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Narrative Review

Radiology Environmental Sustainability in Zimbabwe: A Policy Review, Benchmarking Analysis, and Recommendations for Future Action

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Abstract

Introduction: Improper regulation of radiology departments can lead to significant adverse environmental impacts, which in turn affect both the health workforce and the community they serve. This review aimed to provide an in-depth analysis of the relevant documents, policies, laws, and regulations regarding environmental sustainability in radiology practices in Zimbabwe.

Methods: A qualitative content analysis was performed on documents obtained through an electronic database search, along with a manual search in Google Scholar and relevant reference lists. The selected documents were evaluated using pre-defined eligibility criteria for inclusion. Data management was carried out using NVivo 13, and the collected data were analysed using the READ approach.

Results: Of the nine documents identified and analyzed, five key themes were created, including i. the legal framework for environmental sustainability ii. safety protocols and radiation protection iii. integration of climate change and sustainable practices in education, i.v. waste management considerations, and v. transitioning to modern technologies.

Conclusion: The review highlights that, despite the constitution's support for environmental rights, Zimbabwe lacks specific policies and regulations for environmental sustainability in radiology. To advance sustainable practices, it is imperative to establish a dedicated environmental policy and implement targeted legislation.

Implications for Practice: The study underscores the urgent need for the development and implementation of specific environmental sustainability policies and regulations in radiology departments in Zimbabwe to mitigate adverse environmental impacts and promote the health and safety of both the workforce and the communities they serve

Keywords: Radiology, Environmental Sustainability, Health Policy, Waste Management, Zimbabwe, Radiation Protection

Introduction

An environmentally sustainable health system improves health while reducing its impact on the environment, benefiting both current and future generations.[1,2] Radiology is a vital component of modern healthcare systems, playing a crucial role in the diagnosis and treatment of various medical conditions.[3] However, radiologic procedures can have environmental consequences, including generating hazardous waste, consuming a lot of energy, and posing potential exposure to ionizing radiation.[4] Radiology departments contribute 9% to healthcare carbon emissions, accounting for 4-10% of global greenhouse gas emissions.[5-7] When radiology departments are not effectively designed, equipped, or regulated, they can have severe environmental effects on both their personnel and the communities they serve.[8,9]

In recognition of these challenges, international organizations such as the Royal College of Radiologists (RCR), the Canadian Association of Radiologists (CAR), and the Society of Radiographers (SoR) have made commitments to mitigate the long-term environmental impacts of radiology practices.[9-11] Significant milestones like the 1972 Earth Summit, the 2015 Paris Agreement, and the Sustainable Development

Goals (SDG 13) have urged governments worldwide to adopt declarations for environmental protection.[12-14] Zimbabwe is among the 160 countries that have ratified these commitments,[15]but despite this commitment, the country faces obstacles in implementing sustainability initiatives, particularly in the field of radiology. The challenges include limited resources, inadequate infrastructure, lack of technical expertise, competing health priorities, limited research, weak policy frameworks, limited public engagement, and global inequities.[16-20]

Despite these hurdles, Zimbabwe has the potential to benefit from adopting and adapting international environmental sustainability guidelines in healthcare and radiology. Such initiatives could enhance healthcare resilience; improve diagnostic capabilities and access to international resources; increase training opportunities; the development of evidence-based health policies; and foster a valuable exchange of global knowledge.[8,21,22]

Given radiology's increasing environmental impact, there is an urgent need for a holistic approach to driving effective decision-making regarding investments and changes to protocols, policies, and laws.[23] While high-income countries have developed sustainability frameworks specifically for radiology, Zimbabwe's regulatory landscape in this area remains unexplored. The country faces unique challenges, including infrastructure gaps and competing healthcare priorities.[16,20] This review is the first to (1) systematically evaluate Zimbabwe's current policies on sustainability in radiology, (2) identify critical gaps compared to international benchmarks, and (3) propose a roadmap for policy reform.

