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## **The Role of Nuclear Physics in Radiological Safety in Nigeria: A Review**

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### **Abstract**

This review paper delves into the critical role of nuclear physics in advancing radiological safety in Nigeria, where the use of radiation in medical, industrial, and potential energy sectors is on the rise. The paper provides a detailed examination of how nuclear physics underpins the understanding, management, and mitigation of radiation exposure risks. It offers an in-depth analysis of the current state of radiological safety in Nigeria, focusing on the regulatory framework, specific challenges, and opportunities for enhancement. Key contributions of nuclear physics highlighted include advancements in radiation detection, dosimetry, shielding, and the safe handling of radioactive materials.

The study emphasizes the importance of integrating nuclear physics principles into regulatory practices and public health strategies. It identifies gaps in current practices and recommends actionable steps for improving safety standards, including the need for targeted research, education, and international collaboration. The findings underscore the necessity of a robust, well-coordinated approach to radiological safety, which is vital for protecting public health and the environment. The paper concludes with recommendations for government-led public engagement programs to increase awareness of radiological safety and the pivotal role of nuclear physics in safeguarding against radiation risks.

### **Keywords**

Nuclear Physics; Radiological Safety; Radiation Detection; Dosimetry' Regulatory Framework

### **1. Introduction**

Nuclear physics is a branch of physics that deals with the study of atomic nuclei, their components, and interactions. It explores the fundamental forces that hold the nucleus together, the processes by which nuclei are formed, and how they decay. Key areas of nuclear physics include the study of nuclear reactions, radioactive decay, and the behavior of particles such as protons, neutrons, and electrons (Gambo & Shehu, 2024).

Nuclear physics has profound implications in various fields, including energy production, medicine, industry, and environmental science. Understanding the principles of nuclear physics

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is essential for harnessing nuclear energy, developing medical imaging techniques, and ensuring the safe use of radioactive materials.

### **Importance in Understanding and Managing Radiological Safety**

Radiological safety refers to the measures and practices designed to protect people and the environment from the harmful effects of ionizing radiation, which is radiation that carries enough energy to remove tightly bound electrons from atoms, thus creating ions. Ionizing radiation can originate from natural sources (e.g., cosmic rays, radon gas) or artificial sources (e.g., X-rays, nuclear reactors, radioactive materials used in industry and medicine).

The importance of nuclear physics in radiological safety lies in its ability to provide a deep understanding of radiation sources, how radiation interacts with matter, and the potential health risks associated with exposure. Key aspects of radiological safety that are grounded in nuclear physics include: (Noska et al., 2022).

Nuclear physics is essential for developing accurate radiation detection instruments, understanding radiation effects on biological tissues, managing radioactive decay and half-life, designing effective radiation shielding, and ensuring the safe handling and disposal of radioactive materials (Sidi et al., 2022)

### **Relevance to Public Health and Environmental Protection**

**Public Health:** Radiological safety is critical for protecting public health, especially as radiation is increasingly used in medicine (e.g., X-rays, CT scans, cancer treatment). While these technologies have significant benefits, they also pose risks if not managed properly. For instance, excessive exposure to medical radiation can increase the risk of cancer. Nuclear physics helps healthcare professionals understand these risks and implement protocols to minimize patient and worker exposure, ensuring that the benefits outweigh the potential harms (van Dijk et al., 2024).

**Environmental Protection:** Radiological safety is also essential for safeguarding the environment. Accidental releases of radioactive materials, such as those from nuclear power plant incidents or improper disposal of radioactive waste, can contaminate air, water, and soil, leading to long-term environmental damage. Understanding the behavior of radioactive substances in the environment, including how they disperse and decay, is crucial for developing effective response strategies and remediation efforts (Uwaga & Emmanuel, 2024). Figure 1 shows the radiation caution sign and Figure 2 illustrates the radiation shielding device.

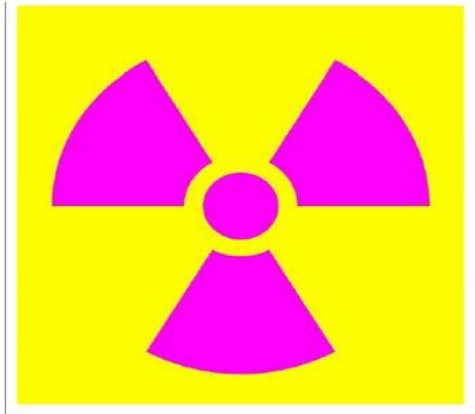


Figure1: Shows Radiation caution  
& Kumar, 2024)



Figure 2: Radiation shielding device (Chougule

### **The Role of Nuclear Physics in Radiological Safety in the Nigerian Context**

Nuclear physics plays a crucial role in ensuring radiological safety in Nigeria, especially as the country advances in key sectors such as medicine, industry, and energy. In the medical field, the increasing use of radiation technologies like diagnostic imaging and radiotherapy is essential for diagnosing and treating serious conditions, including cancer. As more radiotherapy facilities are established to meet growing healthcare needs, ensuring radiological safety becomes even more vital.

