Ambient gamma dose rate measurements at Manyoni uranium deposits, Singida, Tanzania

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Abstract. High levels of natural radiation have been measured at the proposed Manyoni uranium mines in Singida, Tanzania. Pre-mining baseline data of the ambient gamma radiation dose rates have been carried out and serve as reference information during and after the uranium mining. The absorbed gamma dose rates on contact i.e. at the surface and in air (one meter above the surface) were measured with a survey meter. The sampling coordinates were located by a GPS meter. The dose rates due to the naturally occurring radionuclides varied from 131 to 1678 nGy h^{-1} (98 to 1657 nGy h^{-1}) with the mean value of 458 nGy h^{-1} (436 nGy h^{-1}). The maximum value measured is about thirty times the world average of 59 nGy h^{-1}. The annual effective dose rates for the region range from 0.16 to 2.06 mSv y^{-1}. High gamma radiation background is detected at Mwanzi and Kinangali villages and there is a need for conducting studies on health risk assessment for the general public near the proposed uranium mining site.

1. Introduction

Studies on radioactivity and radiation in the environment play an important role in our day to day life and are essential for better protection measures to be taken against the health hazards due to this radiation. Contribution to the background radiation in the environment is mainly from the naturally occurring radioactive materials associated with the formation of the earth's crust and atmosphere (cosmic rays). These materials release radiation everywhere in our surroundings to which humans are exposed. In addition, the exposure to radiation by general public is due to testing of nuclear weapons, disposal of radioactive waste, leakages from nuclear reactors and manufacture of radioactive isotopes [1]. Investigations of background radiation present in natural environmental samples such as vegetation, water, air and soil provide vital information as they help to monitor the radiation levels present in the surroundings and also give an indication about changes in the radiation levels due to human activities [2]. These studies help also to identify and evaluate the distribution of radionuclides in the area [1].

Uranium is a naturally occurring radioactive, heaviest element available in nature, is found in almost all types of soils, rocks, sands and water. Taking into account that uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) are always present in soil, their gamma radiation causes external exposures with the consequent absorbed doses to humans. Excessive natural radiation exposure from uranium mining can also contribute to a variety of health hazards such as skin cancer and genetic effects [3].

In the recent years, extensive uranium exploration and feasibility studies in Tanzania have found several sites with economically viable uranium deposits. In 2009, deposits of uranium were discovered at Mkuju, Namtumbo district, southern Tanzania [4]. This discovery was followed by Manyoni uranium deposits (Singida region) and Bahi uranium deposits (Dodoma region) both in Central Tanzania [5]. Furthermore, several studies of natural radioactivity have been conducted in different parts of Tanzania to assess environmental radioactivity levels in areas with proven uranium deposits and phosphate mining sites. For example, background radioactivity levels and elemental composition at Mkuju uranium deposit was reported by Mwalongo [6]. Baseline data of external ionizing radiation dose at proposed Mkuju uranium mining site and its neighbouring residential areas was reported by Lolila [7]. Natural uranium levels in Bahi district was reported by Orazaliyev [8]. Elisadiki [9] measured the terrestrial background radiation dose rate in the vicinity of proposed Manyoni uranium project using CaF_2 thermoluminescent dosimeters.

Uranium exploration in Manyoni district brought concerns to public residing around the exploration sites and nearby villages. Concerns are mainly on the radiological health hazard which is associated with uranium exploration. During uranium mining and milling operations, large quantities of waste containing naturally occurring radioactive materials (NORMs) are generated and may contaminate the environment and therefore increase ambient radiation level. For this reason, we have carried out measurements of ambient gamma radiation doses in the proposed uranium mining area and surrounding villages. This pre-mining baseline data on the ambient gamma radiation doses serves as a reference information to assess any changes in the ambient background radioactivity levels during and after uranium mining. We present results of our measurements and discuss them comparing background radiation level in regions of Tanzania and other countries and assess the health risks to the workers and general public.

2. Materials and methods

2.1. Description of the study area

Manyoni District is located in the central part of Tanzania. Its geographical coordinates are 5 45' 0" South, 34 50' 0" East. It has an area of 28,620 km^2 with population of 296,763 people [10]. The Manyoni project area (Fig. 1) is situated in the northern section of the Bahi regional uranium province near the town of Manyoni, which is 120 km north-west of Dodoma, the capital of Tanzania. The region incorporates an extensive closed draining system developed over weathered uranium rich granites. This drainage captures dissolved uranium leached from underlying rocks and transports it to suitable precipitation trap sites. The uranium targets in the area are described as calcrete-hosted uranium mineralization near to the surface and sandstone-hosted deposits within buried fluvial channel systems [5].