By examining the current landscape of environmental regulations and practices in radiology, this review seeks to contribute to the ongoing efforts towards enhancing environmental conservation and sustainability in the healthcare sector in Zimbabwe. Additionally, there view seeks to highlight best practices and successful initiatives that promote environmental stewardship in radiology, both locally and globally. Based on these insights, the review will provide actionable recommendations to implement effective strategies for reducing the environmental impact of radiology practices.

Materials and Methods

Study Design

This documentary review employed a qualitative content analysis (QCA) to comprehensively gather and analyse relevant documents, policies, laws, and regulations that directly or indirectly influence environmental sustainability practices in Zimbabwean radiology departments. Qualitative content analysis is the analysis of the content of narrative data to identify prominent themes and patterns among the themes.[24] In this study, content analysis was chosen to effectively summarize information from all relevant national sources. This approach allowed for a comprehensive look at the regulatory frameworks impacting environmental sustainability in the field of radiology in Zimbabwe, enabling the identification of gaps and drawing of meaningful conclusions.[25]

Document Search Strategy

Documents were identified through a systematic search of academic databases, government websites, regulatory bodies, and professional organizations to identify relevant literature and official documents related to environmental sustainability in radiology. Keywords such as "radiography", "radiology', "medical imaging", "environmental sustainability," "climate change", "policies," "laws," "guidelines", "documents", "communications", "regulations", and "Zimbabwe" were used to ensure a thorough retrieval of relevant materials.The search strategy was reviewed and enhanced by an experienced librarian to ensure its relevance and effectiveness.Further searches were conducted using Google Scholar, and the reference lists of relevant papers were manually checked to find any other documents that fulfilled the requirements, guaranteeing comprehensiveness in document selection. Additionally, consultation with subject matter experts and key stakeholders was conducted to access valuable insights and grey literature.

Inclusion and Exclusion Criteria

The inclusion criteria for document selection focused on their relevance to environmental sustainability in radiology. They included available documents such as policies, laws, and regulations regarding radiology practices in Zimbabwe. Primary peer-reviewed research, unpublished studies related to the topic, literature reviews, opinion reports, and published guidelines that did not specifically address environmental sustainability in radiology were excluded. Additionally, redundant,

outdated, or repealed laws and policies that did not align with the study's objectives were also excluded.

Quality Appraisal

A quality appraisal was not performed since the collected documentsare not published journal articles (such as primary research). However, each document was thoroughly assessed for inclusion using the criteria specified above.

Data Analysis and Synthesis

Once the identified documents were collected, a systematic analysis was undertaken employing iterative reading of the documents to extract key themes relevant to environmental sustainability in radiology in Zimbabwe. These documents were then imported into the thematic coding software Nvivo 13.[26] The READ technique according to Daglish et al. was utilised to analyse the data.[27] Specifically, the following steps were followed:

1. Read: The process began with the reviewers familiarizing themselves with the facts through a first read-through of the identified documents. Notes were taken on the key themes, patterns, and any first impressions that stood out.
2. Extract: Relevant data points or segments from the dataset were selected that were critical to achieving the aim of this review which is on environmental sustainability in radiology. This included emphasizing noteworthy phrases, laws, policies, and guidelines.
3. Analyse: The extracted data was examined in detail to uncover connections, contrasts, and relationships. Patterns such as repeating themes or significant trends that emerged from the data were identified.
4. Distil findings: At this point in the review, the reviewers grouped and displayed the results in the form of tables to enhance clarity (Tables 1 and 2). Themes were created by identifying several strands within the materials that contributed to the overall subject. Common comments were evaluated and transformed into themes by combining the key messages identified in each analysed document.

Ethical Consideration

As this study involved the review of existing documents, ethical considerations primarily focused on proper citation and acknowledgment of the sources. All referenced materials were appropriately cited and credited to maintain academic integrity and intellectual property rights.

