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# INVESTIGATION OF NATURAL BACKGROUND GAMMA RAY DOSES IN THE PROPOSED URANIUM MINES AT BAHI AND MANYONI

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**Abstract**

*Tanzania is currently considering to start mining uranium in various parts of the country. Manyoni and Bahi areas were identified as among the potential sites for uranium mining and processing in the country. The study investigated the natural background of gamma ray dose rates in the vicinity of the proposed Manyoni and Bahi uranium deposits in Tanzania. Ambient gamma doses were measured using a RAM DA3-2000, model BAK-1670. The mean and standard deviation background radiation dose to the population at Manyoni and Bahi deposits were 0.26 ± 0.14 mSv/y and 0.18 ± 0.06 mSv/y respectively. A good linear relationship between means of annual effective dose and altitude was observed for each site with $R^2$ values of 87 % and 76 % for Manyoni and Bahi deposits respectively. The comparison of the mean effective dose rate between the Manyoni and Bahi deposits has shown significant difference (P = 0.0276). It is concluded that the mean natural background gamma ray dose at proposed mines is less than the global average value of 0.5 mSv/y and the annual effective dose limit of 1.0 mSv/y recommended by ICRP. The future increase of the radiation after commencement of mining activities is expected which calls for selection and implementation of stringent control measures.*

**Key Words:** *Uranium, Pollution, Gamma Radiation, Dose, Radionuclide*

## Introduction

The assessment of baseline levels of radioactivity in the areas with naturally enriched radionuclide is important especially in the uranium mining context, before, during and after mining activities (Raghavendra *et al*., 2014). It is a known fact that the naturally occurring radionuclides are the major source of ionizing radiations in the environment. The radiations in the form of electromagnetic waves (gamma and x-rays) or particles travel while, exposing humans to these radiations. Usually, when human are exposed to high levels of radiations, beyond threshold limits, detrimental health effects may result. In general, natural radiation consists of two types of contributors; namely high energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides originating from the earth's crust and present in the environment, including the human body itself (Akhtar *et al*., 2005). Natural radiation on the environment is enhanced by the human activities (Tubosun *et al*., 2013) such as mining and milling of mineral ores, nuclear installations, the fuel cycle tail end products and nuclear weapons testing and accidents (Saleh, 2011; IAEA, 2011). The high level of natural radioactivity raised by these activities produce radiation doses which may human beings in the order of several mSv $y^{-1}$ (Jibiri and Temaugee, 2013).

Gamma radiations constitute electromagnetic rays accompanying emission of alpha or beta particles from a nucleus. These rays account for the majority of external human exposure to radiation from all source types due to their high penetration ability (Al-Saleh, 2007), inducing chemical changes that are biologically important for the normal functioning of body cell. Several studies have been conducted to assess the level of the gamma dose rate from the uranium deposits areas (Hazrati *et al*., 2012; Karunakara *et al*., 2014; Pashazadeh *et al*., 2014). Pashazadeh *et al*. (2014) and Karunakara *et al*. (2014) reported lower level of the background gamma rays in uranium deposits sites compared to the global level in Bushehr city and South India respectively. However, Hazrati *et al.* (2012) who investigated natural effective gamma dose rates in Ardebil Province in Iran observed the estimated annual effective dose rate of about 1.70 mSv, which is almost twice higher than weighted average world population dose rate.

Tanzania is currently considering starting mining uranium in the various parties of the country. This results in various studies addressing the high background radiation levels in these areas (Banzi *et al*., 2000; Banzi *et al*., 2015; Kimaro and Mohammed, 2015; Mohammed and Mazunga, 2013). The reports identified the sources of high radiation as being the areas enriched with phosphate such as Minjungu in Arusha and those areas with the viable uranium resources such as Mkuju River, Bahi and Manyoni. Kimaro and Mohammed (2015) study on natural radioactivity levels in the area around the Uranium deposits at Bahi district in Dodoma, indicated a high concentration of $^{226}$Ra and $^{232}$Th in the soil compared to the world average concentration values as reported by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000). Moreover, the study by Banzi *et al*. (2015) on distribution of heavy metals in soils in the vicinity of the proposed Mkuju Uranium deposit in the southern part of Tanzania revealed that the baseline spatial distribution of the heavy metals in the area is comparable to established global concentration ranges, which indicate the distribution is natural whereby the future increase of levels may due to the mining activities. Furthermore, Mohammed and Mazunga (2013) reported high activity concentration of $^{238}$U in Likuyu village which is located about 54 km East of Mkuju River uranium deposit. However, none of these studies investigated the ambient air gamma dose rates which are important for a realistic assessment of the radiological risks to the population before, during and after closing of mining and processing activities. The ambient air assessment will thus contribute to the improvement regulation of uranium mining and process activities and hence lead to protection of the environment and minimize potential health effect to human beings.