Similarly, in the industrial sector, radiation is widely used for non-destructive testing in construction and manufacturing, as well as in agriculture for food preservation and pest control. These applications highlight the importance of nuclear physics in maintaining safety standards and protecting public health (Chougule & Kumar, 2024).

Looking to the future, Nigeria's exploration of nuclear energy as a means to meet its expanding electricity demand further underscores the importance of nuclear physics. The government's interest in developing nuclear power plants, supported by international collaborations, presents both opportunities and challenges in ensuring that safety protocols are rigorously applied (Fathy et al., 2024). Figure 3 shows the radiation monitoring equipment.

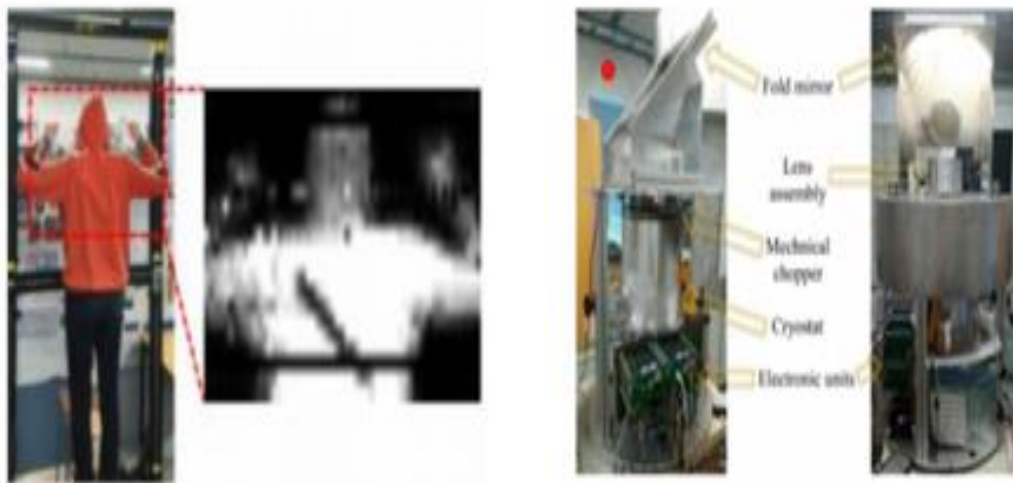


Figure 3: Illustrates the radiation monitoring equipment (Research Council of Finland, 2023).

### **Challenges and Opportunities in Radiological Safety**

Resource limitations and public awareness are two critical factors that impact radiological safety in Nigeria. Many facilities struggle with inadequate equipment and a lack of trained personnel, which can hinder the effective implementation of safety measures. However, a strong understanding of nuclear physics can help maximize the use of available resources, enabling the adoption of cost-effective strategies to maintain safety standards. Additionally, raising public awareness about the benefits and risks of radiation is essential. Educating the public on nuclear physics and radiological safety can reduce misunderstandings and fears, leading to greater acceptance of beneficial technologies and improved overall safety (Fathy et al., 2024).

### **Criticality of Nuclear Physics**

These may include the understanding nuclear physics, proper training of industrial, radiation safety, acceptance and engagement of international collaborators, these are the factors that need to be critically understand and adopt best practices from countries with advanced nuclear programs (Wirajaya et al., 2024).

### **Purpose of the Review**

The purpose of this review is to explore and evaluate the critical contributions of nuclear physics to radiological safety in Nigeria. The review will also assess the effectiveness of current radiological safety

practices, identify challenges and opportunities for improvement, and propose recommendations to enhance the overall safety and regulatory framework in Nigeria.

