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PRELIMINARY RESULTS MEASURING THE GAMMA DOSE RATE DISTRIBUTION IN NORTH EASTERN BURKINA FASO WHERE THE CONCENTRATION OF URANIUM IN THE SOIL IS ELEVATED

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ABSTRACT

On this paper, the gamma dose rate is measured using the IdentiFINDER device which is equipped by a portable gamma-ray spectrometer. Horizontal and depth profiles are then obtained in the study area. The measurements are performed at one meter above the ground and under variables depths often reaching 100 cm on a determined geographical point of interest. The dose rate at one meter above the ground varies between 0.050 $\mu Sv.h^{-1}$ and 0.300 $\mu Sv.h^{-1}$. The mean value in the study area is about 0.128 $\mu Sv.h^{-1}$ which is well higher than the world average of gamma dose rate from natural radioactivity. It is also higher than the established limit of gamma dose rate for the international recommendation of public exposure to the natural source of ionizing radiation. The gamma dose rate also rises with the depth and this variation confirms the terrestrial origin of the anomaly.

KEYWORDS: *Gamma Dose Rate, High Background Radioactivity Area, IdentiFINDER, Natural Radioactivity*

Article History

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INTRODUCTION

Radioactivity is a spontaneous phenomenon manifested by the emission of ionizing radiations by a radionuclide. These radiations are often dangerous for human life and unfortunately, their existence cannot be perceived by the human senses. Radio nuclides are present everywhere in the environment and they are unevenly distributed according to the rock structure of the land. Appropriate devices of measurement are used to detect them. The earth is about 4.5 billion years old and contains several serial chains of long-lived, naturally occurring isotopes in soil. The parent isotopes (and radiological half-lives) of these chains are ^{238}U (4.47 billion years), ^{235}U (0.70 billion years), ^{232}Th (14.05 billion years), ^{237}Np (2.10 million years) which is disappeared because of his relatively short half-life, and ^{40}K (1.27 billion years). The main source of public exposure to ionizing radiation is due to these isotopes, their decay products, and cosmic radiation ([1]). The public exposure to the ionizing radiation can be harmful to health depending on the intensity of the absorbed radiation. This intensity is sometimes evaluated by the value of the dose rate. When the absorbed dose is very high, it is able to damage several cells of the human body that can bring the death of the concerned organs. That situation can lead to the loss of human life. On the other hand, when the absorbed dose is relatively lower, the living cells can undergo modifications and those responsible for the cell division could transmit these aberrations to their descendants or dies. This can lead to leukemia or cancer and even hereditary diseases ([2]).

In Burkina Faso, an airborne gamma spectrometry study reported the presence of uranium anomaly in the Northeastern part of the country ([3]). This locality is said to bear uranium anomaly because of its activity, there, was found to be slightly higher than any other place. In order to know the origin of these anomalies and the level of the dose emitted by them, it is necessary to conduct a study on the ground. That will permit to prevent harmful effects on public health. A preliminary study was therefore conducted by our team and the result will be presented on this paper. Our goal in this work is to locate points with high dose rate and to see the variation of this dose with the depth. After presenting the method, the horizontal distribution of gamma dose rate will be presented before giving the vertical profile.

MATERIAL AND METHODOLOGY

Description of the Study Area

The study area is the northeastern part of Burkina Faso located in the Sahel region where the climate is Sudano-Sahelian. There are mainly two seasons. A dry season which runs from November to May and a rainy one from June to October. The dry season is characterized by a cold period from December to February accompanied by a hot wind coming from the Sahara and a significant heat which takes place in March. During the dry season, the extreme temperatures are reached and they worth 45° C in April and 15° C in January.

The study area essentially consists of three departments which are Bogande, Sebba, and Dori. The population is rural there and about 96.3% of the inhabitants live in rural areas in the provinces of Gnagna (Bogande) and Yagha (Sebba) while in Seno (Dori) this proportion is about 92%.

Determination of the Effective Dose

Ionizing radiation is omnipresent and its interactions with matter allow particles to release energy in the middle. This energy can be evaluated per unit mass of material. It is an average of the dose absorbed by the tissues of the whole body. This dose is a measurable quantity. It can also be calculated in the case of natural exposure. For this purpose, the activities of the main source of exposure to ionizing radiation must be known first. The interaction of ionizing radiation with living tissue results in the deposition of energy in that tissue. The average energy deposition per unit mass (Joule/kg) of tissue is defined as the absorbed dose. The natural radiation background consists of a range of photon energies that must be evaluated in order to convert exposure to dose. Conversion factors [2] will be used to compute the gamma dose rate a tone meter above the ground due to terrestrial radio nuclides. Their values per unit activity concentration in $Bq.kg^{-1}$ corresponds to 0.462 $nGy.h^{-1}$ for uranium, 0.604$nGy.h^{-1}$for thoriumand0.042$nGy.h^{-1}$forpotassium.The method of calculation has been used by several authors after having determined the activitiesof^{238}U,$^{232}Th$and$^{40}K$by the gamma ray spectrometry method[4].The absorbed dose rate is determined by the following equation:

