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Preliminary Study of Gamma Dose Rate Distribution in the Anomaly of the West-Central Region of Burkina Faso: Use of a Portable Gamma Detector

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Abstract: Preliminary work on the measurement of natural radioactivity in the uranium anomaly in west-central Burkina Faso has made it possible to determine the horizontal distribution of gamma dose rate in the study area. The values vary between $0.100 \mu Svh^{-1}$ and $0.281 \mu Svh^{-1}$. The mean value is about $0.193 \mu Svh^{-1}$. This value is significantly higher than the world average of dose rate which worth $0.055 \mu Svh^{-1}$. The gamma dose rate has also been measured according to depths sometimes reaching 100 cm. The variation of the dose with depth shows that the relatively high level of radioactivity is of telluric origin.
Keywords: IdentiFINDER, gamma dose rate, High background radioactivity area, Natural radioactivity

I. INTRODUCTION

Radioactivity is a natural phenomenon manifested by the emission of ionizing radiation by unstable nuclide. The radiations are used in the medical field to diagnose and treat cancer, measure the density of products in the industrial field, check the quality of materials, and irradiate pharmaceuticals as well as food to sterilize them. Ionizing radiation is also used in agriculture to make plant species more resistant and productive. Despite all the benefits of radioactivity, it can also be harmful to human life. Ionizing radiation can lead to diseases such as cataracts, leukemia, cancer or even death [1]. Unfortunately, they are imperceptible to human senses and act in silence. Detectors are used to identify and quantify them. Radioactivity is present everywhere and at any time. It is found in the air, drinking water and soil in very different quantities. An airborne study conducted as part of the SYSMIN project has identified regions of Burkina Faso where the level of radioactivity is relatively high. Are these localities dangerous for the inhabitants' lives? For finding out, it is necessary to conduct a radiological study. Thus, preliminary work was done to determine the gamma dose rate distribution in the west-central region of Burkina Faso. This study has highlighted some anomalies that will be presented in this document. After describing the procedure, the gamma dose rate distribution will be given according to the horizontal and depth profiles.

II. METHOD AND MATERIALS

A. Description Of The Study Area

Burkina Faso is a landlocked country, located in the heart of West Africa with an area of approximately 274 400 km² and a population estimated at nearly twenty million inhabitants. Its climate is Sudano-Sahelian characterized by two seasons. A dry season that manifests from November to May and a rainy season from June to October. The dry season is characterized by a period of cold that takes place from December to February accompanied by dry wind (Harmattan). This season is dominated by the heat that settles in March. The maximum temperature is 45 ° C in April and the minimum is 15 ° C in January. In addition, average amounts of rainwater during the rainy season range from 500mm to 800mm. The study area is located in the Center-West region of Burkina Faso about 80 km from Ouagadougou the capital of the country located at latitude of 12 ° 21'58 " N and longitude of 1 ° 31'05 " W. Three main localities caught our attention during this study. These are Kindi, Villy and Ramongo. Kindi is located at 81km from Ouagadougou. It is reached by going through approximately 28 km of lane through bushwood located at the left turn, just after Lay city. A little bit far away about 66 km from Kindi on the same lane, Villy is located. Ramongo can be found just outside Koudougou city on the direction of Ouagadougou not far from the toll station (see Fig. 1).

B. Gamma Dose Rate Measurement

For the measurement of the gamma dose rate, we used a very high-performance gamma spectrometer with a good sensitivity. This is the idF2-ULK-NGH model of the identiFINDER R-400 that can perform multiple tasks. It is equipped with a gamma detector of sodium iodide (NaI) which makes it possible to acquire a gamma spectrum from which the dose rate is deduced. Indeed, the main radionuclides that cause exposure to a natural source of ionizing radiation are uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K). By the gamma spectrum, the ambient dose rate is determined at one (01) meter above the ground using the following formula [2] :

$$D_R(nGyh^{-1}) = 0.462A_U + 0.604A_{Th} + 0.042A_K$$

Where A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K respectively, expressed in $Bq.kg^{-1}$.

