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RESEARCH ARTICLE

ASSESSMENT OF POTENTIAL RISKS WITHIN THE POPULATION RESIDING IN THE LOCALITY OF POLI, NORTHERN REGION OF CAMEROON: CASE OF INDIGENOUS PEOPLE LIVING ON THE URANIUM-BEARING MOUNTAIN OF KITONGO AND DOMBOULKO

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ABSTRACT

In an environment with a high level of radiological activity, humans are exposed to a high radiation rate which increases the risk of the appearance of health effects depending on the duration of exposure. The purpose of this study is to contribute to the evaluation of the appearance of the risks of radiological affections within the resident populations in the uranium zone of Kitongo in the locality of Poli. A direct reading dosimeter model RAD-35 was used to record external and internal exposures. The sample points were located using the Global Positioning System (GPS) in order to map the study area. The radiometric measurements were taken 1m above the sampled soils. The effective dose was 2.3±0.3mSv/year. It was higher than the limits set for the public by the ICRP, i.e. 1mSv/year and 2.4mSv/year set by the IAEA at the global level. The internal effective dose was 1.91±0.2mSv/year and the external effective dose was 2.70±0.3mSv/year. Within this study population 43.47% of cases of infertility were presented.

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INTRODUCTION

Radiation is classified according to its natural or artificial origin. Ionizing radiation from natural sources is known to be the most significant sources of public exposure (1). In the environment, natural radioactivity is a natural phenomenon which includes, sources of exposure such as cosmic rays, natural radionuclides contained in water, air, soil and rocks, building materials and houses, food and plants which contribute about 0.28 mSv/year to human exposure (2; 3). There is no locality on earth where natural radioactivity does not exist (4; 5). In terms of a physical process, radioactivity is the spontaneous transformation of unstable nuclides to a stable state. It is accompanied by the emission of ionizing radiation or particles (6). The level of terrestrial radiation varies from one geographical location to another (7), resulting in double exposure (external and internal). The radiation deposited in any material per unit mass is known as the dose. Dose refers to the amount of energy absorbed by matter. The issue of public exposure and types of radiation in the environment lies in the process of depositing sufficient energy (dose) to cause ionization in irradiated biological tissue (8).

Exposure refers to the process of depositing energy into living matter and the environment. The total radiation exposure dose for a human being is defined as the sum of internal and external radiation. Radiobiological effects include biological harm from irradiation. To this end, the biological harmfulness does not only depend on the absorbed dose, but also on the type of radiation, the irradiated tissue or organ, that is to say the radiosensitivity of the tissue and/or organ. The radiosensitivity of organs and tissues is the same according to their nature but differs according to their weight and age. According to the International Agency for Research on Cancer (9), radon has been identified as a cause of lung cancer in humans. It was also observed respiratory diseases and several allergic symptoms such as rhinitis, fatigue, loss of tears and many contagious cold diseases. Alongside these answers, it is necessary to take into account the duration of exposure. That is to say the necessary duration of exposure of a given population to natural radiation. The biological effects of exposure to low doses have always been a major area of radiation protection. Regardless of the radiation pathway, ionizing radiation has the potential to create adverse effects due to internal exposure in biological tissue (10). This exposure could alter or damage the DNA, create interference with metabolic pathways and lead to genetic mutations in somatic and germ cells (11).

However, to establish the dose-response relationship, it is first necessary to put in place an approach that simultaneously integrates: the duration of exposure, the dose of exposure and the incidence of effects. The biological organism tends to selectively accumulate radionuclides.

This radioactive selection results in the observation of different types of diseases such as cataracts, heart disease, thyroid disease and high blood pressure (12). From a radiobiological point of view, it is compliant to know the natural risks linked to dose limits (13). If it is known that the distribution of radionuclides in the biological organism takes place selectively in the soft tissues, organs and bones (14); the evaluation of its impact takes into account the chemical and radiobiological effects and the selective powers of the organs vis-à-vis these same radionuclides. In northern Cameroon, several geological prospecting studies were conducted in the 1950s on the existence of natural uranium potential in the locality of Kitongo in Poli (15).

