Sustainability in Radiography: Knowledge, Practices, and Barriers Among Radiographers in Zimbabwe and Zambia

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Introduction

Human activities have contributed to significant environmental impacts and an increase in atmospheric carbon dioxide (CO_2) levels—by 50% in less than two centuries and 10% in the last 15 years (1). The catastrophic impact of these environmental degradation and carbon imprints leading to climate change poses a serious threat to human lives. Therefore, addressing climate change is crucial for the future for all. Radiography, as a technology-driven field with high energy consumption, bears a particular responsibility for sustainability (2). This involves adopting environmentally friendly practices and minimizing waste and resource consumption within medical imaging and radiation therapy (3). With the global demand for radiography services on the rise, departments must assess the environmental impact of their operations and work towards minimizing their carbon footprint.

Recognition of healthcare's contribution to carbon emissions and other environmental costs has led government and professional bodies, including the Intergovernmental Panel on Climate Change, the Institute of Physics and Engineering in Medicine, the American College of Radiology, and the Radiotherapy Board, to focus on reducing the environmental impact emanating from clinical service provision (3,4). Recently, the governments of Zambia and Zimbabwe created the Ministry of Green Economy and Environment (MGEE) and Ministry of Environment, Water and Climate (MEWC) to champion the transition to a green growth pathway, respectively.

According to the World Health Organization (WHO), approximately 3.6 billion diagnostic examinations are conducted worldwide each year (5). The environmental carbon footprint from radiography accounts for approximately 10% of this, with most of it coming from interventional procedures (4,6,7). These environmental impacts also arise from the significant energy usage of equipment like linear accelerators, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) scanners (6), the generation and storage of large amounts of data (8), activities related to radiotherapy treatment, travel by service providers and users, and waste from clinical consumables such as gloves, single-use gowns, syringes and radiopharmaceuticals (9). Additionally, recent evidence shows increased contamination of aquatic environments with waste from radiological contrast media, primarily due to the growing use of contrast-enhanced CT and MRI scans in the past decade (3,4,10). In some developing countries such as our settings, some hospitals still use processing chemicals, adding to radiology waste and health problems. However, the Allied Health Practitioners Council of Zimbabwe (AHPCZ) issued a notice phasing out the film-screen radiography system in February 2024, citing environmental sustainability as a key reason.

Sustainability-driven practices in radiography include reducing radiation dose in medical imaging procedures like CT scans and X-rays while maintaining diagnostic quality (9). This can be achieved through advanced imaging techniques, the adoption of radiology information systems like PACS (7), deep learning sequences such as the NYU FastMRI Dataset (2), low-field MRI (10), critical evaluation of indications (4,8), customized examination protocols, and dose reduction protocols (1). Energy-saving methods, such as low-energy idle and system-off states during non-productive stages, can significantly reduce consumption (6,11). Proper disposal of environmentally unfriendly waste and hazardous materials, like lead aprons and radioactive waste, is also important for minimizing the environmental impact of radiology practices (9). This also includes the disposal of old radiographs and processing chemicals (developer and fixer) still used in some of our radiology departments. Value-based imaging, which focuses on creating added value for patients and the healthcare system, has been suggested as well (2,12). Additionally, the rise of virtual clinics and remote consultations following the pandemic has led to a reduction in carbon emissions related to traveling to hospitals (6). Finally, some researchers have suggested that sustainability should be considered as a quality measure (4).

Literature reports barriers to sustainability in healthcare systems. The WHO identifies three main categories of barriers to sustainability: individual, organizational, and systemic (5). Individual-level barriers include a lack of knowledge/awareness and cultural/psychological factors among radiographers. Organizational barriers involve factors within the organization, such as inappropriate waste containers and poor maintenance of waste management resources (13). Systemic barriers include weak governance and enforcement of regulations (14,15).

Raising awareness among radiographers, radiologists, oncologists, and patients is crucial in reducing the carbon footprint of radiography and the burden on current and future generations (1,8,9). It is important to inform healthcare providers about the environmental impact of their practices and the need to minimize it (7). However, many aspects of sustainability in radiography, especially in low-resource settings, have not been adequately explored (2,4,5,7). No published research was found on this subject to have been conducted in low-resource settings. This is concerning because unsustainable practices disproportionately affect developing countries, despite contributing less to global carbon emissions (16,17).