Fig. 1: Itinerary of the study area

The dose rate is a primary quantity. It is essential for radiation protection purposes to take into account of the measurement, the amount of average energy absorbed by a specific organ or tissue during exposure to an ionizing source of radiation. Unfortunately, the harmful effects of ionizing radiation are not referred by the dose rate. These effects depends not only on the nature of the radiation but also on the irradiate tissue. The radiological (W_R) and tissue (W_T) weighting factors [1] are then introduced to determine the effective equivalent dose rate E which is a protection quantity introduced by the International Commission for Radiological Protection (ICRP) to protect people exposed to ionizing radiation. It has been used to define the dose limits beyond which the risk of harmful effects is high. The effective equivalent dose is given by the following formula [3]:

$$E = \sum_T W_T \sum_R W_R D_{T,R}$$

In this expression, the radiological (W_R) and tissue (W_T) weighting factors as well as the ambient dose rate ($D_{T,R}$) are measurable values. Gamma ray spectrometry method is also used to calculate it according to the following formula:

$$D(mSvy^{-1}) = D_R(nGyh^{-1}) \times 8760\, h \cdot y^{-1} \times 0.7 \times (10^3\, mSv/10^9)\, nGy \times 0.2$$

The detector of the identiFINDER R-400 does not need to be cooled like high purity germanium detectors ([4], [5]). So, it can be used as a portable gamma spectrometer. It is also equipped with a Geiger Müller counter for measuring relatively intense doses.

The dose rate was measured at different depths of the soil and a manual swindler is employed for digging. The collector is composed of three (03) compartments which must be screwed together before being used:

1) A first compartment of the collector is a hollow cylinder with a height of about twenty (20) centimeters. The base of this cylinder has been cut to obtain interlocking hooks allowing to easily sink into the ground following.

2) A second compartment is a stem which is bound to the top of the first compartment. It allows to connect the sample collector (first compartment) to the sleeve.

3) A third compartment is a sleeve which is connected to the other end of the stem. It allows to apply a physical force on the whole collector.

A Garmin GPS has also been used for identifying geographic coordinates of point of interest.

In the study area, the team is passed through randomly in the localities for identifying anomalies. During this time, the identiFINDER is turned on in the basic operating mode which is the dose rate measurement mode. Thus, whenever the device indicates a relatively high dose, we dwell in the locality concerned to find the highest dose rate points. Once a point of interest is identified, its GPS coordinates and the dose rate of the device located one (01) meter above this location are first noted. Then, after mounted the different pieces of the collector, dig the ground at the same location and orient the detector of the identiFINDER into the hole at a specific depth of the ground, the maximum value displayed on the screen during one minute is saved. The dose rate is thus obtained at one meter above the ground and at depths ranging from 20 cm to 100 cm. unfortunately, given the rocky nature of the soil (see Fig. 2), some depths could not be reached.
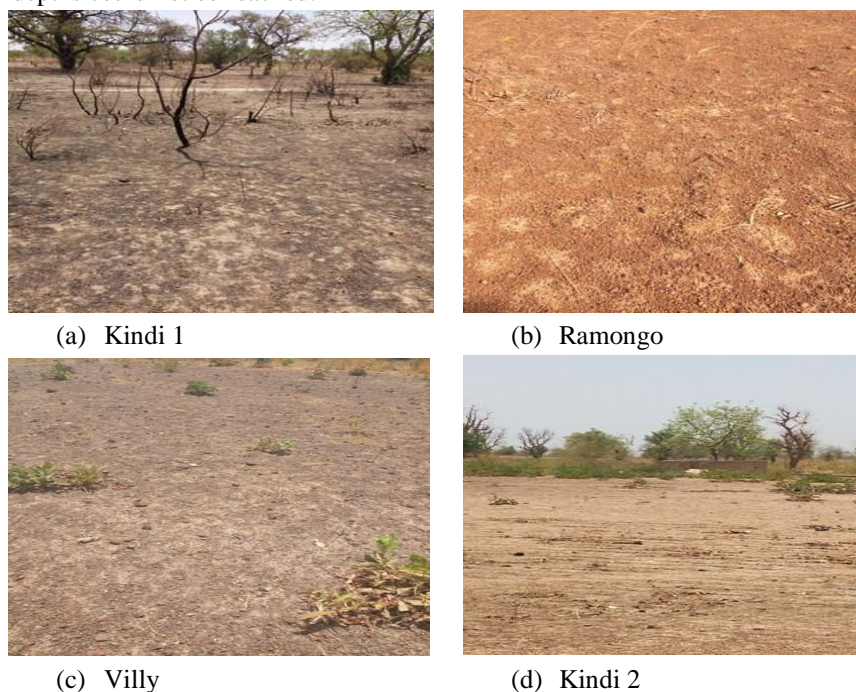