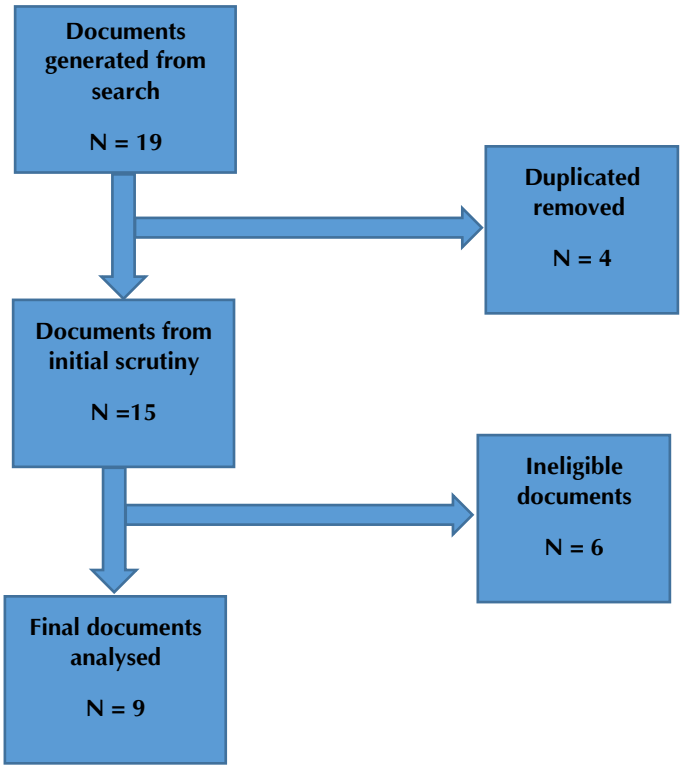

Figure 1. Flow Diagram Showing the Search Process.

Results

Search Results

The review included a total of nine (n = 9) documents that met the eligibility criteria. The article screening process is illustrated in Figure 1, and the extracted data can be found in Table 1 for reference. Out of the nine documents, only one (n = 1) was specifically related to radiology practices in Zimbabwe. The remaining eight (n = 8) documents required further interpretation to apply to the field of radiology.

Key Findings

Five broad themes were created from the key findings, including:

Theme 1: Legal Framework for Environmental Sustainability;

Theme 2: Safety Protocols and Radiation Protection;

Theme 3: Integration of Climate Change and Sustainable Practices in Education;

Theme 4: Waste Management Considerations;

Theme 5: Transitioning to Modern Technologies.

Table 1. Details of Key Findings and Documents Included in the Study

Number	Document	Aim of document	Guidelines from document
1.	Constitution of Zimbabwe[28]	To establish and define the fundamental principles, structure, and powers of a government, as well as to protect the rights and liberties of its citizens.	Section 73. Environmental rights 1. Every person has the right-- a. to an environment that is not harmful to their health or well-being; and b. to have the environment protected for the benefit of present and future generations, through reasonable legislative and other measures that-i. prevent pollution and ecological degradation; ii. promote conservation; and iii. secure ecologically sustainable development and use of natural resources while promoting economic and social development. 2. The State must take reasonable legislative and other measures, within the limits of the resources available to it, to achieve the progressive realisation of the rights set out in this section.
2.	Environmental Management Act: Chapter 20:27[29]	To provide for the sustainable management of natural resources and protection of the environment; the prevention of pollution and environmental degradation; the preparation of a National Environmental Plan and other plans for the management and protection of the environment.	Section 69 Standards for waste The Standards and Enforcement Committee shall recommend to the Board— (*a*) measures necessary to identify materials and processes that are dangerous to human health and the environment; (*b*) the issuance of guidelines and the prescribing of measures for the management of the materials and processes identified under paragraph (*a*); (*c*) the prescribing of standards for waste, their classification and analyses, and advise on standards of disposal methods and means for such waste; (*d*) the prescribing of measures for the handling, storage, transportation, segregation, and destruction of any waste.
3.	Radiation Protection Authority of Zimbabwe: Chapter 15:15[30]	To establish a Radiation Protection Authority and to confer powers and functions on such an Authority about protecting the public and workers from dangers resulting from the use or abuse of equipment, devices, or materials capable of producing ionizing radiation; and to provide for matters connected or incidental to the foregoing.	Section 15 Authorisations (1) No person shall administer ionizing radiation to another person unless the person administering it is in possession of a valid licence issued under this Act. (2) An application for the issuance or renewal of a licence under this Act shall be made in the prescribed form to the Board and shall be accompanied by the prescribed fee. (3) After receiving an application for a licence or renewal of a licence the Board may issue to the applicant the appropriate licence or renew the licence if it is satisfied that the applicant has proper personnel or appropriate facilities required to operate or safely install, use or store any irradiating device or radioactive materials. (4) A licence issued under this Act shall— (*a*) be in the prescribed form; and (*b*) authorise the licensee to own, purchase, acquire, import, export, possess, sell or deal in, install, use or dispose of, as may be required, irradiating devices, radioactive materials, or other sources of ionizing radiation; and (*c*) be valid for such a period as the Board may determine; and (*d*) contain such conditions as the Board may think necessary for the safe use or disposal of irradiating devices or radioactive materials. (5) The holder of a licence shall be responsible for ensuring that

