DEVICES FOR SECURITY CONTROL OF BORDERS EMITTING IONIZING RADIATION IN TOGO: INVENTORY AND IMPLEMENTATION OF RADIATION PROTECTION MEASURES FOR WORKERS

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Abstract. The purpose of this study is to assess the implementation of radiation protection measures for workers involved in the use of security control devices emitting ionizing radiation on Togo's official borders. This work is a descriptive cross-sectional study conducted from July 10 to October 9, 2019, involving all Togolese borders equipped with security control devices emitting ionizing radiation. The following parameters were studied: technical infrastructure, personnel and compliance with radiation protection measures. A total of 43 security control systems were identified: 69.7 % at air borders, 16.3 % at land borders, and 14 % at maritime borders. The systems included 30 baggage scanners, 6 body scanners, and 7 container scanners. Apart from one gamma-emitting container scanner, the other scanners (97.7 %) emitted X-rays. There were 228 workers involved, mostly operators (61.8 %). The devices were located in a closed enclosure in 76.7 % of cases, including 48.5 % in an area of less than 400 m². Pictograms were present in 7 % of the locations, light signals in 88.4 %, and ground markings in 14 %. There were 42 dosimeters, available at the Autonomous harbor of Lomé and Lomé International Airport. Only 7.5 % of workers had a medical record. Security control devices emitting ionizing radiation at Togo's borders did not always comply with standards, and the compliance with radiation protection measures for workers was unsatisfactory.

Key words: Ionizing radiation, industrial radiology, borders, radiation protection, Togo.

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INTRODUCTION

Ionizing radiation has many applications in medicine, industry, and research [4]. In industry, ionizing radiation devices, produced by X-ray generators or radioactive sources, are used for security control purposes at land, sea and air borders. These devices include body scanners, baggage scanners and container or vehicle scanners, installed in the form of gantries, tunnels or enclosures [14, 16]. Due to technological advances, these devices emit low doses of ionizing radiation. Despite the low dose emitted, their use requires strict supervision in accordance with radiation protection rules. Indeed, even low doses of ionizing radiation can cause biological effects, in particular stochastic effects on the body [7, 15].

In Africa, particularly in Benin and Togo, few studies have been published concerning the implementation of radioprotection rules linked to the use of devices emitting ionizing radiation, unlike medical studies [1, 11, 18]. This situation raises questions about the level of application of radiation protection rules for control devices used for several years at the continent's air, sea, and land borders.

This study, undertaken to fill this gap, aims to assess the implementation of radiation protection measures for workers involved in the use of security control devices emitting ionizing radiation on the air, maritime and land borders of Africa, particularly Togo.

MATERIALS AND METHODS

The study took place at the air, sea and land borders of Togo with devices emitting ionizing radiation, notably the Lomé International Airport (the country's capital), the Niamtougou Airport (450 km north of the capital), the Lomé Autonomous harbor and the Noépé Joint Border Post (30 km west of Lomé).

This is a cross-sectional study with a descriptive aim carried out over three (03) months from July 10 to October 9, 2019, and concerned ionizing radiation devices at these borders. The parameters analyzed concerned the inventory of technical infrastructures, the census of human resources and the implementation of radiation protection measures for workers. The data were analyzed with Microsoft Excel 2016 (version 16.0, 2015) software.

RESULTS

The first part provides an inventory of ionizing radiation control devices and available human resources, whereas the second part addresses the implementation of radiation protection measures.

INVENTORY OF IONIZING RADIATION SECURITY CONTROL DEVICES AND HUMAN RESOURCES

Forty-three (43) security control devices were identified at Togo's borders, 69.7 % of which were found at the air borders (Fig. 1).

