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Article

Comparative study of natural radiation exposure to the public in three uranium and oil regions of Cameroon

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Abstract – The objective of this work is to compare natural radiation exposure to the public in the uranium regions of Poli and Lolodorf and the oil region of Bakassi in Cameroon. From some reported studies on natural radiation exposure in Cameroon, the radiation risk was determined. Activity concentrations, external radiation, and the ingestion and inhalation dose of each of the above regions were compared with the world average value given by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). From the total dose, the radiation risk of each region was calculated and compared with the world average value. The specific case of indoor radon exposure was particularly considered. The radiation risk attributed to the indoor radon exposure was compared with the lung cancer rate in Cameroon as given by the International Agency for Research on Cancer (IARC). In conclusion, the local risks are elevated but not necessarily representative of the country as a whole.

Keywords: natural radioactivity / radiation dose / indoor radon / radiation risk / lung cancer

1 Introduction

There have been many surveys to determine the background levels of radionuclides in soil in Cameroon. Saïdou *et al.* (2011) reported radioactivity measurements and a total dose assessment in the uranium region of Poli in Northern Cameroon. They concluded that 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, transfer of 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. Indoor radon measurements were carried out in the uranium regions of Poli and Lolodorf (Saïdou *et al.*, 2014). The results highlighted high levels of indoor radon in these regions. Saïdou *et al.* (2015) reported a study on the radiological exposure of members of the public in the oil-bearing Bakassi Peninsula. The results show high exposure of members of the public to natural radiation. Elevated indoor radon concentrations due to building 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. Ele Abiama *et al.* (2010, 2012) studied the high background radiation and internal / external radiation exposure to the public of the uranium region of Lolodorf in Southwestern Cameroon. These studies evidenced high radioactivity occurring in the uranium region of Lolodorf and showed that computed doses from intake of naturally occurring radionuclides are significantly high.

The objective of the present study is to compare natural radioactivity and the corresponding radiation dose and risk in three uranium and oil regions of Cameroon, namely Poli, Lolodorf and Bakassi. These regions were selected due to the uranium and oil deposits occurring in these areas. Data on activity concentrations and radiation doses come from previously reported studies on the above regions (Saïdou *et al.*, 2011, 2014, 2015; Ele Abiama *et al.*, 2010, 2012) and will be used to determine the corresponding radiation risk. The specific case of indoor radon exposure will particularly be considered. Radiation risk attributed to indoor radon exposure will be compared with the lung cancer rate in Cameroon as given by the International Agency for Research on Cancer (IARC, 2008).

2 Materials and methods

2.1 Activity measurements

2.1.1 Radioactivity in soil

A total of 20, 15 and 15 soil samples were respectively collected in the uranium regions of Poli and Lolodorf and the

