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Note

Natural Radiation Survey in the Uranium and Thorium Bearing Regions of Cameroon

Saïdou[1, 2]*, Shinji Tokonami[3] and Ele Abiama Patrice[1]

[1]*Nuclear Technology Section, Institute of Geological and Mining Research, P.O. Box 4110 Yaoundé, Cameroon*
[2]*Nuclear Physics Laboratory, Faculty of Science, University of Yaoundé I, P.O. Box 812 Yaoundé, Cameroon*
[3]*Department of Radiation Physics, Institute of Radiation Emergency Medicine, Hirosaki University, Hirosaki City, Aomori 036-8564, Japan*

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The present paper summarizes the findings of the preliminary studies carried out in the uranium and thorium bearing regions of Cameroon. It also underlines future prospects for extensive measurements of natural radioactivity for a better radiation dose assessment to the public. After soil and foodstuff sampling, α - and γ - spectrometry were used to determine activity concentrations of natural radionuclides in these samples. Electret Ionization Chambers (EPERM) were deployed in Poli and Lolodorf to measure radon in houses. 20% of dwellings in Poli and 50% in Lolodorf have radon concentrations higher than 300 Bq m^{-3}. Passive integrated radon–thoron discriminative detectors (RADUET) were used only in the high natural radiation areas of Lolodorf to measure simultaneously indoor radon and thoron. 30% of houses have thoron concentrations above 300 Bq m^{-3}. Effective dose to the public and annual excess risk for radon-induced lung cancer of each of the studied regions are higher than the world average values. Difference is mainly attributed to indoor radon exposure. Taking into account of the limited number of analyzed samples and surveyed dwellings, some conclusions should cautiously be considered.

Key words: uranium, thorium, radon, thoron, effective dose, radiation risk

1. Introduction

Since ten years there have been many surveys to determine environmental natural radiation levels in Cameroon, particularly in the uranium and thorium bearing regions. Most of them are carried out in the uranium and thorium regions of Poli and Lolodorf as shown in Figure 1. These studies started by collecting soil, foodstuff and water samples and by deploying Electret Ionization Chambers (EIC) (commercially E-PERM) and passive integrated radon–thoron discriminative detectors (commercially RADUET) in dwellings before determining activity concentrations of natural occurring radionuclides. This determination is followed by assessing inhalation, ingestion and external radiation dose helpful to perform radiation risk assessment. RADUET detectors are only used in the high natural radiation areas of Lolodorf for simultaneous measurements of radon (^{222}Rn) and thoron (^{220}Rn) in houses.

Saïdou *et al.*[1] reported radioactivity measurements and total dose assessment in the uranium region of Poli in Northern Cameroon. Authors concluded that most of the effective dose is attributed to the intake

*Saïdou: Nuclear Technology Section, Institute of Geological and Mining Research, P.O. Box 4110 Yaoundé, Cameroon
E-mail: saidous2002@yahoo.fr