### **Objectives of the Review**

1. To Explore the Fundamental Principles of Nuclear Physics
2. To Evaluate the Role of Nuclear Physics in Enhancing Radiological Safety in Nigeria:
3. To Review the Application of Nuclear Physics in Medical and Industrial Settings in Nigeria
4. To Examine the Regulatory Framework for Radiological Safety in Nigeria:
5. To Identify the Challenges and Opportunities in Implementing Radiological Safety Measures:

### **Fundamentals of Nuclear Physics and Radiological Safety**

Understanding the basics of nuclear physics is essential for comprehending the principles of radiological safety. One key concept is radioactivity, which refers to the spontaneous release of particles or electromagnetic waves from an unstable atomic nucleus as it seeks to reach a more stable energy state. This fundamental process underpins many aspects of radiological safety, as managing and controlling radioactive emissions is crucial for protecting people and the environment (Alkhayal et al., 2023).

### **Types of Radioactive Decay**

1. Radioactive decay can happen through various processes, each resulting in the emission of different types of radiation.

**Alpha Radiation ( $\alpha$ ):** Alpha particles consist of two protons and two neutrons, essentially making them helium nuclei. They are relatively heavy and carry a +2 charge.

**Penetration Power:** Due to their mass and charge, alpha particles have low penetration power and can be stopped by a sheet of paper or human skin. However, they can be dangerous if ingested or inhaled, as they can cause significant damage to internal tissues.

**Beta Radiation ( $\beta$ ):** Beta particles are high-energy, high-speed electrons ( $\beta^-$ ) or positrons ( $\beta^+$ ) emitted by certain types of radioactive nuclei. Beta particles are lighter than alpha particles and have greater penetration power, capable of passing through paper but generally stopped by a few millimeters of aluminum or plastic (Simon et al., 2022).

**Gamma Radiation ( $\gamma$ ):** Gamma rays are electromagnetic waves, similar to X-rays but with higher energy. They are emitted from the nucleus of a radioactive atom following alpha or beta decay, as the

nucleus releases excess energy to reach a stable state. It has very high penetration power and can pass through the human body and several centimeters of lead. This makes them particularly dangerous, requiring dense materials for effective shielding.

2. Nuclear Reactions: Nuclear reaction occurs when the nucleus of an atom is altered through bombardment with subatomic particles, such as neutrons or protons. This can result in the formation of new elements, the release of energy, and the emission of radiation. Examples Fission\*\*: The process by which a heavy nucleus (e.g., uranium-235) splits into two lighter nuclei upon absorbing a neutron, releasing a significant amount of energy and additional neutrons. This reaction is the basis for nuclear power and atomic bombs. (Neils, 2022).

Fusion: The process where two light nuclei (e.g., hydrogen isotopes) combine to form a heavier nucleus (e.g., helium), releasing energy. Fusion powers the sun and holds potential for future energy production.

### Decay Processes

Alpha Decay In alpha decay, an unstable nucleus emits an alpha particle, reducing its atomic number by 2 and its mass number by 4. For example, uranium-238 decays to thorium-234 through alpha emission,  ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\text{He}$  (1)

In beta decay, a neutron in an unstable nucleus is transformed into a proton and an electron (beta particle), which is then emitted. This increases the atomic number by 1 without changing the mass number. An example is the decay of carbon-14 to nitrogen-14.



Here  $\bar{\nu}_e$  represents the antineutrino, a particle also emitted during the process (Kannan *et al.*, 2020).

This decay chain was illustrated in Figure 4, and also the Table of nuclear decay chain shows the summary of decay chain.

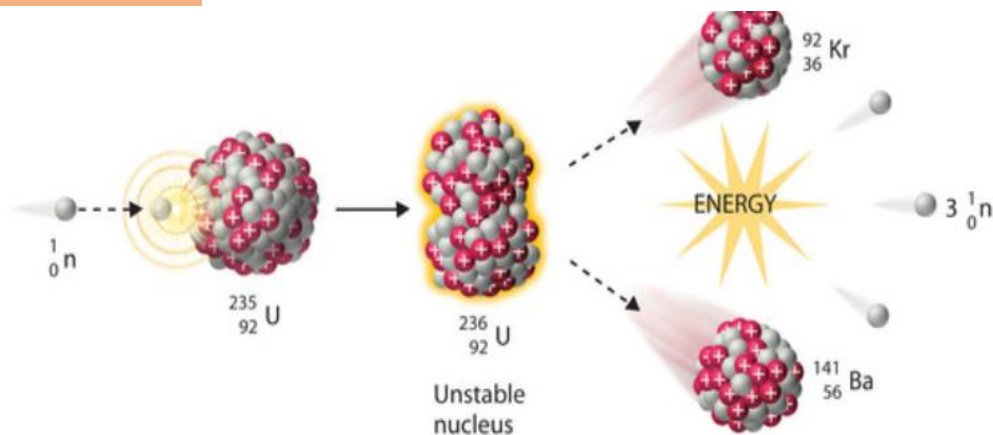


Figure 4: Uranium Decay chain (sources: Neils, 2022).