These assessments mentioned that the Kitongo uranium deposit contains a historical resource of 10,000t U_3O_8, graded at 0.1%. In addition to reassessments, uranium resources have been estimated at over 13,000t U_3O_8 (16). The Cameroonian potential has not escaped the attention of industrialists. This is how the Kitongo Mountains were the subject of a uranium research permit. This type of exploitation is ecologically viable because it generates less greenhouse gases, the fact remains that in practice this exploitation is harmful with regard to the results of the characteristics of the concentrations of radionuclides obtained in the locality of Poli. Moreover, no study has established a relationship between the dose levels and the biological effects observed within the population naturally subjected to exposure in this study locality. The work opposite aims to present the contribution of the assessment of the health status of resident populations in areas with high levels of natural irradiation from Kitongo to Poli in relation to exposure levels.

MATERIALS AND METHOD

The study site is located on the Kitongo mountains, a locality located in the region which is the subject of a uranium research permit in the concession called Poli zone in the Department of Faro, in northern Cameroon. The inhabitants live mainly from agriculture who, after the harvest, resell the foodstuffs at the local Poli market and thus buy the necessary equipment. The populations living on these mountains use the raw stabilized land for the construction of dwelling houses. These soils are taken from the same radioactive environment that serves as a support for agriculture and building materials. The figure below illustrates the mapping of the study area.

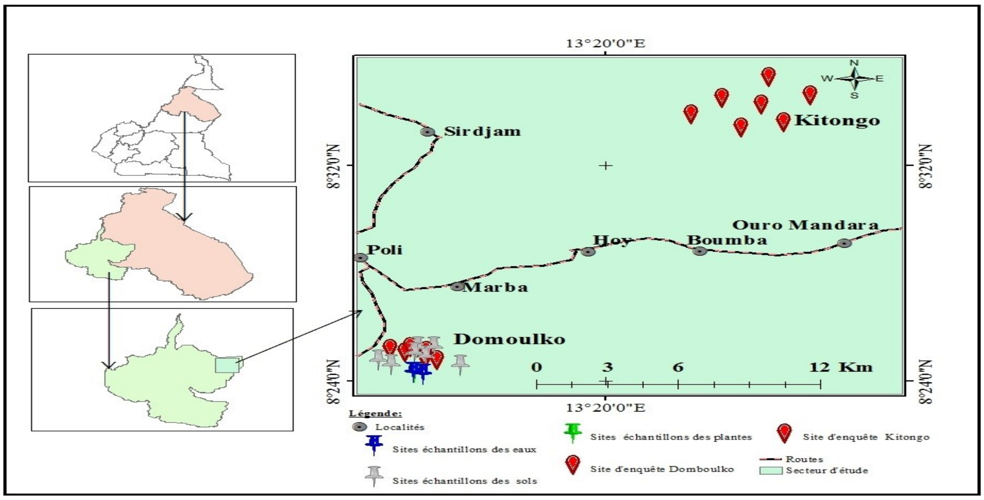


Figure 1. Mapping of the Kitongo study area

Data gathering : We collected 114 radiometric data inside and at the entrance of each of the housing concessions but also in the cultivable areas in the environment from 34 people representing the total population of the Kitongo mountains. Sociodemographic, radiobiological and radiological data were collected from residents of the locality of Kitongo.

Sociodemographic data were collected using pre-established questionnaires including age, number of children, length of residence in the locality. Each resident answered according to the different questions asked. The potential radiobiological effects and symptoms observed within the resident populations on these mountains have been grouped into the endocrine system, the osteo-articular system and the respiratory system, reproductive system. The radiometric data were taken above the exploited soils, in the dwelling houses.

They were taken 1m above the ground using a Radiometer model RAD-35 as listed to obtain a secular balance. The measurements were reported when they showed stability in each measurement point in order to minimize the error. The doses obtained corresponded to those of the most radioactive zones according to the dosimeter. Earth exposure readings were in micro-Sievert per hour (µSv/h) then converted to Sievert per year. The GPS (Global Positioning System) coordinates were used for the cartographic representation of the study background. The internal dose was taken in the dwelling houses after closing all the orifices (windows, doors) using our dosimeter.