			exposure to ionizing radiation results directly or indirectly from its operation, conditions of storage, transport, or disposal are kept as low as reasonably practicable and below the prescribed limits. (6) A licence issued under this Act may be— (*a*) amended by the Board if the amendment is necessary for public safety; or (*b*) suspended or revoked by the Board, if the holder fails to comply with the conditions contained in the licence. Section 18 Inspection and enforcement (1) The Chief Executive Officer or a radiation protection officer in his or her capacity as an inspector may— (*a*) enter, inspect, and examine any facility or premises, if there is reasonable cause to believe that an irradiation the device, radioactive material, or any other radiation source is stored, used, transported, or disposed of; (*b*) require the production of a licence authorising the use of any irradiating device, radioactive material
4.	Environmental Management (Control of Hazardous Substances) (General) Regulations, 2018[31]	To provide rules relative to the placing on the market of a hazardous substance, i.e. any substance, whether solid, liquid, or gaseous, or any organism that is injurious to human health or the environment (and including hazardous waste)	*General handling of hazardous substances* 4. (1) No person shall manufacture, store, sell, use, import, export, transport, or distribute any hazardous substance in a manner which— (a) access thereto would present a direct hazard to the public; or (b) present a hazard to the environment; or
5.	The National Environmental Policy and Strategies[32]	To alleviate poverty improve the quality of life of the people of Zimbabwe and avoid irreversible environmental damage.	Guiding Principle 42 'The people of Zimbabwe have a right to safe and affordable energy produced at minimum environmental cost.' Furthermore, NEP Strategic Directions call for the Government of Zimbabwe, in collaboration with stakeholders, to: • Promote economic policies that encourage efficient use of energy and discourage the over-exploitation of non-renewable energy sources • Promote, through the introduction of appropriate incentives, investment in and use of renewable sources of energy
6.	The National Climate Change Response Strategy[33]	To create a climate change resilient nation while its mission is to ensure sustainable development and a climate-proofed economy by engaging all stakeholders in recognizing the vulnerable nature of Zimbabwe's natural resources and society.	4.2.1. Climate Change Education and Training Strategies a) Enhance the teaching and learning of climate change at all levels of education (formal and informal). b) Provide relevant training on climate change issues for educators and practitioners working with communities 5.1.2. Climate Change Institutional Framework Strategies a) Institutionalize the climate change response governance framework at national, provincial, district, and ward levels (p.63)
7.	Public Health Act[34]	To promote the prevention, and limitation of infectious and contagious diseases inZimbabwe.	113 Health care waste management *(1)* The ministry shall prescribe for the management of healthcare waste in all healthcare delivery institutions_ (:2) Under subsection (1) the minister may make regulations on health care waste management concerning hazardous substances and articles of public health importance.
8.	Zimbabwe Climate Policy[35]	To climate-proof all the socio-economic sectors to reduce the country's vulnerability to climate change and develop a low-carbon pathway.	Goal 5 Seeks to increase public awareness of climate change and its effects. This awareness is meant to ensure that the public meaningfully participates in making decisions that affect them.
9.	Allied Health Practitioners Council Communication on darkroom processing of films[36]	Phasing out x-ray units with a dark room system	Allied Health Practitioners Council of Zimbabwe wishes to inform radiographers and sonographers that the use of X-ray Units with dark room systems is being phased out with effect from 1 March 2024, only computed and digital radiography systems will be acceptable.

