IOP Publishing | Society for Radiological Protection Journal of Radiological Protection

J. Radiol. Prot. **40** (2020) R141–R150 (10pp) https://doi.org/10.1088/1361-6498/aba402

Review

A systematic review of occupational radiation individual dose monitoring among healthcare workers exposed in Africa

Arnaud A Gbetchedji[1,2,3,4,5], **Gilles D Houndetoungan**[4], **Hubert C Hounsossou**[5], **Neige Journy**[1,2,3], **Nadia Haddy**[1,2,3], **Carole Rubino**[1,2,3], **Olivier Biaou**[4], **Daton Medenou**[5], **Kuassi M Amoussou-Guenou**[4], **Florent de Vathaire**[1,2,3] and **Rodrigue S Allodji**[1,2,3,5]

[1] Université Paris-Saclay, UVSQ, Univ. Paris-Sud, Inserm, Équipe Cancer and Radiation, CESP, Villejuif 94807, France
[2] INSERM, CESP, Cancer and Radiation Team, Villejuif 94805, France
[3] Gustave Roussy, Department of Clinical Research, Cancer and Radiation Team, Villejuif 94805, France
[4] Faculté des Sciences de la Santé, Université d'Abomey-Calavi, P.O. Box 188, Cotonou, Bénin
[5] Ecole Polytechnique d'Abomey-Calavi (EPAC), Université d'Abomey-Calavi, 01 P.O. Box 2009, Cotonou, Benin

E-mail: rodrigue.allodji@gustaveroussy.fr

Received 25 March 2020; revised 17 June 2020
Accepted for publication 8 July 2020
Published 20 November 2020

Abstract

Dosimetric monitoring is useful to limit exposures to ionising radiation in medical occupational settings, and reduce subsequent health risks. Scientific literatures, such as the UNSCEAR report 2017 and International Atomic Energy Agency Report 2014b, updated information on this subject; however, few African works have been found. This is the reason why we undertook this study, which summarises existing information on monitoring external radiation exposure doses for the whole body, using data from medical workers on this continent. Using standard terms and combining different keyword searches for radiation dose monitoring among radiology healthcare workers in Africa, from the titles, abstracts, and full texts, we found 3139 articles in the PubMed/MEDLINE, Google Scholar and INIS databases. Two reviewers screened the retrieved publications based on predefined eligibility criteria to identify relevant studies, extract key information from each, and summarise the data in table form. A total of 20 potentially relevant articles were identified. Among these 20 articles, 15 reported the overall average annual effective dose. Studies included in this systematic review represent an inventory of the radiation protection of medical workers in various African countries, with a focus on the monitoring of occupational radiation exposure. The size of studied populations ranged between 81 and 5152 occupational exposed workers. The mean annual effective doses ranged from 0.44 to 8.20 mSv in all specialities of medical sectors, while diagnostic radiology ranged from 0.07 to 4.37 mSv. For the nuclear medicine and radiotherapy from medical groups, the mean annual effective dose varied between 0.56 and 6.30 mSv. Industrial and research/teaching sectors data varied between 0.38 to 19.40 mSv. In conclusion, more studies implemented on dosimetric monitoring in Africa are needed to get a real picture of occupational exposure in the continent.

Keywords: healthcare workers, dose monitoring, occupational radiation exposure, diagnostic radiology, diagnostic x-ray, medical imaging, Africa

(Some figures may appear in colour only in the online journal)

ALARA	As Low As Reasonably Achievable
IAEA	International Atomic Energy Agency
INIS	International Nuclear Information System
OEW	Occupational Exposed Workers
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TLD	Thermo luminescent Dosimeter
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

1. Introduction

Occupational exposure to ionising radiation occurs in many professions, including medicine, research/teaching and industry workers [1]. Diagnostic investigations using radiation have become a critical feature of medical practice. As such, it raises concern about the potential risk that these advancements may pose for both patients and professionals [2].