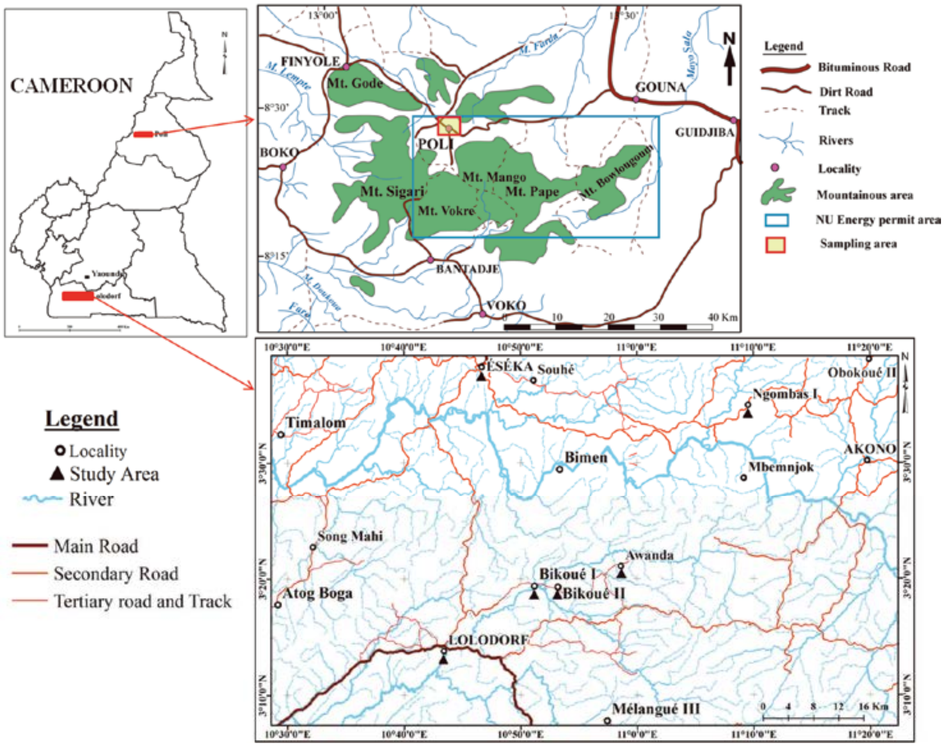

Fig. 1. Location of the uranium and thorium regions of Poli and Lolodorf in the Northeastern and Southwestern parts of Cameroon[1, 6].

of radon and high levels of ^{210}Po and ^{210}Pb contained in vegetables, food items which constitute an important part of the diet in Northern Cameroon. Indoor radon measurements were extended in the towns of Poli and Lolodorf located in the uranium regions[2] highlighting high levels of indoor radon. Saïdou *et al.*[3] reported a study on radiological exposure of members of the public in the oil bearing Bakassi Peninsula. Results showed high exposure of members of the public to natural radiations. Elevated indoor radon concentrations due to building construction habits (building materials, ventilation, and type of floor) were observed and high exposure to ^{210}Po due to the dietary habits of the local population, mainly consisting of seafood was found out. Ele Abiama *et al.*[4, 5] studied the high background radiation and internal/external radiation exposure to the public of the uranium region of Lolodorf in Southwestern Cameroon. This study evidenced high radioactivity in soil and showed that computed doses from intake of natural occurring radionuclides are significantly high. Saïdou *et al.*[6] showed that radon and thoron have on average the same contribution in terms of inhalation dose. They concluded that thoron cannot be neglected when assessing radiation dose in the thorium bearing region of Lolodorf.

The present paper summarizes the findings of the above preliminary studies performed in the uranium and thorium bearing regions of Cameroon. It also underlines future prospects for extensive measurements of natural radioactivity for a better radiation dose assessment to the public before hypothetic epidemiological study in case high radiation doses were observed.

2. Current status of the environmental radiation survey

Study areas

Since 1950 many geological studies for the prospecting and assessment of the uranium potential of the Kitongo deposit, situated in the region of Poli in northern Cameroon, have been conducted[7, 8]. They concluded that the metasomatic uranium deposit of Kitongo could contain a historic resource of 10,000 tU_3O_8 at a grade of 0.1%. Additional ongoing revaluation could lead to a resource well greater than 13,000 tU_3O_8. The International Atomic Energy Agency through the World Distribution of Uranium Deposits (UDEPA) software gives a value ranging between 10,000-25,000 tU_3O_8[9, 10]. Other geological studies were carried out from 1978 to 1985 in the southwestern region of Cameroon[11]. These studies evidenced the occurrence of the uranium deposit of Lolodorf that could contain thousands of tU_3O_8 at a grade ranging from 0.1% to 1%.

Sampling and measurements

Twenty (20) soil and various foodstuff samples (flour

Table 1. Average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in 20 and 15 soil samples collected respectively in the uranium and thorium regions of Poli and Lolodorf[1, 4]. These concentrations are compared to the world average value given by UNSCEAR[14]

Study area	Radionuclide	Mean activity (Bq kg^{-1})	Range (Bq kg^{-1})
Poli	^{238}U	23.6	12.4 - 57
	^{232}Th	28	14.6 - 58
	^{40}K	506	112 - 1124
Lolodorf	^{238}U	130	60 - 270
	^{232}Th	390	100 - 700
	^{40}K	850	370 - 1530
World (UNSCEAR)	^{238}U	33	16 - 110
	^{232}Th	45	11 - 64
	^{40}K	420	140 - 850

Table 2. Activity concentrations of some natural radionuclides in foodstuffs sampled in the uranium and thorium regions of Poli and Lolodorf[1, 5]. Each activity concentration is averaged from three different samples of a same type of foodstuff. These concentrations are compared to the world average value given by UNSCEAR[14]