The documents collectively contributed to five key themes. Specifically:

- Three documents (n = 3) focused on the legal framework for environmental sustainability.[28,29,33]
- Two documents (n = 2) addressed safety protocols and radiation protection.[30,31]
- Two documents (n = 1) discussed the integration of climate change and sustainable practices in education.[33,35]
- Three documents (n = 3) contributed to waste management considerations.[28,29,34]
- Lastly, two documents (n = 1) focused on transitioning to modern technologies.[35,36]

This distribution highlights the diverse areas of emphasis within the overall body of literature. Table 2 summarises these findings.

Table 2. Thematic Summary of Key Findings Obtained from the Included Documents

Reference Document	Theme 1: Legal Framework for Environmental Sustainability	Theme 2: Safety Protocols and Radiation Protection	Theme 3: Integration of Climate Change and Sustainable Practices in Education	Theme 4: Waste Management Considerations	Theme 5: Transitioning to Modern Technologies
1. Constitution of Zimbabwe[28]	Environmental rights			Prevent pollution and ecological degradation	
2. Environmental Management Act: Chapter 20:27[29]	Sustainable management of natural resources and protection of the environment			The prescribing of standards for waste, their classification and analyses, and advice on standards of disposal methods and means for such waste	
3. Radiation Protection Authority of Zimbabwe: Chapter 15:15[30]		Confer powers and functions on such an Authority about protecting the public and workers from dangers resulting from the use or abuse of equipment, devices, or materials capable of producing ionizing radiation; and to provide for matters connected or incidental to the foregoing.			
4. Environmental Management (Control of Hazardous Substances) (General) Regulations, 2018)[31]		No person shall manufacture, store, sell, use, import, export, transport, or distribute any hazardous substance in a manner which— (a) access thereto would present a direct hazard to the public, or (b) present a hazard to the environment			
5. The National Environmental Policy and Strategies[32]					Promote economic policies that encourage efficient use of energy
6. The National	Institutionalize the		a) Enhance the		

	Climate Change Response Strategy[33]	climate change response governance framework at national, provincial, district, and ward levels	teaching and learning of climate change at all levels of education (formal and informal). b) Provide relevant training on climate change issues for educators and practitioners working with communities		
7.	Public Health Act[34]			The ministry shall prescribe for the management of healthcare waste in all healthcare delivery institutions_ (:2) Under subsection (1) the minister may make regulations on health care waste management concerning hazardous substances and articles of public health importance.	
8.	Zimbabwe Climate Policy[35]		Seeks to increase public awareness of climate change and its effects. This awareness is meant to ensure that the public meaningfully participates in making decisions that affect them.		
9.	Allied Health Practitioners Council Communication on darkroom processing of films[36]				The use of X-ray Units with dark room systems is being phased out with effect from 1 March 2024, only computed and digital radiography systems will be acceptable.

Discussion

This review sought to critically analyse relevant documents, policies, laws, and regulations to provide a comprehensive overview of environmental sustainability frameworks related to radiology practices in Zimbabwe. To the author's knowledge, this is the first study to critically analyse the environmental sustainability regulatory situation in Zimbabwe.

