
	Academia	1	33.3

4.5.3 Evaluation results of the developed radiation safety model

Table 4.12 shows expert evaluation results of the new model. In summary the experts gave a thump up to the new model as it is feasible, relevant, and comprehensive.

Table 4.12 Results of new model evaluation by experts

Parameter	Outcome	Comment or quote
Feasibility of the framework	The experts stated that the framework was a practical and context sensitive tool which could be implemented in Zimbabwean healthcare set-ups. The inclusion of peer learning, compliance audits and scenario-based training was viewed as suitable for both high and low resource environments. However, it was noted that its feasibility depended on institutional leadership commitment, availability of RSOs (radiation safety officers) and monitoring equipment. They also cautioned that successful implementation would require staggered process, starting with better -resourced urban hospitals	*"The framework is workable, but requires leadership buy-in and a structured roll-out plan tailored to existing hospital capacities"*
Relevance to current practice	All participants were agreeable that the new framework addresses critical gaps in existing radiation safety practices, particularly the gap in routine training, inadequate monitoring, and poor behavioural reinforcement. The framework is relevant and grounded in Zimbabwean radiation regulations and day to day operational realities in both private and public hospitals	*"This framework talks to the realities we face every day-inexperienced staff, inadequate institutional monitoring and lack of radiation safety culture. It is relevant and comes at a right time"*

Comprehensiveness of the framework	The experts note that it efficiently integrates knowledge attainment, behavioural theory (HBM and PMT), leadership support, and policy enforcement. They also appreciated its balance between theory and practical intervention tools. There was also suggestion to make strong components related to staff motivation, internal feedback systems and communication strategies for continuous improvement	*"It's unusual to see a framework that connects behaviour, training, leadership and regulation in one place-great package"*
Recommendation for future improvement	Develop a step-by step operational toolkit for hospital implementation	*"Hospitals need practical tools. A step-by-step guide would make this framework easy to adopt, even in lower-tier facilities."*
	Test the model in different hospital setting, including rural and urban hospitals	*"Context matters. What works in a central hospital may not be feasible in a rural clinic—pilot testing will help refine the model realistically."*
	Integrate a self-assessment tool for internal audits and tracking	*"Regular internal audits would empower departments to take ownership of radiation safety instead of waiting for external inspections."*
	Strengthen policy links by aligning framework indicators with professional licensing and hospital accreditation systems	*"If safety indicators are tied to licensing and accreditation, compliance will become a priority—not just a recommendation."*

CHAPTER 5: DISCUSSIONS

5. Discussion

5.1 Demographic characteristics of respondents

The demographic profile of the respondents gives a deeper understanding of the diversity and representativeness of workers in hospitals involved in radiation safety practice. Both gender and age groups were well represented, with professionals such as radiographers typically dominating numerically in radiation emitting departments. The demographic structure is consistent with workforce profiles reported in similar regional studies, such as Maina et al., (2020) in Kenya and Martinucci (2025) in South Africa. Gaps in training coverage, particularly for non-radiographer staff, raise concerns about inclusiveness in radiation protection programs—a trend also noted by Adhikari et al. (2021) in a multi-country study across low-income settings

5.2 Determined the level of radiation safety knowledge and practice among hospital workers

Radiation safety knowledge and practice levels among the hospital workers in radiation emitting environment were moderate with mean scores of 66.8% and 63.4% respectively indicating a relatively good understanding of radiation safety principles, especially among radiographers and those with postgraduate qualifications. However, knowledge and practice were not always strongly aligned, agreeing with findings done in Nigeria and Ethiopia, where knowledge many times exceeded actual practice compliance (Balla &Hagger,2025)

Training done in the last two years was significantly associated with higher scores, reinforcing the importance of periodic professional development. This echoes conclusion by Shafiee et al., (2020) who reported that refresher training improved not only theoretical understanding but also practical adherence. In contrast, gender and department type were not significantly associated with score differences, suggesting that radiation safety knowledge cuts across various roles but application may depend on training and institutional policies and culture.

5.3 Determined the level of compliance to radiation safety regulations in Zimbabwean hospitals

Zimbabwe has radiation regulations such as the Radiation protection Act (Chapter15:15) and statutory instrument 62 of 2011, but compliance to radiation varied widely. The verification done on the ground using observation checklist showed that while dosimeter use, signage, and PPE availability were common, critical elements such as emergency procedure visibility and regular safety talks were poorly executed. These patterns are consistent with findings by Umaru et al., (2024), who noted partial implementation of safety regulations in Ghana due to resource constraints and weak policy enforcement.