Table of Nuclear Decay chain and their symbol

Identity	Symbol	Charge	Mass (amu)
Helium nucleus	${}^2_4\alpha$	+2	4.001506
Electron	${}_{-1}^0\beta$ or $\beta^-$	-1	0.000549
Photon	${}^0_0\gamma$	—	—
Neutron	${}^0_0n$	0	1.008665
Proton	${}^0_0p$	+1	1.007276
Positron	${}_{+1}^0\beta$ or $\beta^+$	+1	0.000549

Source: (Neils, 2022).

### Radiological Safety Principles

Radiological safety principles are essential guidelines and practices designed to protect individuals, workers, and the environment from the harmful effects of ionizing radiation. These principles are grounded in the science of nuclear physics and are critical for ensuring the safe use of radiation in various applications. Below is an explanation of the key principles of radiological safety (Ghanbari *et al.*, 2024).

### Dosimetry (dose limits)

Dose limits refer to the maximum amount of radiation exposure that is considered acceptable for individuals, particularly for occupational exposure (e.g., workers in medical, industrial, or nuclear fields) and the general public. These limits are set to minimize the risk of harmful effects, such as cancer, while allowing for the beneficial use of radiation.

Units: Radiation dose is measured in sieverts (Sv), which accounts for both the energy absorbed by tissues and the biological effect of the type of radiation (UNSCEAR, 2021).

### **Application:**

Occupational Exposure: Workers who are regularly exposed to radiation are subject to stricter dose limits, typically not exceeding 20 millisieverts (mSv) per year, averaged over five years, with no more than 50 mSv in any single year (UNSCEAR, 2021).

Public Exposure: For the general public, dose limits are much lower, usually set at 1 mSv per year, to account for the more sensitive nature of the general population.

Importance: Understanding nuclear physics is essential for calculating and monitoring radiation doses accurately. This involves knowing how different types of radiation interact with matter, the potential biological effects, and the factors that influence dose distribution within the body.

### **Shielding**

Shielding refers to the use of materials to absorb or block radiation, reducing the exposure to people and the environment. The effectiveness of shielding depends on the type of radiation and the material used (UNSCEAR, 2021).

### **Types of Shielding**

Alpha Radiation: Since alpha particles have low penetration power, they can be stopped by simple barriers such as paper or skin.

Beta Radiation: Beta particles require denser materials like plastic, glass, or aluminum to be effectively shielded (UNSCEAR, 2021).

Gamma Radiation: Due to their high penetration power, gamma rays require heavy and dense materials, such as lead or concrete, for effective shielding.

Application: Shielding is a critical component in the design of facilities where radiation is used or stored, such as medical imaging rooms, nuclear power plants, and radioactive waste storage sites.



Importance: Knowledge of nuclear physics allows for the accurate calculation of the necessary thickness and type of shielding material required to reduce radiation to safe levels, based on the energy and type of radiation involved (UNSCEAR, 2021).

### **Monitoring**

Monitoring involves the continuous or periodic measurement of radiation levels in the environment, workplaces, and on individuals to ensure that radiation doses remain within safe limits (UNSCEAR, 2021).

### **Types of Monitoring**

Effective radiological safety relies on several types of monitoring:

- **Personal Dosimeters:** These are devices worn by workers to track their accumulated radiation dose over time. They help ensure that individual exposure remains within safe limits.
- **Environmental Monitoring:** This involves using detectors to measure radiation levels in the environment, making sure they do not exceed established safety thresholds (Esan et al., 2022).
- **Area Monitoring:** In workplaces where radiation is used, monitoring devices are strategically placed to measure radiation levels and confirm they stay within safe boundaries (Liu et al., 2022).

### **Application and Importance of Monitoring**

Monitoring is crucial for identifying potential exposure risks, ensuring adherence to dose limits, and taking corrective actions when needed. A solid understanding of nuclear physics is essential for accurately interpreting monitoring data. This knowledge enables one to comprehend the behavior of different types of radiation and respond appropriately to any detected levels, ensuring effective radiological safety (Gideon *et al.*, 2024).