Legal Framework for Environmental Sustainability

The Constitution of Zimbabwe serves as the cornerstone of environmental rights and sustainability, as articulated in Section 73.[28] The provision asserts that every individual has a right to a safe and healthy environment, thereby establishing a fundamental legal basis for promoting environmental sustainability. Environmental rights are now globally recognised human rights.[37] Environmental protection is a key part of national legal frameworks, with many countries establishing comprehensive governance systems to

address threats and protect people's rights.[15] Over 35 countries in Africa recognise a right to a healthy environment in their national constitutions, and virtually all countries include environmental rights provisions in their national environmental laws and policies.[37] This could be influenced by the global movement, dating back to the 1972 Earth Summit and the 2015 Paris Agreement.[12,13] This right inherently suggests that all sectors, including healthcare and radiology, are obligated to prevent environmental degradation while using natural resources responsibly. The dual emphasis on promoting conservation and ensuring sustainable development resonates with the evolving ethos in healthcare practices, urging radiology departments to adopt greener practices.

While there has been a growing legal recognition of environmental rights across Africa, the implementation and enforcement of these rights have not been robust, particularly in the healthcare and radiology sectors.[37] For example, studies involving Zimbabwean radiographers have identified several barriers to environmental sustainability efforts, including a lack of prioritization for sustainability from leadership and organizations, insufficient incentives for sustainable practices, and a lack of partnerships between suppliers and consumers aimed at improving diagnosis, patient safety, and sustainability.[20,38]

Safety Protocols and Radiation Protection

A significant part of environmental sustainability in radiology practices revolves around the Radiation Protection Authority of Zimbabwe Act [3 Act] (Chapter 15:15).[30] The licensing requirements and safety standards set forth are crucial for ensuring that radiological procedures do not adversely affect the environment or public health. The emphasis on the safe use and disposal of irradiating materials is vital in mitigating risks associated with radiation exposure.

The Environmental Management (Control of Hazardous Substances) (General) Regulations (2018),[31] dovetail with the RPAZ Act,[30] stipulating that no person shall manufacture, store, sell, use, import, export, transport, or distribute any hazardous substance in a manner which—

(a) access there to would present a direct hazard to the public, or

(b) presents a hazard to the environment.

The mandatory inspection and enforcement protocols specified in sections 15 and 18 of the RPAZ Act,[30] ensure that radiological facilities comply with safety standards, reinforcing a culture of accountability and environmental stewardship among practitioners. The RPAZ Act is in line with international guidelines for protecting the environment from radiation.

As a member of the International Atomic Energy Agency (IAEA), Zimbabwe must adhere to the IAEA Code of Conduct on the Safety and Security of Radioactive Sources.[39] This code requires countries to create laws and regulations assigning responsibilities to governments, ensuring effective control, setting radiation protection requirements, establishing safety measures, and creating a national register for significant risks. The RPAZ Act ensures environmental sustainability in radiology by enforcing licensing, safety standards, and inspections, aligning with international guidelines to protect public health and mitigate radiation exposure risks.[30]

Integration of Climate Change and Sustainable Practices in Education

The National Climate Change Response Strategy and the Zimbabwe Climate Policy reflect the country's commitment to enhancing resilience against the impacts of climate change across various sectors, including healthcare.[33] These policies underscore the importance of climate change education, which is coordinated by the Climate Change Management Department in collaboration with the Ministry of Primary and Secondary Education and the Ministry of Higher and Tertiary Education, Innovation, Science, and Technology Development.[33] This framework for climate governance is essential for equipping radiology practitioners with a comprehensive understanding of the significance of sustainability practices.

Likewise, the Zimbabwe Climate Policy,[35] *"seeks to increase public awareness of climate change and its effects. This awareness is meant to ensure that the public meaningfully participates in making decisions that affect them*" Similar calls for sustainability in education have been made by regional organizations, such as the Southern African Regional Universities Association (SARUA), which highlights the critical importance of sustainability due to the Southern African region's vulnerability to climate change.[40] Research suggests that education plays a vital role in driving behaviour change, and the level of education is

the strongest predictor of climate change awareness worldwide.[41-43] A recent study in Zimbabwe shows that while sustainable healthcare education is integrated into the radiography curriculum, undergraduate radiography students still lack confidence in the subject and have no consensus on preferred teaching methods.[41] This highlights the need for ongoing education and awareness campaigns to bridge the gap between understanding the importance of sustainability and effectively implementing it in radiology practice. Increasing public awareness and education on climate issues could catalyse improved decision-making within radiological practices, fostering more sustainable practices.