(a) Kindi 1   (b) Ramongo

(c) Villy   (d) Kindi 2

Fig. 2: The soil nature in the study area

III. RESULTS AND DISCUSSION

A. Horizontal Distribution Of Gamma Dose Rate

An in-situ measurement of the gamma dose rate was carried out on eleven (11) geographical points of which three (03) are located in the village of Manevire into the rural commune of Kindi, five (05) in the rural commune of Villy and three (03) points intto Ramongo. The maximum value of the gamma dose rate measured at one (01) meter above the ground, was obtained at Manevire and its value is equal to $0.281 \mu Svh^{-1}$. It is also in this village that the minimum value has been noted. It is about $0.100 \mu Svh^{-1}$. The gamma dose rate mean value in the study area is about $0.191 \mu Svh^{-1}$. This value exceeds three times the worldwide average of the dose rate. This worldwide average is also measured at one (01) meter above the ground and it is about $0.48 mSvy^{-1}$ which is worth $0.055 \mu Svh^{-1}$:

$$0.48 mSvy^{-1} = 480 \mu Sv \cdot (8760h)^{-1} = 0.055 \mu Svh^{-1}$$

The maximum value of the dose rate is worth five (05) times the world average, while the minimum value is twice the world average. Fig. 3 shows the dose rate distribution of the study area using a bar graph. Each stick in the diagram represents a measurement point and Villy is the locality where the value of the dose rate seems to be the most stable because it varies less. This is not the case for Manevire, which has both maximum and minimum dose rate values for the study area. As a result, in all the villages of the study area, the average value of the dose rate obtained at Villy is higher than those of Manevire and Ramongo. This is illustrated in Fig. 4 which is a comparison of the average dose rate values of the main localities with the world average and the recommended values of gamma dose rate.

From left to right, we have the average value of Manevire, Villy, Ramongo and that of the study area. It is noted that the dose rate at Villy is the highest and all of the localities have a gamma dose rate well above the worldwide average and the recommended limit values. This limit has been established for people exposed to naturally occurring ionizing radiation to protect them from harm. Its value is equal to $1 mSvy^{-1}$ [3] and worth $0.114 mSvy^{-1}$.
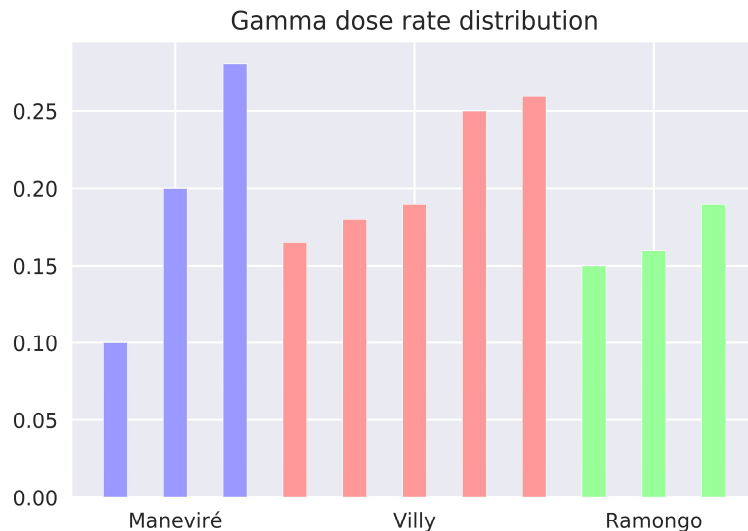