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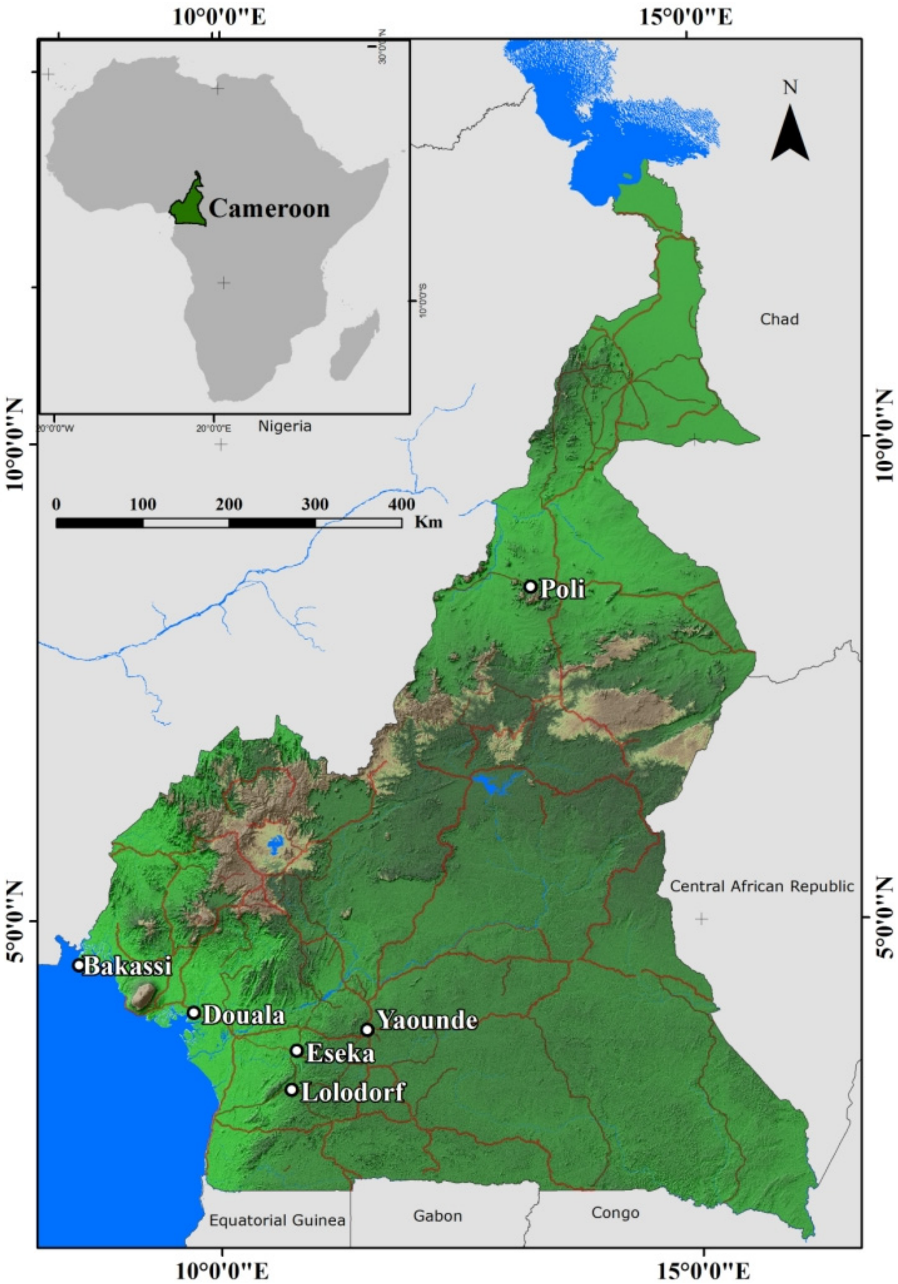

Figure 1. Location of the study areas (Poli, Lolodorf and Bakassi) in Cameroon.

oil region of Bakassi, shown in Figure 1. To measure radioactivity in these samples, alpha and gamma spectrometry were used. Hyper-Pure Germanium (HPGe) detectors were used for gamma spectrometry and Passivated Implanted Planar Silicon (PIPS) detectors for alpha spectrometry for samples collected in the uranium regions of Poli and Lolodorf. A sodium iodide (NaI) detector was used to measure radioactivity in samples collected in Bakassi. Uncertainty assessment of activity concentrations is well described in Saïdou *et al.* (2007, 2008). More details about the sampling and conditioning, characteristics, energy and efficiency calibration of the above detectors can be found in references (Saïdou *et al.*, 2007, 2008, 2011; Ele Abiama *et al.*, 2010, 2012).

2.1.2 Radioactivity in foodstuffs

Alpha and gamma spectrometry were used to measure radioactivity in foodstuffs. Alpha spectrometry using automated borate fusion and sequential extraction and exchange chromatography were used to determine the uranium and thorium isotopes in the samples collected in Poli (Saïdou *et al.*, 2008). Alpha spectrometry using microwave acid digestion under pressure for sample mineralization was used to measure ^{210}Po in the foodstuffs collected in Poli and Bakassi (Saïdou *et al.*, 2007). Gamma spectrometry was also used to measure radioactivity in the foodstuffs collected in Poli, Lolodorf and Bakassi. The types of foodstuffs collected are given in Table 2.

Table 1. Air kerma conversion coefficients [(nGy.h^{-1})/(Bq.kg^{-1})] of radioactivity in soil (UNSCEAR, 1993).