Waste Management Considerations

The Environmental Management Act (Chapter 20:27),[29] emphasises the importance of waste management and hazardous substances in handling materials affecting human health and the environment. Section 69 outlines standards applicable to radiology practices, ensuring safe disposal methods and minimizing ecological footprint. The Public Health Act (Section 113),[34] also emphasizes the need for effective healthcare waste management, including radiological waste. Waste products in radiography primarily arise from therapeutic procedures and imaging investigations that use commonly employed radioactive substances such as Cobalt-60 (60Co), Technetium-99m (99mTc), Iodine-131 (131I), and Iridium-192 (192Ir).[44,45] Radioactive waste products are considered the most hazardous waste produced in healthcare.[46] Additionally, waste is generated from leftover contrast agents, used lead aprons, film packaging, chemical developers and fixers, expired film, disposable gloves, contaminated materials, and electronic waste like old X-ray machines and computer equipment.[4,44] Furthermore, the common use of single-use products in interventional procedures, such as catheters, syringes, sheaths, guide wires, devices, coils, and sterile drapes and towels, contributes significantly to waste generation in radiology departments.[47-49]

Nevertheless, previous studies have shown that healthcare waste management is not being given the high priority it deserves in developing countries like Zimbabwe.[45,46,50,51] This is due to a lack of awareness of the dangers associated with it, inadequate training in waste management, a lack of administration and disposal systems, and the competing needs with other sectors of the economy for the very limited resources available.[41,46,52,53] The need for regulations guiding the management of healthcare waste—including hazardous waste from radiology—emphasises the urgency for compliance and strategic implementation of waste management protocols. The emphasis on prescribing regulations reinforces the need for radiology departments to incorporate environmentally sound practices into their waste management strategies, thus reducing their ecological footprint.

Transitioning to Modern Technologies

Finally, the communication from the Allied Health Practitioners Council of Zimbabwe (AHPCZ),[36] regarding the phasing out of X-ray units with darkroom systems aligns with global trends towards more environmentally sustainable technologies.[20] Traditional film-based radiography operations in resource-limited settings require careful handling, storage, and waste disposal of processing chemicals, impacting reliability, quality, and cost.[44,54] However, most X-ray departments in developing countries like Zimbabwe are still restricted to film-based imaging.[54-56] Digital radiography and the adoption of teleradiology reduce radiation doses by 50% without compromising image quality, offer superior diagnostic performance, easier transmission and storage, and eliminate harmful chemical environmental disposal issues.[57,58] Therefore, the shift towards digital radiography systems not only enhances efficiency and reduces chemical waste but also signifies a broader movement within the healthcare sector towards adopting eco-friendly technologies.[4,20]

While digital radiography, artificial intelligence (AI), and teleradiology have the potential to reduce carbon emissions in Zimbabwe, several challenges could undermine these efforts. Issues such as a lack of funding for eco-friendly medical imaging equipment and poor internet connectivity may hinder the sustainable implementation of these technologies.[16,59,60]

Furthermore, sustainability is not currently integrated into the procurement function in a structured way. The procurement process is reactive, based on department-set criteria and industry tender trends for imaging modalities, equipment, disposables, and radiopharmaceuticals. Radiology in Zimbabwe needs to develop policies and standards for driving sustainability, as well as the necessary skills, competencies, and know-

how to make informed decisions about purchasing responsibly.[23] Some radiology equipment manufacturers, like General Electric (GE), are making progress toward carbon neutrality in their manufacturing and transportation processes. One of their initiatives includes partnering with the Science Based Targets initiative (SBTi) to develop innovations that promote precision health, digitization of healthcare, and improved access to care.[61]

Gaps and Recommendations

While Zimbabwe has a legal and policy framework aimed at promoting environmental sustainability in radiology, the provisions are mostly implied rather than explicitly stated. This means that the policies are not specifically tailored to radiology and require interpretation to apply them effectively. The absence of a clear and cohesive policy or guidelines for radiology has led to a disjointed regulatory landscape. For instance, in the United Kingdom (UK), governmental commitment to reducing greenhouse gas emissions is evident through initiatives like the Net Zero Strategy,[62] and the Health and Care Act of 2022,[63] which embeds net-zero targets into National Health Service (NHS) legislation. Similarly, in Canada, legislation such as Ontario's Broader Public Sector Accountability Act,[64] requires procurement guidelines to take environmental impacts into account, encouraging radiology departments to adopt sustainable practices.