The current study is therefore, an effort to assess gamma dose rate from uranium deposits in Bahi and Manyoni aiming at highlighting the health risks and developing mitigation measures. The data obtained will also act as a reference in future when assessing contamination of the area from uranium mining.

## Materials and Methods

### *Study Areas*

The Manyoni and Bahi uranium deposits are located in the central part of Tanzania in Singida and Dodoma regions, respectively as shown in Figure 1. The Bahi deposits are located at latitudes 5° 51′ and 06° 20′ South and longitude 34° 59′ and 35° 21′ East. Uranium deposits at Bahi are found in Bahi wetlands, which is located 60 km North-West of the Tanzania capital city of Dodoma. It covers an area of about 2000 $km^2$ and with inhabits of about 150,000 people (Mbogoro, 2010). The Manyoni deposits are located at latitude 5° 59' 0" South and longitude 35° 19' 0" East, covering an area of 28,620 $km^2$, which is about 58% of the entire area of Singida Region (URT, 2012). According to the 2012 population and housing census, the Manyoni district had a total population of 296,763 people with a growth rate of 2.7% (URT, 2012). The economies of Manyoni and Bahi districts depend mainly on agriculture (crops and livestock production) and other economic activities including fishing and also salt production. In terms of climate, both districts are situated in semi-arid areas and have a dry savannah type of climate which is characterized by a long dry season, unimodal and erratic rainfall that falls between November and April. The mean annual rainfall for Manyoni is 624 mm while that of Bahi range from 500 to700 mm. The annual mean temperatures for these districts are 22.6 °C and 22 °C for Bahi and Manyoni districts respectively.