2.2. Measurement of gamma dose rates

Dose rate measurements were taken over a large area on the sites stretching from the expected mining zones to the the neighbouring residential areas (town and villages). The dose rates on contact (on the ground surface) as well as in air (at 1 meter above the ground) in the study areas were measured using a gamma radiation survey meter (Model: RAM DA-3-2000, Serial no. 8312-035) provided by the Tanzania Atomic Energy Commission (TAEC), Arusha. It was calibrated by the national calibration laboratory for ionizing radiation which is traceable to the International Measurement System through the International Atomic Energy Agency (IAEA) with an overall uncertainty of 10%. The energy response of the detector ranged from 60 keV to

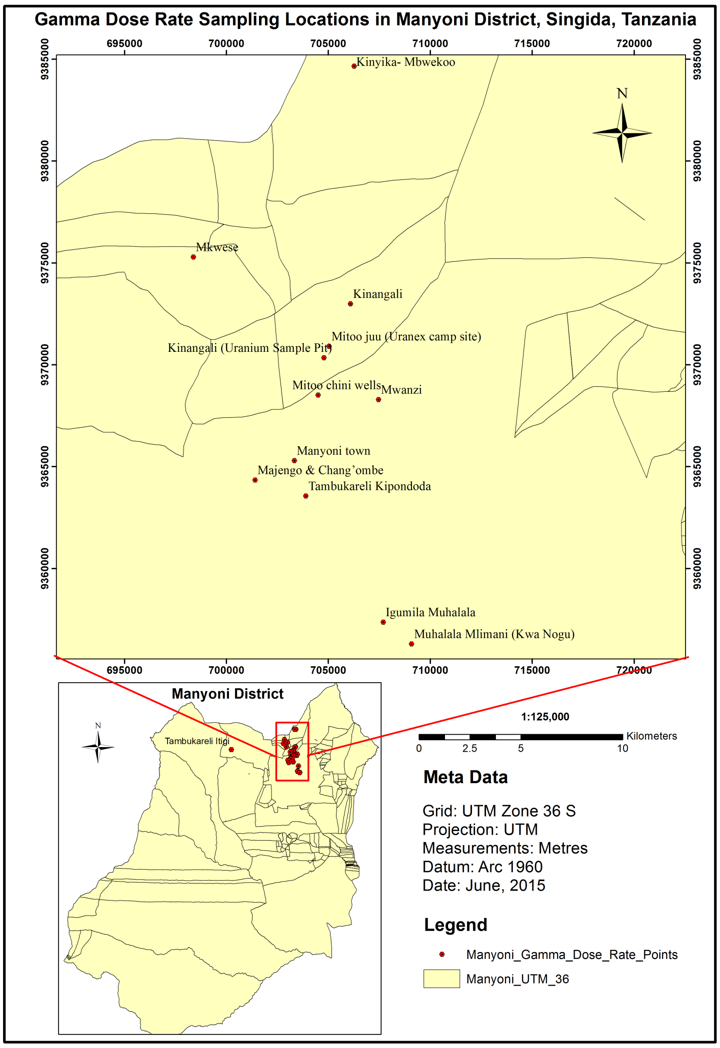

Figure 1. Map of Manyoni district, Singida, Tanzania with sample locations where ambient gamma dose rates are measured. Tambukareli Itigi is shown in the Manyoni district map and the remaining locations are shown in the expanded view.

1.3 MeV. The measurements were taken by positioning the survey meter at each point, switched on and allowed to stabilize for one minute and the readings were recorded. At each location, fifteen data points (n = 15) were recorded. Coordinates of all measurement points were located and recorded by using a Global Positioning System (GPS) meter. For Masigati (row 12 of Table 1) coordinates are not recorded.

2.3. Calculation of annual effective absorbed dose rate

The measured gamma dose rates were converted into annual effective dose rates using the equation below [3]:

$$EDR = D \times f \times v \times T \times 10^{-6} \tag{1}$$

where, EDR = Annual effective absorbed dose rate in mSv y^{-1}, D = measured absorbed dose rate in outdoor (nGy h^{-1}), f = conversion coefficient (0.7 Sv Gy^{-1}), v = outdoor occupancy factor (0.2), T = Time in hours (8760 hours per year) and the factor 10^{-6} is to convert nano Sievert to milli Sievert.

3. Results and Discussion

The data taken at different locations are shown in Table 1. Presented in the table are the minimum and maximum of the data at each location. The absorbed dose data taken at the surface (column 2), one meter above the surface (column 3), the average dose of all the data taken at each location (column 4), annual effective dose rates on surface and at 1 m (column 5 and 6, respectively) are presented in this table. The uncertainty in the measured absorbed dose rates lies between 10 - 15%.

Table 1. Absorbed and average radiation dose rates and annual effective dose at different locations in Manyoni area. The number of data points at each location are fifteen (n = 15) unless otherwise indicated.