Climate change exacerbates healthcare disparities and hinders efforts to keep individuals and populations healthy (9). Therefore, this study aims to investigate the knowledge, practices, and barriers to sustainability in radiography practice among radiographers in Zimbabwe and Zambia. The ultimate goal is to identify opportunities and guidance in making radiography more sustainable, especially in our settings where imaging processing is changing from conventional to digital radiography which has less impact on the environment. Radiographers play a key role in driving change, both within their departments and through influencing the organizations they work for and the equipment they purchase (6). Specifically, this study intended to address the following objectives;

- *To assess radiographers' knowledge of sustainability in radiography*
- *To evaluate the sustainability practices of radiography departments*
- *To evaluate the barriers to sustainability practices in radiography*

Methods

Research design

This study employed a quantitative cross-sectional study design and utilized an online questionnaire as the data collection instrument. The study was conducted between January 23 and February 5, 2024, and adhered to the STROBE guidelines for reporting cross-sectional studies (18).

Research setting

Zambia and Zimbabwe are low-resource neighboring states in Southern Africa, separated by the Zambezi River. Both countries have 10 provinces each. Zimbabwe has a smaller population than Zambia, with around 15.1 million people compared to

Zambia's 19.1 million. Both countries are members of the Southern African Development Community (SADC) and the African Union (AU). From 1953 to 1963, they were part of the Federation of Rhodesia and Nyasaland along with Nyasaland (now Malawi) (19). As part of the British colony, Zambia and Zimbabwe shared public services, including healthcare, which promoted cooperation (20). Both countries have struggling economies and allocate less than 15% of their GDP to healthcare, which falls short of the requirements outlined in the Abuja Declaration (21). According to the World Bank's latest available data, Zambia spent 5.62% of its 29.16 billion US dollars GDP on healthcare in 2020, while Zimbabwe spent 3.43% of 27.37 billion US dollars in the same year (22). Zambia's economy was sabotaged by the fall in copper prices in 1975, while Zimbabwe's economy was damaged by the fast-track land reform program of the 2000s. In 2022, Zambia and Zimbabwe had per capita CO_2 emissions of 0.4t and 0.5t, respectively, compared to 14.9t in the United States of America (23). Figure 1 shows the map of Zimbabwe and Zambia.

Figure 1. Map of Zambia and Zimbabwe (FDFA, 2023).

Population and Sampling

The AHPCZ has 330 registered radiographers, and the Health Professions Council of Zambia (HPCZ) has 908, totaling 1238 registered radiographers between the two countries. Cochran's formula for cross-sectional studies with a finite population scorrection was used to determine the number of radiographers to be recruited for the study in each country (24). A total sample size of 185 radiographers was calculated for both countries (84 from Zimbabwe and 101 from Zambia). The required number of participants was consecutively sampled. This involved recruiting all the people from an accessible population who met the eligibility criteria and who consented to take part until the desired sample size was reached (25).

Data collection instrument and procedure

A survey questionnaire was used to collect the data. The questions in the questionnaire (see Appendix 1) were developed by a team of expert radiography academics and are grounded in existing literature (5,7,8), and topical issues related to sustainability in radiography. The research instrument was then peer-reviewed by a different group of radiography academics from another institution. This questionnaire comprised 4 sections, Section A – Demographic information, Section B – Knowledge of sustainability, Section C – practices of sustainability in the respective departments, and Section D - barriers to sustainability.

The questionnaire was created in Google Forms (a web-based survey tool provided by Google) and the link to the questionnaire was circulated via different WhatsApp groups of radiographers in Zimbabwe and Zambia. The questionnaire included a research information sheet and a consent-seeking section which helped to obtain from radiographers before participating in the study. The data were then collated into a Microsoft Excel spreadsheet (26), where it was cleaned and formatted for further analysis in Stata 13 (27).