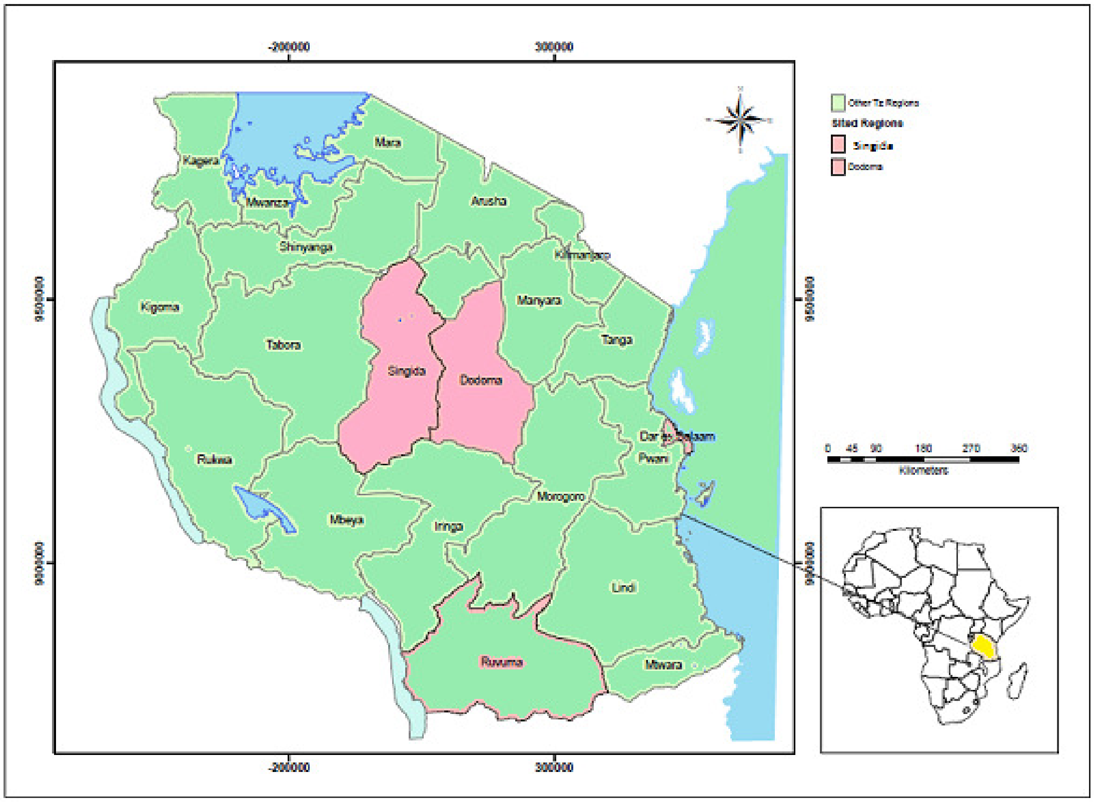


Fig. 1: Map of Tanzania showing the location of Singida and Dodoma Regions

***Gamma Dose Rate Measurements***

Dose rate is defined as the amount of radiation absorbed by a person per unit time. Gamma dose rate is a result of the exposure to the gamma radiation. exposure to gamma radiation in large doses could damage cells of a human being, cause cancer and sometimes resulting into death.

Ambient gamma dose rates were measured using a RAM DA3-2000, model BAK-1670 in 44 locations. The RAM DA3-2000 meter is designed to measure highly reliable alpha, beta, gamma and X-ray radiations. The instrument has wide range gamma fields measurement from 0.5μSv/h to 1 Sv/h while the sampling locations were selected in the identified uranium deposits sites located in various wards as shown in Figure 2. The sampling involved drilling points identified during the exploration activities, other points were randomly selected for reference purposes. The altitude, latitude and longitude of each sampling points were accurately recorded using the Global Positioning System (GPS) model GPs 60CSx Garmin. In order to avoid the effects of the ground surface on ambient measurements, the detector was placed at a height of one meter (1m) above the ground. The readings were collected in triplicate in each sampling point and the average was considered the representative value of the gamma dose rate for the selected location unless wider deviations and variation were observed.