Study area	Radionuclide	Activity concentration range (Bq kg^{-1})
Poli	^{226}Ra	0.04 - 2.3
	^{210}Pb	1.9 - 29.7
	^{210}Po	0.24 - 28
	^{40}K	94 - 677
Lolodorf	^{226}Ra	0.04 - 11
	^{228}Ra	0.2 - 13
	^{40}K	48 - 234

of maize, groundnut paste, beef, baobab leaves, and beans) were collected in the uranium bearing Poli. Fifteen (15) soil and various foodstuff samples (plantain, groundnuts, cassava leaves and roots, cocoyam) were collected in the uranium and thorium bearing region of Lolodorf. Alpha spectrometry using Passivated Implanted Planar Silicon (PIPS) detectors in a Canberra Alpha Analyst spectrometer and gamma spectrometry using a Canberra p-type Hyper Pure Germanium (HPGe) well detector (GCW4523) were used to determine activity concentrations in samples collected in Poli. Canberra p-type HPGe detector (GR3019) was used for samples collected in Lolodorf. E-PERM detectors were deployed for three months in 50 dwellings of Lolodorf and 103 dwellings of Poli to measure radon. They were placed relatively far from doors and windows at 1 m above ground. RADUET detectors developed at the National Institute of Radiological Sciences (NIRS) in Japan were deployed in 70 houses in the high natural radiation areas of Lolodorf (Bikoue I, Bikoue II, Ngombas) to measure simultaneously radon and thoron. They were placed at a height of 1–2 m and 20 cm from the wall in 70 dwellings for two months. More details about sampling, material and methods are given in the references[1-6, 12, 13].

Radioactivity in soil, foodstuff and airborne

Table 1 shows mean activity concentrations found in soil samples collected respectively in the uranium and thorium bearing regions of Poli and Loldorf. These values are compared to the world average values estimated by UNSCEAR from data stemming from nationwide radiation surveys around the world[14]: 33 Bq kg^{-1}, 45 Bq kg^{-1} and 420 Bq kg^{-1} respectively for ^{238}U, ^{232}Th and ^{40}K. Natural radiation level in soil collected in the uranium region of Poli is low compared to UNSCEAR values[1]. It should be noted that the uranium deposits are deeply located. In the uranium and thorium region of Lolodorf, radioactivity levels are higher than the world average values[4]. High activity concentrations of ^{232}Th are observed with maximum value of 270 Bq kg^{-1} for ^{238}U and 700 Bq kg^{-1} for ^{232}Th. The uranium and thorium deposits are near surface located.

The maximum activity concentration of ^{210}Pb and ^{210}Po, as displayed in Table 2, is respectively 29.7 Bq kg^{-1} and 28 Bq kg^{-1} in baobab leaves collected in Poli and well consumed by local populations. This high level of ^{210}Pb

Table 3. Mean concentrations of indoor radon in the uranium and thorium bearing regions of Poli and Lolodorf compared to the world average value given by UNSCEAR[14)]

Exposure area	Mean concentration (Bq m^{-3})
Poli	294
Lolodorf	735
World	40

Table 4. Arithmetic, geometric and median concentrations of indoor radon and thoron in the high natural radiation areas of Lolodorf[6)]

Radon	Arithmetic mean (Bq m^{-3})	Geometric mean (Bq m^{-3})	Median (Bq m^{-3})
^{222}Rn	92	72	66
^{220}Rn	260	213	242

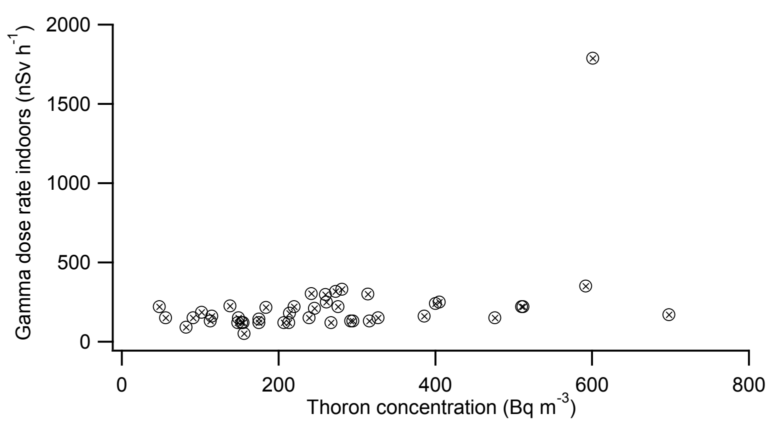

Fig. 2. Gamma dose rate indoors versus thoron concentration in the high natural radiation areas of Bikoue and Ngombas[6)].

and ^{210}Po can be explained by the atmospheric deposition of radon daughters in the uranium bearing region of Poli[1)]. These radionuclides are not yet measured in the uranium and thorium region of Lolodorf. ^{40}K activity concentrations in foodstuffs are relatively high but no health effect expected due to the homeostatic regulation of potassium in the body. More details about types of foodstuffs and the diet model of the study areas are given in the references[1, 5)].