Radiation risk parameters

Equivalent radium activity (Ra_{eq}): Exposure to γ radiation is defined in terms of the equivalent activity of radium (Ra_{eq}). This is a common index used to represent the risks associated with the concentrations of ^{226}Ra, ^{232}Th and ^{40}K contained in construction materials (17). The equivalent radium activity (Ra_{eq}) is calculated based on the estimate that 370Bq/kg of ^{226}Ra, 259Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same doses of gamma radiation. The contribution of ^{238}U and other ^{226}Ra precursors is expressed in the equations according to Kreiger, (1981); Bertkaet Mathew, (1985) (18; 19):

$$Ra_{eq}(Bq/kg) = \left(\frac{370\ _{Ra}}{370} + \frac{370A_{Th}}{259} + \frac{370A_K}{4810}\right) \leq 370$$

External risk index (H_{ex}) : The external risk index (H_{ex}) is a criterion used for the evaluation of external exposure to gamma radiation in the air. In general, the safety of construction materials is said to be negligible if the result is below one unit (20). That is to say at the upper limit of Ra_{eq} (370Bq/kg). This index was used by Beretkaet Mathew (1985) (19).

$$H_{ex} = \frac{A_{Ra}}{370\ (Bq/kg)} + \frac{A_{Th}}{259(Bq/kg)} + \frac{A_K}{4810\ (Bq/kg)} \leq 1$$

Internal risk index (H_{in}) : The internal risk index (H_{in}) is generally defined to reduce the maximum permitted concentration of ^{226}Ra to half as appropriate (21). Internal exposure occurs by inhalation of terrestrial radionuclides very close in the air, dust particles containing radionuclides from the decay series of the ^{238}U and ^{232}Th chain.

$$H_{in} = \frac{A_{Ra}}{180\ (Bq/kg)} + \frac{A_{Th}}{259(Bq/kg)} + \frac{A_K}{4810\ (Bq/kg)} \leq 1$$

