# Outdoor/Indoor Exposure to Terrestrial γ Radiation Background in Kadugli town, Nuba Mountains, Sudan.

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## Abstract:

We report on the outdoor/indoor natural radiation background exposure in Kadugli town, in the Nuba Mountains, western of the Sudan.

A commercial Gamma Scout survey meter for environmental radiation measurements, was used to scan the absorbed dose all over the city. The survey meter was held 1.0 m above surface. The city was divided into five sub-areas (North, West, South, East, and Center), and twenty readings were taken in different locations and averaged for each sub-area. The effective dose was then calculated based on a value of 0.2 for the occupancy factor for the outdoor radiation exposure. It was found that the values of the absorbed dose ranged from 50-400 $nSv.h^{-1}$, with a mean total absorbed dose rate 185$nSv.h^{-1}$ for the town. The corresponding effective dose was found from calculations to range from 87-701 $\mu Sv.y^{-1}$, with a mean value equals 324 $\mu Sv.y^{-1}$. In case of indoor exposure, it was found that the absorbed dose rate $0.29 \pm 0.04$ $\mu Sv.h^{-1}$, and the effective dose $2.05 \pm 0.28$ $\mu Sv.y^{-1}$. These values are small relative to other locations in the region marked as high radiation background areas (HRBA) like Lake Miri or Uro village, but when considering the world's average value for effective dose, estimated by the UNSEAR which is ~70 $\mu Sv.y^{-1}$, the effective dose in Kadugli town is almost 5-folds higher.

**Key words**: *Natural radiation background, dose rate, effective dose,Kadugli town, Nuba Mountains.*

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## Introduction

It is always important to evaluate the amount of radiation exposure within populated areas, for environmental and health risk assessment purposes. Levels of natural radiation background (NRB) are estimated in absorbed dose (dose rate in $nSv.h^{-1}$) and effective dose or (annual absorbed dose in $\mu Sv.y^{-1}$ or $mSv.y^{-1}$). Many countries in the world recorded absorbed doses not exceeding 85 nGy.h-1 (i.e. 60 $nSv.h^{-1}$). The world's average value for effective dose, estimated by the UNSEAR is ~70 $\mu Sv.y^{-1}$ [(1)]. Some locations in the world are classified as high radiation background areas (HRBA) with levels of NRB few $mSv.y^{-1}$. These include [(2-5)] Ramsar in Iran, Kerala in India, Yangjiang in China, which are classified as well studied HRBAs. Other areas in the world were also detected in Africa, Europe, Asia, and the USA, but they still need detailed studies.

Previous studies [6-10] identified the Nuba Mountains in the center of Sudan, as one of the regions which contains HRBAs in Sudan. However, these studies mainly based on radioactivity measurements, from which external doses were derived. It is therefore of vital importance to assess the environmental NRB in the high population areas within this region.

This study was initiated with aims to survey the external doses from gamma terrestrial radiation in the most populated town in Southern Kordofan State (Kadugli town). In this study outdoor and indoor exposure to terrestrial gamma radiation was studied and environmentally evaluated.

## Materials and methods

### Area under study

Kadugli town is underlined and surrounded by what is known as basement complex rocks of granitic, microgranitic, seynitic and granitoid intrusions. They form elongated mass that extend for several kilometers in the NW direction. These granites are composed mainly of quartz and soddic varieties of feldspars and amphiboles, minor zircon. Lake Miri twenty kilometers west of Kadugli is the closest HRBA. A fault zone characterized by brecciation and Uranium mineralization related to intrusions is interpreted to be responsible for gamma radiation in the area. The population of the city due to data from 2010 national census is $1.2*10^5$ persons on average. It is the higher populated town in the Nuba Mountains region western Sudan. Other populated towns in this region include Dilling, Abu Gibaiha, Abbassia, Lagawa, Talodi, Hiban. The total population of the whole area is almost $3.5*10^6$ persons.

### Outdoor/indoor radiation monitoring

Measurements of the quantity ambient dose equivalent were made using a commercial radiation monitoring survey meter type (Gamma Scout). The GAMMA-SCOUT unit No. 01668 calibrated at the Institute for Radiochemistry and Radiation Protection of the Public College of Technology and Design (Germany) in a dose equivalent range up to 10 $\mu Sv.h^{-1}$, with error less than ±5%. The survey meter was held at the gonad level (i.e. 1.0 m above earth surface). The effective dose was then calculated based on a value of 0.2 and 0.8 occupancy factor for the outdoor and indoor radiation exposure respectively.

The city was divided into five sub-areas (North, West, South, East, and Center), and twenty readings were taken in different locations and averaged for each sub-area, before taking the average value for the whole city.