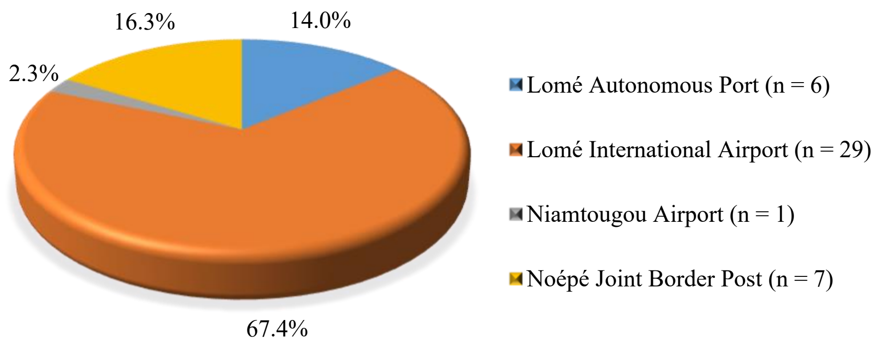

Fig. 1. Breakdown of ionizing radiation security screening devices by type of border.

The 43 security control devices on the different borders were dominated by baggage scanners, numbering 30 (*i.e.* 69.8 %), followed by container scanners, numbering 7 (*i.e.* 16.3 %) and transmission scanners body, 6 in number, *i.e.* 13.9 % (Table 1).

Table 1

Types of security control devices at different borders

	LIA		NA		LAH		NJBP		**Total**	
	n	%	n	%	n	%	n	%	**n**	**%**
Baggage scanner	27	90.0	1	3.3	0	0.0	2	6.7	**30**	**69.8**
Container scanner	0	0.0	0	0.0	6	85.7	1	14.3	**7**	**16.3**
Body scanner	2	33.3	0	0.0	0	0.0	4	66.7	**6**	**13.9**
Total (n = 43)	**29**	**67.4**	**01**	**2.4**	**6**	**13.9**	**7**	**16.3**	**43**	**100.0**

LIA: Lomé International Airport, NA: Niamtougou Airport, LAH: Lomé Autonomous Harbor, NJBP: Noépé Joint Border Post.

Forty-two of the 43 security screening devices identified (97.7 %) emitted X-rays. Only one security screening device emitted gamma rays. It was a container scanner installed at the Autonomous Harbor of Lomé.

The majority of X-ray machines (71.4 %) had an operating voltage of 160 kV and an operating charge of 70 mAs (Table 2). All X-ray machines had automatic settings.

Table 2

Operating voltage and charge of X-ray security screening devices

	140 kV/60 mAs		160 kV/70 mAs		400 kV/700 mAs		**Total**	
	n	%	n	%	n	%	**n**	**%**
Baggage scanner	0	0	30	100	0	0	**30**	**71.4**
Container scanner	0	0	0	0	6	100.0	**6**	**14.3**
Body scanner	6	100.0	0	0	0	0	**6**	**14.3**
Total (n = 42)	**6**	**14.3**	**30**	**71.4**	**6**	**14.3**	**42**	**100.0**

The majority of ionizing radiation security control devices (88.1 %) were installed after 2013 (Table 3).

Table 3

Year of installation of ionizing radiation security control devices

	Before 2009		2009 to 2013		2013 to 2018		**Total**	
	n	%	n	%	n	%	**n**	**%**
Baggage scanner	0	0.0	0	0.0	32	100.0	**32**	**71.4**
Container scanner	1	14.3	5	71.4	1	14.3	**7**	**16.3**
Body scanner	0	0.0	0	0.0	4	100.0	**4**	**9.3**
Total (n = 43)	**1**	**2.3**	**5**	**11.6**	**37**	**88.1**	**42**	**100**

Regarding human resources, 228 agents were counted at the borders using ionizing radiation security control devices, with a clear predominance of male subjects, numbering 196 (*i.e.* 86 %) The majority of workers (68.8 %) were recorded at the air borders. Operators were the most represented professional category (Table 4).

Table 4

Professional qualification of workers at different borders

	LIA		NA		LAH		NJBP		**Total**	
	n	%	n	%	n	%	n	%	**n**	**%**
Operators	84	36.8	4	1.8	44	19.3	9	4.0	**141**	**61.8**
Administrative staff	30	13.2	2	0.9	6	2.7	2	0.9	**40**	**17.6**
Cleaners	28	12.3	01	0.4	4	1.8	1	0.4	**34**	**14.9**
Maintenance technician	5	2.2	1	0.4	3	1.3	0	0.0	**9**	**4.0**
Quality expert	1	0.4	1	0.4	1	0.4	0	0.0	**3**	**1.3**
RPO	0	0.0	0	0.0	1	0.4	0	0.0	**1**	**0.4**
Total (n = 228)	**148**	**64.9**	**9**	**3.9**	**59**	**25.9**	**12**	**5.3**	**228**	**100**