Data analysis

Data were scanned for out-of-range values using frequency distribution tables, and box and whisker plots. Continuous variables were summarized using mean and standard deviation if normally distributed, or median and interquartile range if not normally distributed. Categorical variables are summarized using frequencies and percentages. Statistical significance is set at 95% ($p = 0.05$) level.

Exploratory factor analysis using principal component analysis was conducted on the 44 items which were measured on the 5-point Likert scale with the following scores: 1- strongly disagree up to 5 - strongly agree with negatively worded statements being reverse scored. These items were divided into three categories namely knowledge of sustainability (11 items), practices of sustainability (21 items), and barriers to sustainability (12 items). The Cronbach's alpha for these 44 items was 0.93.

To determine if these items were suitable for factor analysis, a correlation matrix was run for each of the three categories, and the resultant correlation matrix showed several coefficients with $r \geq 0.3$ in all three categories thus indicating a high correlation among factors for factor analysis. The Bartlett test of sphericity had a p-value of <0.001 for all three categories which confirms a strong correlation for the application of dimensionality reduction (28). The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.82 for knowledge of sustainability items, 0.89 for practices of sustainability items, and 0.90 for barriers to sustainability items which confirms the adequacy of the sample for factor analysis (29). Factor extraction was performed using principal component analysis, and factors with Eigen values >1 were retained as per Kaiser's criterion (30). To visualize the factors and to help in determining which factors to retain, scree plots were used. Factor rotation was achieved using varimax and items with factor loadings of at least 0.4 were considered to be contributing meaningfully to a factor (29,31). Cronbach's alpha was used to assess the internal consistency of the items loading onto a factor, with a threshold of 0.45 being used (32).

Ethical considerations

Ethical approval was obtained from the Harare Institute of Technology Institutional Research Ethics Committee (SAHS/DR00003/24). Permission was also sought from the

Radiography Association of Zimbabwe (RAZ) and the Radiological Society of Zambia (RSZ) to administer the questionnaire to their members. The study adhered to ethical principles including autonomy, beneficence, non-maleficence, and justice (25). Participants were informed about the voluntary nature of the study and assured of confidentiality and anonymity. The study is expected to benefit the radiography profession without posing any risks to participants. All participants were subjected to the same questions.

Results

Demographics

A total of 216 radiographers from Zambia and Zimbabwe participated in the survey, with 150 (69.44%) from Zambia and 66 (30.56%) from Zimbabwe. The median (IQR) age was 34 (28; 39) [Zambia: 34 (29; 40), Zimbabwe: 35 (25; 39)] years. More than half of the respondents (54.63%) were males. Most radiographers (90.74%) were diagnostic radiographers, with basic-grade radiographers contributing a higher proportion of respondents (66.98%). Table 1 summarizes the demographic characteristics of the participants.

Table 1: Demographic characteristics of the participants

Knowledge of sustainability

Overall, knowledge of sustainability was fairly high among respondents from both countries, with only 19.33% of radiographers from Zambia and 16.67% from Zimbabwe indicating that they were not familiar with the concept of sustainability. Altogether, 81.49% of the radiographers who participated in this survey had some familiarity with the concept of sustainability in radiography. General radiography (49.66%) and Nuclear medicine (47.69%) were identified as the most common sources of emission/waste in the radiography departments in Zambia and Zimbabwe, respectively. A sizeable proportion of radiographers (48.36%) were able to identify that greenhouse gas emissions were not a measurable benefit of environmental sustainability. In addition, 72.69% of the radiographers disagreed/strongly disagreed with the notion that low-resource settings are not affected by the consequences of unsustainability. However, despite the good knowledge of sustainability among radiographers, the radiography educational curriculum was singled out as lacking sufficient content on sustainability (44.44%). Table 2 summarizes the knowledge of sustainability among radiographers.

Table 2: Knowledge of sustainability among radiographers

In the exploratory factor analysis, three factors emerged, explaining 51.12% of the variation in knowledge of sustainability among radiographers in both countries. Factor 1 with an eigenvalue of 3.35 had 5 items loading on it, explaining 30.49% of the variation in knowledge of sustainability. The item with the highest factor loading (0.75) on this factor was *'Sustainability in radiography can contribute to the overall quality of patient care and the environment'* which implies that radiographers are aware of the impact of sustainability on patient care and the environment at large. Additionally, radiographers knew that the effects of sustainability are independent of the wealth classification of a country, as shown by the 2 items loaded on factor one, which were negatively worded, i.e. *'Only rich nations need to be concerned about sustainability'; and 'Low resource settings are not affected by the consequences of unsustainability'* with factor loadings -0.71 and -0.64 respectively.