The discrepancy between policy and practice may be attributed to leadership gaps and the absence of institutional accountability mechanisms. Similar observations were made by Bryant (2021), who found that policy presence alone does not guarantee adherence in the absence of management follow-through. The study confirms the need for both top-down (policy enforcement) and bottom-up (training and monitoring) strategies to close the compliance gap.

5.4 Identified barriers to radiation safety compliance

Thematic analysis from key informant interviews highlighted five major barriers which are inadequate personal protective equipment (PPE), staff shortages, insufficient training, weak leadership support, and poor policy enforcement. These barriers are consistent with previously documented systemic barriers in sub-Saharan African hospitals (Rasheed et al.,2025). staff shortages were noted among radiographers and support staff, contributing to prolonged exposure and unsafe practices due to workload pressure.

Training gaps were evident among nurses and non-radiology personnel, a challenge also reported in a regional study by Behzadmehr et al., (2021), where support staff lacked access to structured radiation safety training. Weak leadership was frequently cited, with concerns that hospital managers often lacked understanding of radiation safety priorities, similar findings were obtained by Fahim et al., (2020) in Pakistan.

5.5 Developed an evidence-based radiation safety framework to improve worker protection

Responding to the gaps that were observed, the study developed and evaluated the integrated radiation safety knowledge and practice model (IRS-KPM). The feasibility and relevancy of the framework was confirmed by radiation experts, which highlight the alignment with practical healthcare challenges. The model's structure incorporates behavioural theories (HBM, PMT), monitoring tools, leadership engagement, and training strategies. This comprehensive approach ensures that both individual behaviours and systemic enablers are addressed.

Experts recommended that the IRS-KPM be piloted in both urban and rural hospitals, supported by a step-by-step implementation toolkit and self-assessment checklists. These suggestions echo WHO's call for adaptable, evidence-based frameworks in radiation safety (WHO,2016).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6. Conclusions and recommendations

6.1 Conclusions

This study assessed radiation safety knowledge, practice, compliance, and barriers among hospital workers in radiation -emitting environment in Zimbabwe and developed an evidence-based framework (IRS-KPM) to address identified gaps. The findings revealed moderate knowledge and practice levels, partial compliance with existing safety regulations, and systemic barriers including inadequate training, poor leadership support, and limited resources. Although the IRS-KPM framework was found to be feasible and contextually relevant, the results imply that regulatory frameworks alone are insufficient without institutional accountability and routine training. The results of the study, though done in 6 provinces, are transferrable to similar health systems in low- and middle-income countries. The strength of the study lies in its practical framework, grounded in real-world challenges and expert validation. The limitations of the study include cross-sectional design and potential self-reporting bias. Future research should focus on piloting the IRS-KPM framework in diverse settings and evaluating its long-term impact on radiation safety compliance.

6.2 Recommendations:

- Integrate structured radiation safety training into routine hospital programs, with focus on those staff not adequately trained such as nurses and support personnel
- Adopt and pilot IRS-KPM framework in both urban and rural healthcare settings supported by a toolkit and internal self-assessment checklist
- Align radiation performance indicators with licensing and hospital accreditation standards to enhance institutional accountability and compliance

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APPENDIX 1

QUESTIONNAIRE

P. BAG 1020 Tel. (263) 712 842 712-4

Bindura,

Researcher: Magadzire Fletcher Schweppes Zimbabwe, Harare

E-mail: fmagadzire@schweppes.co.zw Cell: +263782092093

Supervisor: Dr. A. Kanda: Department of Environmental Science, Bindura

E-mail: akanda@buse.ac.zw Cell: 0772 773 560

Radiation safety protection knowledge and practice questionnaire

Introduction

My name is Magadzire Fletcher, Iam a final year student at Bindura University of Science Education (Registration no. B241657A) doing my Master's degree in Occupational Safety Health and Environment Management. As part of my curriculum requirements, I am undertaking research entitled "*Radiation safety protection knowledge and practice among Zimbabwe hospital health workers working in radiation-emitting environments*". Findings from this study will be useful to inform policy development, guide resource allocation, and help establish evidence-based training programmes for healthcare workers. I request you to assist me with some information on this matter, provided you are willing to take part in the study. It will take between 20 and 30 minutes.

Ethical statement

The study has been cleared by Bindura University of Science Education through the department of Environmental Science, Radiation Protection Authority of Zimbabwe (RPAZ) and Research Council of Zimbabwe (RCZ). Confidentiality and anonymity of shared information are guaranteed. By willingly participating in the study it infers that you understand its purpose and how you will be involved. This also means that you have provided your informed consent. If you wish to discontinue the survey, kindly feel free to indicate it.