RESULTS

RESULTS OF DESCRIPTIVE AND ANALYTICAL DATA TESTS

Sociodemographic characteristics

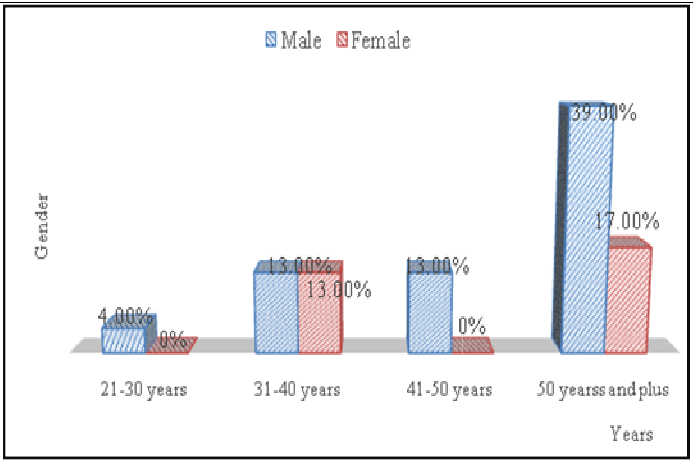


Figure 2: Intersection between gender and age of respondents

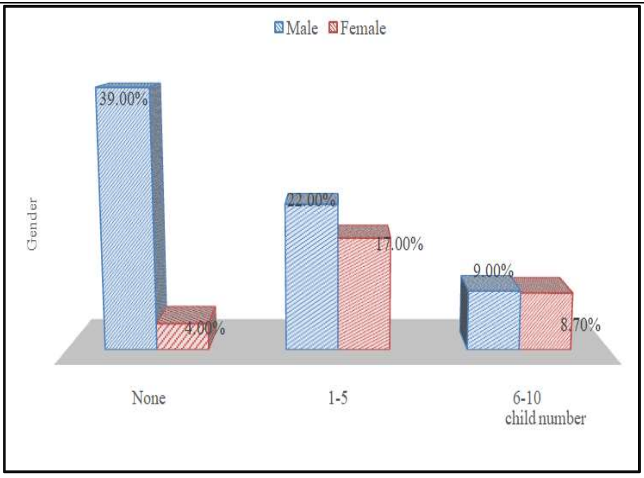


Figure 3: Crossover between gender and gesture

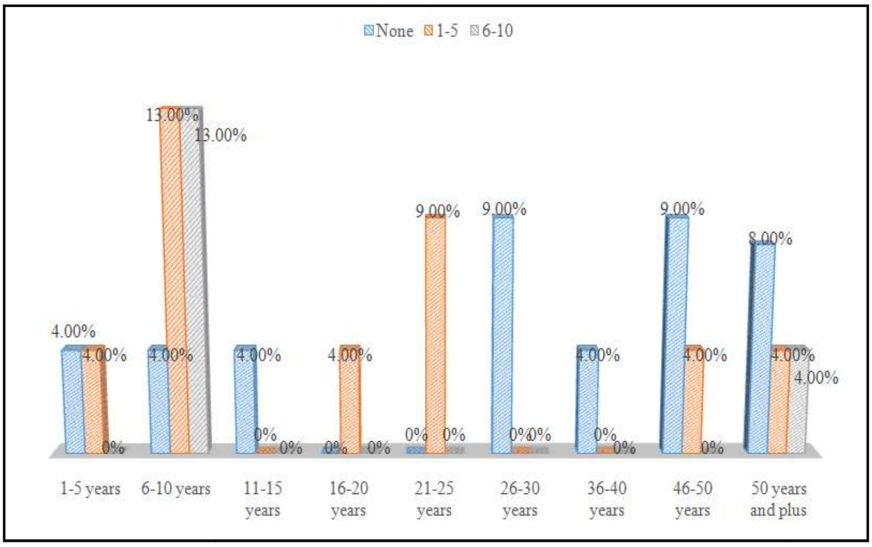


Figure 4. Growth between the duration of residence in the locality of Kitongo and the number of gestures

Dosimetric assessments

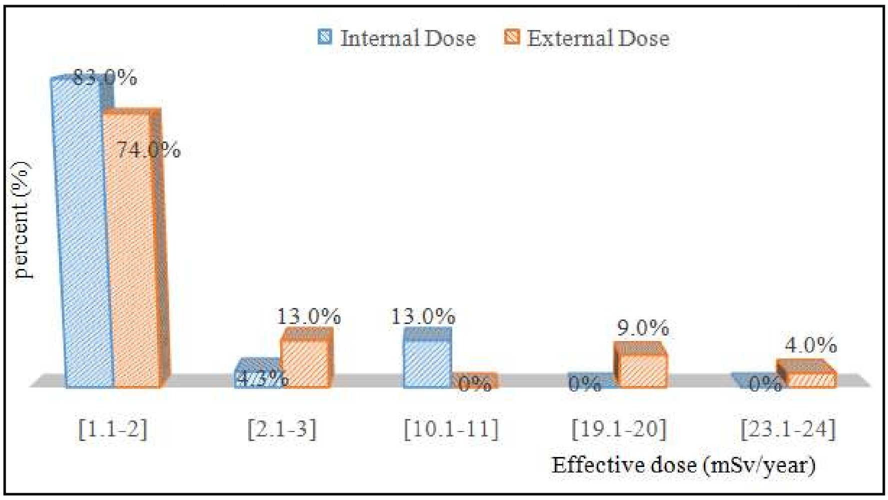


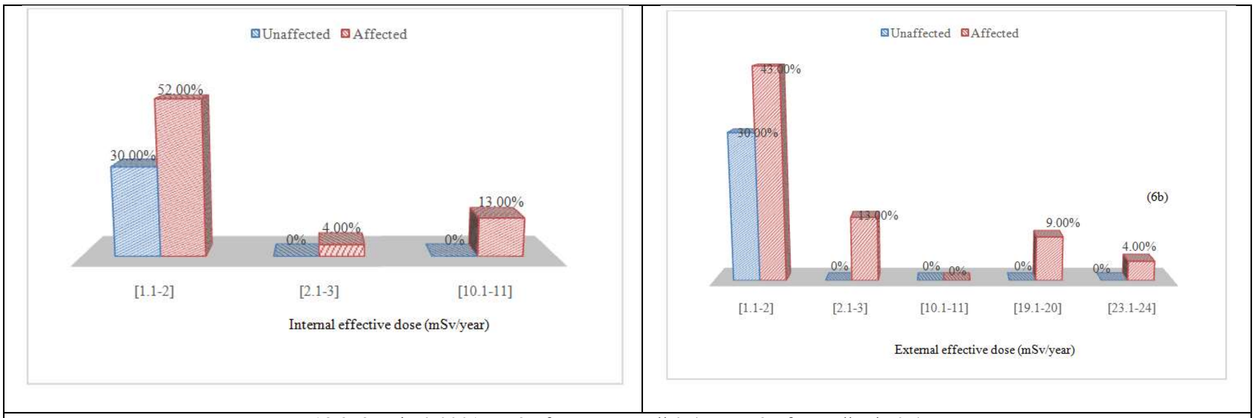
Figure 5. Breakdown of annual exposure levels in (mSv)