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

Where A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K respectively

The absorbed dose rate is used to assess the risk associated with the exposure to ionizing radiation. This risk depends not only on the nature of the particles but also on the nature of the tissue of organs which is in concern by the interaction with radiation. The radiological risk depends on the type of ionizing particles since they carry energies of different quantities. Then, a radiological weighting factor W_R ([2]) is introduced to differentiate the type of radiation. This factor makes it possible to calculate a radiological protection quantity, the equivalent dose H_T defined according to ([5]):

$$H_T = \sum_R W_R D_{T,R} \tag{2}$$

In the above relation, $D_{T,R}$ is the average of dose absorbed into a tissue or an organ, caused by R-type radiation (gamma, alpha, beta, neutron, etc.). The equivalent dose at the level of the skin $H_P(0.07)$ is a measurable quantity. It refers to the absorbed dose at a depth of $0.07mm$ of the skin. This value is obtained through the use of an individual dosimeter.

For taking into account the tissue sensitivity, a tissue weighting factor W_T is introduced too. Thus, one can determine the effective dose E which is a protective quantity ([5]) given by the following formula:

$$E = \sum_T W_T \sum_R W_R D_{T,R} \tag{3}$$

The effective dose can also be computed after determining the specific activities of the main telluric radio nuclides by gamma-ray spectrometry method. These activities are used to determine the absorbed dose rate. Then, the result is multiplied by the conversion coefficient $\left(0.7SvGy^{-1}\right)$ and the outdoor occupancy factor (0.2) proposed by ([2]). This factor is obtained by considering that the proportion of time, people spend outside the apartment is about 20%. Therefore, the annual effective dose is given by the following formula:

$$D(mSvy^{-1}) = D_R(nGyh^{-1}) \times 8760h \cdot y^{-1} \times 0.7 \times (10^3 mSv / 10^9) nGy \times 0.2 \tag{4}$$

The IdentiFINDER R-400 is equipped with a portable gamma detector for acquiring the spectrum of a radiation source. This spectrum permits the device to calculate the equivalent dose rate. In many cases, this dose is obtained after laboratory analysis of the samples taken from the source. Generally, a personal dosimeter is used to determine an operational measurement which is an effective dose at a depth of $10mm$ of the tissue $H_P(10)$. In the present work, data obtained by the IdentiFINDER R-400 are equivalent dose rate expressed in μSvh^{-1}.

Gamma Dose Rate Measurement

The device used in this work, for the dose rate measurement, is the IdentiFINDER R-400 model ideF2-ULK-NGH. It is equipped with a 35mm (1.38 in) x 51mm (2.01 in) sodium iodide (NaI) gamma detector ([6]). It does not need to be cooled as it is the case with High Purity Germanium detectors ([7]) which makes it easily portable. This detector allows the device to acquire gamma spectrum and to deduce the equivalent dose rate. An external potassium (K-40) source is used for energy calibration before using. The IdentiFINDER R-400 is also equipped with a neutron proportional counter and a Geiger Muller tube capable to measure intense doses.

Using a GPS for recording geographic coordinates and an IdentiFINDER device, started on dose rate mode, the team went through the study area to look for locations where the dose rate is quite high. When a point of interest is located, the dose rate is measured at one meter above the ground and then, using a drill, the soil is dug to a depth of 1m at intervals of twenty centimeters. Unfortunately, in most cases, the rocky nature of the soil Figure 1 just permit to dig up to 40cm.