Radionuclides	Air kerma conversion coefficient (nGy.h^{-1})/(Bq.kg^{-1})
^{238}U series	0.46
^{232}Th series	0.60
^{40}K	0.042

Uncertainty assessment of activity concentrations is well described in Saïdou *et al.* (2007, 2008). More details about the sampling and conditioning, the characteristics of the detectors and their energy and efficiency calibration are given in references (Saïdou *et al.*, 2011, 2015; Ele Abiama *et al.*, 2012).

2.1.3 Radon in dwellings

Electret ionization chambers (EICs) were exposed for three months to measure indoor radon in the above regions. Respectively 100, 50 and 15 dwellings were considered for the uranium regions of Poli and Lolodorf and the oil region of Bakassi. Radon concentrations were determined using equation (1):

$$C_{Rn}(Bq.m^{-3}) = 37 \times \left(\frac{I-F}{CF.D} - BG\right) f_{corr}^{att}(pCi.l^{-1}) \quad (1)$$

$$CF = A + B\frac{I+F}{2} \quad (2)$$

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 [$pCi.l^{-1}$], and f_{corr}^{att} is the correction factor, taking into account the dwelling's altitude (alt) above sea level. Uncertainty assessment of radon concentrations is well described in Saïdou *et al.* (2014).

2.2 Radiation dose assessment

2.2.1 External radiation dose

The corresponding ground radiation dose in the uranium regions of Poli and Lolodorf and the oil region of Bakassi was assessed using the dose conversion factors in Table 1 given by UNSCEAR (1993) for ^{238}U and ^{232}Th series and ^{40}K. It is given by the following equation:

$$\mathrm{E_{ext}} = \mathrm{F_c} \times [(1 - \mathrm{F_{occ}}) + F_{occ}F_b] \times \sum_{i=1}^{3} A_i \times (KCF)_i t \quad (3)$$

where F_c is the conversion coefficient of 0.7 mSv.mGy^{-1} used to determine the corresponding effective annual dose, and F_{occ} is the indoor occupancy factor of 0.6, which implies that people spend 40% of the time outdoors. However, since the materials used in the construction of most of these buildings also contain radionuclides, the average factor F_b of 1.4 was applied to take into account their contribution and estimate the indoor dose rate. A_i are average activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, and $(KCF)_i$ are corresponding air kerma conversion factors given in Table 1.

2.2.2 Ingestion dose

The ingestion dose is given by the following equation:

$$E_{ing} = \sum_i A_{ing}^i \times m_{ing} \times e_{ing}^i \times t. \quad (4)$$

A_{ing}^i is the average activity concentration of the i radionuclide in Bq.kg^{-1}, m_{ing} is the mass of the daily ingested food in kg, e_{ing}^i is the ingestion dose conversion factor of the same radionuclide in Sv.Bq^{-1} and t is the exposure time in days. The daily consumption mass of ingested food is given in Table 2. The ingestion dose conversion factors used in the present work were calculated by the ICRP (1994, 1995).

2.2.3 Inhalation dose

The inhalation dose from radon and its daughters is given by the following equation (UNSCEAR, 2000):

$$E_{inh} = A_{inh} \times e_{inh} \times F_{occ} \times F_{eq} \times t. \quad (5)$$

A_{inh} is the median radon concentration, e_{inh} is the inhalation dose conversion factor of 9 nSv/(Bq.h.m^{-3}), F_{occ} is the occupancy factor of 0.6 for the studied areas, F_{eq} is the equilibrium factor considered of 0.4 and t corresponds to a year expressed in hours. The occupancy factor was derived from an *in situ* inquiry performed in the studied areas during field work. The equilibrium factor used is the default value given by UNSCEAR and will be measured for the study areas and reported very soon.

3 Radiation risk assessment

3.1 Radiation risk due to natural radioactivity

According to the ICRP in the low-dose range, it is scientifically plausible to assume that the incidence of cancer or heritable effects will rise in direct proportion to an increase in the equivalent dose in the relevant organs and tissues. The ICRP proposed nominal probability coefficients for detriment-adjusted cancer risk as 5.5 × 10^{-2} Sv^{-1} for the whole population and 4.1 × 10^{-2} Sv^{-1} for adult workers (ICRP, 2007). Radiation risk is given by the equation:

$$RR = 5.5 \times 10^{-2} \times (E_{ext} + E_{inh} + E_{ing}) \quad (6)$$

where E_{ext}, E_{inh} and E_{ing} given above are expressed in Sv.