Location	Absorbed dose (nGy h^{-1})		Average dose	Effective dose (mSv y^{-1})	
	surface	at 1 meter	(nGy h^{-1})	surface	at 1 meter
Manyoni town	185 - 338	164 -316	234 - 254	0.23 - 0.41	0.20 - 0.39
Mitoo Chini wells	131 - 283	98 - 262	181 - 204	0.16 - 0.35	0.12 - 0.32
Mwanzi (n = 21)	927 - 1678	883 - 1657	1317 - 1343	1.14 - 2.06	1.08 - 2.03
Kinangali	785 - 1439	741 - 1428	1098 - 1132	0.96 - 1.76	0.91 - 1.75
Tambukareli Kipondoda	262 - 382	251 - 360	305 - 323	0.32 - 0.47	0.31 - 0.44
Changombe & Majengo	174 - 273	153 - 262	205 - 226	0.21 - 0.33	0.19 - 0.32
Kinyika-Mbwekoo	382 - 829	360 - 807	533 - 562	0.47 - 1.02	0.44 - 0.99
Igumila-Muhalala	174 - 305	164 - 273	216 - 235	0.21 - 0.37	0.20 - 0.33
Muhalala Mlimani	273 - 458	262 - 436	334 - 355	0.33 - 0.56	0.32 - 0.53
Mitoo juu	164 - 240	131 - 229	179 - 201	0.20 - 0.29	0.16 - 0.28
Tambukareli Itigi	196 - 305	164 - 283	222 - 242	0.24 - 0.37	0.20 - 0.35
Masigati	371 - 501	338 - 491	406 - 424	0.45 - 0.62	0.41 - 0.60

From Table 1, Mwanzi and Kinangali (row 3 and 4) showed the highest levels of gamma radiation dose. The effective dose rates at Mwanzi and Kinangali are twice the recommended value of the annual effective dose rate for the general public. The total absorbed dose estimated on the surface varies from 131 to 1678 nGy h^{-1} with an average value of 458 nGy h^{-1}. The maximum value measured is about 30 times higher than the world average of 59 nGy h^{-1} while the obtained average is 8 times higher than the world average.

The corresponding outdoor annual effective dose range from 0.16 to 2.06 mSv y^{-1} with an average value of 1.14 mSv y^{-1}; while the world wide average annual effective dose is approximately 0.5 mSv y^{-1} and the results for individual countries being generally within the 0.3 to 0.6 mSv y^{-1} range for outdoors [9]. The total absorbed dose estimated at 1 meter above the ground varies from 98 to 1657 nGy h^{-1} with an average value of 436 nGy h^{-1}. The maximum value measured is about 30 times higher than the world average of 59 nGy h^{-1} while the obtained average is 7 times higher than the world average.

In Table 2 absorbed doses reported at other locations in Tanzania and other countries are given. The values at Mwanzi and Kinangali are about the same as the average doses reported at Minjingu phosphate mine. The minimum absorbed dose reported at Mkuju uranium mining site is more than four times higher than the maximum measured at Mwanzi. However, the absorbed

Table 2. Comparison of gamma radiation absorbed and average dose rates at different locations in Tanzania and from other countries. The dose rates given are minimum and maximum for the location.

Country	Location	Absorbed dose rate (nGy h^{-1})	Average (nGy h^{-1})	Reference
Tanzania	Manyoni region	131 - 1678	458	This work
	Bahi region	121 - 594		[8]
	Minjingu phosphate mine	1375-1475		[11]
	Mkuju river	24.8 - 260	99.8	[7]
	Likuyu village	24 - 148	55.5	[7]
	Mkuju uranium mining site	7804.8 - 23360		[6]
Other	Ramsar, Iran	69.63 - 29630.37	1141.55	[12]
	Kerala, India	20.55 - 1100.46	55.94	[3]
	Norway	20.55 - 1200.91	73.06	[3]
	Italy	3.42 - 228.31	74.20	[3]
	Hongkong	51.37 - 119.86	86.76	[3]
	World average	18.26 - 93.61	59	[3]

dose reported from Bahi area, Mkuju river and Likuyu village are well below our values. The comparative results of absorbed dose rates for high background radiation areas around the world are shown in Table 2. All data reported in Table 2 for Tanzania are higher than the world average with the exception of Likuyu village.

4. Conclusions

In conclusion, we have measured the ambient gamma dose rates in Manyoni town and eleven locations near the proposed uranium mines at Manyoni, Tanzania. At two locations: Mwanzi and Kinangali, the measured values are about thirty times higher than the world average and the remaining locations also have higher background radiation levels. The annual effective dose rate at two places is twice the limit to the general public. These places need a full analysis of all exposure pathways (radon, diet, dust etc.) that may lead to health hazard to the members of public residing in these areas.

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