The cancerous and non-cancerous diseases caused by the effects of radiation exposure on humans have major implications for public health and radiation standard setting [3]. Public interest in the long-term effects of radiation on humans has therefore increased, and has been focused on carcinogenic effects from protracted exposure to low doses.

The role of individual monitoring in the nuclear industry is undisputed, with the need for good record keeping and regular review [4]. Individual monitoring in the medical sector is also important for occupational exposed workers (OEW). The monitoring of medical workers chronically exposed to ionising radiation is common practice in many countries, but remains limited on the African continent. This is evidenced in the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2017 report [1]. It states that literature dealing with medical exposure in Africa, Asia and Latin America is limited [1]. Our study will focus on Africa, because according to the literature [5], it remains the continent with the lowest participation rate in international surveys on radiation protection. The updating of information on this subject through scientific literature, such as the UNSCEAR report [1] and International Atomic Energy Agency [5], led us to undertake this study. It consists of summarising existing information on monitoring of doses of external radiation exposure for the whole body of medical workers on this continent. It will also highlight the improvement in dosimetric monitoring between the different countries, after analysis of the annual effective mean doses between different practices.

2. Methods

2.1. Search strategy and study selection

We searched the PubMed/MEDLINE, Google Scholar and INIS databases using a combination of the following keywords with the Boolean operators 'OR' 'AND': dose monitoring, occupational exposure, diagnostic radiology OR radiography OR diagnostic x-ray OR medical imaging Africa AND medical workers, in the titles, abstracts, AND full texts. The reference lists of eligible articles were also reviewed to identify studies that we might have missed by searching terms in the titles and abstracts. We included articles, published in English or French up to the 31 August 2019, with an update on 20 May 2020, which reported results regarding the dose monitoring of occupational radiation exposure from IR. We excluded studies that only provided descriptions of the system of radiation protection or did not report information on the dose monitoring of occupational radiation exposure from ionising radiation for the whole body. Similarly, studies focused only on the radiation protection of patients or monitoring doses of the hand in interventional radiology were excluded. In this review, inclusion criteria were (i) articles fully available in English or French languages; and (ii) articles that provided mean annual effective doses related to different medical, industrial and research specialities or teacher. The results of the identification and selection process are displayed in a flow diagram (figure 1), as requested in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [6].

2.2. Data extraction

Information on country, study design, source population, sample size and period were extracted from the articles using a predefined data extraction form (table 1). Data extraction was performed independently by two reviewers (AG, RA), who cross-checked their reports to validate the information extracted from the original articles and reach a consensus data synthesis.

3. Results

3.1. Study selection and characteristics Using the defined key words, 3139 articles were identified (figure 1). At the end, the 20 selected studies have been published between 1986 and 2018. These articles provide data on the dosimetric monitoring of workers exposed to ionising radiation (whole body) and some described dosimetric monitoring practices. Among these 20 articles (table 1), 15 reported the overall mean annual effective dose (tables 2 and 3). Five studies not reported in tables 2 and 3 addressed issues of whether or not dosimetric monitoring exists in the facilities concerned, or the assessment of compliance to international radiation protection standards, without reporting the individual radiation doses. From 20 studies, 70% and 15% of the studies were cross-sectional (reporting exposures during a one-year period) and retrospective (reporting mean annual effective doses during a period of 16 years on average), respectively. The largest size of the source populations was 5152, provided in the field of diagnostic radiology by Ghana between 2000 and 2009. It was followed by Tanzania with 757 diagnostic radiology workers of 1000, while Tapsoba *et al* [8] reported only 81 medical workers of 157, in Ouagadougou at Burkina Faso. The different studies reported data on