As displayed in Table 3, the average concentrations of indoor radon in Poli and Lolodorf are respectively 294 Bq m^{-3} and 735 Bq m^{-3}. 20% of houses in the town of Poli and 50% in the town of Lolodorf have indoor radon above the reference value of 300 Bq m^{-3}. These high concentrations of radon could be explained by the building construction habits (building materials, ventilation, and type of floor) of the local populations[2)].

By using the passive integrated radon–thoron discriminative detectors, as displayed in Table 4 arithmetic, geometric and median concentrations are respectively 92 Bq m^{-3}, 72 Bq m^{-3}, and 66 Bq m^{-3} for radon and 260 Bq m^{-3}, 213 Bq m^{-3}, and 242 Bq m^{-3} for thoron. The maximum radon and thoron concentrations are respectively 937 Bq m^{-3} and 700 Bq m^{-3} with corresponding houses ventilated[6)]. As shown in Figure 2, the maximum gamma dose rate indoors is 1.8 μSv h^{-1}. 30% of houses have thoron concentrations above 300 Bq m^{-3} against 2 % for radon. It should be noted that the reference level of 300 Bq m^{-3} is only valid for radon. No reference value is yet defined for thoron. Floor type of houses is ground and walls are totally made using soil rich in thorium collected from the same areas. UNSCEAR gives conversion factors of 9 nSv (Bq h m^{-3})$^{-1}$ for radon and 40 nSv (Bq h m^{-3})$^{-1}$ for thoron and equilibrium factors of 0.4 for radon and 0.02 for thoron for inhalation dose calculations[6, 14)].

Because of its short half life, thoron concentrations decrease rapidly with distance from its main sources in a room such as the walls and floor. Because of this in the experimental work described in the present study, where only a single thoron gas measurement was made in each room, the thoron concentration value obtained cannot, in any way, be considered as representative of the room

Table 5. Effective dose components of the uranium regions of Poli and Lolodorf compared to the world average values as given by UNSCEAR[14]. Cosmic rays radiation and thoron contribution are not taken into account in dose calculations. The occupancy factor is 0.6

Effective dose (mSv yr^{-1})	Poli	Lolodorf	World
External dose	0.6	0.7	0.5
Ingestion dose	2.2	0.7	0.3
Inhalation dose	3.1	4	1
Total dose	5.9	5.4	1.8

Table 6. Annual excess risk due to indoor radon exposure in the uranium and thorium bearing regions of Poli and Lolodorf compared to the world average value[16]. This calculation takes into account of the contribution of thoron for Lolodorf

Exposure area	Radiation risk (%)
Poli	0.027
Lolodorf	0.033
World	0.007

in which it was made. In addition no thoron progeny measurements were made which are necessary to obtain a value of the equilibrium factor. Therefore the quoted UNSCEAR dose conversion factor for thoron and its progeny could not be used and only the dose conversion factor for radon could be used. It should, however, be noted that in ongoing work in this project thoron progeny concentrations are being made. This should permit meaningful thoron progeny doses to be estimated.

Mean inhalation dose for adult age due to radon using RADUET detectors is 1.74 mSv yr^{-1}. Its value using EPERM detectors is 6.2 mSv yr^{-1}. Thus the average inhalation dose for the uranium and thorium bearing region of Lolodorf is 4 mSv yr^{-1} as displayed in Table 5. It should be noted that the study areas are different although belonging to the uranium and thorium bearing region of Lolodorf. Moreover radon measurements using Electret Ionization Chambers (EIC) are influenced by parameters as humidity, the presence of thoron, etc. Sorimachi *et al.*[15] studied how the presence of humidity, ambient aerosols and thoron influences the detection responses of an EIC. The humidity in the region of Lolodorf is higher than 80%. More details about dose calculations for adult age are given in the reference[6, 16].

For dose calculations thoron is not considered for the studied areas. Extensive indoor radon, thoron and thoron progeny measurements are being made in the uranium and thorium bearing regions of Poli and Lolodorf making the contribution of thoron to be considered in dose calculations. In Table 5 effective dose values are high compared to the world average value. Difference is explained by the dietary and building construction habits of the population.

