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Indoor radon measurements in the uranium regions of Poli and Lolodorf, Cameroon

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A B S T R A C T

The objective of this work is to carry out indoor radon measurements in the uranium regions of Poli and Lolodorf in which lie the uranium deposits of Kitongo and Lolodorf, prior to their impending exploitation. The indoor radon concentration was measured in 103 and 50 dwellings located respectively in Poli and Lolodorf using E-PERM electret chamber detectors. Indoor radon distributions in Poli and Lolodorf follow the lognormal law. Radon concentrations range respectively in Poli and Lolodorf between 29 and 2240 Bq m^{-3} and 24–4390 Bq m^{-3} with corresponding median values of 165 Bq m^{-3} and 331 Bq m^{-3}. Corresponding arithmetic and geometric means are respectively 294 Bq m^{-3} and 200 Bq m^{-3} for the uranium region of Poli, 687 Bq m^{-3} and 318 Bq m^{-3} for the uranium region of Lolodorf. For the uranium region of Poli, 80% of dwellings have radon concentration above the reference level of 100 Bq m^{-3} and 20% of dwellings show a radon concentration above 300 Bq m^{-3}. For the uranium region of Lolodorf, 80% of dwellings have radon concentration above 100 Bq m^{-3} and 50% of dwellings show a radon concentration above 300 Bq m^{-3}. Thus radon monitoring and mitigation plan are required to better protect people against harmful effects of radon.

1. Introduction

^{222}Radon is a naturally occurring radioactive gas, with a half-life of 3.8 days. It is formed as the decay product of ^{226}Ra, which is a member of the ^{238}U decay chain. Uranium and radium occur naturally in soil and rocks and provide a continuous source of radon. Radon gas emanates from the earth crust and as a consequence is present in the outdoor air and indoor air of residential buildings and workplaces. There is a large variation of indoor air concentrations of radon depending mainly on the geology of the area and factors that affect the pressure differential between the inside and outside of the building, such as ventilation rates, heating within the building and meteorological conditions. Because radon is inert, nearly all of the gas that is inhaled is subsequently exhaled. However, ^{222}Rn decays into a series of solid short-lived radioisotopes which deposit within the respiratory tract. Because of their relatively short half-lives, the radon progeny decays mainly in the lungs before clearance can take place (ICRP, 2011a). Radon tends to concentrate in enclosed spaces like underground mines or houses. Soil gas infiltration is recognized as the most important source of residential radon. Radon is a major contributor to the ionizing radiation dose received by the general population (WHO, 2009).

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 (Gehnes and Thoste, 1981; Thoste, 1985; Oesterlen, 1985). They concluded that the metasomatic uranium deposit of Kitongo could contain a historic resource of 10,000 t U_3O_8 at a grade of 0.1%. This is based on the work completed, the geological setting and the mineralized occurrences observed outside the area of the initial drilling. The geological similarity of this deposit compared with those of other metasomatic uranium deposit sizes further confirms this assessment (Meadon, 2006; Saïdou et al., 2012). Additional ongoing revaluation could lead to a resource well greater than 13,000 t U_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 t U_3O_8 (IAEA, 2009).

Other geological studies were carried out from 1978 to 1985 in the southwestern region of Cameroon (Maurizot, 1986). These

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studies evidenced the occurrence of the uranium deposit of Lolodorf that could contain thousands of t U_3O_8 at a grade ranging from 0.1% to 1%. The revaluation of this deposit is ongoing and could lead to a resource much greater than the initial estimate.

Several studies on natural radioactivity and corresponding dose assessment were carried out in Cameroon. Saïdou et al. (2011) reported radioactivity measurements and total dose assessment in the uranium region of Poli. Most of the total dose assessed is attributable to the intake 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. Consequently, bringing uranium ore from underground to the surface might lead to an increased dose for the population of Poli through a higher deposition of ^{222}Rn decay products on leafy vegetables. Saïdou et al. (submitted for publication) studied the radiological exposure of the public in the oil bearing Bakassi Peninsula in Cameroon. This study showed elevated indoor radon concentrations due to building habits and high exposure to ^{210}Po attributable to the dietary habits of the local population, mainly consisting of seafood. Ele Abiama et al. (2010) and Beyala Ateba et al. (2011) studied the high background radiation and internal/external radiation exposure to the public of the uranium region of Lolodorf. These studies evidenced high radioactivity occurring in the uranium region of Lolodorf. Ngachin et al. (2007) reported a study on external radiation exposure from building materials used in Cameroon. This study concluded that all the materials examined are acceptable for use as building materials as defined by the Organization for Economic Cooperation and Development criterion (OECD, 1979).