### **Radiation Protection Standards**

Radiation protection standards are guidelines and regulations established by national and international organizations (e.g., International Commission on Radiological Protection, ICRP) to ensure safe practices in the use of radiation.

Application: These standards apply across various sectors, including healthcare, industry, research, and nuclear energy. Compliance with these standards is mandatory and enforced by regulatory bodies to protect workers, the public, and the environment.

Importance: Implementing radiation protection standards effectively requires a deep understanding of nuclear physics, as it provides the basis for setting dose limits, designing shielding, and developing monitoring protocols (Liu et al., 2022).

### **Importance of Understanding Nuclear Physics for Implementing Radiological Safety Measures**

Understanding nuclear physics is fundamental to the effective implementation of radiological safety measures for several reasons:

1. **Accurate Risk Assessment:** Knowledge of nuclear physics allows professionals to assess the risks associated with different types of radiation and their interactions with matter, enabling the development of appropriate safety measures.
2. **Effective Shielding Design:** Understanding the properties of various types of radiation helps in designing effective shielding to protect against exposure. This involves selecting the right materials and calculating their required thickness.
3. **Precise Monitoring and Measurement:** Nuclear physics provides the foundation for the development and use of radiation detectors and dosimeters, which are essential for monitoring radiation levels and ensuring they remain within safe limits.
4. **Informed Decision-Making:** Professionals equipped with nuclear physics knowledge can make informed decisions about the use of radiation in various applications, balancing the benefits with the potential risks and ensuring compliance with safety standards.
5. **Public and Worker Education:** A thorough understanding of nuclear physics is essential for educating workers and the public about radiation risks and safety practices, which is crucial for fostering a culture of safety in environments where radiation is present.

### **Challenges and Opportunities in Radiological Safety in Nigeria**

- i. **Inadequate infrastructure** poses a major challenge to radiological safety in Nigeria, as many healthcare facilities, industrial sites, and research institutions lack the necessary equipment to monitor and manage radiation exposure effectively. This shortfall increases the risk of overexposure for workers, patients, and the public, while the absence of advanced monitoring systems hampers prompt response to potential radiation incidents (Yusuf *et al.*, 2020).
- ii. **Lack of Skilled Personnel:** There is a shortage of trained professionals in nuclear physics, radiological safety, and radiation protection in Nigeria. This includes a limited number of qualified radiologists, medical physicists, radiation safety officers, and regulatory inspectors. **Impact:** The lack of skilled personnel can result in improper handling of

radioactive materials, inadequate implementation of safety protocols, and insufficient regulatory oversight. This gap in expertise hinders the ability to maintain high standards of radiological safety across various sectors (Yusuf *et al.*, 2020).

- iii. **Limited Public Awareness:** Public awareness of the risks and benefits of radiation is generally low in Nigeria. Many people are unaware of the potential dangers of radiation exposure, particularly from medical procedures or industrial activities, and may not understand the importance of following safety guidelines. Impact: Limited public awareness can lead to resistance against beneficial technologies, such as nuclear medicine, due to fear and misinformation. It can also result in non-compliance with safety measures, increasing the risk of radiation-related incidents.
- iv. **Regulatory Challenges:** While Nigeria has established regulatory bodies, such as the Nigerian Nuclear Regulatory Authority (NNRA), to oversee the use of radiation, these agencies often face challenges in enforcing regulations due to limited resources, lack of coordination, and bureaucratic delays. Impact: Weak regulatory oversight can lead to inconsistent application of safety standards, allowing unsafe practices to persist. This can jeopardize both public health and environmental safety.
- v. **Resource Constraints:** Many radiological safety initiatives require significant financial investment, which can be challenging to secure in a resource-constrained environment. This includes funding for advanced equipment, training programs, and research. Impact: The lack of resources can result in outdated or inadequate safety measures, increasing the risk of accidents and long-term health effects related to radiation exposure.

### **Opportunities for Improvement**

**Investing in Research and Development:** Opportunity: Increasing investment in research related to nuclear physics and radiological safety can drive innovations that improve safety protocols and technologies. By fostering research, Nigeria can develop new methods for radiation detection, more effective shielding materials, and improved safety procedures.

#### **Action Steps**

- i. Support collaboration between universities, research institutions, and industry to conduct applied research in nuclear physics.
- ii. Establish dedicated research funds and grants to encourage studies focused on radiological safety.

### **Improving Regulatory Oversight**

Strengthening regulatory oversight by enhancing training programs for inspectors, implementing stricter licensing and certification processes, and increasing funding and resources for agencies like the NNRA is essential to improving radiological safety and ensuring compliance with international standards (Aruah et al., 2020).