LIA: Lomé International Airport, NA: Niamtougou Airport, LAH: Lomé Autonomous Harbor, NJBP: Noépé Joint Border Post, RPO: Radiation Protection Officer

IMPLEMENTATION OF RADIATION PROTECTION MEASURES

More than three-quarters of the ionizing radiation security screening devices were in closed enclosures and were mostly baggage scanners; a single container scanner was installed in a closed enclosure (Fig. 2).

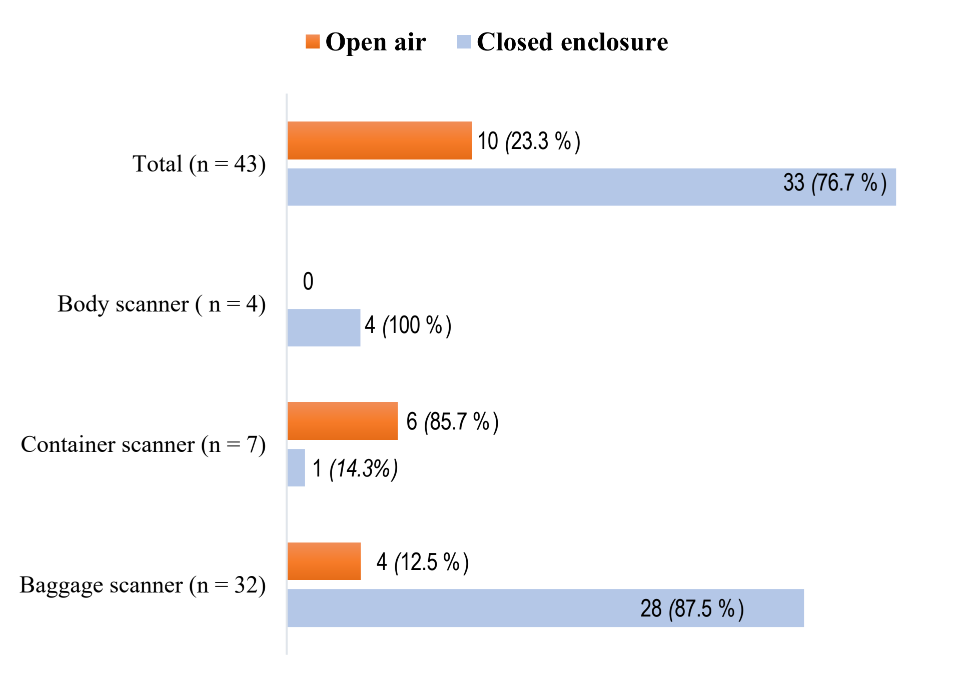

Fig. 2. Types of border security control device installations.

Nearly half (48.5 %) of the security control devices were installed in closed enclosures with areas of less than 400 m^2 (Table 5).

Table 5

Surface areas of closed enclosures housing ionizing radiation devices

	Baggage scanner		Container scanner		Body scanners*		**Total**	
Areas (in m^2)	N	%	n	%	n	%	**n**	**%**
≤ 400	12	75.0	0	0	4	25	**16**	**48.5**
[400, 800]	6	85.7	1	14.3	0	0	**7**	**21.2**
[800, 1200]	4	100.0	0	0	0	0	**4**	**12.1**
[1200, 2000]	4	100.0	0	0	0	0	**4**	**12.1**
≥ 2000	2	100.0	0	0	0	0	**2**	**06.1**
Total (n = 33)	**28**	**84.9**	**1**	**3.0**	**4**	**12.1**	**43**	**100**

* The body scanners were X-ray transmission scanners.

The doors of the enclosures were mainly made of wood and the walls were made of bricks or aluminum; neither the doors nor the walls were leaded (Table 6).