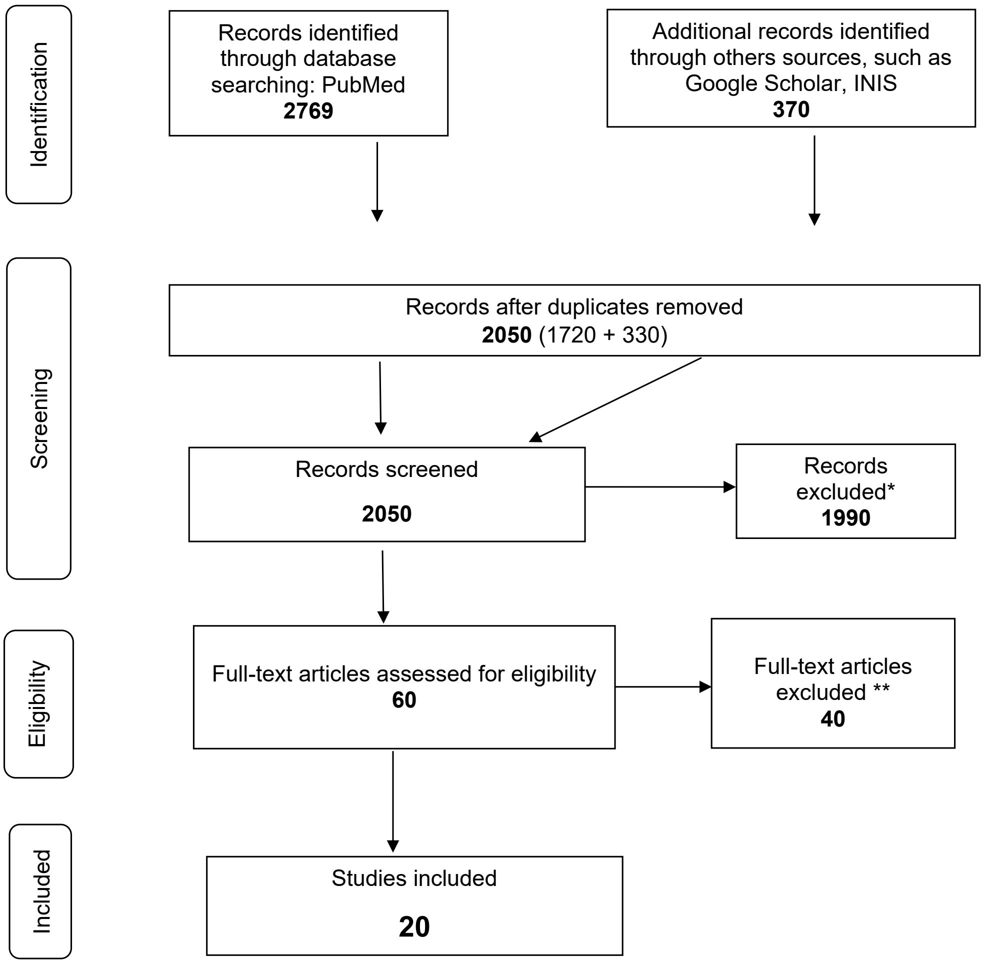

Figure 1. PRISMA diagram selection processes for paper published.

workers exposed to ionising radiation in all fields using ionising radiation, but more particularly in different specialities from medical sectors (table 2). All medical sector, industrial and research/teaching data are presented in table 3 for comparison.

3.2. Annual effective mean dose Among the included studies, 15 had published the individual radiation doses. The thermoluminescent dosimeter (TLD) was the monitoring equipment in all studies. It is worn at chest height requested by IAEA [27]. It reported an overall mean annual effective dose in medical, industrial and research/teaching fields. Considering the different doses provided by the studies summarised in table 3, the mean annual effective doses ranged from 0.44 to 8.20 mSv in all specialities of Medical sectors, while diagnostic radiology ranged from 0.07 to 4.37 mSv (table 2). For the Nuclear medicine and radiotherapy specialities of medical sector, the mean annual effective dose varied between 0.56 and 6.30 mSv (table 2).

Table 1. Summary of 20 selected studies.