Assessment of potential risks of biological conditions among residents

Case of disorders of the osteo-articular system

Table 1: Biological risk assessment parameters

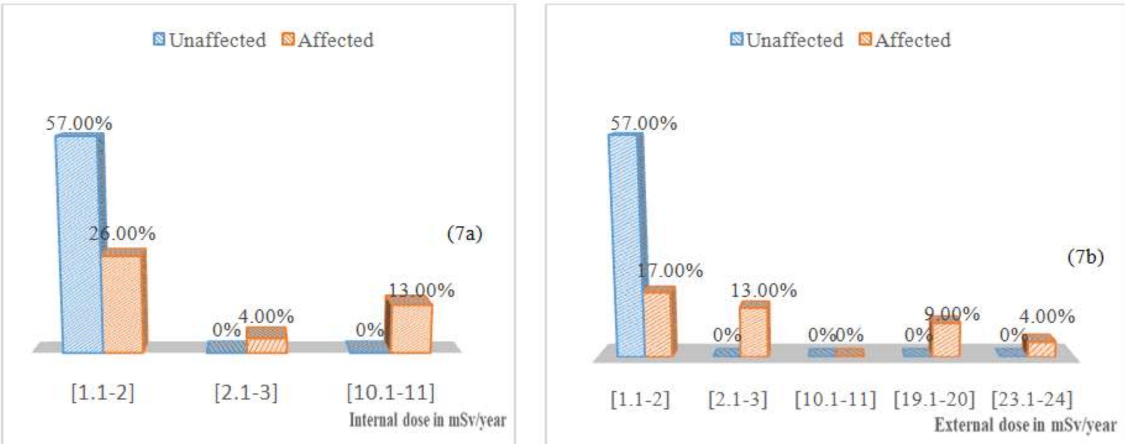
Ra_{eq}	H_{ex}	H_{in}	I_{γ}
109.41	0.3	0.36	0.41



18.253 ; Sig.0.0001 ; R 2 of Cox &; Snell 0.477 ; R 2 of Nagelkerke0.477

Figure 6. Cross-referencing of endocrine disorders and internal and external effective doses

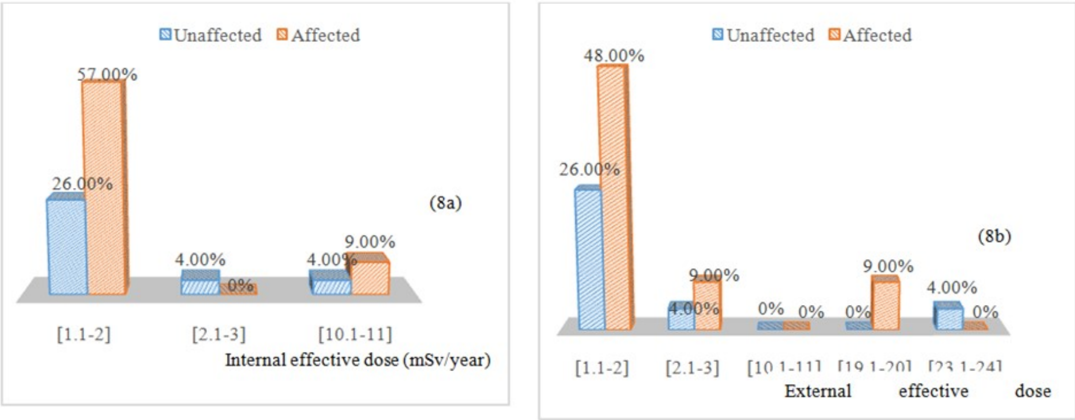
Case of diseases of the respiratory system



χ^2_{cal} =13.880; dof = 3; Sig.<0.003; R^2 of Cox &Snell=0.276; R^2 of Nagelkerke=0.371

Figure 7. Combination between respiratory diseases and internal and external effective doses

Case of disorders of the osteo-articular system



3.029; Sig. 0.387; R 2 of Cox & Snell 0.068; R 2 of Nagelkerke0.100

Figure 8. Cross-referencing of musculoskeletal conditions and effective internal and external doses

DISCUSSION

Socio-demographic data are presented according to gender, number of children and length of residence. The age of respondants were grouped into groups. Regarding the intersection between age and gender, the male gender was the most represented with 69.55% compared to 30.45% of women, which is a sex ratio of 2.84 in favor of men. The age of respondants were classified into modal class of 10 to facilitate calculations. The most represented residents were aged 50 and above with 56.53%; followed by the age of respondants between 31-40 years old with 26.08%. The youngest residents in the locality of Kitongo were aged between 21-30 years, or only 4.13% of the total population. There are no young people under the age of 20 years residing in the Kitongo Mountains. Based on the analysis, we noted a very aging population.