Factor 2, explaining 10.75% of the variation in knowledge of sustainability with an eigenvalue of 1.18 had 3 items loading onto it. The item with the highest factor loading (0.75) was *'Radiology centre has to be Green Certified to be allowed to operate in the near future,'* thus revealing the understanding of the importance of going green in radiography practice among radiographers.

Items loading on factor 3 had low internal consistency, as evidenced by Cronbach's alpha of 0.30, falling short of the cut-off value of 0.45. Thus, items loading on factor 3 do not necessarily measure the same construct on knowledge of sustainability. These findings are presented in Tables 3 and 4.

Table 3: Knowledge of sustainability exploratory factor analysis findings

Table 4: Factor loadings

Practices of sustainability

In both countries, more than half of the radiographers reported the absence of sustainable practices in place in their respective radiology departments (Zambia 51.02%, Zimbabwe 54.69%). However, despite the lack of deliberate sustainable practices being implemented in most radiology departments, radiographers identified a few sustainable practices that they implement at their individual units and levels. These include turning off equipment overnight (during unproductive hours) and using low-power mode during off-peak hours (84%), reducing the number of repeat examinations (92.13%), and shutting down reporting stations/computers when not in use (77.77%) among others. Meanwhile, the use of motion detector lights outside of working hours as a sustainability practice was more common in radiology departments in Zambia (42%) compared to those in Zimbabwe (31.82%), and this difference was statistically significant ($p = 0.02$). Table 5 presents the sustainability practices used within radiology departments and also adopted by the radiographers.

Table 5: Sustainability practices within radiology departments and also adopted by radiographers

Exploratory factor analysis identified four factors, explaining 52.15% of the variation in radiographers' practices of sustainability. Factor 1, with an eigenvalue of 6.87, and explaining 32.72% of the variation, had 5 items loading onto it. The item with the highest factor loading (0.82) was *'Turning off equipment overnight (during unproductive hours) and use of low power mode during off-peak hours'*. This implies that radiographers are indeed incorporating some sustainability measures in their day-to-day practice. In addition, they also shut down reporting stations/computers when not in use (factor loading 0.78) and reduce the number of repeat examinations (factor loading 0.70), thereby reducing the energy consumption within the imaging departments, which is one of the facets of sustainability.

Factor 2 had an eigenvalue of 1.78, explaining 8.49% of the variation in practices of sustainability by radiographers. The adoption of multi-use surgical instruments had the highest factor loading of 0.73, implying that most radiology departments recycle most of the equipment that they use in their day-to-day practice. These findings are presented in Tables 6 and 7.

Table 6: Description of factors

Table 7: Factor loadings

Barriers to sustainability

The majority of radiographers alluded to the presence of barriers/challenges to successfully implementing sustainable practices within radiology departments in both countries (Zambia 85.91% & Zimbabwe 87.69%). Some of the identified barriers to sustainability include a lack of priority for sustainability from leadership and organization (73.61%), a lack of incentives for sustainability (75.46%), and a lack of partnerships between suppliers and consumers on ways to improve diagnosis, patient safety and sustainability (82.4%) were some of the barriers to sustainability identified by radiographers. Details of the identified barriers are presented in Table 8.

Table 8: Barriers to implementation of sustainable practices in radiology departments

Exploring barriers to sustainability using exploratory factor analysis revealed a two-factor structure explaining about 50% of the variation in the data. Factor 1, with an eigenvalue of 4.91, explaining 40.96% of the variation had 5 items loading onto it. These items generally explain the absence of proper structures within radiology departments to implement sustainable practices. The item with the highest factor loading (0.74) was *'lack of awareness, concern and time to address waste'*. This was followed by a *'lack of priority for sustainability from leadership and organization'* with a factor loading of 0.73. It shows that there are no properly defined sustainability measures in place in radiology departments that radiographers are expected to follow.