Authors	Country	Type of studies	Source population (sample size)	Provided mean annual individual doses (Yes/No)	Provided collective annual doses (Yes/No)	>Period
[7]	Burkina Faso	Longitudinal	OEW of Medical (3 to 121)	Yes	No	2007–2010
[8]	Burkina Faso	Cross-sectional	OEW in diagnostic radiology department (81)	Yes	No	2010–2011
[9]	Egypt	Retrospective	OEW (radioactive source) (27)	No	No	2002–2012
[10]	Ethiopia	-	OEW (100 to 450)	Yes	Yes	1977–1988
[11]	Ghana	Cross-sectional	OEW of medicine, industrial, research and education and teaching (650)	Yes	Yes	2002–2007
[12]	Ghana	Retrospective	OEW of diagnostic radiology (5152), radiotherapy (747), nuclear medicine (87)	Yes	Yes	2000–2009
[13]	Ghana	Cross-sectional	OEW of medicine, industrial and research/teaching: radiotherapy (8), diagnostics (556), nuclear medicine (4)	Yes	Yes	2008–2009
[14]	Ghana	Cross-sectional	OEW in medicine, industrial, research and education and teaching (254 to 761)	Yes	Yes	1988–1995
[15]	Kenya	Cross-sectional	OEW in diagnostic radiology department (367)	Yes	Yes	2007

Table 1. continued

Authors	Country	Type of studies	Source population (sample size)	Provided mean annual individual doses (Yes/No)	Provided collective annual doses (Yes/No)	>Period
[18]	Nigeria	Longitudinal	OEW of medicine, industrial, and research (640)	Yes	Yes	1990–1999
[16]	Madagascar	Cross-sectional	OEW in diagnostic radiology department (260)	Yes	No	1990–2000
[17]	Malawi	Cross-sectional	OEW in diagnostic radiology department (Number of workers not defined)	No	No	2018
[19]	Nigeria	Cross-sectional	OEW of Medical (30 to 192)	Yes	Yes	1999–2001
[20]	Nigeria	Cross-sectional	Radiographs (500)	No	No	2009
[21]	Nigeria	Cross-sectional	OEW (Number of workers not defined)	No	No	2011
[22]	Nigeria	Cross-sectional	OEW of medicine and industrial (500)	Yes	Yes	2000–2001
[23]	Nigeria	Cross-sectional	OEW of medicine, radiographers and radiologists (59)	Yes	No	2005–2007
[24]	Sudan	Cross-sectional	OEW in cardiology department (Number of workers not defined)	No	No	2010
[25]	Tanzania	Retrospective	OEW in medicine, industrial, research and education and teaching (730)	Yes	Yes	1996–2010
[26]	Tanzania	Cross-sectional	OEW in medicine, industrial, research and education and teaching (1000)	Yes	Yes	1986–1997

OEW: occupational exposed worker.

Table 2. Summary of height articles from the 15 included studies reporting mean annual individual doses for different specialities of medical sectors.

		Mean annual individual doses (in mSv)		
Authors	Type of dosimeter	Diagnostic Radiology	Nuclear Medicine	Radiotherapy
[12]	TLD	2.94	6.30	5.24
[25]	TLD	1.50	1.50	-
[23]	TLD	4.37	-	-
[14]	TLD	0.80	0.56	1.12
[8]	TLD	0.07–0.47	–	–
[15]	TLD	2.52	–	–
[7]	TLD	In mean 85.22% of doses <0.10	–	–
[16]	TLD	0.90–2.00	–	–

TLD: thermoluminescent dosimeter.

Table 3. Summary of seven articles from the 15 included studies reporting mean annual individual doses for all specialities of medical sectors and others sectors (industrial/research/teaching).

		Mean annual individual doses (in mSv)		
			Others sectors	
Authors	Type of dosimeter	Medical sectors	Industrial	Research/Teaching group
[18]	TLD	8.20	2.34	4.39
[10]	TLD	4.51	–	–
[11]	TLD	0.57	0.54	–
[13]	TLD	0.44	0.54	0.38
[19]	TLD	3.20–3.70	4.70–19.40	–
[26]	TLD	1.68	0.93	0.92
[22]	TLD	2.7	16.25	–

TLD: thermoluminescent dosimeter.