Signature: ……………………………......… Date……… ………………….. 2025

Instructions

1. For multiple-choice questions, tick (✓) or mark (X) against your response.

2. You should complete the questionnaire without discussing answers with colleagues.

3. After completion, please return the questionnaire to the designated researcher in person or if completing electronically, submit it via the provided email or online form before the deadline, copying the supervisor.

Section A: Demographic Information

1. **Province** **1**. Harare **2**. Mash West **3**. Mash central **4**. Midlands **5**. Manicaland 6. Bulawayo
2. **Name of health facility** **1**. Parirenyatwa Hospital **2**. West End Hospital **3**. Avenues Hospital **4**. CIMAS Harare medical centre 5. UBH 6. Mata Dei Hospital 7. Kwekwe General hospital 8. Unki Mine medical clinic 9. Zimplats Medical clinic 10. Chinhoyi Hospital 11. Mutare General Hospital 12. Bindura General hospital
3. Type of healthcare facility **1**. Public hospital **2**. Private hospital **3**. Clinic

   4. Research institution **5**. Other (Specify) __________
4. Category of profession **1**. Radiologist **2**. Radiographer **3**. Physician **4**. Nurse

   5. Radiation safety officer **6**. Other (Specify) __________
5. Gender **1**. Male **2**. Female
6. Age group (years) **1**. 18 – 25 **2**. 26 – 35 **3**. 36 – 45 **4**. 46 and above
7. Highest professional qualification: **1**. Certificate **2**. Diploma **3**. undergraduate degree **4**. postgraduate diploma **5**. Post graduate degree
8. Department of work: **1.** Radiology **2**. Nuclear medicine **3**. Radiation oncology

   4. Other (Specify) __________
9. Work experience in radiation-emitting environment (years):

   1. Less than 1 2. 1 – 5 3. 6 – 10 4. More than 10

10**.** Have you received formal radiation safety training in the last two years?

1. Yes **2**. No

Section B: Radiation safety knowledge

11**.** What is the recommended annual dose limit for occupational radiation exposure (mSv)?

1. 1 **2**. 20 **3**. 50 **4**. 100

12. The ALARA principle stands for:

1. As Low As Reasonably Achievable
2. Acceptable Levels Are Readily Available
3. As Long As Radiation Allows
4. All Levels Are Radiation Approved

13. Which of the following is most sensitive to radioactive emission /material?

1. Skin   2. Bone marrow   3. Muscle   4. Fat

14. What is the inverse square law?

1. Radiation intensity increases with distance
2. Radiation intensity decreases with the square of the distance
3. Radiation intensity remains constant
4. Radiation intensity doubles with distance

15. What is the recommended annual dose limit for the lens of the eye (in mSv)?

1. 15   2. 20   3. 50   4. 150

16. Which of the following is not a radiation protection measure?

1. Time   2. Distance   3. Absorption   4. Shielding

17. Pregnant radiation workers should:

1. Stop working immediately
2. Wear a double lead apron
3. Be monitored with an additional dosimeter
4. Work only with mobile X-ray units