### **Enhancing Public and Professional Education**

Enhancing public and professional education on radiological safety is crucial; by developing accessible educational materials, introducing specialized training programs, and promoting media campaigns, we can empower both the general public and professionals to understand radiation risks and practices, ensuring its safe and beneficial use.

### **Building Infrastructure and Capacity**

Investing in infrastructure for radiological safety; such as advanced monitoring equipment, safe waste disposal facilities, and robust emergency response systems can significantly reduce radiation exposure risks, supported by securing funding, establishing centralized waste management, and developing comprehensive response plans with regular training and drills.

### **Fostering International Collaboration**

Fostering international collaboration by engaging in training programs, partnering with global organizations like the IAEA, and seeking technical assistance can bridge gaps in Nigeria's radiological safety expertise and infrastructure, while addressing existing study gaps such as the lack of focus on Nigeria's specific conditions, integration of nuclear physics into national policies, and the need for improved public awareness and application of advanced nuclear technologies (Islam et al., 2021).

## **2. Methodology**

This review systematically examines the role of Nuclear Physics in radiological safety in Nigeria, following a multi-stage process, research design, literature search, selection criteria, data analysis, and synthesis. A systematic review approach was employed to explore the contributions of Nuclear Physics to radiological safety, with a focus on challenges and opportunities specific to Nigeria. However, a comprehensive search was conducted in databases such as PubMed, Scopus, IEEE Xplore, and Google Scholar. Studies published between 2020-2024, relevant to Nuclear Physics and radiological safety in Nigeria, were included.

Moreover, the results were compared with global best practices, offering insights into how Nuclear Physics can improve radiological safety in Nigeria. The discussion underscores the implications for policymakers, researchers, and practitioners.

### 3. Literature Review

Akinlade et al., (2023) conducted research on assessment of can risk associated with it and the results obtained was exceeded the world average limit.

Yusuf *et al.*, (2022) Assessment of the Knowledge and Attitude to Radiation Safety Standards of the Radiological Staff in Damaturu, Yobe State, Nigeria Radiation Physics View project Environmental Assessment View project Assessment of the Knowledge and Attitude to Radiation Safety Standards of the Radiological Staff in Damaturu, Yobe State, Nigeria.

Olarinoye *et al.*, (2023) conducted research on the indoor gamma radiation on building materials and the results found exceed the limit of the world average recommended.

radiobiology, and radiation physics.

Sopoh *et al.*, (2022) his study was evaluated the level of compliance with standard radiation protection protocols in medical imaging units within the Atlantique and Littoral departments of Benin. This due to inadequate adherence to standard radiation protection procedures poses risks to the safety and health of the population and medical staff.

Van *et al.*, (2024) Modeling Fallout from Nuclear Weapon Detonations: Efficient Activity and Dose Calculation of Radionuclides and Their Progeny

Olowookere et al., (2022) Effective Doses and Excess Lifetime Cancer Risks from Absorbed Dose Rates Measured in Facilities of Two Tertiary Institutions in Nigeria

Abubakar *etal.*, (2021) Determination Of Radon-222 Concentration In Some Selected Drinking Water Sources At Geidam Town, Geidam Local Government Area.

### Challenges in Infrastructure and Impact on Radiological Safety in Nigeria

Nigeria faces significant infrastructure challenges that directly impact the effectiveness of radiological safety measures. These challenges include the limited availability of advanced nuclear facilities, outdated equipment, and the absence of specialized laboratories, all of which are crucial for ensuring comprehensive radiation protection across various sectors as highlighted below (Modarai *et al.*, 2023).

#### i. Limited Number of Nuclear Facilities

One of the primary challenges in Nigeria is the scarcity of nuclear facilities. The country has only a few operational nuclear reactors and radiotherapy centers, which are often concentrated in major

urban areas. This uneven distribution leaves vast rural regions without adequate access to essential radiological safety services. The limited number of facilities restricts the ability to conduct widespread radiation monitoring and safety enforcement, particularly in industries such as mining, oil and gas, and healthcare, where radiation exposure is prevalent sectors (Modarai *et al.*, 2023).

#### ii. Outdated Equipment and Maintenance Issues

Many of Nigeria's nuclear facilities are equipped with outdated and aging equipment. Devices like gamma spectrometers, neutron detectors, and radiation monitoring systems often lack the precision and reliability needed to meet modern safety standards. Frequent breakdowns and difficulties in obtaining replacement parts further exacerbate these issues, leading to prolonged downtimes and disruptions in safety operations.

