ESTABLISHMENT OF BACKGROUND RADIATION DOSE RATE IN THE VICINITY OF THE PROPOSED MANYONI URANIUM PROJECT, SINGIDA

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ABSTRACT

The absorbed dose rate in air in the vicinity of the proposed Manyoni uranium mining project located in Singida region, Tanzania, was determined so as to establish the baseline data for background radiation dose rate data prior to commencement of uranium mining activities. Twenty stations in seven villages were selected and monitored for six months from June 2012 to November 2012. The absorbed dose rate in air was measured by means of CaF_2:Dythermoluminescent dosimeters (TLD-200). The annual effective dose was estimated using outdoor occupancy factor of 0.2 and conversion coefficient factor of 0.7 SvG y^{-1}. The mean dose rate was found to range from 16.68 - 507.00 nGy h^{-1} with an average of 74.86 nGy h^{-1}. Maximum average dose rate of 396.7 nGy h^{-1} was found at station number 8 situated in Mwanzi Village which was about 7 times higher than the world average value of 59 nGy h^{-1} (UNSCEAR 2008) corresponding to annual effective dose of 0.5mSv y^{-1}. This value is 2 fold lower than the recommended limit of 1 mSv y^{-1} for a member of the public (ICRP 1990). Minimum avarage dose rates of 30.9 nGy h^{-1} was found in station number 16 and 17 located in Aghondi village, corresponding to annual effective dose of 0.04 mSv y^{-1}. This implies that prior to commencement of uranium mining activities in the proposed area the external exposure rates due to the natural background radiation are lower than the world recommended value.

Key words: Absorbed dose rate, Uranium mining, Background radiation, Thermoluminescent dosimeter, Annual effective dose.

INTRODUCTION

The exploration for uranium in Tanzania started in 1976 where air-borne magnetic and radiometric survey of the whole country took place. Wide spread uranium anomalism and uranium deposits in a number of different geological structures were discovered. The data which were obtained in that survey provide a valuable base of information to the recent exploration activities in this period of rising uranium demand (http://www.uranex.com.au/Projects/Tanzania.aspx). Various deposits are well thought-out and exploration activities are now in progress. These deposits include Mkuju in Ruvuma region, Bahi in Dodoma region and Manyoni located in Singida Region.

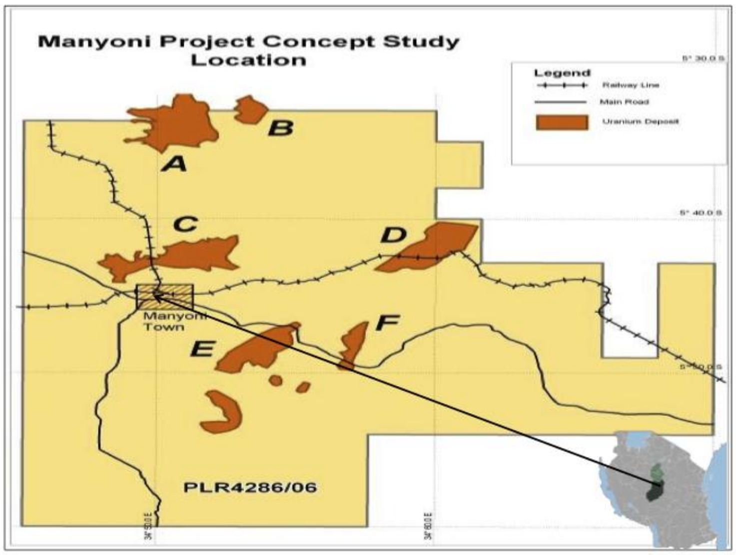

Figure 1: Location of Manyoni project with Playa Lakes/Mbuga A, B, C, D, E & F (Adapted from URANEX website, http://www.uranex.com.au/Projects/ Tanzania.aspx).