18. What is the correct placement of a Thermoluminescent Dosimeter (TLD) badge?

1. Under the lead apron at chest level
2. Over the lead apron at chest level
3. On the thyroid collar
4. On the wrist

19. Which of the following is a short-term (deterministic) effect of high-dose radiation exposure?

1. Cancer   2. Genetic mutations   3. Cataracts   4. Leukaemia

20. What is the maximum annual radiation dose limit for the general public (in mSv) according to national guidelines??

1. 1 **2**. 5 **3**. 10 **4**. 20

21. What is the permissible radiation dose limit to the foetus during pregnancy (in mSv)?

1. 1 **2**. 2 **3**. 5 **4**. 10

22. Who is the '10-day rule' in radiation protection most relevant to?

1. all female patients **2**. pregnant patients only

3. women of child-bearing age **4**. female radiation workers

Section C: Radiation safety practice

23. How often do you wear a radiation monitoring badge?

1. Always **2**. Sometimes **3**. Rarely **4**. Never

24. How frequently do you review your radiation dose records?

1. Monthly **2.** Quarterly **3.** Annually **4**. Never

25. How often do you wear a lead apron when exposed to radiation during procedures?

1. Always **2**. Most of the time **3**. Sometimes **4**. Never

26. What safety action is taken when performing radiological procedures on a potentially pregnant patient?

1. Refuse to perform the examination

2. Perform without additional precautions

3. Use additional shielding and document justification

4. Refer to another facility

27. How often do you attend radiation safety training?

1. Every 6 months **2**. Annually **3**. Every 2 years

4. Only when an opportunity arises

28. What action do you take if radiation exposure exceeds dose limits?

1. Continue working normally **2**. Report to the Radiation safety officer

3. Stop working immediately **4**. No action

29. What is your practice for paediatric radiation protection?

1. Use adult protocols

2. Use paediatric-specific protocols with reduced exposure

3. No special considerations needed

4. Refer all paediatric cases

30. How often is patient exposure information (e.g. dose, time, justification) recorded in medical or radiation logs?

1. Always **2.** Only for high-dose procedures **3**. When requested **4**. Never

31. How often is gonad shielding used when exposing patients to radiation?

1. Always **2**. Only for patients of reproductive age **3**. When requested 4. Never

32. How do you store radiation protection equipment?

1. In a designated area with proper hanging

2. Leave on equipment after use

3. Store wherever convenient

4. No specific storage protocol

END OF QUESTIONAIRE

APPENDIX 2

Dissertation supervision acceptance letter

The Chairperson
Department of Environmental Science
Bindura University of Science Education

8th November, 2024

RE: MSc. DISSERTATION SUPERVISION ACCEPTANCE LETTER FOR F. MAGADZIRE (B241657A)

The above matter refers.

I wish to inform you that I am accepting *Fletcher Magadzire* as my student to guide his dissertation research leading to attainment of an MSc. MOHSEM degree with Bindura University Science and Education. I will supervise him throughout the research process.

Proposed title (can be amended slightly):

Radiation safety protection knowledge and practice among Zimbabwean hospital health workers working in radiation environment

Sincerely,

A. Kanda (PhD PH, MSc WREM, BSc Hons Chem, PostGrad Dip WSS, Dip Sci. Ed)

APPENDIX 3

Radiation safety protection knowledge and practice observation checklist

Name of hospital……………………………… Province……………………..

Department…………………………………… Observer………………………

Date of observation……………………………

Parameter	Yes	No	Partially	Comments
1. Staff use personal protective gear (e.g., lead aprons, thyroid shields) as appropriate				
2. Radiation badges/dosimeters are worn visibly and positioned correctly				
3. Radiation warning signs and symbols are posted at relevant points (e.g., doorways)?				
4. Safe distancing is practiced during radiation exposure (time, distance, shielding)				
5. Mobile or fixed protective barriers are used correctly during procedures				
6. Radiation-emitting equipment has valid inspection tags or service stickers				
7. Radiation dose/exposure logs are updated and accessible				
8. Emergency procedures (e.g., for overexposure) are posted and clearly visible				
9. Staff demonstrate knowledge of minimizing exposure time				
10. Radiation safety training materials are visibly available (manuals, posters, SOPs)				
11. Department holds regular safety briefings or awareness sessions				
12. A Radiation Safety Officer (RSO) or delegated safety lead is present or identifiable				
13. Patients (including children and pregnant women) are shielded appropriately				
14. Staff inquire about pregnancy status when appropriate				
15. Gonad and thyroid shields are available and used correctly when needed				

Key:

Yes*- indicates full compliance*

No*- indicates non-compliance*

Partially*- means the item was observed inconsistently or inadequate*

APPENDIX 4

Radiation safety protection knowledge and practice KII guide

Institution…………………………………………

Date…………………………………………………

Venue………………………………………………

Gender………………………………………………

Position………………………………………………

Work experience (years)………………………………

Highest educational qualification………………………

Researcher introductions (time): 2 minutes…………………..

Main questions (time): 15 minutes……………………………

1. Based on your experience and role, what are the main challenges that are faced by personnel working in radiation-emitting environments in Zimbabwe?

Follow up 1: How do you think these challenges may be addressed?

Follow up 2: Which groups of staff are most affected (e.g., nurses, doctors, radiographers)?

2. What is the focus of current radiation safety training in Zimbabwe?

Follow up 1: What topics and skills do you think should be added to the curriculum?

Follow up 2: Who typically receives this training, and how often?

3.What role does hospital management or leadership play in promoting radiation safety?

Folow up 1: How can leadership improve safety culture?

APPENDIX 5

Radiation Protection Authority of Zimbabwe

Head Office:
18 Armadale Road
Borrowdale
Harare,
Zimbabwe
Tel: +263 (242) 334953,
335792, 304982,
335627
E-mail: officialmail@rpaz.co.zw
Website: www.rpaz.co.zw

Regional (South) Office:
SF02 ZITF Grounds
Hillside
P.O Box 103
Bulawayo
Tel: +263 29 60831/2

RPAD/1/95/332

May 06, 2025

The Executive Director
Research Council of Zimbabwe (RCZ)

APPROVAL FOR MR. FLETCHER MAGADZIRE TO CONDUCT RESEARCH FOR MSC DISSERTATION

Dear Sir/Madam,

The Radiation Protection Authority of Zimbabwe (RPAZ) is pleased to grant approval for Mr. Fletcher Magadzire to undertake academic research in partial fulfilment of the requirements for his Master of Science in Occupational Health, Safety and Environmental Management (MOHSEM) degree with Bindura University of Science Education.