The inadequacy of equipment not only affects routine monitoring but also compromises the country's ability to respond effectively to radiation emergencies. In situations where rapid and accurate radiation assessment is critical, outdated equipment poses a significant risk to both public health and environmental safety sectors (Modarai *et al.*, 2023).

#### iii. Absence of Specialized Laboratories

The absence of well-equipped, specialized laboratories is another major infrastructure challenge in Nigeria. Such laboratories are essential for conducting detailed radiological analyses, including the testing of radioactive materials and environmental samples. However, the limited number of these laboratories in Nigeria often means that many critical analyses must be outsourced to facilities abroad, leading to delays, higher costs, and potential compromises in data quality.

This lack of local laboratory capacity also impedes the development of expertise in radiological safety. Without the infrastructure to support ongoing research and analysis, Nigeria struggles to build a self-sufficient system capable of managing radiation risks independently. Additionally, the absence of specialized laboratories hampers the implementation of safety protocols in industries that regularly handle radioactive materials, increasing the likelihood of undetected radiation hazards.

### **Impact on Radiological Safety**

The infrastructure challenges in Nigeria significantly weaken the country's radiological safety framework. The scarcity of facilities, outdated equipment, and the lack of specialized laboratories create critical gaps in the ability to monitor, assess, and respond to radiation risks. These deficiencies not only endanger workers in radiation-prone industries but also pose broader risks to public health and environmental safety.

Addressing these infrastructure challenges is crucial for enhancing radiological safety in Nigeria. Investments in modernizing nuclear facilities, upgrading equipment, and establishing specialized laboratories are essential steps toward building a robust and effective radiological safety infrastructure. By overcoming these challenges, Nigeria can better protect its population and environment from the dangers associated with radiation exposure (Trauernicht *et al.*, 2022).

#### 4. Results Discussion

This review was set to highlight the Fundamental Principles and Applications of Nuclear Physics in Radiological Safety, understanding these principles of nuclear physics is essential for effective application. Including the structure of atomic nuclei, nuclear interactions, and radiation types (alpha, beta, gamma), provide the foundation for various practical applications in energy production, medical diagnostics, and radiological safety. However, to evaluate the Role of Nuclear Physics in Enhancing Radiological Safety in Nigeria, nuclear physics plays a critical role in ensuring radiological safety across various sectors in Nigeria, including healthcare, industry, and environmental monitoring. By applying nuclear principles, it's possible to assess the effectiveness of radiation shielding techniques, the accuracy of dose measurements, and the implementation of safety protocols. Collaborating with academic institutions and research centers can further advance the understanding of radiation interactions and lead to the development of improved safety measures tailored to the Nigerian context.

##### **Reviewing the Application of Nuclear Physics in Medical and Industrial Settings in Nigeria**

Nuclear physics is extensively applied in Nigerian medical and industrial settings, particularly in medical imaging, cancer treatment, and non-destructive testing. A detailed review reveals that while these applications are beneficial, there are gaps in safety protocols and opportunities for further enhancing operational efficiency and safety. Surveys, case studies, and field observations indicate that while nuclear physics has improved these practices, there is still a need for better adherence to safety measures and training.

##### **Examining the Regulatory Framework for Radiological Safety in Nigeria**

The regulatory framework for radiological safety in Nigeria includes various laws, guidelines, and enforcement mechanisms. However, the effectiveness of these regulations in meeting international standards and ensuring safety varies. Engaging with regulatory bodies and reviewing policy documents shows that while there are strong regulations in place, their implementation is inconsistent. Recommendations for strengthening these regulations include updating laws to reflect current best practices and improving enforcement.

##### **Identifying Challenges and Opportunities in Implementing Radiological Safety Measures**

Key challenges in implementing radiological safety measures in Nigeria include inadequate

infrastructure, limited expertise, and insufficient public awareness. However, there are also significant opportunities for improvement, such as investing in training programs, enhancing safety equipment, and promoting research in nuclear physics. Addressing these challenges and leveraging these opportunities will require a coordinated effort from professionals, regulatory bodies, and educational institutions.