Figure 2 shows the intersection between the gender and age of respondants in the locality of Kitongo. It appears that the male gender aging from 50 years and above had the greatest representation with 39.13%. In this locality, there is no young person under the age of 20.

Figure 3 shows the intersection between the gender and number of children residing in the study location. It appears that 39.13% of male residing had no children compared to 4.34% of women who had no children. We observe a high rate of infertility in the localities studied with 43.47% of respondants who don’t have children. Only 39.13% of respondants claimed to have a number of children between 1-5 and 17.4% who claimed to have a number of children between 6-10.

According to the results of Figure 4, for a rate of 43.47% of infertility within the study population, the highest rates of infertility of those residing in the locality of the Kitongo mountains were presented by those who had lived between 26-30 years old; 46-50 years old; 50 years and above with 8.7% in a time scale.According to BEIR, (1990) (22) people who have lived for a long period in the same radioactive locality present more biological effects.

Long periods of exposure to radiation levels increase the risk of biological disease. Depending on the length of time in the locality of Kitongo, a uranium mining area, there is an effect of accumulation of doses in biological tissues which positively influences the biological conditions observed. Similarly, Manyacka and Nguepjouo (2008) (23) made too this observation of low birth rates and low density in the localities around the Kitongo de Poli Mountains. Scherb and al (2019) (24) also highlighted the reduction in the number of births within populations located near nuclear sites in France and Germany. In the same order, Pereira and al (2014) (25) noted an alteration in the reproductive functions of the population exposed around mines in Portugal.

Figure 5 presents the distributions of annual internal and external exposure levels in mSv. It appears that, the local people were more exposed to the level of internal and external irradiation of between 1.1-2mSv/year with 82.6% and 73.9%. The maximum extreme of the external dose was between 23.1-24mSv/year with 4.3%. It appears that the annual effective dose was 3.46±0.3 mSv. It was higher than the limits set for the public by the ICRP, i.e. 1mSv/year and 2.4mSv/year set by the IAEA at the global level. The internal effective dose was 1.91±0.2 mSv/year and the external effective dose was 2.70±0.3mSv/year. Within this study population, this result is explained by the fact that, the Kitongo mountains are recognized areas with high uranium potential. The results demonstrate an overexposure of the local people which have justified the appearance of disorders of certain biological systems of the local people in our study. These results were lower than those estimated by Bersimbaev and al., (2015) (26) in Kazaksthan, that is 8mSv/year, and those estimated by Achola and al., (2019) (27) in Kenya with 5.7mSv/year. This is explained by the fact that Kazakhstan has 12% of the world's uranium resources and its mining sector is booming, producing around 22,830 tonnes of uranium, compared to 13,000 tonnes of uranium oxide estimated in Kitongo.

Depending on the period of residence in the study localities, a dose however minimum it is should must be taken into account because the spread of the dose is generally taken into account at the level of its minimum impact because in the additive model, the rate of appearance of pathological conditions is proportional to the dose received. The strong correlations with conditions of the endocrine and respiratory systems sufficiently demonstrate the stochastic effects within indigenous residents. In the domain of medium and high doses, that is to say above 100 to 200mSv, the linear relationship seems acquired, which is not the case below 100mSv. The notion of absence of threshold is highly contested, because if there is no risk, we can talk of accepted residual risk. As a precaution, it is generally accepted in the field of low doses, that is to say less than 100mSv, the linear law without threshold which can be legitimate in a security framework. Furthermore, there is a linear dose-response relationship between the levels of exposure to ionizing radiation and the health effects observed. As such, cases of exposure to low doses or low chronic exposure generate a very low risk of harmful effects on hereditary health. The mechanisms that lead to harmful effects on health after exposure to ionizing radiation, mainly the possible distribution of damage resulting from the spread of low doses over long periods of exposure.

Lower doses would produce proportionately lower risks. However, there is no direct evidence that low doses of radiation increase the risk of non-cancer diseases.