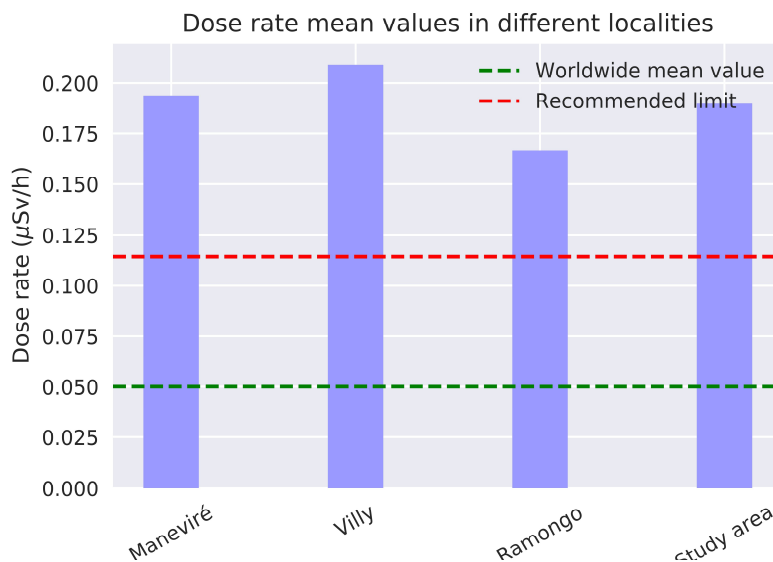Fig.3: Gamma dose rate distribution at 1m above the ground

Fig.4: Mean values of gamma dose rate

B. Depth Profile Of Gamma Dose Rate

Gamma dose rate was measured at different depths ranging from 20cm to 100cm. However, considering the nature of the soil, the only sampling point having reached 100cm is at Villy. For most points, only a depth of 20cm has been reached. At this depth, the average doses recorded at Manevire, Villy and Ramongo are $0.255 \mu Svh^{-1}$, $0.266 \mu Svh^{-1}$ and $0.205 \mu Svh^{-1}$ respectively. For a depth of 40cm, there is an increase in the dose rate that reaches $0.298 \mu Svh^{-1}$ and $0.368 \mu Svh^{-1}$ respectively at Manevire and Villy. This increase into the dose rate is about 16.86% at Manevire and 38.34% at Villy from 20cm to 40cm depth. The different doses measured are shown in the diagram of Fig. 5.

The highest dose is measured in Manevire. The dose value at the concerned point varies from $0.281 \mu Svh^{-1}$ at one (01) meter above the ground, to $0.387 \mu Svh^{-1}$ at 20cm depth, then to $0.424 \mu Svh^{-1}$ for a depth of 40cm. Fig. 6 illustrates the variation of the minimum and maximum values as well as the average of the study area as a function of depth. These variations clearly indicate that the dose rate is increasing and that the radiological anomaly is of terrestrial origin.
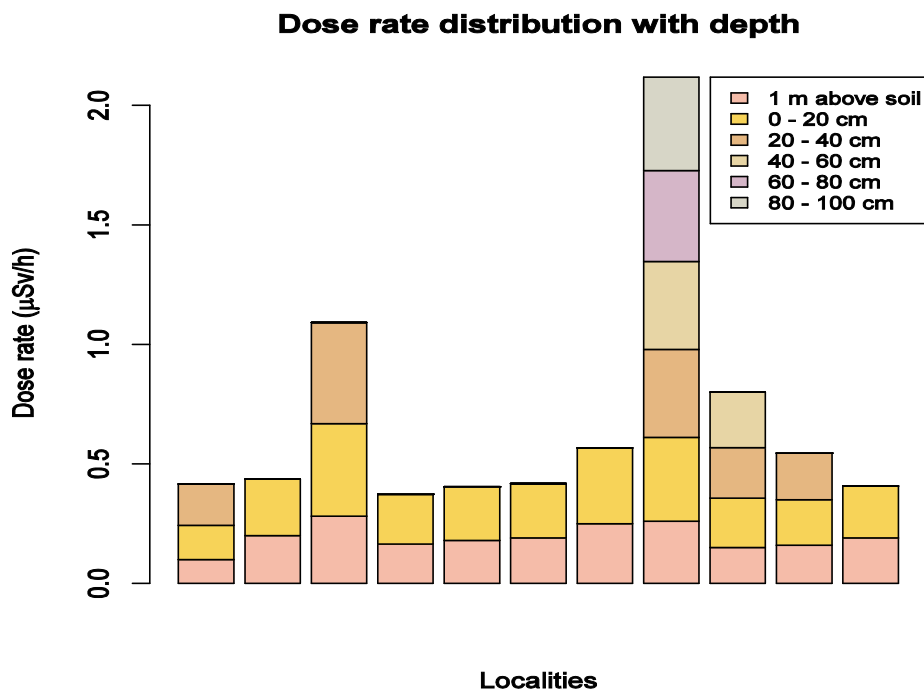