One should note that ICRP coefficients are not given to evaluate a risk of developing cancers. They were obtained from a long-term survey of Hiroshima and Nagasaki survivors and therefore express the life risk of a specific population. Thus, this radiation risk assessment should be cautiously considered because the calculations done here with the ICRP data are just to have a broad overview of the risk.

Table 2. Daily consumption mass of ingested food in the Poli, Lolodorf and Bakassi areas (Saïdou *et al.*, 2011, 2015; Ele Abiama *et al.*, 2012).

Region	Foodstuff	Daily consumption mass (g)
Poli	Flour of maize	850
	Groundnut paste	25
	Beef	100
	Leaf powder (baobab/ "lalo") or dry gombo	30
	White bean	20
	Water (cooking + drinking)	4500
Lolodorf	Groundnuts	82
	Plantain	274
	Cassava leaves	137
	Cassava roots	274
	Cocoyam	164
Bakassi	Tapioca (cassava by-product)	400
	Fish	200
	Shrimps	50
	Waterleaf	50
	Eru leaf	50
	Cowpea	50

3.2 Radiation risk due to indoor radon

Epidemiological studies of occupational exposure of miners and residential exposure of the public have provided evidence of the risks of lung cancer following inhalation of radon and its progeny. For radon exposure the ICRP (2011a) recommended that a lifetime excess absolute risk (LEAR) of 5×10^{-4} per WLM should be used as the nominal probability coefficient for radon- and radon-progeny-induced lung cancer, updating the Publication 65 (ICRP, 1993) value of 2.8×10^{-4} per WLM.

$$\mathrm{WLM} = 6.37 \times 10^{5}/(F_{eq}.\mathrm{Bq.h.m^{-3}}). \quad (7)$$

The lifetime excess absolute risk due to indoor radon used in the present study is given by the following equation:

$$\mathrm{LEAR} = 5 \times 10^{-4} \times \mathrm{WLM}^{-1} = 7.85 \times 10^{-10}(F_{eq}\mathrm{Bq.h.m^{-3}}). \quad (8)$$

To assess the LEAR of each investigated area, occupancy and equilibrium factors of 0.6 and 0.4, respectively, were used. The risk coefficients used to analyze the case of the uranium and oil regions of Cameroon come from the results of epidemiological studies of populations exposed to ionizing radiation. There are sources of uncertainty in analyzing the results of these epidemiological studies, specifically the uncertainties in information on health effects, and in information on exposure, dose assessment and the dose-response model in risk assessment. There are also uncertainties in transferring risk quantities from given studies to other exposure conditions or populations of interest, uncertainties of selected risk evaluations. More details are given in UNSCEAR (2012).

4 Results and discussion

4.1 Activity measurements

4.1.1 Radioactivity in soil

The average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil of the uranium regions of Poli and Lolodorf and the oil region of Bakassi are given in Table 3. It can be noted that radioactivity level of the region of Poli is low compared with the world average activity concentrations as estimated by UNSCEAR (2000): 33 Bq.kg^{-1} for ^{238}U, 45 Bq.kg^{-1} for ^{232}Th and 420 Bq.kg^{-1} for ^{40}K. This is consistent since the uranium mining and milling processes of the Kitongo deposits have not yet started. Finally, the fact that radioactivity is low in the Poli region does not infer the absence of a uranium deposit in Kitongo. According to Saïdou *et al.* (2011), the uranium ores are probably deeply situated. The above worldwide average activity concentrations were estimated by UNSCEAR (2000) using natural radiation survey data from countries including uranium mining regions, although they are not well represented.

In the uranium region of Lolodorf, the high concentration of ^{226}Ra observed in soil samples can be explained by the presence of uranium-bearing radiogenic heavy minerals. The very high concentration of ^{232}Th indicates the presence of thorium-bearing minerals in the soil samples (Ele Abiama *et al.*, 2010). The average values of the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in different studied locations are much higher than the world average values (UNSCEAR, 2000).