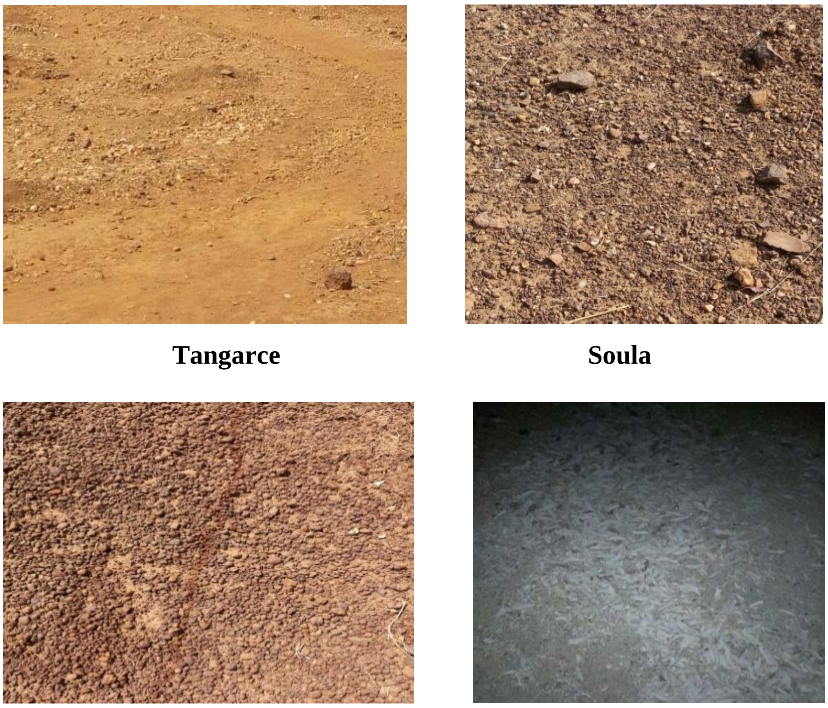

Figure 1: The Soil Nature in the Study Area

RESULTS AND DISCUSSIONS

Horizontal Distribution of Gamma Dose Rate

Measurements have been taken at 1m above the ground of twenty-eight points in the study area. The results revealed that dose rates vary between $0.050\mu Svh^{-1}$ and $0.300\mu Svh^{-1}$. The minimum value is obtained in the village of Tangarce while the maximum one is found at Niapsi. The average value of the dose rate in the study area is $0.128\mu Svh^{-1}$. This value is well above the world mean value of dose rate $0.48mSvy^{-1}$ which is worth $0.055\mu Svh^{-1}$.

$$0.48mSvy^{-1} = 480\mu Sv \cdot (8760h)^{-1} = 0.055\mu Svh^{-1} \quad (5)$$

The maximum dose obtained at Niapsi almost worth six times the world average. Figure 2 is a graphical representation of the gamma dose rate distribution in the study area. It shows that the most intense dose is observed at Sebba. Figure 3 shows the average value of gamma dose rate in some villages of the study area. These dose rates are compared to the world average and the recommended limit values ([5]). The doses rate of the study area are higher than or equal to the world mean value. In addition, three villages have been identified where the dose rate is well above the limit of the international recommendation. This limit has been established for public exposure to a natural source of ionizing radiation. Its value is about $1mSvy^{-1}$ which is worth $0.114\mu Svh^{-1}$. This is actually a lower limit established in the context of radiological protection in order to prevent the harmful effects of ionizing radiation. The localities marked by a fairly significant gamma dose rate are Pougbonne, Niapsi, and Gourgnel. These areas have a high-level radioactivity background. There are similar places in the world where the level of natural radiation is quite high. This is the case, for example of Kerala and Kalpakkam in India ([8], [9]), the southeastern region of Brazil ([10]) and the west-central of Burkina Faso [11].