As shown in Table 6, annual excess risk for radon-induced lung cancer in Poli and Lolodorf is respectively 27/100 000 and 33/100 000[16]. In Central Africa countries the age-adjusted death rate for lung cancer is 2.7/100 000 persons/year in 2008[17]. Based on the annual excess risk values, we can still make the point that a comparison of local radiological risks with national cancer incidence data allows to conclude that the local risks are elevated but not necessarily representative of the country as a whole. More details on risk assessment are given in the reference[16]. Due to the limited number of analyzed samples and surveyed dwellings, conclusions of the present study should cautiously be considered.

3. Future prospects

Extensive radioactivity measurements including radon and thoron are being made in the uranium and thorium bearing regions of Poli and Lolodorf. Special attention should be paid to thoron in dose calculations to avoid inhalation dose underestimate. In case high radiation doses are observed, epidemiological work should be planned. Preliminary natural radiation survey is previously carried out in the oil and gold mining areas of Cameroon. Results confirm the importance to extend environmental natural radiation survey at the nationwide level. Extensive radon and thoron measurements in the uranium and thorium bearing regions of Poli, Lolodorf and nationwide are required for better definition of reference levels for radon and thoron in Cameroon and for better dose assessment.

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Disclosure

The authors declare that they have no conflict of interest.

References

1. Saïdou, et al. (2011) Natural radioactivity measurements and dose calculations to the public: case of the uranium-bearing region of Poli in Cameroon. Radiat Meas 46:254–260.
2. Saïdou, et al. (2014) Indoor radon measurements in the uranium regions of Poli and Lolodorf, Cameroon. J Environ Radioact 136:36–40.
3. Saïdou, et al. (2015) Natural Radiation Exposure to the Public in the oil bearing Bakassi Peninsula, Cameroon. Radioprotection 50:35–41.
4. Ele Abiama P, et al. (2010) High background radiation investigated by gamma spectrometry of the soil in the southwestern region of Cameroon. J Environ Radioact 101:739–743.
5. Ele Abiama P, et al. (2012) Annual intakes of ^{226}Ra, ^{228}Ra and ^{40}K in staple foodstuffs from a high background radiation area in the southwest region of Cameroon. J Environ Radioact 110:59–63.
6. Saïdou, et al. (2015) Radon-thoron discriminative measurements in the high natural radiation areas of Southwestern Cameroon. J Environ Radioact 150:242–246.
7. Meadon HM (2006) Nuclear Energy Corporation, Geological review of the Kitongo uranium deposit, Poli area, Northern Cameroon.
8. Thoste V (1985) Uranium exploration in North Cameroon, region of Poli. Project definition, execution and results, Jan. 1982-Dec. 1984. Unpublished report, Hannover, Germany.
9. International Atomic Energy Agency (2009) World distribution of uranium deposits (UDEPA) with uranium deposit classification. IAEA TECDOC 1689, Vienna, Austria.
10. Saïdou (2012) Uranium: from occurrence, mining, human exposure to remediation. Chapter 10. Chemistry Research and Applications, Nuclear Materials and Disaster Research. ISBN 978-1-62081-207-5, Nova publishers, New York, USA.
11. Maurizot P, et al. (1986) Etude et prospection minière du Sud-Ouest Cameroun. Synthèse des travaux du BGRM, de 1978 à 1985.
12. Saïdou, et al. (2007) Calibration of an HPGe detector and self-attenuation correction for ^{210}Pb: Verification by alpha spectrometry of ^{210}Po in environmental samples. Nucl Instr Meth A 578:515-522.
13. Saïdou et al. (2008) A comparison of alpha and gamma spectrometry for environmental radioactivity surveys. Appl Radiat Isot 66:215–222.
14. United Nations Scientific Committee on the Effects of Atomic Radiation (2000) Sources and effects of ionizing radiation. UNSCEAR 2000 Report, United Nations publication, Vienna, Austria.
15. Sorimachi A, Takahashi H, Tokonami S (2009) Influence of the presence of humidity, ambient aerosols and thoron on the detection responses of electret radon monitors. Radiat Meas 44:111–115.
16. Saïdou, Ele Abiama P, Tokonami S (2015) Comparative study of natural radiation exposure to the public in three uranium and oil regions of Cameroon. Radioprotection 50:265–271.
17. International Agency for Research on Cancer (2008) World Cancer report 2008. IARC Library Cataloguing in Publication Data, Lyon, France.