Table 6

Door panels and walls of closed enclosures housing ionizing radiation devices

	Door panels		Walls	
	n	%	n	%
Iron	31	94	0	0.0
Aluminum	1	3	17	51.5
Wood	1	3	0	0.0
Lead	0	0	0	0.0
Brick/Concrete	NA	NA	16	48.5
Total (n = 33)	**33**	**100**	**33**	**100.0**

NA: not applicable

The delimitation of controlled and monitored areas, the availability of a radiation protection program as well as light signals were effective in more than 80 % of ionizing radiation device installations; floor markings and pictograms were found in less than 15 % of installations (Fig. 3).

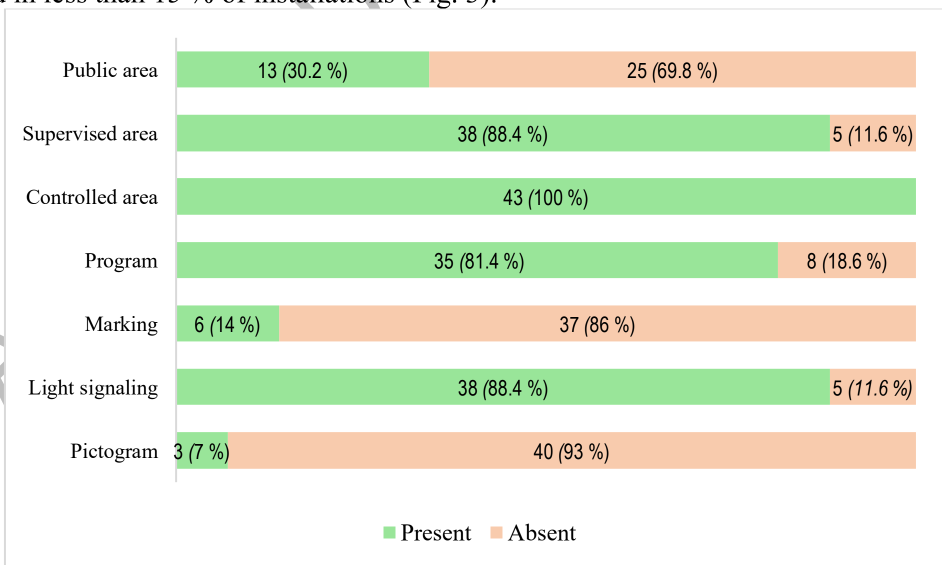

Fig. 3. Zoning, signage and radiation protection program.

Forty-four manipulators, *i.e*. 19.1 % of border workers using ionizing radiation devices, are classified and treated as A category workers. Only the employer of the Autonomous harbor of Lomé categorizes its staff. All operators of ionizing radiation border security control devices in Togo were all initially trained in radioscopic imaging and had certification adapted to professional practices.

The available dosimeters (42 for 228 agents, *i.e*. 18.4 %), were dominated by passive dosimeters (Table 7).

Table 7

Types of dosimeters at the borders

	LAH		LIA		NA		NJBP		**Total**	
	n	%	n	%	n	%	n	%	**n**	**%**
Passive dosimeter	32	59.6	5	0.0	0	0	0	0	**37**	**84.1**
Active dosimeter	4	80.0	1	20.0	0	0	0	0	**5**	**15.9**
Total (n = 42)	**36**	**85.7**	**6**	**14.3**	**6**	**0**	**0**	**0**	**42**	**100.0**

LIA: Lomé International Airport, NA: Lomé Autonomous Port, LAH: Lomé Autonomous Harbor, NJBP: Noépé Joint Border Post, RPO: Radiation Protection Officer

Only 17 workers out of the 228, or 7.5 % of the staff, had regular medical monitoring and had an individual medical file.

DISCUSSION

This study on the inventory of border security control devices emitting ionizing radiation and the implementation of radiation protection rules is the first of its kind in Togo. No other similar study has been reported in the literature, although several works on radiation protection in the medical field have been published in Togo and Benin [1, 11, 18]. This situation reflects a lack of attention paid by industrial players to the risks of ionizing radiation, in contrast to the medical sector where these risks are better recognized and managed.

The security checkpoints were located mainly at air, sea and land borders, with a significant concentration (67.4 %) at Lomé International Airport, a modern airport with heavy passenger traffic [8]. This concentration can be explained by the increase in terrorist threats since September, 11th, 2001, which has led to a tightening of security measures at airports [5].