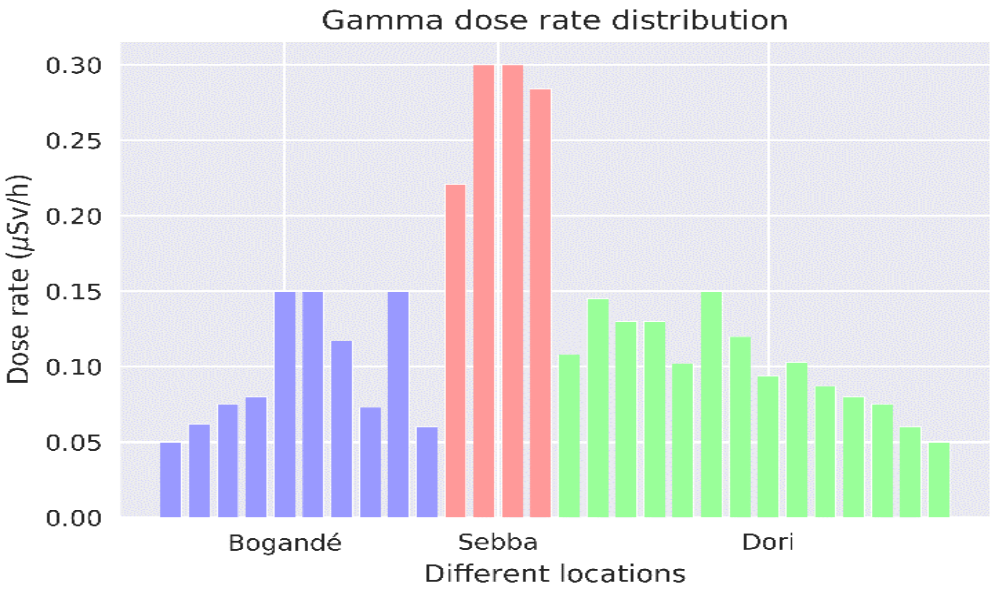

Figure 2: Gamma Dose Rate Distribution at 1m above the Ground

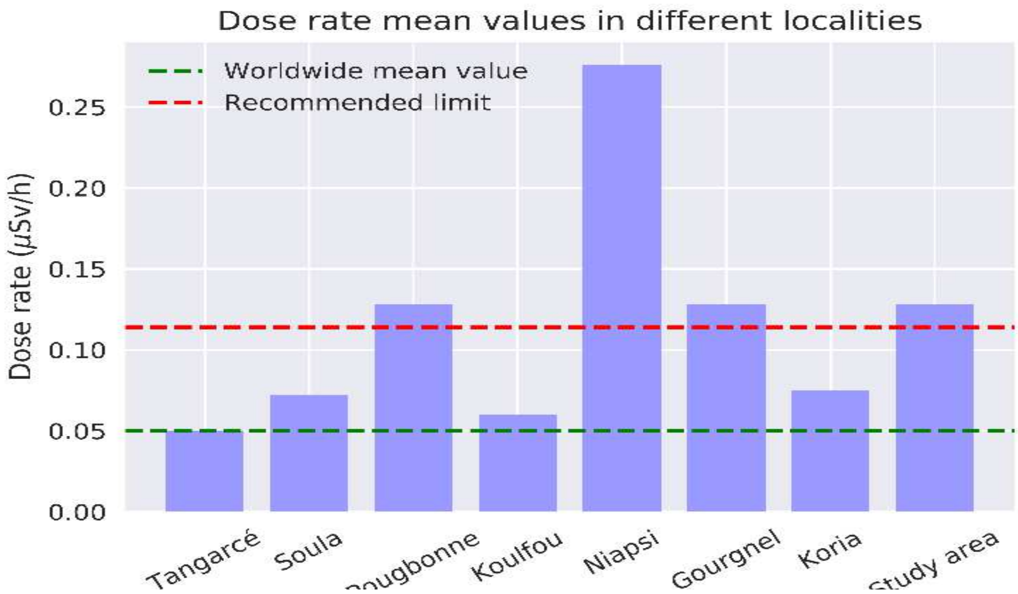

Figure 3: Mean Values of Gamma Dose Rate

Vertical Profile of Gamma Dose Rate

In some localities, the gamma dose rate has been measured according to the depth of the ground. This has been done for seeing the evolution of the dose rate with depth. In some places, however, the soil could not be dug, sometimes because of its rocky nature. The results are represented on the diagram of Figure 4. The dose rate mostly rises very slightly with the depth. This can be shown on Figure 5 where the variation of minimum, maximum and mean values of gamma dose rate with depth is represented. For each of these cases, the dose rate increase with depth. This confirms that the radiological anomaly is of terrestrial origin since the radiation source seems to concentrate more into the subsoil. It is necessary to specify that the dose measured at any depth is not only for that but also contain the contribution of all the above one. What is wanted to show is that the overall dose increases with the depth.