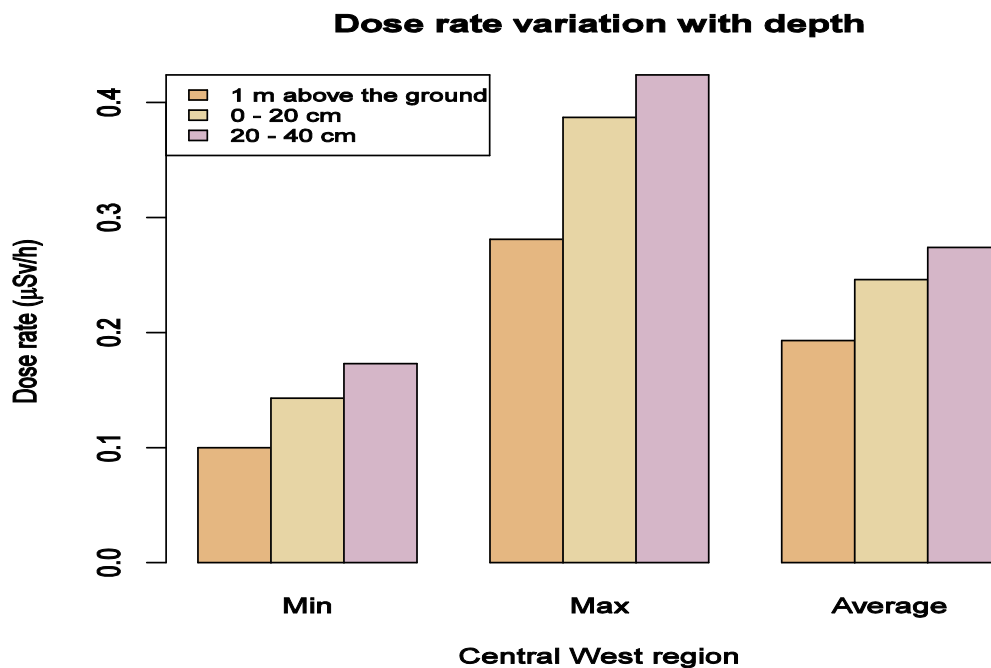Fig. 5: Depth profile of the gamma dose rate

Fig. 6: Gamma dose rate minimum, maximum and mean values variation

IV. CONCLUSION

Radioactivity is a natural phenomenon unevenly distributed in the environment. In this study, gamma dose rate was measured using the identiFINDER R-400 to establish its distribution in the anomaly in west central region of Burkina Faso. These measurements have shown that doses in the study area are well above the global average dose and the recommended dose limit for people exposed to naturally occurring ionizing radiation. This should attract the attention of the competent authorities in the field of radiation protection because investigations must be carried out there to assess radiological hazards.

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