Most of the devices inventoried were baggage and container scanners (93.1 %). This is due to the large flow of baggage and goods across borders and the new terrorist threats involving parcel bombs [13, 17].

Most of the ionizing radiation devices had a charge of 70 mAs and were mainly baggage scanners installed at Lomé International Airport. More than two thirds of the ionizing radiation devices had a voltage of 160 kV and only 9.3 % had a voltage of less than 160 kV. X-ray transmission body scanners operate under lower parameters (140 kV and 40 mAs) to minimize passengers' exposure to X-rays. X-ray transmission body scanners have the advantage of detecting even objects buried in the body, unlike X-ray backscatter body scanners, which only detect superficial objects in the clothing, at the cost of relatively higher irradiation [3, 10]. In modern airports, X-ray transmission body scanners operate at a lower voltage, as is the case in Canada where the Radiation Protection Committee recommends a voltage of 100 to 110 kV for X-ray transmission body scanners [3].

Radiation protection measures for the use of body scanners are becoming increasingly stringent, because unlike medical X-ray emitting devices, these security screening devices do not provide any health benefits for exposed travelers. The principle of dose optimization must be scrupulously observed. Passenger exposure is minimal, and there is no evidence that the low doses of radiation received during body scans cause health problems. However, repeated exposure increases the accumulation of radiation doses in the body. While no dose can be considered entirely safe from stochastic effects, such as cancers and genetic abnormalities, it is possible that the increased risk of cancer due to exposure to X-rays from security scanners is so small that it cannot be distinguished from the effects of natural radiation or the natural risk due to other factors [3, 12, 19].

As for baggage and container scanners, their use is a potential source of exposure for workers. When baggage scanners are in a closed enclosure with adequately shielded walls and doors, worker exposure remains very low, even below the limit set for the protection of the public [4]. Unfortunately, the walls and doors of the enclosures housing the scanners, identified in this study, were not shielded. In addition, almost a quarter (23.3 %) of the scanners were installed in the open air. Although the primary X-ray rays are directed at the baggage to be inspected, the secondary scattered radiation is a source of exposure for staff, passengers and the environment [6, 15].

Thirty-three scanner installations, *i.e*. 76.7 % of the country, had solid brick or concrete walls according to our study. The construction requirements for a room housing an X-ray tube operating at a voltage of less than 600 kV are set out in the French construction standard NF C 15-160 of 1975, revised in March 2011 [2]. In particular, this standard defines the minimum thicknesses of lead to be used to protect the premises adjoining the X-ray room. It also describes the safety devices to be installed, such as warning lights and emergency stops. Our study reported that 51.5 % of closed enclosures housing safety control devices in Togo were made of aluminum.

Only 19.1 % of workers were categorized by their employers. This low rate is linked to the fact that the employers of certain ionizing radiation safety checkpoints downplayed the importance of categorizing staff directly assigned to work using ionizing radiation. The purpose of categorizing workers is to define their optimum dosimetric and medical monitoring arrangements [7, 15, 19]. Dosimetric monitoring of workers was not optimal. Very few of the staff working on ionizing radiation devices had dosimetric monitoring. Even if exposure to ionizing radiation is minimal, all workers should have regular dosimetric monitoring. In our study, only 7.5 % of workers were subject to medical surveillance. Professional medical surveillance must be carried out for all workers likely to be exposed to ionizing radiation. This low rate of medical monitoring could be explained on the one hand by a lack of knowledge of the effects that the use of ionizing radiation could have on employees' health, and on the other hand by the lack of a competent authority to assess employees' medical intake. Dosimetric monitoring makes it possible to assess the level of exposure of workers and thus to take the appropriate precautions to prevent the regulatory exposure limit being reached [9]. It is compulsory that all exposed workers must be monitored to prevent potential stochastic effects such as cancers and genetic abnormalities.