The cost of implementing sustainable practices as well as concerns regarding implementation of sustainable practices is another barrier identified (factor 2) with an eigenvalue of 1.04 and explaining 8.63% of the variation in data. The lack of incentives for sustainability with a factor loading of 0.74 and cultural and psychological barriers with a factor loading of 0.73 loaded heavily on factor 2. Radiographers believe that to successfully implement sustainable practices, there should be incentives in place that favour sustainable practices compared to traditional unsustainable practices, the domains of which can be explored. Equally, the presence of cultural and psychological barriers plays a huge part in successfully rolling out sustainable practices as there could be no one-size-fits-all approach, without looking at the context and background of those involved. These findings are presented in Tables 9 and 10.

Table 9: Description of factors

Table 10: Factor loadings

Discussion

The environmental carbon footprint from radiography makes up about 10% of hospital emissions, with the majority coming from radiotherapy, CT, MRI, and interventional procedures (4,6,7). Consequently, radiography departments need to be mindful of the environmental impact of their practices and strive to reduce their carbon footprint. However, the assessment of sustainability issues in radiography, especially in low-resource settings, is still lacking. Hence, this study investigated the knowledge, practices, and barriers to sustainability in radiography practice among radiographers in Zimbabwe and Zambia. The findings could raise awareness, improve daily practices, and contribute to a healthier environment and better resource management within radiography departments. Additionally, it is anticipated that the study will shed light on the impact of unsustainable practices in low-resource settings and provide potential mitigation recommendations while providing baseline information for future research in this area.

Knowledge of sustainability among radiographers

In the current study, 81% of radiographers were familiar with sustainability, compared to only 31%-42% in a 2023 European study conducted across 31 countries (33). The European study linked the low awareness of sustainability to the incomplete application of sustainability concepts in healthcare. In the current study, higher knowledge levels may be attributed to extensive climate change awareness campaigns by both governmental and non-governmental organizations in Africa, a region that has faced relatively severe consequences of unsustainability (34). Some of the organizations in both Zimbabwe and Zambia that have been promoting sustainability include The United Nations Children's Fund (UNICEF) (35), SNV Zimbabwe (36), CAN Zimbabwe (37), Zambia Energy and Environmental Organization (38), Zambia Climate Change Network (39), CARE Zambia (40), among others. Despite Africa's lower greenhouse gas emissions, most of the countries within the continent, including Zambia and Zimbabwe, have signed international agreements to combat climate change such as the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the 2016 Paris Agreement on Climate Change (41). Afrobarometer found that in 29 out of 34 surveyed African countries, at least half of citizens are familiar with sustainability (42).

Despite the generally good knowledge of sustainability among radiographers, 44% of respondents in this work felt that the radiography educational curriculum lacked sufficient content on sustainability. This finding is consistent with a recent European study that highlighted the importance of sustainability training for radiographers (33). The same study emphasized that these skills should be a concern for this professional group and that green skills should be integrated into the education of radiographers. While having a general understanding of sustainability is beneficial, detailed knowledge of how radiographers can enhance their sustainability practices can only be gained through formal instruction in the radiography curriculum. However, deficiencies in sustainability issues in the curriculum were reported in European and South African studies (33,43), underscoring the need for educational reforms. Research indicates that education is a crucial factor in behavior change, and the level of education is the strongest predictor of climate change awareness worldwide (44,45). Soares *et al.* suggested that sustainability training should start early and continue throughout a radiographer's professional career (33). Furthermore, Anudjo *et al.* express similar sentiments by stressing that education and awareness are crucial in providing a comprehensive understanding of the environmental impact of radiography (3). Nevertheless, further research is needed to explore sustainability integration in radiography curricula in low-resource settings.

The study also revealed that general radiography and nuclear medicine were the perceived primary sources of emission and waste in radiography departments in Zambia and Zimbabwe, respectively. This situation can be attributed to the limited number of CT and MRI scanners in both countries (46,47). At the time of this research, Zimbabwe had 22 CT and 10 MRI scanners, while Zambia had 40 CT and 8 MRI scanners (48,49). Additionally, there is a scarcity of interventional procedures being performed. For example, there is only one interventional radiologist at a single private center in Zimbabwe currently officially performing interventional procedures.