The external doses express the radiometric values at the entrance to concessions and in the environment corresponding either to the residential courtyard and/or to the agricultural environment depending on the attendance and use of said environment they represent. This value was followed between 2.1-3mSv/year with 23.3%. On the other hand, exposure levels between 19.1-20mSv/year and 23.1-24mSv/year are low but with very significant representations, that is 7% and 2.3% respectively. According to the calculation of the cumulative dose based on the duration of residence in these localities, the highest representations of time span were those of 50 and 70 years old. The cumulative dose would be proportional or greater than 173-242mSv. These values correspond to the reference exposure level of solid cancers according to the UNSCEAR report (2012) (28). The cumulative dose according to the highest residence times is 0.12Gy a value very close to that estimated by (Gresser, 2004) (29) at 0.15Gy. This dosimetric value is equivalent to the admissible threshold for temporary infertility in men. Considering these dosimetric values, we can understand the low fertility observed in these study locations; hence the observation of an aging population. We can describe that radiometric exposure has an impact on cells germs. It is important to force the relocation and resettlement of the rest of the population as in 2006 during the installation of the Poli uranium project by the Canadian company Nu Energy Corporation in order to perpetuate the human species in this part of the Poli locality. Calculating the cumulative dose based on the lifespan spent in the locality gave us a value of 250mSv/year. This value corresponds to the longest lifespan in the locality, that is 51 years and above.

The endocrine system disorders were goiters, sore throats and thyroid aplasia : Figure 6a presents the intersection between endocrine conditions and effective internal doses in mSv/year. It appears that the largest proportion of cases of endocrine system disorders (52.17%) was attributed to the annual effective dose of between 1.1-2mSv/year; followed by the dose between 10.1-11mSv/year with 13.04% of case conditions. Figure 6b presents the intersection between endocrine system conditions and external effective doses in mSv/year. It appears that 43.47% of cases of endocrine system disease were attributable to the annual effective dose of between 1.1-2mSv/year; followed by the external dose of between 2.1-3mSv/year with 13.04% of cases disease. The results obtained from the exploration of the endocrine system revealed two main radiation-induced effects, including sore throats (62%) followed by goiters (32%). These results are also similar to those found by Manyacka and Nguepjouo (2008) (23) who found a predominance of goiters in the endocrine system. Abubakar and al (2015) (30) in China noted high levels of thyroid pathologies and goiter. These results, similar to those obtained elsewhere, reflect the impact of ionizing radiation resulting from radioelements on the thyroid as a hormonal gland. It should be added that the appearance of thyroid pathologies could be visualized for doses greater than 100mSv according to the IRSN.

According to the results, with regard to the endocrine system, we have a18.253 at 3 degrees of freedom with a very good significance of a threshold of 0.00 compared to a Chi-square read at 3 degrees of freedom worth 7.815 for a significance threshold equal to 5% which is much lower. This allows us to validate the existence of strong causal links between dependent variables (the conditions observed on the endocrine system) and independent variables (internal and external effective dose and time spend of residence in the localities).
The strength of association of the variables used in the endocrine model system is established by examining Nagelkerke's R^2, which represents the variance explained by the model. Here it has a value of 0.477. Which means that the model explains 47.7% of the variance in the dependent variables such as the appearance of goiter, sore throat, thyroid aplasia or the association between these differences in the system and in relation to effective doses. . In addition, the goodness of fit of the model is observed from the Cox and Snell R^2 value. We observe a good fit of the quality of the model with regard to the Cox and Snell R^2 coefficient equal to 0.346.

Respiratory system conditions were chest pain, hemoptysis, chronic cough, bronchorrhea,digital hypocratism and cigarette smoking : Figure 7a presents the intersection between respiratory system conditions and internal effective dose levels in mSv/year. It appears that 26.08% case of respiratory system conditions were attributable to the effective annual internal dose of between 1.1-2mSv/year; followed by the dose between 10.1-11mSv/year with 13.04% case conditions. Figure 7b presents the intersection between respiratory system conditions and external effective dose levels in mSv/year. It appears that 17.39% cases of respiratory system illnesses were attributed to the annual effective dose between 1.1-2mSv/year; followed by the external dose between 2.1-3mSv/year with 13.04% cases of disease. The pathologies observed in the respiratory system were: cough (28%), chest pain (51%), bronchial pain (16%), and hemoptisia (5%) with a predominance of two pathologies including chest pain (51%). %) and cough (28%). These results differ from those found by Bersimbaev and al (2015) (31) who estimated that lung cancer was the main respiratory pathology. However, it should be noted that lung cancer could be caused by the inhalation of high concentrations of radon highlighted by Saidou and al, (2015) (32) in the locality of Kitongo in Poli. This radon concentration was estimated at 294Bq/m3. The appearance of radon-induced cancer have a concentration greater than 100Bq/m3 in our study; the detection of lung cancer should be highlighted by the use of a radiological technique like the CT which could explain the cases observed in our results. Concerning the respiratory system, we have a 13.880 at 3 degrees of freedom with a very good significance of a threshold of 0.003 compared to a Chi-square read at 3 degrees of freedom which is worth 7.815 for a significance threshold equal to 5%, which is much lower. This allows us to confirm the existence of the association between the dependent variables (respiratory system conditions) and the independent variables (internal and external effective dose and period of time of residence in localities) used to characterize respiratory conditions.The strength of association of the model by examining Nagelkerke's R^2, representing the variance explained by the model. Here it has a value of 0.371. This means that the model explains 37.1% of the variance of the dependent variables which are the appearance of chest pain, Bronchorrhea, chronic cough, hemoptysis, clubbing and smoking. In other words, there is a fairly significant relationship between the signs observed on the respiratory system and the irradiation levels and duration in the locality. We observe a good fit of the quality of the model with a Cox and Snell R^2 coefficient equal to 0.276.