Only five dwellings were considered in the previous study for indoor radon measurements in the uranium region of Poli (Saïdou et al., 2011). This study highlighted the importance to extend indoor radon measurements for a more representative number of surveyed dwellings. No indoor radon was measured in the uranium region of Lolodorf before the present study.

The main objective of the present study is to carry out indoor radon measurements in the uranium bearing regions of Poli and Lolodorf. At the national level some recommendations will be addressed to the Government for sensitization on health effects of radon.

2. Materials and methods

2.1. Study area

The Kitongo deposit is located in the northern part of Cameroon, some 15 km south east of the small city of Poli hosting the largest population in this region. The plains around Poli are typical savannah grassland with occasional trees. Poli falls within the tropics but has a dry season from November to April and a rainy period between June and September. The annual rainfall is 1500 mm. The temperatures in this region vary between 15 and 40 °C. In the dry season, during the months of December and January, the nights are cold (10 °C), but during the daytime the Harmattan, a hot north-easterly wind from the Sahara, brings dust and gray skies (Oesterlen, 1985).

The uranium region of Lolodorf, located in the southern part of Cameroon, extends over the equatorial climatic zone. 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 color and hydromorphic soils found in the southwestern region of Cameroon (Sighomnou, 2004).

2.2. Methodology

E-PERM Electret Ion Chambers (EICs) were used to carry out the present study. The E-PERM EICs were manufactured by Rad Elec Inc., 5714-C Industry Lane, Frederick, MD 21704, USA. Detailed descriptions of their design and operation have been given in Rad Elec Manual and also published (Kotrappa et al., 1996). EIC for monitoring radon consists of a stable electret (electrically charged Teflon® disc) mounted inside an electrically conducting chamber. The electret serves both as a source of the electric field and as a sensor. The ions produced inside the chamber are collected by the electret. The reduction in charge of the electret is related to total ionization during the period of exposure. This charge reduction is measured using a battery operated Electret Voltage Reader. Using appropriate calibration factors and the exposure time, the desired parameters such as airborne radon concentration in air is calculated. Normally encountered temperatures, humidities and mechanical shocks do not affect the performance of the EICs making them robust for field use (Fig. 1).

Two sampling sites were investigated for this study. Respectively 103 and 50 EICs type LLT (Low Sensitivity L + Electret Long Term LT) were randomly distributed in dry season in Poli (North–Cameroon) and in rainy season in Lolodorf (South-Cameroon) both located in the uranium regions. We should note that after random selection of dwellings, in-situ request was addressed to the resident to put an EIC inside the house. EICs were exposed for three months relatively far from the open access of dwellings at 1 m above ground to avoid biased measurements due to the influence of outdoor air. Poli and Lolodorf are the most populated towns of the two uranium regions representing about 50% of people living in each of the two regions. About 30,000 and 60,000 inhabitants live respectively in Lolodorf and Poli. Although the area covered by the survey in the two regions could represent less than 10% of each uranium region confirming the status of a preliminary study, about 10% of dwellings randomly chosen in Poli and Lolodorf were monitored. Most of surveyed dwellings were built using soil bricks locally made, sometimes covered by a thick layer of cement.

A shortcoming of the research design is the fact that one survey was made in the rainy season and the other in the dry season because of the limited fund allocated to the study. Although indoor radon concentrations are submitted to seasonal variations, no correction was carried out. Radon concentrations were given by the following equation:

$$C_{Rn}\left(\mathrm{Bq}/\mathrm{m}^3\right) = 37 \times \left(\frac{I-F}{\mathrm{CF}\cdot D} - \mathrm{BG}\right) f_{\mathrm{corr}}^{\mathrm{att}} (\mathrm{pCi}/l)$$

$$\mathrm{CF} = A + B\frac{I+F}{2}$$

where I and F are the initial and final voltages of the electret expressed in volts [V], CF is the calibration factor [V/pCi l^{-1} days], D is the duration of the exposure [days], BG is the background due to the ambient dose expressed in radon equivalent concentration [pCi l^{-1}], $f_{\mathrm{corr}}^{\mathrm{att}}$ is the correction factor taking into account of the dwelling altitude (alt) above sea level. The fitting parameters A and B are given by the manufacturer. $A = 0.02383$ and $B = 0.0000112$.

$$f_{\mathrm{corr}} = 0.996 + 0.00016 \cdot \mathrm{alt}(m)$$

EICs are sensitive to background gamma radiation. The equivalent radon signal in picoCuries per liter (pCi l^{-1}) per unit