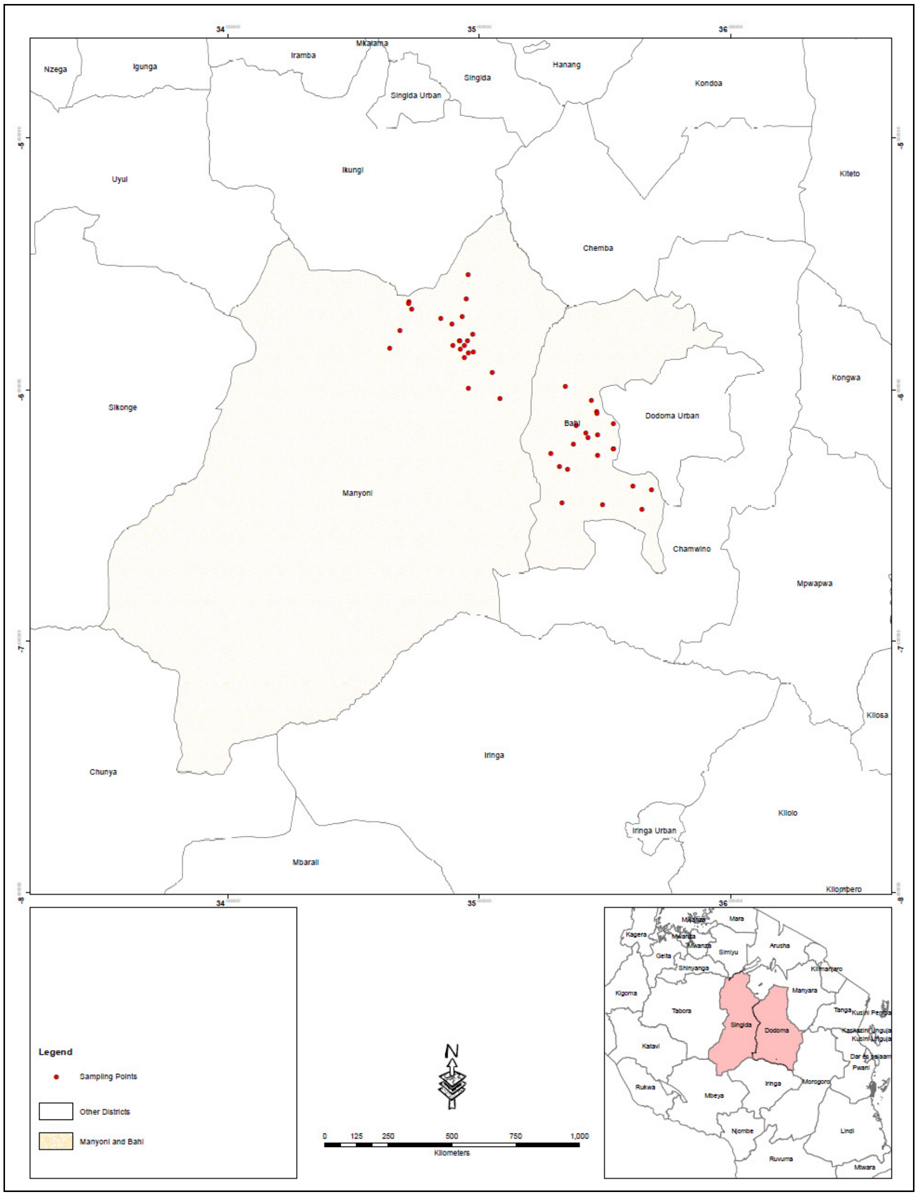


Fig. 2: Map showing the location of Manyoni and Bahi sampling points

Annual effective dose is computed from hourly dose rate measured directly from the environment using the outdoor occupancy factors of 0.2 (UNSCEAR, 2008) and some important conversion factors as is indicated in equation 2.1. The annual effective dose is considered the amount that the people around the proposed uranium deposits is exposed to and determined by using Equation (2.1) and respective values reported in Table 1 and Table 2 for Manyoni and Bahi deposits respectively.

$$HD_{eff.} = HR * C * T \ * OF_{out} * 10^{-6} \text{.........1}$$

Where;

$HD_{eff}$ =Annual Effective dose (mSv $y^{-1}$)

HR= Measured Dose Rate in outdoor (nGy $h^{-1}$)

C = Conversion coefficient (0.7Sv $Gy^{-1}$)

T=Time in hours (8760 hours for a year)
$OF_{out}$= Occupancy Factor 0.2 (UNSCEAR, 2008)
$10^{-6}$=Conversion factor from nanosievert to millsievert

**Results**

Ambient effective annual dose is determined by using Equation 2.1. The average annual effective dose and standard deviations of the obtained dose rate for each site were calculated. Table 1 and 2 present the average measured dose, calculated annual effective dose rate at different sampling points and at different altitude. The measured dose rate in outdoor environment for Manyoni showed the values ranging from 60 - 516 $nGyh^{-1}$, with an average values of 210 $nGyh^{-1}$ while the calculated annual effective dose rate from measured values range from 0.07- 0.63 mSv $y^{-1}$ with mean values of 0.26 ± 0.14 mSv $y^{-1}$ for all points as shown in Table 1.

Table 1: Manyoni Average measured dose and annual effective dose rate at different sampling points and at different altitude