The proposed dissertation topic is: "Radiation Safety Protection Knowledge and Practice Among Zimbabwean Hospital Health Workers Working in Radiation Environments" We acknowledge the importance and relevance of this study, particularly in advancing national understanding and practice of radiation safety in the healthcare sector. The Authority supports such initiatives that align with its mandate to promote radiation protection and safety in Zimbabwe.

This approval is granted on the condition that:

- The study complies with ethical research standards.
- Confidentiality and data protection protocols are maintained.
- A final copy of the dissertation is submitted to RPAZ for reference upon completion.

Should further institutionally support or clarification be required, please do not hesitate to contact our office.

Thank you

CHIEF EXECUTIVE OFFICER
RADIATION PROTECTION
AUTHORITY OF ZIMBABWE
06 MAY 2025

I. Mayida

ACTING CHIEF EXECUTIVE OFFICER

APPENDIX 6

DEPARTMENT OF ENVIRONMENTA SCIENCE

Bindura University of Science Education

Bag 1020 **BINDURA, Zimbabwe**
Tel: 263 - 71 – 6505
Cell :0778371588
Email : tnyamugure@buse.ac.zw

BINDURA UNIVERSITY OF SCIENCE EDUCATION

9th April 2025

To Whom It May Concern,

RE: Departmental Approval to Conduct Research

This letter serves to confirm that **Mr. Fletcher Magadzire**, a registered Master's degree student (Reg B241657A) in the Department of Environmental Science at Bindura University of Science Education, has been granted departmental approval to conduct academic research as part of his postgraduate studies.

His research project is titled:
"Radiation Safety Protection Knowledge and Practice Among Hospital Health Workers Working in Radiation-Emitting Environments."

The study will involve health institutions across provinces in Zimbabwe and is expected to contribute valuable insights to inform radiation safety policy and improve occupational health practices in medical settings.

The Department supports this study and kindly requests your cooperation in allowing the student to collect data at your institution, subject to your internal approvals and ethical standards. All information collected will be treated with strict confidentiality and used solely for academic purposes.

Please feel free to contact the undersigned for any clarifications.

Thank you for your assistance.

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
Bindura University Of Science Education
P. BAG 1020, BINDURA
ZIMBABWE
OFFICIAL

Yours faithfully

Mr T. Nyamugure **(Chairman- Environmental Science)**

APPENDIX 7

Reliability statistics

Statistic	**Value**
Cronbach's alpha	0.85
No. of items	30
Standardized Cronbach's alpha	0.84
Variance of total score	12.34
No. of respondents	6

Item	**Corrected item-total correlation**	**Cronbach's Alpha if item is deleted**
Item 1	0.65	0.82
Item 2	0.70	0.81
Item 3	0.60	0.83
……..	………	……..
Item 30	0.55	0.84

Appendix 8

PARKVIEW HOSPITAL
MEZZANINE FLOOR
56 BAINES AVENUE
HARARE, ZIMBABWE
TEL: +263 8677008254, +263 8677008228, +263 242 701665
email: customercare@psmi.co.zw

PSMI
PREMIER SERVICE MEDICAL INVESTMENTS (Pvt) Ltd

Hospitals, Healthcare, Pharmaceuticals, Dental Clinics, Optometry, Clinical Laboratories, Rehabilitation, Ambulances, Renal, Radiology

22 May 2025

Attention: Mr. Fletcher Magadzire
MSc. Student – Occupational Safety Health and Environmental Management
Bindura University of Science Education
Bindura

Dear Mr Madzire

RE: REQUEST FOR PERMISSION TO CONDUCT A RESEARCH SURVEY AT PSMI

I refer to your letter dated 20th of May 2022 and the contents therein. I wish to advise you that your request to conduct a Research Survey within PSMI has been approved. You shall be allowed to access the PSMI Radiology Services for your research from Tuesday 27th of May 2025 to Friday 30th of May 2025.

For purposes of this research and any further enquiries, kindly contact Mr. G Njobela – Acting Head of Department for Radiology on *+263 77 322 3558.*

Regards,

Dr N M Mapesa
ACTING MANAGING DIRECTOR

Premier Service Medical Investments
MANAGING DIRECTOR
2025 -05- 22
APPROVED