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Radon-thoron discriminative measurements in the high natural radiation areas of southwestern Cameroon

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ABSTRACT

Although indoor radon was initially measured in the uranium regions of Poli and Lolodorf using Electret Ionization Chambers, discriminative RADUET detectors were deployed in 70 houses of the high natural radiation areas of Bikoue and Ngombas in the uranium region of Lolodorf in Southwestern Cameroon. Radon and thoron concentrations were determined using Image-J and Microscope Methods for track evaluation. Radon and thoron concentrations follow lognormal distributions and ranged respectively from 27 ± 26 to 937 ± 5 Bq m^{-3} and from 48 ± 40 to 700 ± 128 Bq m^{-3}. The arithmetic means of radon and thoron concentrations were found to be 92 ± 3 Bq m^{-3} and 260 ± 13 Bq m$^{-3.}$ Less than 2% of houses have indoor radon above the reference level of 300 Bq m^{-3} and 30% of houses have thoron concentrations above 300 Bq m$^{-3.}$ Inhalation doses due to radon and thoron range respectively between 0.6 −17.7 mSv yr^{-1} and 0.2−3 mSv yr^{-1} with the mean values of 1.4 mSv yr^{-1} and 1 mSv yr^{-1}. The contribution of indoor thoron to the total inhalation dose ranges between 15%- 78.5% with the mean value of 47%. Thus thoron cannot be neglected when assessing radiation dose.

1. Introduction

Radon (^{222}Rn) and its progeny are well known as the main contributors to the dose from natural radiation sources. Although the importance of radon in terms of radiation dose is established long time ago, the contribution of thoron (^{220}Rn) has recently been recognized. Thoron is present everywhere together with radon, and thoron concentration is sometimes much larger than that of radon in dwellings (Tokonami et al., 2004; Janik et al., 2010). The presence of thoron has an effect on accurate radon measurement and its measurement is usually more complicated than that of radon. Thoron concentration is highly inhomogeneous with a strong dependence on the distance from the source (Németh et al., 2010). Many studies showed that thoron can be a significant contributor to the radiation exposure in residential homes in some Asian, European and American countries (Chen et al., 2008; Janik et al., 2013).

Geological studies were carried out from 1978 to 1985 in the southwestern region of Cameroon. 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%. The revaluation of this deposit is ongoing and could lead to a resource well greater than the initial estimate. Indoor radon measurements in the uranium regions of Poli and Lolodorf using Electrets Ionization Chambers (commercially EPERM) were performed and reported by Saïdou et al. (2014). Results highlighted high levels of radon in the uranium region of Lolodorf. Ele Abiama et al. (2010) studied the high background radiation exposure to the public of the uranium region of Lolodorf. This study concluded that high concentration of ^{226}Ra observed in soil samples can be explained by the presence of uranium bearing radiogenic heavy minerals and very high concentrations of ^{232}Th indicate the occurrence of thorium bearing minerals in soil samples.

The objective of this study is to carry out simultaneous measurements of radon and thoron in houses of the high natural radiation areas (HNRAs) of Bikoue and Ngombas located in the uranium region of Lolodorf using Passive integrated radon−thoron

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discriminative detectors (commercially RADUET). Image-J and Microscope methods were used for track evaluation to determine radon and thoron concentrations in dwellings. Some recommendations should be drawn to extend radon and thoron measurements and to put in place a national radon plan in the country.

2. Material and methods

2.1. Study area

The uranium region of Lolodorf as shown in Fig. 1 is located in southwest Cameroon. It extends over the equatorial climatic zone and the mean temperature of the zone varies from 25 to 26 °C with two rainy and two dry seasons. The dry season is caused by a tropical continental air mass blowing from the Sahara Desert between December–February and July–August. The rainy season is brought about by a tropical maritime air mass blowing from the Atlantic Ocean between September–November and March–June. The annual rainfall range is 1500–2000 mm, with a relative humidity of 70–80% recorded throughout the year. The soils of the studied area consist of two types namely ferralitic soils with deep-red and yellow-red soil colour and hydromorphic soils found in the southwestern region of Cameroon (Sighomnou, 2004).

2.2. Methodology

In passive radon monitors with closed chambers, air exchange rates can control thoron entry rate, although radon entry rate is constant, based on their quite different half-lives. Using these two diffusion chambers with the same geometry but with two different air exchange rates (Omori et al., 2012), thoron concentrations can be determined in the presence of radon. To determine the concentrations of radon and thoron, RADUET detectors developed at the National Institute of Radiological Sciences (NIRS) in Japan was used in this study (Tokonami et al., 2005). CR-39 was used to detect alpha particles emitted from radon and thoron as well as their progenies and was placed at the bottom of the chamber with sticky clays. Radon gas diffuses into the chamber through an invisible air gap between the lid and bottom of the chamber. Since this air gap functions as a high diffusion barrier, little thoron enters the chamber due to its very short half-life (55.6 s), compared with that of radon (3.82 d). In order to detect thoron more effectively, six holes of 6 mm in diameter are opened at the side of the other chamber and are covered with an electro conductive sponge.