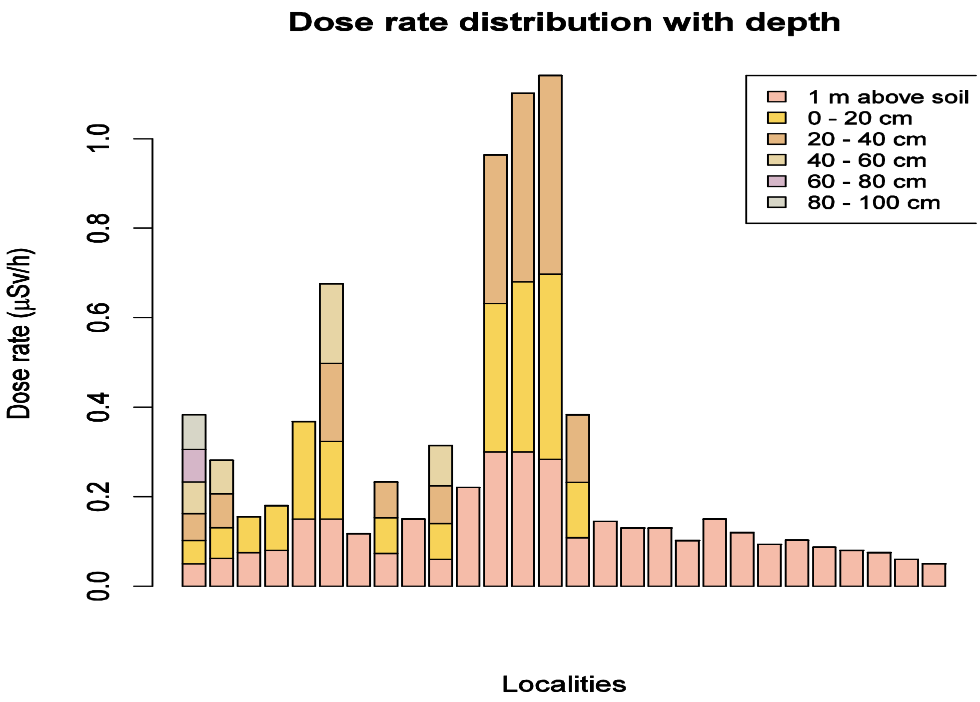

Figure 4: Vertical Profile of the Gamma Dose Rate

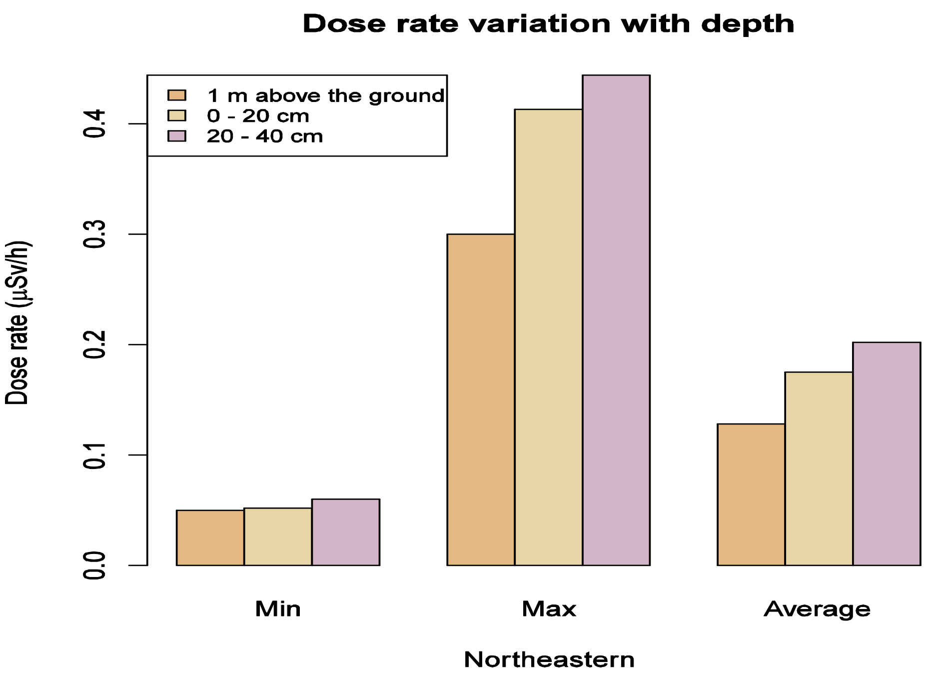

Figure 5: Gamma Dose Rate Minimum, Maximum and Mean Values Variation with Depth

CONCLUSIONS

The work presented in this paper is a preliminary study for locating radiological anomalies and confirming their telluric origins. It was made using an IdentiFINDER R-400 equipped by a portable gamma detector. This detector measured the gamma dose rate at one meter above the ground in several localities in the northeastern part of Burkina Faso, resulting in the horizontal distribution of gamma dose rate due to natural exposure. This distribution revealed fairly high levels of exposure to ionizing radiation in the localities of Pougbonne, Niapsi, and Gourgnel. Indeed, these villages have gamma dose rate levels well above the worldwide mean value and the lower limit of the international recommendation. In addition, measurements were performed according to the depth of the ground. This permits to obtain the vertical profile in some localities. The profile has shown that the dose rate increases with depth and this confirms the telluric origin of the anomaly. In the villages where the level of gamma radiation is quite high, it is important to carryout radiological monitoring to prevent the risks related to the harmful effects of ionizing radiation on the health of inhabitants. Then, a radiological analysis by gamma-ray spectrometry of some samples could make it possible to know the distribution of the radio nuclides at the origin of the high level of gamma radiation. This would allow the evaluation of radiological risks.

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