4. Discussion

The updating of information on this subject through scientific literature, such as the UNSCEAR report [1] and International Atomic Energy Agency [5] where African countries were very under-represented, led us to undertake this study, which consists of summarising existing information on monitoring of doses of external radiation exposure for the whole body of medical workers on this continent. Studies included in this systematic review represent, across various countries, an update of dosimetric monitoring of medical workers in Africa, with a focus on the monitoring of occupational radiation exposure in the diagnostic radiology sector, because a large number of medical workers are exposed to lower doses, which may not be without consequences. We were able to find articles only from 11 countries out of 54 in Africa. This number is not representative, as monitoring programmes are available in some other countries, but they did not publish papers on occupational radiation doses. The annual mean effective doses were provided by a little less than half of the studies selected for several exposed groups (medical, industry and research/teaching groups). The scarcity of dose monitoring data in African countries may be explained in part by the low participation rates of these countries in International Atomic Energy Agency (IAEA) technical studies. The results showed that, out of 55 countries that participated in the study from the IAEA on individual dosimetric monitoring of interventional cardiology from the medical sector [5], only two were in Africa, and it had the lowest participation rate of 6% (two countries among 32 representing the total number of participating countries). No specific study produced by the IAEA for the field of diagnostic radiology and nuclear medicine was found.

In addition, several African countries (Benin, Burundi, Cape Verde, Central African Republic, Comoros, Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Guinea, Guinea-Bissau, Lesotho, Liberia, Malawi, Rwanda, Chad, Togo) [28] do not yet have a dosimetry service functional in their country, despite the steps taken by the Mission Radiation Protection Advisory Team, IAEA, since 1984 [29]. However, the countries that do have this may not publish the results of their surveillance. During the IAEA meeting in 2017 in Africa as part of Strengthening National Capabilities on Occupational Radiation Protection, 21 out of 28 participating countries had a dosimetric monitoring program [28]. The IAEA would have declared that only 17 countries participated in an intercomparison study [28]. This would confirm the thesis of the UNSCEAR 2017 report of the low participation of African countries in the studies [1].

The requested dose limit for an effective dose is 20 mSv per year on average over 5 consecutive years (100 mSv in 5 years) and 50 mSv in one year [30]. A wide range of data has been produced by the different articles that have been selected. However, as part of our study, we also compared the mean annual effective doses between medical practices on the one hand and between disciplines on the other hand. In medical sector workers in a study carried out by Farai and Obed, the OEW have received a mean annual effective dose above the 1/3 of 20 mSv annual dose limit requested. However, in three articles some extreme values are above the annual requested dose limit [7, 14, 26]. There is the case of one OEW from study carried out in Burkina Faso in 1990 by Yakoro *et al* [7] where the value is 42.84 mSv in two months' monitoring. The reason advanced by the authors is the improper location of the said dosimeter. This is the same reason provided by other authors.

In all height articles (table 2), the diagnostic radiology group had the lowest values and for seven articles in table 3, the medical sectors presents the lowest values of mean annual effective doses, except for the study by Farai and Obed [18]. We also found, when a comparison was made between the mean of the annual effective doses inside the medical specialities (diagnostic radiology, nuclear medicine and radiotherapy), diagnostic radiology was favoured, presenting the low annual effective dose means. However, we have observed in this study between different countries, the mean annual effective doses ranged from 0,07 to 4.37 mSv (table 2), between 2011 and 2007, at Burkina Faso and Nigeria respectively, for the diagnostic radiology group. This difference observed from one country to another can be explained by the fact that organisational characteristics of medical fields can be different. Improvement of practices and devices over time can influence exposure time. That is the reason why the mean annual effective doses has decreased during the period from 2007 to 2011 between Burkina Faso [8] and Nigeria [23]. However, we observe that in the year 2007, at the level of the diagnostic radiology sector, several countries presented the highest annual dose mean values [12, 15, 23]. This is for the same reason that between 1990 and 1999, and 2008 and 2009 for studies carried out in Nigeria [18] and Ghana [13] respectively, there is a decreasing considerable of mean annual effective doses. The same trends are observed through the studies performed by Bayou *et al* [10] in Ethiopia and Gordon *et al* [11] in Ghana, where the mean annual effective doses decrease from 4.51 to 0.57 mSv between 1988 and 2011, respectively. However, we note the heterogeneity of mean annual effective doses for the same year where the measures were carried out between different countries, in medical sectors. The types of device (high or low dose rate) or radiation protection systems in place can explain this heterogeneity. The same conclusion on improvement of practices can be drawn regarding the comparative study intra-countries of the annual effective mean doses for the medical sector between Gordon and Adjei's studies, where the doses decrease from 0.57 to 0.44 mSv between 2002 and 2009 in Ghana. In Nigeria, Farai and Ogundare's studies show a decrease in the annual mean effective doses from 8.20 to 3.70 mSv between 1990 and 2001. In contrast to these two countries, the studies carried out in Burkina Faso show an opposite trend; from 2007 to 2011, the dose increased by <0.10 to 0.47 mSv according to studies by Yakoro and Tapsoba. This situation is certainly due to a growth in radiological procedures performed on the same devices in recent years.