| Sampling Points | Average Measured Dose (nGy $h^{-1}$) | Annual Effective dose (mSv $y^{-1}$) | Altitude (m) |
|---|---|---|---|
| 1 | 60 ± 0.02 | 0.07 | 1248 |
| 2 | 93.3 ± 0.02 | 0.11 | 1254 |
| 3 | 103.1± 0.03 | 0.13 | 1256 |
| 4 | 116.6 ± 0.03 | 0.14 | 1261 |
| 5 | 120 ± 0.04 | 0.15 | 1262 |
| 6 | 140 ± 0.02 | 0.17 | 1262 |
| 7 | 150 ± 0.03 | 0.18 | 1263 |
| 8 | 160 ± 0.02 | 0.20 | 1264 |
| 9 | 160 ± 0.02 | 0.20 | 1272 |
| 10 | 166.7 ± 0.01 | 0.20 | 1274 |
| 11 | 173.3 ± 0.02 | 0.21 | 1278 |
| 12 | 183.3 ± 0.005 | 0.22 | 1286 |
| 13 | 183.8 ± 0.001 | 0.23 | 1293 |
| 14 | 183.4 ± 0.001 | 0.22 | 1328 |
| 15 | 226.6 ± 0.005 | 0.28 | 1331 |
| 16 | 240.2 ± 0.01 | 0.29 | 1337 |
| 17 | 250 ± 0.06 | 0.31 | 1346 |
| 18 | 263.3 ± 0.05 | 0.32 | 1387 |
| 19 | 366.5 ± 0.03 | 0.45 | 1396 |
| 20 | 376.7 ± 0.02 | 0.46 | 1402 |
| 21 | 376.7 ± 0.02 | 0.46 | 1403 |
| 22 | 516.7 ± 0.04 | 0.63 | 1408 |
| Mean | 210 ± 0.02 | 0.26 ± 0.14 | |
| Min | 60 | 0.07 | |
| Max | 516.7 | 0.63 | |

The Bahi measured dose rate in the outdoor environment ranged from 83.3 - 240 $nGyh^{-1}$ with an average of 144.36 ± 0.04 $nGyh^{-1}$ while the calculated annual effective gamma dose from measured range from 0.10-0.29 $mSvy^{-1}$ with mean values of 0.18 ± 0.06 $mSvy^{-1}$ as shown in Table 2.

Table 2: Bahi Average measured dose and annual effective dose rate at different sampling points and at different altitude (m)

| Sampling Points | Average Measured Dose (nGy h-1) | Annual Effective dose (mSv y-1) | Altitude (m) |
|---|---|---|---|
| 1 | 83.33 ± 0.29 | 0.10 | 829 |
| 2 | 96.67 ± 0.35 | 0.12 | 832 |
| 3 | 106.67 ± 0.33 | 0.13 | 833 |
| 4 | 123.33 ± 0.04 | 0.15 | 838 |
| 5 | 116.67 ± 0.03 | 0.14 | 842 |
| 6 | 140.00 ± 0.03 | 0.17 | 847 |
| 7 | 106.67 ± 0.03 | 0.13 | 848 |
| 8 | 133.33 ± 0.04 | 0.16 | 853 |
| 9 | 106.67 ± 0.03 | 0.13 | 855 |
| 10 | 116.67± 0.01 | 0.14 | 857 |
| 11 | 143.33 ±0.02 | 0.18 | 860 |
| 12 | 133.33 ± 0.01 | 0.16 | 861 |
| 13 | 153.33 ± 0.02 | 0.19 | 868 |
| 14 | 156.67 ± 0.01 | 0.19 | 876 |
| 15 | 160.00 ± 0.04 | 0.20 | 912 |
| 16 | 190.00 ± 0.04 | 0.23 | 920 |
| 17 | 240 ± 0.03 | 0.29 | 944 |
| 18 | 220.00 ± 0.02 | 0.27 | 950 |
| 19 | 166.67 ± 0.03 | 0.20 | 971 |
| 20 | 226.67 ± 0.04 | 0.28 | 981 |
| 21 | 170.00 ± 0.05 | 0.21 | 985 |
| 22 | 233.33 ± 0.06 | 0.29 | 1057 |
| Mean | 151. 06 ± 0.10 | 0.18 ± 0.06 | |
| Min | 83.3 | 0.10 | |
| Max | 240 | 0.29 | |

The effective annual dose for different sampling points at Manyoni and Bahi when plotted with corresponding altitude, revealed a good linear relationship with regression coefficient ($R^{2)}$ at 87 % and 76 % respectively, as presented in Figure 3 and Figure 4 for Manyoni and Bahi uranium deposits correspondingly.