The mining of uranium has raised radiological health apprehension to the general public since uranium and its daughters are radioactive materials in nature. Normally, tons of radioactive rocks are crushed to produce dust and leave behind fine radioactive particles prone to wind and water erosion (Koziowska*et al*. 2008). Literature reported that uranium tailings retain 5-10% of the uranium and 85% of the initial radioactivity of the ore (Shirinian-Orlando 2007, UNSCEAR 2008). These generate an enhancement of radionuclide concentrations in the environment (Osoro*et al*. 2011) that may cause increased radiological exposure to mankind. Thus, uranium mining might be a potential source of radiation exposure to workers, the members of the public and the environment in the vicinity of the mining area.

In order to quantify the total exposure to ionizing radiation that members of the public are exposed to as a result of uranium mining activities, the amount of the exposure due to natural background radiation must be determined prior to the commencement of mining and milling activities. Since natural radiation is the main source of human exposure, studies of the dose from this source are of great importance as a reference when standards and regulatory control measures on radiation protection are established (Abd El-mageed*et al*. 2010).

External exposures to gamma radiation outdoors arise from terrestrial radionuclides occurring in all ground formations (Tzortzis*et al*. 2004). These radionuclides include Potassium-40 (40K), Uranium -238 (238U) and Thorium-232 (232Th) and their decay products (Alaamer 2008, Kinyua*et al*. 2011). Therefore, environmental background radiation for a given location varies according to the geographical and geological structures of soil and rocks (Florou and Kritids 1992, Onuk*et al*. 2010). It has been reported that soils associated with minerals containing high concentration of uranium and/or radium has elevated radiation levels with dose rate exceeding the average global background value of 59 nGy h^{-1} (UNSCEAR 2008).

Manyoni being one of the potential uranium deposits in Tanzania is expected to have high background radiation dose rate compared to other places where there is no uranium deposits. This fact raises concern about the health of the residents at Manyoni when mining activities starts. Uranium mining and milling activities if not well managed may cause potential enhancement of radioactivity in the environment and become source of radiation exposure to the public. Therefore, radiological surveillance and the assessment of the radiation risk to the population living in the vicinity of the mining area are highly encouraged (Carvalho*et al*. 2007, 2009). Surveillance will be successful if there are pre- mining data to compare with.

Table 1: Location selected for TLD placement at Manyoni.

Village	Station No.	Place name	Coordinates		Altitude (m)
			Longitudes (E)	Latitudes(S)	
Manyoni Town	1	Manyoni District Hospital	34° 49′40.2″	05° 44′ 46.9″	1270
	2	Manyoni Sec.School	34° 49′ 48.0″	05° 44′ 16.2″	1289
	3	Tambukareli Primary School	34° 50′ 29.0″	05° 45′ 21.3″	1249
Kipondoda	4	Manyoni District office	34° 50′ 24.0″	05° 44′ 52.3″	1280
	5	Mlewa Sec. School	34°48′ 45.1″	05° 45′ 05.5″	1270
Mwanzi	6	Mwanzi Sec School	34° 50′ 50.3″	05° 44′ 34.9″	1293
	7	Mwanzi Primary School	34° 51′ 29.1″	05° 44′ 35.7″	1282
	8	Fade Kudwashili family	34° 52′ 10.0″	05° 42′ 08.0″	1256
Mitoo	9	Hamisi Njiku Family	34° 49′ 52.5″	05° 41′ 05.9″	1288
	10	Mitoo Primary School	34° 49′ 31.6″	05° 41′ 11.3″	1300
	11	Jackson Ntandu Family	34° 49′ 28.9″	05° 41′ 30.6″	1292
Mkwese	12	Ligoha Family	34° 48′ 27.2″	05° 38′ 32.5″	1347
	13	Charles Dude Family	34° 48′ 00.3″	05° 37′ 15.6″	1393
	14	Mkwese Sec School	34° 48′ 05.5″	05° 38′ 09.3″	1372
Aghondi	15	Aghondi Primary School	34° 41′ 49.0″	05° 45′ 26.7″	1303
	16	Nasoro Swedi Family	34° 42′ 06.8″	05° 45′ 30.5″	1311
	17	Alex Kagusa Family	34° 41′ 58.5″	05° 45′ 37.0″	1310
Muhalala	18	Muhalala Village office	34° 52′ 55.4″	05° 47′ 03.9″	1149
	19	Idan Njelika Family	34° 53′ 38.5″	05° 47′ 02.2″	1125
	20	Yona Yoram Family	34° 52′ 57.2″	05° 48′ 13.2″	1118