5. Conclusion

This study showed that few countries in Africa publish the results of their dosimetric monitoring. It also shows that the doses recorded are sometimes relatively high, hence the need to encourage systematic dosimetric monitoring of all exposed workers for better monitoring of their state of health.

The paucity of international publications of dosimetric monitoring data in African countries does not reveal the manifold efforts made by them to optimise the protection of workers and the public. However, several countries have shown, through published studies, an improvement in occupational radiation protection .

Acknowledgments

This work was supported by the Division for Africa, Department of Technical Cooperation of International Atomic Energy Agency. We especially thank Catherine Luccioni and Olivier Laurent for their involvement in reading and revising the manuscript. We are also grateful to Imène Mansouri and Françoise Terrier for their unfailing support and advice.

Conflicts of interest

The authors declare that there is no conflict of interest.

ORCID iDs

Arnaud A Gbetchedji https://orcid.org/0000-0002-9100-0166
Rodrigue S Allodji https://orcid.org/0000-0002-1895-8415

References

[1] UNSCEAR 2017 *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation* (New York: United Nations)
[2] Dauda A M, Ozoh J O and Towobola O A 2019 Medical doctors' awareness of radiation exposure in diagnostic radiology investigations in a South African academic institution *South Afr. J. Radiol.* **23** a1707
[3] Wang J X, Zhang L A, Li B X, Zhao Y C, Wang Z Q, Zhang J Y and Aoyama T 2002 Cancer incidence and risk estimation among medical x-ray workers in China, 1950–1995 *Health Phys.* **82** 455–66
[4] International Atomic Energy Agency 2014a *The Information System on Occupational Exposure in Medicine, Industry and Research (ISEMIR): Industrial Radiography* (Vienna: IAEA)