Practices of sustainability

Radiographers play a crucial role in promoting sustainability through their daily practices (3). In both Zambia and Zimbabwe, more than half of the radiographers noted a lack of deliberate sustainable practices in their departments, which is driven by policy, reflecting a broader trend in the literature (13,33). This emphasizes the need for intentional departmental sustainability practices in Zambia and Zimbabwe. While radiographers can implement sustainable practices at the individual level, organizational change is needed, requiring advocacy at the organizational and policy levels for successful sustainability efforts. This study unveils several day-to-day practices that radiographers can take to become more sustainable. Radiographers in this work identified several sustainable practices that they do implement, such as turning off equipment during unproductive hours and using low power mode during off-peak hours, reducing the number of repeat examinations, and shutting down reporting stations/computers when not in use, among others. Several scholars in the literature have also identified these practices (1,6,9,11). Interestingly, the use of motion detector lights outside of regular hours as a sustainability practice was more prevalent in Zambian radiology departments compared to those in Zimbabwe, and this difference was found to be statistically significant. Earlier studies have shown that electricity use is the primary contributor to the carbon footprint in departments (7,50,51). Therefore, implementing simple changes in lighting configurations, such as motion detector lights, can enhance the radiography department's sustainability (50).

Potential future research in the field of sustainability within radiography lies in making examinations and procedures more sustainable; in other words: improving sustainability in the core practice of radiographers.

Barriers to sustainability

This study identifies barriers to sustainability as the challenges encountered in implementing sustainability efforts (52). The WHO categorizes barriers to sustainability into three main types: individual, organizational, and systemic (5). The top three reported barriers in the current study include a lack of priority for sustainability from leadership and the organization, an absence of incentives for sustainability, and a lack of partnerships between suppliers and consumers to enhance diagnosis, patient safety, and sustainability. Interestingly, these barriers are predominantly systemic or organizational, reflecting the broader characteristics of the setting. Both systemic and organizational barriers are basic and are experienced by the whole of the organization not just particular parts of it (5,52). The findings align with previous literature showing that sustainability barriers are mostly organizational or systemic, with a lack of leadership priority for sustainability being the most common barrier (7,13,53). Prioritizing leadership on sustainability is, hence, crucial for the successful implementation of sustainability initiatives. However, leaders in healthcare settings should take into account the individual characteristics of each healthcare setting when working to implement the suggested solutions.

Limitations of the study

The study's internal validity may be compromised due to potential sampling bias, as a lower response rate was observed among Zimbabwean participants, and there is a possibility of social desirability bias because the survey relied on self-reported data. Additionally, the study was carried out by distributing an online survey through WhatsApp groups. As a result, radiographers who have limited or no access to WhatsApp or related IT skills may have unintentionally been left out of the study's sample.

Conclusion

The findings of this study revealed a relatively high level of sustainability knowledge among radiographers, potentially influenced by extensive climate change awareness campaigns in Africa and governmental initiatives to promote sustainability. However, the study also reports a perceived lack of sustainability content in the radiography educational curriculum. This emphasizes the need for educational reforms and the integration of sustainability skills into the education of radiographers.

While radiographers can implement sustainable practices at the individual level, the study underscores the need for intentional departmental, organizational, and systemic practices to drive successful sustainability efforts. In the future, research should focus on improving the sustainability of radiographic examinations and procedures, ultimately improving the core practice of radiographers.

Barriers to sustainability primarily revolve around systemic and organizational challenges, with a lack of leadership priority for sustainability being a common issue. Prioritizing sustainability through leadership is essential for successful sustainability implementation. However, leaders must take into account the unique needs of each healthcare setting when working to implement sustainable solutions.

In a nutshell, this study offers valuable insights into the current state of sustainability in radiography in Zambia and Zimbabwe, highlighting the need for academic reforms, intentional departmental practices, and systemic changes to drive sustainable efforts in the field.

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