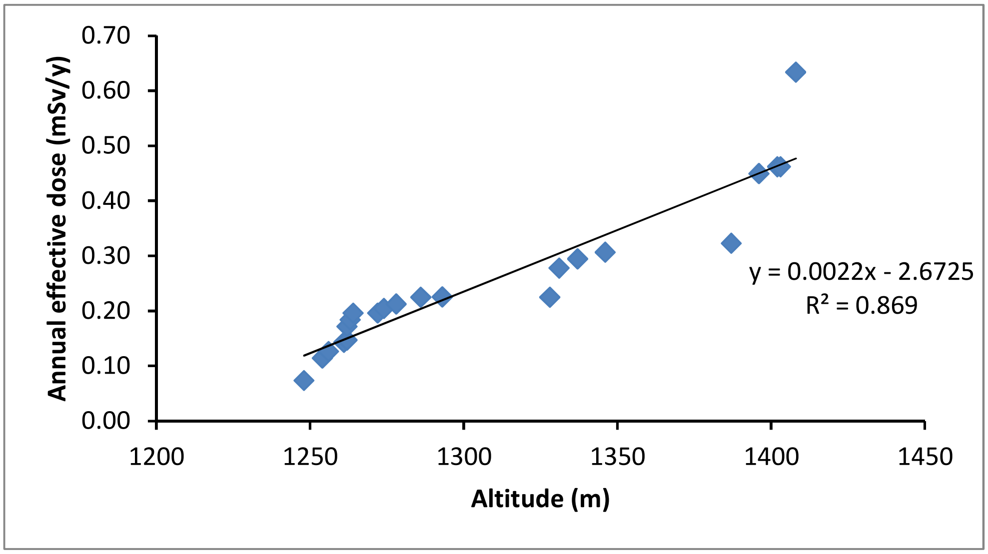


Fig. 3: Manyoni Annual Effective dose at different altitude

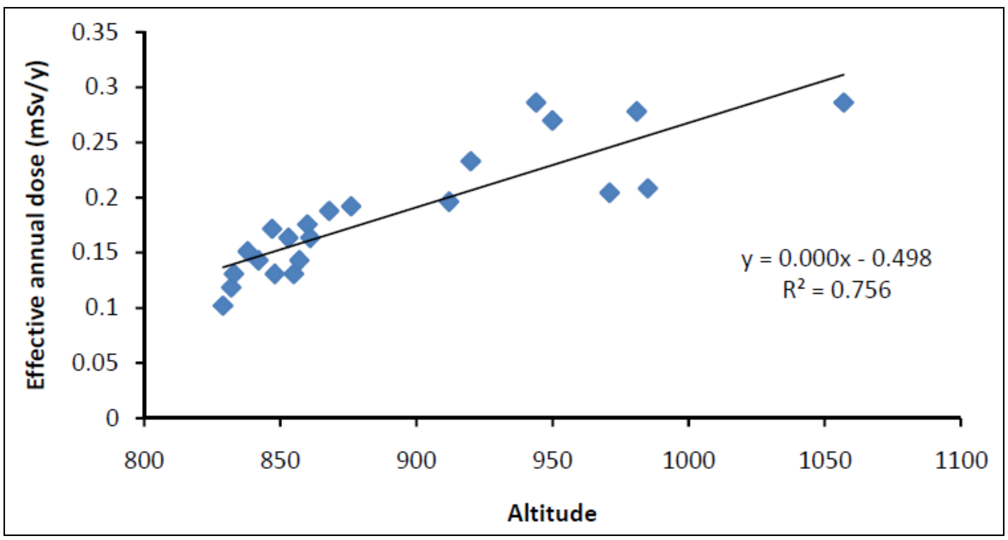


Fig. 4: Bahi Annual Effective dose (mSv/y) at different Altitude

**Discussion**

Results obtained in this study are compared with data obtained elsewhere. Mean annual effective doses from baseline gamma radiation in Manyoni and Bahi districts at 0.26 mSvy-1 and 0.18 mSvy-1 respectively were below than global acceptable rate of 1 mSvy-1 for members of the public as recommended by ICRP (ICRP, 2010).