For the indoor exposure ten schools at different sites in the town were chosen. A number of classrooms in each school were scanned out for gamma ray exposure, and the data were averaged to obtain the mean absorbed dose and equivalent effective dose. The main equation used [11] is the following:

$$D_{eff} = \delta * u * 365.25 * 24 \qquad (1)$$

where;

$D_{eff}$ : annual absorbed dose (mSv.y$^{-1}$)

$\delta$: average absorbed dose rate (μSv.h$^{-1}$)

u: occupancy factor

## Results and analysis

Data obtained during this work are summarized in tables 1 and 2 below. These include both outdoor and indoor measurements of radiation background in Kadugli town. In table (1-a) data of the outdoor measurements for the dose rate (in μSv.h$^{-1}$) at the five zones of the town are shown. The minimum value recorded was 0.05μSv.h$^{-1}$, and the maximum value recorded was 0.40 μSv.h$^{-1}$. After calculations the mean absorbed dose of the five zones ranged from 0.17 to 0.20 μSv.h$^{-1}$, and average value equals 0.19 ± 0.01 μSv.h$^{-1}$.

**Table (1-a)**: Dose rate (in μSv.h$^{-1}$) at different parts of Kadugli town.

| Location No. | Center | South | West | East | North |
|---|---|---|---|---|---|
| 1 | 0.15 | 0.29 | 0.27 | 0.18 | 0.20 |
| 2 | 0.16 | 0.15 | 0.20 | 0.15 | 0.07 |
| 3 | 0.30 | 0.11 | 0.15 | 0.20 | 0.19 |
| 4 | 0.11 | 0.10 | 0.15 | 0.11 | 0.17 |
| 5 | 0.19 | 0.23 | 0.19 | 0.30 | 0.10 |
| 6 | 0.17 | 0.19 | 0.14 | 0.30 | 0.09 |
| 7 | 0.10 | 0.29 | 0.15 | 0.25 | 0.18 |
| 8 | 0.20 | 0.15 | 0.16 | 0.20 | 0.22 |
| 9 | 0.16 | 0.19 | 0.20 | 0.22 | 0.16 |
| 10 | **0.40** | 0.16 | 0.17 | 0.24 | 0.20 |
| 11 | 0.34 | 0.19 | 0.15 | 0.19 | 0.16 |
| 12 | 0.33 | 0.18 | 0.13 | 0.06 | 0.23 |
| 13 | 0.28 | 0.21 | 0.20 | 0.07 | 0.33 |
| 14 | 0.24 | **0.40** | 0.14 | 0.11 | 0.07 |
| 15 | 0.14 | 0.22 | 0.16 | 0.09 | 0.11 |
| 16 | 0.13 | 0.20 | 0.11 | 0.15 | 0.23 |
| 17 | 0.14 | 0.30 | 0.19 | 0.25 | 0.19 |
| 18 | 0.16 | 0.07 | 0.21 | 0.31 | 0.24 |
| 19 | 0.21 | 0.19 | 0.12 | 0.22 | 0.23 |
| 20 | 0.10 | 0.18 | 0.10 | 0.13 | **0.05** |
| Mean | 0.20 | 0.20 | 0.17 | 0.19 | 0.17 |

Table (1-b) shows the equivalent effective dose for outdoor exposure in the town, based on data of table (1-a) and occupancy factor equals 0.2. It came out from these calculations that the mean value is between 0.30 to 0.35 $mSv.h^{-1}$, with an average equivalent effective dose $0.32 \pm 0.04$ $mSv.y^{-1}$.

**Table (1-b)**: Effective dose ($\mu Sv.y^{-1}$) at different parts of Kadugli town.

| Location No. | Center | South | West | East | North |
|---|---|---|---|---|---|
| 1 | 262.98 | 508.43 | 473.36 | 315.58 | 350.64 |
| 2 | 280.51 | 262.98 | 350.64 | 262.98 | 122.72 |
| 3 | 525.96 | 192.85 | 262.98 | 350.64 | 333.11 |
| 4 | 192.85 | 175.32 | 262.98 | 192.85 | 298.04 |
| 5 | 333.11 | 403.24 | 333.11 | 525.96 | 175.32 |
| 6 | 298.04 | 333.11 | 245.45 | 525.96 | 157.79 |
| 7 | 175.32 | 508.43 | 262.98 | 438.30 | 315.58 |
| 8 | 350.64 | 262.98 | 280.51 | 350.64 | 385.70 |
| 9 | 280.51 | 333.11 | 350.64 | 385.70 | 280.51 |
| 10 | **701.28** | 280.51 | 298.04 | 420.77 | 350.64 |
| 11 | 596.09 | 333.11 | 262.98 | 333.11 | 280.51 |
| 12 | 578.56 | 315.58 | 227.92 | 105.19 | 403.24 |
| 13 | 490.90 | 368.17 | 350.64 | 122.72 | 578.56 |
| 14 | 420.77 | **701.28** | 245.45 | 192.85 | 122.72 |
| 15 | 245.45 | 385.70 | 280.51 | 157.79 | 192.85 |
| 16 | 227.92 | 350.64 | 192.85 | 262.98 | 403.24 |
| 17 | 245.45 | 525.96 | 333.11 | 438.30 | 333.11 |
| 18 | 280.51 | 122.72 | 368.17 | 543.49 | 420.77 |
| 19 | 368.17 | 333.11 | 210.38 | 385.70 | 403.24 |
| 20 | 175.32 | 315.58 | 175.32 | 227.92 | **087.66** |
| Mean | 351.52 | 350.64 | 288.40 | 326.97 | 299.80 |