### **Statistical Analysis of Radiological Safety in Kano Metropolis, Nigeria**

In comparison to the theoretical discussion above, recent empirical data from a study conducted in the Kano metropolis provides valuable insights into the current state of radiological safety in Nigeria. This study, which surveyed radiographers in Federal Government Hospitals (FGHs), State Government Hospitals (SGHs), and Private Radio Diagnostic Centers (PRDCs), highlights both achievements and gaps in radiological safety as segmented through the following points:

#### **X-ray Room Design**

The study found that 66.7% of the surveyed radiological facilities had sufficient X-ray room designs, indicating that most facilities meet the necessary standards for physical setup. This aligns with the fundamental principles of nuclear physics, which emphasize the importance of proper infrastructure in ensuring radiological safety (Sidi *et al.*, 2022).

#### **Availability and Utilization of Personal Protective Devices**

Despite the adequate room design, the study revealed a significant shortfall in the availability of personal protective devices, with 46.9% of respondents reporting insufficient supplies. Moreover, even when available, 23.9% of respondents noted poor utilization of these devices, suggesting a disconnect between safety protocols and actual practice. This highlights the need for better training and enforcement of safety measures, as discussed in the context of nuclear physics applications (Sidi *et al.*, 2022).

#### **Registration and Records of Radiation Safety Measures**

Only 26% of the facilities maintained sufficient records of radiation safety measures, indicating a lack of systematic tracking that is crucial for ongoing safety management. This finding underscores the importance of a robust regulatory framework that ensures compliance and continuous monitoring, as previously discussed (Sidi *et al.*, 2022).

#### **Quality Assurance (QA) Committees and Support from Medical Physicists/Engineers**

While 47.5% of facilities had a QA committee and 51.5% had access to medical physicists or



engineers, the absence of these resources in a significant portion of facilities suggests potential oversight in maintaining consistent quality and safety practices. This gap points to the need for a stronger emphasis on nuclear physics education and the involvement of qualified professionals in radiological safety (Sidi *et al.*, 2022).

### **Presence of Radiation Safety Officers and Correlation with Staff Training**

Only 25.7% of facilities had radiation safety officers, which are crucial for overseeing radiation protection. Additionally, a weak negative correlation was found between the availability of lead aprons and gloves and the level of staff training, indicating that better training could lead to more consistent use of protective equipment. This correlation further supports the need for improved training and safety protocols in the implementation of nuclear physics principles (Sidi *et al.*, 2022).

### **Key finding**

To address the gaps highlighted in the review, the key findings emphasize the necessity of developing a comprehensive radiological safety framework, enhancing training for professionals, investing in advanced monitoring technologies, strengthening regulatory enforcement, and launching public awareness campaigns. Additionally, the review suggests exploring new research avenues to assess radiation exposure risks, evaluate effective shielding materials, and advance emergency response strategies, offering innovative solutions to improve Nigeria's radiological safety infrastructure.

### **Conclusion**

This review makes a significant contribution by identifying critical gaps in Nigeria's radiological safety, such as inadequate training and outdated monitoring technologies. It proposes practical solutions, including the development of a comprehensive safety framework, enhanced training programs, and investment in modern monitoring systems. The paper also emphasizes the importance of aligning national efforts with international standards and highlights the need for public awareness campaigns. Additionally, it fosters future research by suggesting studies on radiation exposure risks, shielding materials, and emergency response strategies. These contributions offer actionable steps to improve radiological safety in Nigeria.

### **Recommendations**

To enhance the integration of nuclear physics in radiological safety efforts, the following policy recommendations are proposed:

1. **Increased Funding for Research:** Allocate dedicated funding to support research in nuclear physics, focusing on innovative methods for radiation protection and the development of advanced shielding materials. This investment will foster technological advancements and

improve safety measures across various sectors.

2. Updates to Safety Regulations: Regularly review and update radiological safety regulations to incorporate the latest scientific findings in nuclear physics. This ensures that safety standards remain relevant and effective, particularly as new technologies and applications of radiation emerge.
3. Public Engagement Initiatives: Implement comprehensive public engagement programs to raise awareness about the importance of radiological safety and the role of nuclear physics. These initiatives should aim to educate the public, healthcare professionals, and industry workers about radiation risks and safety practices, promoting a culture of safety and compliance.
4. Strengthening Regulatory Oversight: Enhance the capacity of regulatory bodies to monitor and enforce compliance with radiological safety standards. This includes training regulators in nuclear physics principles and providing them with the necessary tools to assess and manage radiation risks effectively.
5. Collaboration and Partnerships: Encourage partnerships between government agencies, academic institutions, and the private sector to facilitate the exchange of knowledge and best practices in nuclear physics and radiological safety. Collaborative efforts can lead to more comprehensive safety frameworks and better protection for the public and the environment

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