In Tanzania few studies have been conducted to establish baseline data for radiological surveillance (Lolila 2011, Mazunga 2011 and Mwalongo 2011). These studies were conducted at Mkuju uranium deposit in Ruvuma and in selected villages in the neighborhood of the deposit. Lolila (2011) reported an average dose rate in air from external irradiation of 99.8 nGy h^{-1} and annual effective dose of about 0.12 mSv at Mkujuriver. The dose rate in air at the proposed uranium mine was found to range from 647.2 to 23360 $nGyh^{-1}$ which corresponds to annual effective dose of 9.57 mSv and 26.39 mSv respectively. Therefore this study aims at establishing baseline data by assessing the levels of natural background radiation in the vicinity of the proposed uranium mining sites at Manyoni Uranium project.

MATERIALS AND METHODS

Description of Study area

Manyoni District is located in the central part of Tanzania. Its geographical coordinates lies between Latitudes 5° 30' 0" and 7° 34' 0"South of the equator and Longitudes 33° 27' 0" and 35° 26' 0" East of Greenwich. It has an area of 28,620 km2 with population of 205,423 people (United Republic of Tanzania census 2002).

The Manyoni uranium Project is situated in the northern section of the Bahi province near the town of Manyoni, which is 120 km NW of Dodoma, the capital of Tanzania. The region combines an extensive locked draining system developed over weathered uranium rich granites. This drainage captures dissolved uranium that leaked from underlying rocks and transports it to appropriate precipitation trap sites (mbuga/playa lakes A, B, C, D, E & F) shown in figure 1. (URANEX website: http://www.uranex.com.au/Projects/Tanzania.aspx).

Selection of Sampling Points and location of Field Dosimeters

Seven (7) villages which are located close to the uranium mineralized zone were selected to cover almost the whole proposed mining area including Manyoni town for the placement of the TLDs, namely Kipondoda, Mhalala, Mwanzi, Mitoo, Mkwese and Aghondi. A total of 20 locations were selected and numbered from 1 to 20; 3 from each village except Kipondoda village where two locations were selected. The locations were selected randomly but taking into the security of the TLDs. The geographical position of each location was determined by a Global Positioning System (GPS) and recorded (Table 1).

Measurement of Dose Rate

Among the large number of methods available for the determination of radiation dose rate in air, thermoluminescent dosimeters (TLDs) are widely used (Nambi*et al*. 1987, Benkrid*et al*. 1992, Zarate-Morales and Buenfil 1996, A1-Ghorabie 2004, Miah 2004, Aleissa and Enany 2012). This is because TLDs are small, reusable, and economical, measurements are performed under laboratory conditions and sensitivity, accuracy and dependability over extreme environmental conditions are satisfactory (Mathur 1983, Mollah*et al*. 1986). The most commonly used TL phosphors for dosimetry are: lithium fluoride (LiF), Lithium borate ($Li_2B_4O_7$), calcium fluoride (CaF_2), calcium sulphate ($CaSO_4$), aluminum oxide (Al_2O_3), berylli1um-oxide (BeO), and magnesium borate (MgB_4O_7) (Mathur 1983).

In this study, calcium fluoride doped with dysprosium (CaF_2: Dy) also known as TLD-200 dosimeters were used because of their higher sensitivity. This tremendously high sensitivity makes it a best thermoluminescent material for short term (no more than 30 days) environmental monitoring; however, the higher fading rate does limit its effectiveness for long duration environmental measurements (Harshaw 2002).