Data obtained from indoor measurements are tabulated in table (2). A number of six classrooms were scanned out in each school, before calculating the average dose rate. The equivalent effective dose was calculated from equation (1) taking the occupancy factor to be 0.8. From data of table (2) the average dose rate was found to be ($0.29 \pm 0.04$) $\mu Sv.h^{-1}$, with the equivalent effective dose equals ($2.05 \pm 0.28$) $mSv.y^{-1}$.

**Table (2):** Indoor exposure at ten selected schools in Kadugli town.

| location | Range ($\mu Sv\ h^{-1}$) | Average Absorbed dose ($\mu Sv\ h^{-1}$) | Equivalent effective dose ($mSv\ y^{-1}$) |
|---|---|---|---|
| 1 | 0.23 – 0.55 | 0.35 | 2.46 |
| 2 | 0.27 – 0.33 | 0.32 | 2.24 |
| 3 | 0.24 – 0.29 | 0.28 | 1.96 |
| 4 | 0.23 – 0.35 | 0.29 | 2.03 |
| 5 | 0.22 – 0.31 | 0.29 | 2.03 |
| 6 | 0.07 – 0.35 | 0.22 | 1.54 |
| 7 | 0.23 – 0.29 | 0.27 | 1.89 |
| 8 | 0.33 – 0.50 | 0.40 | 2.81 |
| 9 | 0.15 – 0.35 | 0.25 | 1.75 |
| 10 | 0.14 - 0.34 | 0.25 | 1.75 |
| Mean | ------ | 0.29 ± 0.04 | 2.05 ± 0.28 |

## Discussion

From the data obtained in tables (1 & 2), it can be seen that average dose rate of the outdoor exposure to gamma radiation in Kadugli town is 0.19 ± 0.01 $\mu Sv.h^{-1}$.This is almost five times the world's average absorbed dose rate, estimated by the UNSCEAR 1988 for outdoor exposure to gamma radiation (i.e. 60 $nGy.h^{-1}$ or 42 $nSv.h^{-1}$). The equivalent average annual effective dose was then found to be 0.32 ± 0.04 $mSv.y^{-1}$.

The indoor average absorbed dose rate measured in this work was in the range between 0.22 and 0.40 $\mu Sv.h^{-1}$, with overall mean value of 0.29±0.04 $\mu Sv.h^{-1}$. The world's average absorbed dose for the indoor exposure suggested by the UNSCEAR 2000 is 84 $nGy.h^{-1}$ or 59 $nSv.h^{-1}$. The indoor dose rate in Kadugli town is five times this value. The indoor/outdoor ratio is 1.5. The mean annual indoor effective dose equivalent to the recorded absorbed dose rate is 2.05±0.28 $mSv.y^{-1}$.

The total annual effective dose (outdoor +indoor) is thus 2.37 $mSv.y^{-1}$. This value is far from normal, although it doesn't set the town as HBRA.

To obtain a reliable value of the annual effective dose, this value must be multiplied by adult's conversion coefficient which is 0.7, leading to a value of 1.66 $mSv.y^{-1}$. To calculate the annual collective effective dose in units of (man-Sv), the total population size (i.e. $1.2*10^5$person) is multiplied by the equivalent effective dose leading to 199.2 man-Sv.

## Conclusion

This study aimed to assess the outdoor and indoor exposure to gamma radiation in Kadugli town, which is the most populated area in the Nuba Mountains. It came out from this study that the amount of exposure is bellow the level of HNRB, although it is higher than the world's average values estimated by the UNSCEAR. Outdoor absorbed dose rate ranged between 50 and 400 $nSv.h^{-1}$, with a mean value equals 185±40 $nSv.h^{-1}$. The equivalent effective dose was found to be 0.32±0.04 mSv $y^{-1}$. In the case of indoor exposure the absorbed dose rate was found to be 290 ± 40 $nSv.h^{-1}$, and 2.05 ± 0.28 mSv $y^{-1}$. For adults the annual effective dose was 1.66 $mSv.y^{-1}$, and the annual collective effective dose was found to be 199.2 man-Sv.

These results urge the calculation of population dose distribution in other towns within the region, as a prerequisite for the population dose distribution to the Nuba Mountains region as a whole, which is known to contain many localities of HNRA.

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