In the oil region of Bakassi, the activity concentrations of ^{238}U, ^{232}Th and ^{40}K are lower than the average activity observed in the world (UNSCEAR, 2000). The level of natural radioactivity is in agreement with what can be expected when there is no contamination. Finally, no radioactive contamination is evidenced due to the presence of offshore production platforms in the Bakassi Peninsula (Saïdou *et al.*, 2015).

Table 3. Average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in 20, 15 and 15 soil samples collected, respectively, in the uranium regions of Poli and Lolodorf and the oil region of Bakassi (Saïdou *et al.*, 2011, 2015; Ele Abiama *et al.*, 2010). Standard uncertainties are expressed for $k = 1$, using the approach developed in ISO (1995).

Study area	Radionuclide	Mean activity ($Bq.kg^{-1}$)	Minimum–Maximum activity ($Bq.kg^{-1}$)
Poli	^{238}U	23.6 ± 0.6	12.4 ± 1.5–57 ± 4
	^{232}Th	28 ± 0.6	14.6 ± 1.5–58 ± 5
	^{40}K	506 ± 3	112 ± 4–1124 ± 27
Lolodorf	^{238}U	130 ± 10	60 ± 10–270 ± 20
	^{232}Th	390 ± 30	100 ± 10–700 ± 50
	^{40}K	850 ± 70	370 ± 20–1530 ± 110
Bakassi	^{238}U	19 ± 4	15.6 ± 3.1–23.2 ± 4.6
	^{232}Th	32 ± 6	26.5 ± 5.3–37.8 ± 7.5
	^{40}K	110 ± 22	93 ± 18–138 ± 27

Table 4. Activity concentration ranges of ^{226}Ra, ^{228}Ra, ^{210}Pb, ^{210}Po and ^{40}K in foodstuffs sampled in the uranium regions of Poli and Lolodorf and the oil region of Bakassi (Saïdou *et al.*, 2011, 2015; Ele Abiama *et al.*, 2012). Each activity concentration is averaged from three different samples of the same type of foodstuff in Table 2. Standard uncertainties are expressed for $k = 1$.

Study area	Radionuclide	Activity concentration ($Bq.kg^{-1}$)
Poli	^{226}Ra	0.04 ± 0.008–2.3 ± 0.6
	^{210}Pb	1.9 ± 0.4–29.7 ± 2.3
	^{210}Po	0.24 ± 0.05–28.0 ± 0.8
	^{40}K	94 ± 2–677 ± 9
Lolodorf	^{226}Ra	0.04 ± 0.01–11 ± 3
	^{228}Ra	0.2 ± 0.06–13 ± 4
	^{40}K	48 ± 2–234 ± 4
Bakassi	^{226}Ra	1.2 ± 0.3–35 ± 15
	^{210}Pb	1.6 ± 0.3–64 ± 16
	^{210}Po	0.33 ± 0.04–122 ± 4
	^{40}K	111 ± 9–1880 ± 32

4.1.2 Radioactivity in foodstuffs

The activity concentrations of the main natural radionuclides in foodstuffs are summarized in Table 4. In the uranium region of Poli, the activities of ^{210}Po and ^{210}Pb were higher in vegetables due to the atmospheric deposition of radon decay products. These vegetables are frequently consumed by the inhabitants of Poli. Consequently, transfer of 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.*, 2011). Moreover, weathering of material stemming from excavations during exploration and development works of the Kitongo deposit in Poli could contribute to increasing the radiation dose to the public. On the other hand, in the uranium region of Lolodorf, the activity concentrations of ^{226}Ra and ^{228}Ra in each type of food were much higher than the world average values as given in UNSCEAR (2000). This can be explained by the high level of these radionuclides in soil, the specific radionuclide uptake by some food items and their high consumption (Ele Abiama *et al.*, 2012). No activity concentrations of ^{210}P and ^{210}Pb in foodstuffs are currently reported for the uranium region of Lolodorf.

Finally, in Bakassi, high activity concentrations of ^{210}Po and sometimes ^{210}Pb were observed, notably in seafood (fish, shrimps). ^{210}Pb and ^{210}Po are very radiotoxic and present in relatively high concentrations in the marine biota due to their enhanced bioaccumulation and strong affinity for binding with certain internal tissues.