The comparison of the average gamma dose rates for Manyoni at 0.26 mSvy-1 and Bahi at 0.18 mSvy-1 indicate that Manyoni uranium deposit has higher mean dose compared to Bahi uranium deposit. This indicates that people living at Bahi district receive slightly less radiation than those living at Manyoni district. The calculated means of annual effective dose of Manyoni and

Bahi were compared using t-test which revealed that, there were significant difference between the Manyoni and Bahi average gamma dose rate at 95 % significant level, whereby P= 0.0276. The dose difference between two sites may be due to different altitude of the sites. According to Shahbazi (2003) and Hazrati *et al*. (2012), the baseline gamma dose rate radiation decreases with altitude of a given area. The altitude and gamma dose rate scientific reason beyond based on the fact that at the lower altitude areas, there is a low amount of neutrons whereby the neutron component of the cosmic ray cannot penetrate deeply into atmosphere to reach to the ground and also the directly-ionizing component of the cosmic ray is more attenuated at lower altitudes (UNSCEAR, 2000).

Gamma dose rates recorded for Manyoni and Bahi sites are higher than values reported at Mkuju River and Likuyu area. In Mkuju River and Likuyu area, surveys of outdoor radiation doses showed potential gamma exposures ranging from 24.8 - 200 nGy h-1 and 24 - 148 nGy h-1 with mean values of 99. 8 nGy $h^{-1}$ and 55.8 nGy $h^{-1}$correspondingly. The calculated annual effective dose rate for Mkuju River and Likuyu area are thus 0.122 mSv $y^{-1}$ and 0.068 mSv $y^{-1}$ respectively (Lolila, 2011). On other hand, the gamma dose rates recorded for Manyoni and Bahi uranium deposits were lower than values reported in the literature for other locations with uranium deposits in the world as shown in Table 3. As such, the values in Table 3 indicate that gamma radiation dose rate recorded in locations outside Tanzania were in average higher than international limit of 1 mSv $y^{-1}$ by a factor of 2–4.

Table 3: Natural Gamma Dose Rates (mSv/yr) Reported for Some Locations in the World

| Country | Location | Gamma Dose Rate (mSv/yr) | Reference |
|---|---|---|---|
| Tanzania | Mkuju River | 0.12 | Lolila (2011) |
| | Likuyu | 0.07 | |
| Others | Kermanshah(Iran) | 2.24 | Tavakoli *et al*. (2012) |
| | Caspian Coastal (Iran) | 0.53 | Amiri *et al*. (2011) |
| | Bushehr city (Iran) | 0.36 | Pashazadeh *et al*. (2014) |
| | Lorestan province (Iran) | 0.72 | Gholami *et al*. (2011) |
| | South India | 0.91 | Karunakara *et al*. (2014) |
| | Gopalpur (India) | 3.77 | Rao *et al*. (2015) |
| | Chhatrapur (India) | 4.47 | |
| | Rushikulya (India) | 3.57 | |
| | Bory Stobrawskie forests (PL), Opole Poland | 0.44 | Agnieszka Dołhańczuk-Śródka (2012). |
| | Sao Paulo City, Brazil | 1.3 | Carneiro *et al*. (2011) |

## Conclusions

Based on data analysis for a total of 132 dose rate measurements performed from 44 different locations in Manyoni and Bahi uranium deposits sites to determine gamma radiation background dose, the following conclusion can be made: The observed gamma dose rate values at all the sampling locations were found to be within the permissible limit of 1 mSv/y. The highest doses were observed in Manyoni with a value of 0.63 mSv/y. There are significant differences between the means of effective doses for Manyoni and Bahi with P value of 0.0276 at 95% significant level. The effective dose is found to be linearly related with altitude for both Manyoni and Bahi deposts areas with linear regration coefficient ($R^2$) of 87 % and 76 % respectively. Gamma dose rates recorded for Manyoni and Bahi sites are higher than values reported at Mkuju River and Likuyu area. The gamma dose rates recorded for Manyoni and Bahi uranium deposits were lower than values reported in the literature for other locations with uranium deposits in the world. The study reveal that, people living at Bahi district may receive less dose than those living at Manyoni district.

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