TLDs as a passive detector provide measurement of the dose integrated during a time interval (days to months), thus only an average dose rate for this period can be estimated. The routine techniques for using a passive detector monitoring system involve three steps which are described in the next section: preparation of the detector along with testing the performance of the system, field exposure and read out (Harshaw 2002, Luo 2007).

Preparation of TLDs

The TLDs were calibrated at the Tanzania Atomic Energy Commission's laboratory using Harshaw TLD System Model 4500 Manual TLD Reader with WinREMS TM to ensure that all cards in a system give nearly the same response to a given radiation exposure. The calibration process includes the annealing of TLDs, generation of calibration dosimeters, calibration of the TLD reader and calibration of field TLDs. Through these processes bad dosimeters, golden cards and field dosimeters were identified from a batch of 100 cards. Procedures on how to calibrate are described elsewhere (Harshaw 2002).

Exposure and read out

Two sets of TLDs were kept in wooden boxes where each box was placed in open space at 1 m above the ground in each location to be exposed to background radiations in order to obtain the absorbed dose. The radiation levels were monitored for a period of six months; June 2012 to November 2012 by collecting and replacing TLDs at each location every month. The collection and the replacement of TLDs were done simultaneously to ensure continuity of monitoring for the mentioned period. The collected TLDs were taken to the laboratory for dose evaluation using calibrated Harshaw TLD System model 4500 under the flow of nitrogen gas at a constant rate. The TLD reader was connected to the personal computer equipped with Harshaw system for processing and performing a complete analysis of TL glow curves. The reader computed the dose (in μGy) in terms of ambient equivalent dose H*(10).

Table 2: Mean outdoor dose rate and range measured at 20 stations located in Manyoni district.

Station No.	Dose rate			
	Minimum (nGy h-1)	Maximum (nGy h^{-1})	Mean (nGy h^{-1})	Std. Error
1	29.66	71.67	45.50	6.40
2	83.42	118.61	97.15	6.03
3	72.38	137.60	108.32	10.80
4	48.90	72.93	56.43	3.66
5	44.94	106.04	79.76	10.10
6	53.17	101.40	69.71	7.40
7	30.02	63.89	49.61	4.98
8	313.01	507.00	396.69	28.65
9	20.27	52.02	31.20	5.36
10	35.93	73.68	56.37	6.29
11	38.49	66.12	49.38	4.96
12	52.30	80.19	61.55	4.48
13	42.58	83.22	57.41	6.09
14	31.50	100.56	51.75	10.81
15	30.66	70.82	41.16	6.17
16	16.68	46.07	30.84	5.09
17	19.58	43.64	30.89	3.81
18	50.52	99.50	76.93	7.54
19	44.78	84.11	55.49	6.35
20	28.78	83.33	51.07	9.16

Evaluation of Dose Rate

The average background dose rates R ($nGyh^{-1}$) for a batch of two TLDs was determined using equation 1 below after been modified (Banzi*et al*. 2002).

$$R = \frac{1}{Nt}\left[\sum_i \left(\frac{g_i - m}{S_i}\right) FK\right] - D \qquad (1)$$

where N is the number of dosimeters; t is time in hours between TLD placement and withdrawal, gi is gross readout of individual dosimeters from the field; m is mean readout of background dosimeters, which were retained in the laboratory; Si is the mean value of relative sensitivity of individual dosimeters; F is calibration factor for the TLD reader during the monitoring period; K is the correction factor for the fading calculated from continuous irradiation mode (dose lost due to TLD handling); and D is a correction for transit dose (nGy h^{-1}). The sensitivity of each TLD (Si) and the correction factor (K) were automatically calculated by the system and incorporated in the values of measured dose i.e. Gross readout of individual dosimeters from the field (gi) and (m) readout of background dosimeters, which were retained in the laboratory and the fading factor F was obtained experimentally as described by Furreta (1937) and was found to be 1.24%.