Table 5. Arithmetic, geometric and median concentrations of indoor radon in the uranium regions of Poli and Lolodorf and the oil region of Bakassi (Saïdou *et al.*, 2014, 2015) compared with the world average value given by UNSCEAR (2000).

Study area	Arithmetic mean ($Bq.m^{-3}$)	Geometric mean ($Bq.m^{-3}$)	Median ($Bq.m^{-3}$)
Poli	294	200	165
Lolodorf	735	318	331
Bakassi	1280		907
World	40	30	–

4.1.3 Indoor radon

As summarized in Table 5, the indoor radon concentrations in Poli, Lolodorf and Bakassi range, respectively, between 29–2240 $Bq.m^{-3}$, 24–4390 $Bq.m^{-3}$ and 51–4230 $Bq.m^{-3}$ with corresponding mean values of 294 $Bq.m^{-3}$, 735 $Bq.m^{-3}$ and 1280 $Bq.m^{-3}$ and median values of 165 $Bq.m^{-3}$, 331 $Bq.m^{-3}$ and 907 $Bq.m^{-3}$. Twenty percent of houses in Poli, 50% in Lolodorf and 60% in Bakassi have indoor radon above the ICRP reference level of 300 $Bq.m^{-3}$ (ICRP, 2011b), requiring radon mitigation (Saïdou *et al.*, 2014, 2015). This level of exposure, largely above the world average value of 40 $Bq.m^{-3}$ estimated by UNSCEAR (2000), probably has an impact on human health, leading to an increase in the probability of developing lung cancer (Darby *et al.*, 2005).

Finally, the high indoor radon distribution observed in the uranium regions of Poli and Lolodorf and the oil region of Bakassi could stem from the use of soil bricks as building materials and ground as a floor type. Moreover, a non-negligible fraction of dwellings is not ventilated. One should note that the bricks are made using soil collected from the study areas.

Table 6. Radiation dose components of the uranium regions of Poli and Lolodorf and the oil region of Bakassi compared with the world average values as given by UNSCEAR (2000). Cosmic ray radiation is not taken into account in the calculations.

Exposure pathway	Poli	Lolodorf	Bakassi	World
External irradiation (mSv.y^{-1})	0.6	0.7	0.3	0.5
Ingestion (mSv.y^{-1})	2.2	0.7	4.8	0.3
Inhalation (mSv.y^{-1})	3.1	6.2	17.2	1
Total dose (mSv.y^{-1})	5.9	7.6	22.3	1.8

Table 7. Annual excess risk due to natural radiation exposure in the uranium regions of Poli and Lolodorf and the oil region of Bakassi compared with the world average value.

Study area	Radiation risk (%)
Poli	0.03
Lolodorf	0.04
Bakassi	0.1
World	0.01

Table 8. Annual excess risk due to indoor radon exposure in the uranium regions of Poli and Lolodorf and the oil region of Bakassi compared with the world average value.

Exposure area	Radiological risk (%)
Poli	0.027
Lolodorf	0.05
Bakassi	0.15
World	0.007

4.2 Radiation dose assessment

The main exposure pathways are displayed in Table 6: external radiation (ground, inhalation and ingestion). The average values of the total dose for the uranium-bearing regions of Poli and Lolodorf and the oil region of Bakassi are high compared with the world average value of 1.8 mSv.y^{-1}. The difference from the world average value is easily explained by the dietary habits of the local population and the high level of indoor radon exposure, mainly attributed to the building habits (building materials, ventilation and floor type). The values of the radiation dose shown in Table 6 can be compared with the dose to the public in the high natural radiation areas of Ramsar in Iran and Kerala in India. People in some areas of Ramsar, a city in northern Iran, receive an annual radiation absorbed dose from background radiation that is up to 260 mGy.y^{-1}, and average exposure rates to the public are about 10 mGy.y^{-1} (Ghiassi-nejad *et al.*, 2002). Some areas in India have high levels of natural radiation due to the presence of monazite (9% thorium and 0.3% uranium). In Kerala, on the southwest coast of India, the annual average dose to the public is 15–25 mGy (Kesavan, 1997).