CONCLUSION

This study revealed significant gaps in compliance with radiation protection standards and in the protection of workers at Togolese borders. Concerted efforts are needed to improve radiation protection infrastructure, strengthen dosimetric and medical monitoring of workers, and raise awareness among industrial stakeholders about the risks associated with ionizing radiation. The implementation of these measures will help to protect the health of workers and minimize the risks associated with the use of safety control devices.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: K.A. put the idea and the design of the study. K.A., G.D.H, A.B.K. had contributed to data collection and to the conception and design of the manuscript. Y.A.A, K.M.B. had contributed to the conception and design of the manuscript. All authors have been involved in drafting and revising the manuscript. All authors read and approved the final manuscript.

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REFERENCES

1. ADAMBOUNOU, K., A.M. ADIGO, Y.A. AGBOBLI, Evaluation de la mise en œuvre de la radioprotection des travailleurs exposés aux rayonnements ionisants en milieu médical au Togo, *J. Recherche Sci. Université Lomé,* 2017*,* **19**(2), 489–497.

2. ASSOCIATION FRANÇAISE DE NORMALISATION, *Normes françaises de construction NF C 15-160*, 2011, www.afnor.org, accessed May 10, 2024.
3. COMITE DE RADIOPROTECTION FEDERAL PROVINCIAL TERRITORIAL, *Guide de Radioprotection Concernant les Scanners Corporels de Sécurité a Transmission de Rayons X*, Canada, 2022.
4. COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, *L'homme et les rayonnements,* Maya Press, Paris, 2014.
5. COOSEMANS, T., Les dispositifs de sécurité avant et après les attentats du 11 septembre 2001, *Courrier hebdomadaire du CRISP,* 2002, **17**, 5–86.
6. INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection, ICRP publication 103, *Ann. ICRP,* 2007, **37(2–4)**, 1–332.
7. IMONET, C., H. MOTERIER, *Personne compétente en radioprotection. Principes de radioprotection-réglementation*, EDP Science, Paris, 2007.
8. KPEMOUA, P., *Trafics maritime, aérien et croissance économique au Togo,* ⟨hal-01874954⟩. https://hal.archives-ouvertes.fr/hal-01874954/, 2018, accessed on April 4, 2023.
9. MAHARAJ, H.P., Dispositifs à rayons X pour l'inspection des bagages – précautions à prendre- (Code de sécurité 29), ISBN: 0-660-94230-5; Catalogue n° H46-3/2-1993F; Canada, 1993.
10. METHA, P., SMITH-BINDMAN R., Airport Full Body Screening: What is the Risk? *Arch. Intern. Med., 2011,* **171**(12), 1112–1115.
11. SAVI DE TOVE, K.M., H. FACHINAN, F. GOUNONGBE F, Radioprotection en imagerie médicale dans les hôpitaux du nord Bénin, *J. Afr. Imag. Méd.,* 2020, **12**(3), 138–144.
12. SCIENTIFIC COMMITTEE ON EMERGING AND NEWLY IDENTIFIED HEALTH RISKS, *Health effects of security scanners for passenger screening (based on X-ray technology*), 2012, https://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_036.pdf, accessed June 22, 2024.
13. SUTTON, S.R., Alleviating the public's concerns about airport scanners: Radiation exposure and privacy, *Radiol. Technol.,* 2014, **86**, 104–109.
14. THOLEN, B., The changing border: developments and risks in border control management of Western countries, *Int. Rev. Adm. Sci,* 2010, **76**(2), 259–278.
15. VAILLANT, L., T. SCHNEIDER, Evaluation du détriment associé à l'exposition aux faibles doses et faibles débits de dose dans le système de radioprotection, *Environ Risque Sante,* 2012, **11,** 149–159.
16. VOGEL, H., X-ray control of borders and of internal security, *JBR–BTR,* 2010, **93,** 210–214.
17. WETTER, O.E., Imaging in airport security: Past, present, future, and the link to forensic and clinical radiology, *JOFRI,* 2013, **1**, 152–160.
18. YEKPE AHOUANSOU, P., S. ADJADOHOUN, C. LEGONOU, État des lieux de la radioprotection du personnel de services d'imagerie médicale du sud Benin en 2019, *J. Afr. Imag. Méd.,* 2020, **12**(4), 213–219.
19. ZANOTTI-FREGONAR, P., Radiation risk from airport X-ray backscatter scanners: Should we fear the microsievert? *Radiology,* 2011, **261**(1), 330–331.