The conditions of osteoarticular system were bone pain, bone lesions, joint pain, bone and joint pain : Figure 8a presents the intersection between osteoarticular system conditions and external effective dose levels in mSv/year. It appears that 56.52% of cases of osteoarticular system disorders were attributed to the annual effective dose of between 1.1-2mSv/year; followed by the external dose between 10.1-11mSv/year with 8.69% of cases of osteoarticular conditions.

Figure 8b presents the intersection between osteoarticular system conditions and internal effective dose levels in mSv/year. It appears that 47.82% of cases of osteoarticular system disorders were attributable to the effective annual internal dose between 1.1-2 mSv/year; followed by doses between 2.1-3mSv/year and 19.1-20mSv/year with 8.69% of cases of osteo-articular conditions respectively. The results obtained, according to Auger and al (2010) (33), be explained by a common ingestion of uranium 238 which causes bone pain because uranium remains stored in the bone for a long period of time, another radionuclide responsible for this pain would be strontium 90, in fact it is stored in the bone according to UNSCEAR, (2008) (34) and causes bone disorders causing pain as it's the case in our study.

Concerning the osteoarticular system, we have a 3.029 at 3 degrees of freedom with a very low significance of a threshold of 0.387 compared to a Chi-square read at 3 dof worth 7.815. This indicates that, the dependent variables observed (conditions on the osteoarticular system) are very little influenced by the independent variables used to characterize the conditions observed and are not strongly linked.According to Nagelkerke's R^2 which represents the variance is explained by the model. Here it has a value of 0.100. Which means that the model explains 10.0% of the variance in the dependent variables which are the appearance of bone and osteoarticular pain or both at the same time. In other words, there is a very insignificant relationship between the effects observed on the osteoarticular system and the irradiation levels and the duration in the locality. In addition, this table provides information on the quality of fit of the model based on the Cox and Snell R^2 value. We observe a very weak adjustment with regard to this Cox and Snell R^2 coefficient equal to 0.068.

CONCLUSION

This study made it possible to evaluate the levels of radiological exposure in accordance with the biological conditions observed within the populations residing on the Kitongo de Poli mountains. At the end of this study, the duration of exposure, the internal dose, the external dose positively influences the appearance and the increase of the biological affections of the residents of the locality of Kitongo. The most represented age group was that of 50 years and over with 56.53% followed by that between 41-50 years with 13.04%. The study population consisted mainly of indigenous adults and elderly people. We observed a high rate of infertility in the locality of Kitongo with 43.47%. The housing compounds, i.e. 100%, were made of mud bricks which resulted in increased radiation levels inside the compounds due to the porosity of the floor and the type of radioactive material collected and used in the same environment.

The internal and external dosimetric exposure levels were evaluated through a direct-reading dosimeter model RAD-35, serial number 3517331. The internal and external dosimetric data were taken at 1m above the ground in micro-Sievert by hour (µSv⁄h) then converted into Sievert per year (mSv⁄an). The internal dosimetry corresponded to the highest energy values taken in the housing concessions and the external dosimetry to that of the environment and the exploited surfaces. The various conditions observed have shown the importance of the study in order to take significant measures to relocate the rest of the population living in this naturally radioactive high-risk area.

Conflict of interest: The authors declared that they had no conflict of interest related to this work.

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