4.3 Radiation risk assessment

The annual excess radiation risk of the uranium regions of Poli and Lolodorf and the oil region of Bakassi was calculated from the radiation dose of each region. As shown in Table 7, the radiation risk of each region is higher than the average value corresponding to the rest of the world. This result was expected because the radiation risk increases with the radiation dose. This radiation risk assessment should be cautiously considered because calculations made with the ICRP data are just to have a broad overview of the risk, and to compare with the natural cancer rate. According to the World Health Organization (IARC, 2008), the age-standardized rate of cancer deaths in Cameroon in 2002 was 150/100 000 persons/year.

Table 7 shows that the annual excess risk due to natural radiation in Poli, Lolodorf and Bakassi is respectively 30/100 000, 40/100 000 and 100/100 000, *i.e.* less than the age-standardized rate of cancer deaths of 150/100 000 in Cameroon. The annual excess risk in Bakassi is particularly high; this is mainly justified by the high exposure of members of the public to indoor radon (see below).

4.3.1 Radiation risk assessment: the case of indoor radon

Extensive measurements of radon concentrations in homes show that although concentrations vary widely, radon is universally present, raising concerns that radon in homes increases the lung cancer risk for the general population (NRC, 1999). Radon is the second cause of lung cancer after smoking. Current estimates of the worldwide proportion of lung cancer due to radon ranges between 3–14% (WHO, 2009). Epidemiological studies have provided strong evidence of an association between indoor radon exposure and lung cancer, even at the relatively low radon levels commonly found in residential buildings (Darby *et al.*, 2005). The analyses indicate that the lung cancer risk increases proportionally with increasing radon exposure (WHO, 2009). This risk is about 20% per 100 Bq.m^{-3}. Radon in the home accounts for about 9% of deaths from lung cancer and about 2% of all deaths from cancer in Europe (Darby *et al.*, 2005). According to the WHO, 2.3% of all deaths in the world were attributed to lung cancer in 2008, leading to about 1.38 million lung cancer victims worldwide (IARC, 2008).

In Central African countries such as Cameroon, the age-adjusted death rate for lung cancer was 2.7/100 000 persons/year in 2008 (IARC, 2008). It is known that smoking is the first cause of lung cancer. According to the National Institute of Statistics in Cameroon, in 2015 there are 1.1 million smokers in the country (13.9% of Cameroonian men and 4.3% of Cameroonian women are smokers, on average 8.9% of adults).

Based on the annual excess risk values as shown in Table 8, we can still make the point that a comparison of local radiological risks with national cancer incidence data allows us to conclude that the local risks are elevated but not necessarily representative of the country as a whole.

This value of risk should be cautiously considered, particularly in Bakassi where radon was measured in only

15 dwellings, meaning that the radon measurements are not representative enough of the investigated area. Thus, extensive measurements are needed for a reliable comparison. One should note that from sampling and radioactivity measurements to radiation dose and risk assessment, substantial uncertainties are expected, influencing the values to compare.

Data were obtained by calculating the dose from inhalation to the ICRP detriment. For instance, the risk in Poli should be half of the total risk (Table 7) since the dose from inhalation is half of the total dose. Moreover, if the calculation is done in that way, it is important to note that the ICRP detriment is calculated for whole-body cancer, whereas radon causes only lung cancers. The models used to calculate the risks due to natural radiation exposure and due to radon are not the same. Moreover, the sources of uncertainty of risk assessment mentioned above should be regarded.

5 Conclusion

Comparison of natural radioactivity and the corresponding radiation dose and risk in the uranium regions of Poli and Lolodorf and the oil region of Bakassi was performed. It clearly appears that the radiation dose and radiological risk of each of the studied regions are higher than the world average values. This difference can be explained by the dietary and building habits (building materials, ventilation and floor type) of the populations living in the investigated areas.

A comparison of local radiological risks with national cancer incidence data allows us to conclude that the local risks are elevated but not necessarily representative of the country as a whole.

For the specific case of radon-induced lung cancer, an epidemiological study could be needed after extensive radon and thoron measurements in the whole country, because available data are sparse and not sufficiently representative to perform a strictly valuable comparison.

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