[5] International Atomic Energy Agency 2014b *The Information System on Occupational Exposure in Medicine, Industry, and Research (ISEMIR): interventional cardiology* (Vienna: IAEA)
[6] Moher D, Liberati A, Tetzlaff J and Altman D G 2009 Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement *Ann. Intern. Med.* **151** 7
[7] Tapsoba T L, Ouattara F, Ouédraogo S, Sanon H, Yanaba D H and Gansonré V 2012 État du suivi dosimétrique des travailleurs dans les services de radiologie de la ville de Ouagadougou *Médecine Nucléaire* **36** 539–44
[8] Yakoro A, Ouédraogo N and Traoré S 2010 First assessment of individual monitoring of medical workers occupationally exposed to ionizing radiation in Burkina Faso (Vienna: IAEA) 7
[9] Alramlawi S A, Alsaqr A S, Zayat D M A and Galal M 2015 Assessing the occupational radiation doses for medical workers at Cairo university hospital based on job categories *Arab J. Nucl. Sci. Appl.* **48** 40–3
[10] Bayou T 1991 Levels of doses to radiological workers in Ethiopia: 1977-1988 *Ethiop. Med. J.* **29** 119–26
[11] Gordon S W, Schandorf C and Yeboah J 2011 Optimization of radiation protection for the control of occupational exposure in Ghana *Radiat. Prot. Dosim.* **147** 386–93
[12] Hasford F, Owusu-Banahene J, Amoako J K, Otoo F, Darko E O, Emi-Reynolds G, Yeboah J, Arwui C C and Adu S 2012 Assessment of annual whole-body occupational radiation exposure in medical practice in Ghana (2000-09) *Radiat. Prot. Dosim.* **149** 431–7
[13] Adjei D, Darko E O, Schandorf C, Owusu-Manteaw P and Akrobortu E 2012 Personal dose analysis of TLD glow curve data from individual monitoring records *Radiat. Prot. Dosim.* **152** 273–8
[14] Osei E K 1997 Occupational radiation exposure in Ghana *Radiat. Prot. Dosim.* **71** 207–14
[15] Korir G K, Wambani J S and Korir I K 2011 Estimation of annual occupational effective doses from external ionising radiation at medical institutions in Kenya *South Afr. J. Radiol.* **15** 116
[16] Andriambololona R, Ratovonjanahary J F, Randriantsizafy R D, Rakotoson E and Razafindrabe R L 2002 Thermoluminescence external personnel monitoring of workers in diagnostic radiology in Madagascar *Hep-Mad '01 Proc. 1st Madagascar Int. Conf. High-Energy Physics (Antananarivo, Madagascar: World scientific)* pp 13–15
[17] Chinangwa G, Amoako J K and Fletcher J J 2018 Investigation of the status of occupational radiation protection in Malawian hospital *Malawi Med. J.* **30** 22
[18] Farai P I and Obed I R 2001 Occupational radiation protection dosimetry in Nigeria *Radiat. Prot. Dosim.* **95** 53–58
[19] Ogundare F O and Balogun F A 2003 Whole-body doses of occupationally exposed female workers in Nigeria (1999–2001) *J. Radiol. Prot.* **23** 201–8
[20] Okeji M, Anakwue A and Agwuna K 2010 Radiation exposure from diagnostic radiography: an assessment of x-ray beam collimation practice in some Nigerian hospitals *Internet J. Med. Update – Ejournal.* **5** 31–33
[21] Eze K, Marchie T, Eze T, Nzotta C and Okegbunam B 2011 The state of occupational radiation protection and monitoring in public and private x-ray facilities in Edo state, Nigeria *Niger. J. Clin. Pract.* **14** 308
[22] Ogundare F O and Balogun F A 2003 Analysis of occupational doses of workers on the dose registry of the federal radiation protection service in 2000 and 2001 *Radiat. Prot. Dosim.* **103** 57–62
[23] Nzotta C C and Chiaghanam N O 2010 Occupational radiation dose to x-ray workers in radiological units in South Eastern Nigeria *Afr. J. Med. Phy. Biomed. Eng. & Sc.* **2** 64–6
[24] Ahmed N A, Nayl A I and Suliman I I 2012 Equipment performance and radiation protection status in x-ray fluoroscopy units in Sudan *Radiat. Prot. Dosim.* **148** 174–80
[25] Muhogora W E *et al* 2013 Occupational radiation exposure in Tanzania (1996-2010): status and trends *Radiat. Prot. Dosim.* **153** 403–10
[26] Muhogora W E, Nyanda A M, Ngaile J E and Lema U S 1997 Occupational dose trends in Tanzania (Vienna: IAEA) **7** 105–11
[27] International Atomic Energy Agency and International Labour Office 2018 Occupational radiation protection: general safety guide (Vienna: IAEA)
[28] IAEA 2016 *The Role of Dosimetry in Protecting Workers Exposed to Ionizing Radiation* (Vienna: IAEA)
[29] International Atomic Energy Agency 1989 *IAEA Bulletin 1989.pdf*
[30] International Atomic Energy Agency A 2016 *Radiation Protection and Safety of Radiation Sources: Basic International Safety Standards* (Vienna: IAEA)