Additionally, the current legal framework in Zimbabwe lacks sufficient economic instruments to encourage radiology practitioners to adopt sustainable practices. The economic instruments may include eco-friendly equipment subsidies, sustainability project grants, tax incentives for departments that invest in green practices, environmental pricing (e.g. pollution fees and resource consumption charges), sustainable procurement mandates, funded training programs, and research grants.One example of an economic instrument designed to promote sustainability in radiology is France's December 2023 law on social security financing.[65] This law aims to integrate environmental sustainability into healthcare and extend its impact on pricing decisions.[66]

It is crucial to develop a standalone environmental sustainability policy specifically for radiology. This policy should be accompanied by targeted regulations concerning the management of radiological waste, the procurement of medical equipment, the disposal of outdated equipment and consumables, and green practices within the radiology department. Furthermore, establishing a Green Energy Fund (GEF) could support rural and mission hospitals in adopting green energy technologies, especially since they may lack the financial resources to make this transition.

Environmental sustainability in radiology is an emerging area of research, and several potential avenues for future research include:

1. Exploring sustainable practices among radiology professionals, including radiographers, radiologists, and radiology nurses.
2. Analysing the future trajectory of radiology-related emissions under various investment, development, and growth scenarios, and assessing their implications for carbon emissions.
3. Conducting national and sub-national research on the climate footprint of radiology using a standardized methodology.
4. Developing a structural path analysis of climate emissions within the radiology supply chain to identify key leverage points for decarbonisation.
5. Performing an economic analysis of the costs and benefits associated with transitioning to digital imaging and other eco-friendly equipment, along with identifying the necessary investment and financing mechanisms to facilitate this transition.

Limitations of the Study

First, the study is reliant on document analysis, which may neglect practical insights from healthcare professionals who work directly in radiology practices. Second, given Zimbabwe's unique socio-political and economic setting, the conclusions may not be generalizable. Furthermore, the study does not account for differences in the application of environmental policies across health institutions, which may distort our understanding of sustainability challenges. Finally, there is a dearth of detailed quantitative data to accurately measure the effects of current policies, which may provide a more complete picture of radiology sustainability practices.

Conclusion

This review of documents provides useful insights into the concepts that guide environmental sustainability in Zimbabwean radiology practices. While the

Constitution provides a legal foundation for environmental rights, its implementation in the healthcare sector, notably radiology, remains inadequate. Possible barriers to sustainable practices include insufficient leadership prioritising, a lack of economic incentives, and ineffective collaborations. The review emphasises that existing safety measures, particularly those established by the Radiation Protection Authority, are insufficient to fully assure environmental sustainability in light of current challenges. Furthermore, the urgent need for enhanced waste management, particularly for hazardous compounds produced in radiology, is apparent. Effective legislation and education are required to increase awareness and compliance with proper waste management. Transitioning to current technology such as digital radiography and teleradiology promises to reduce both environmental impact and operational inefficiencies, but significant challenges like funding and infrastructure remain.

To improve sustainability efforts, a specialised environmental sustainability policy for radiology is required, as well as targeted legislation for waste management and equipment procurement processes. As Zimbabwe navigates these difficulties, closing gaps and encouraging sustainable healthcare practices will be critical to protecting public health and the environment for future generations.

Conflict of Interest

The authors declare no conflicts of interest.

Declaration of Generative AI and AI-Assisted Technologies

GenAI was utilized to enhance the readability of the manuscript. The authors proofread and take full responsibility for the content.

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