To determine conversion factors of radon and thoron concentrations, these detectors were placed into the radon and thoron chambers at NIRS, respectively (Janik et al., 2010; Tokonami et al., 2008). After exposure tests, CR-39 plates were taken out of the chamber and chemically etched with a 6.25 M NaOH solution at 90 °C over 6 h, and alpha tracks were counted with a track reading system. The evaluation of track in Image J and Microscope methods is well described by Bator et al. (2015). Using two alpha track densities of low and high air-exchange rate chambers (N_L and N_H), radon and thoron concentrations are determined by solving the following equations (Tokonami et al., 2005):

$$N_H = X_{Rn} \cdot CF_{Rn2} \cdot T + X_{Tn} \cdot CF_{Tn2} \cdot T + B \quad (1)$$

$$N_L = X_{Rn} \cdot CF_{Rn1} \cdot T + X_{Tn} \cdot CF_{Tn1} \cdot T + B \quad (2)$$

where X_{Rn} and X_{Tn} are the mean concentrations of radon and thoron during the exposure period in Bq m^{-3}, CF_{Rn1} and CF_{Tn1} are respectively the radon and thoron conversion factors for the low air-exchange rate chamber in tracks of 2.3 cm^{-2} kBq^{-1} m^3 h^{-1} and

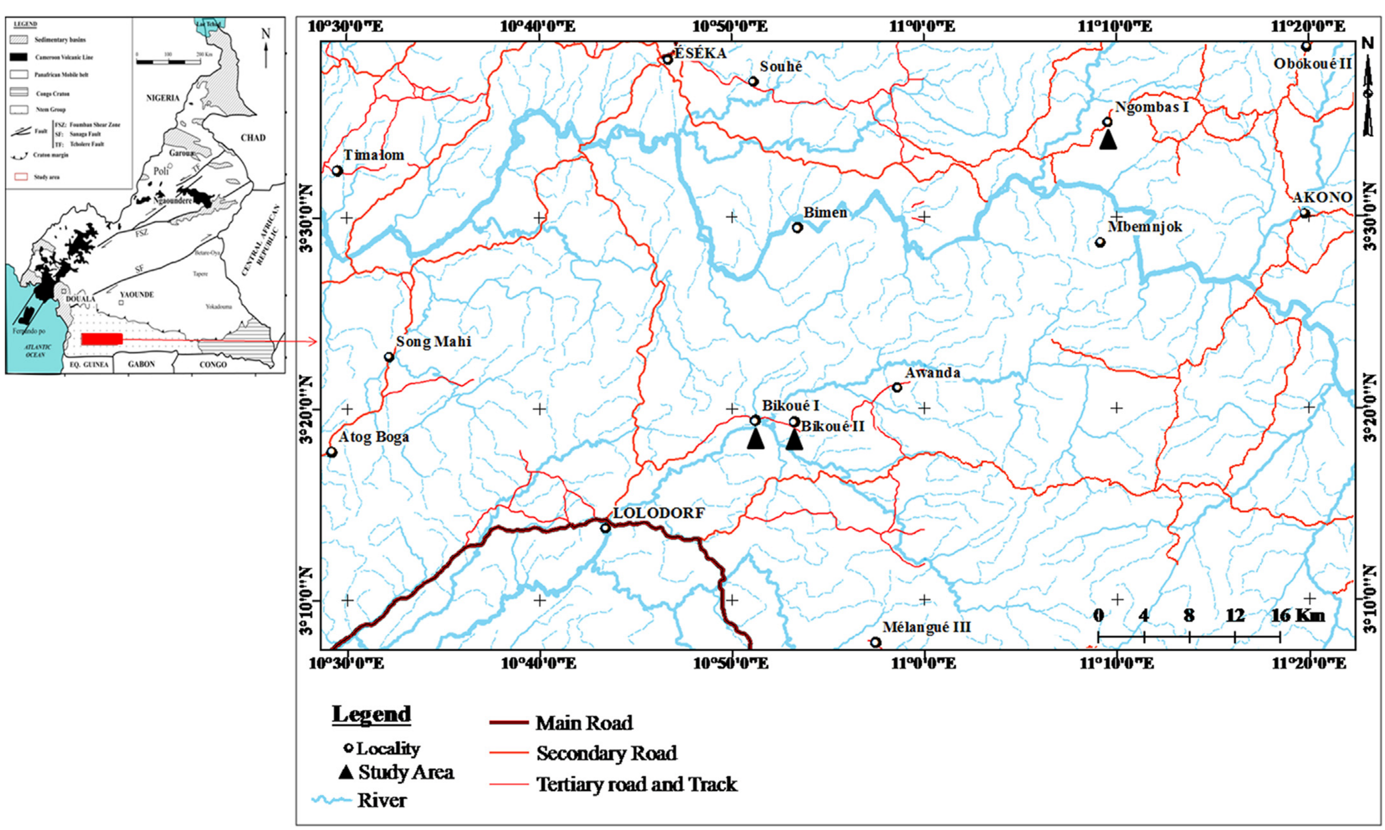

Fig. 1. Location of the uranium region of Lolodorf in southwest Cameroon where the HNRAs of Bikoue and Ngombas are located.