Determination of Annual Effective Dose

The basic quantity used to describe public exposure is the effective dose and it was developed for protection and for exposure purposes. Since doses to the member of the public cannot be measured directly usually these are assessed on the basis of the environmental measurements (UNSCEAR 2008). Therefore value of dose rate measured was used to estimate the annual effective dose, E_D, for the member of the public by using equation (2) (Dragovic *et al*. 2007, El-Daly *et al*. 2008, Amekudizie *et al*. 2011).

$$E_D = R \times T \times T_C \times F \qquad (2)$$

where, E_D is in Sv, R is the absorbed dose rate in $nGyh^{-1}$, T is the annual exposure time in hours (i.e. 8760), T_C is the outdoor time conversion factor equal to 0.2 and F is the dose conversion factor equal to 0.7 SvG y^{-1}.

RESULTS AND DISCUSSION

Dose rate measured in selected locations at the vicinity of Manyoni uranium deposit

The mean and range of dose rates evaluated from six (6) measurements made for six consecutive months (June to November 2012) at a height of 1 m above the ground at each location indicated by number 1 to 20 is summarized in table 2.

The mean dose rates range from 16.68 to 507.00 nGy h^{-1} with an average of 74.86 nGy h^{-1}. This average value is higher than the world's average of 59 nGy h^{-1} of outdoor dose rate in air due to natural background radiation (UNSCEAR 2008) and The average value of 99.8 nGy h^{-1} was reported for Mkuju River in Namtumbo district (Lolila, 2011). On the other hand, it is lower than the average value of 104 nGy h^{-1} (98-121 nGy h^{-1}) reported in a similar survey carried out in other parts of Tanzania (Banzi*et al*. 2002).

Station number 15, 16 and 17 located in Aghondi village and station 9 and 11 located in Mitoo village had a mean dose rate value much small than the world average value. This also has been reported in station number 1, 7 and 20. This may be due to the reason that stations 15, 16 and 17 are located far away from the deposit i.e. mbuga C and D as seen in fig 1. Furthermore, it is interesting to note that station 8 located in Mwanzi village had significantly higher dose rates which is 6.7 times the world's average value. The reason for this reasonably high dose rate may perhaps be due to the fact that this point is located in the Mbuga/playa lake C, which is one of the uranium deposits. The remaining stations had dose rates that are not significantly higher than the world average value.

Estimation of Annual Effective

The absorbed dose rates measured were converted to effective dose in order to determine the radiological risks. Using equation (2), the mean annual effective dose for each station was estimated and presented in Table 3 .

Table 3: Absorbed dose rates with their corresponding annual effective dose in 20 stations located at Manyoni.

Station No.	Average Dose Rate (nGy h^{-1})	Annual Effective Dose E_D (mSv y^{-1})
1	45.50	0.06
2	97.15	0.12
3	108.32	0.13
4	56.43	0.07
5	79.76	0.10
6	69.71	0.09
7	49.61	0.06
8	396.69	0.49
9	31.20	0.04
10	56.37	0.07
11	49.38	0.06
12	61.55	0.08
13	57.41	0.07
14	51.75	0.06
15	41.16	0.05
16	30.84	0.04
17	30.89	0.04
18	76.93	0.09
19	55.49	0.07
20	51.07	0.06

The minimum and maximum effective doses were 0.04 and 0.49 mSv y^{-1} respectively with average of 0.09 mSv y^{-1}. The maximum and minimum effective doses were 25 and 2 fold lower than the recommended limit of 1 mSv y^{-1} for a member of the public (ICRP 1990). This work find out that the estimated annual effective dose from the external exposure in each station is lower than recommended limit of 1 mSv y^{-1}. It implies that prior to the commencement of mining operations in the proposed area; the external exposures rates due to the natural background radiation are lower than the world recommended value and thus do not pose any radiological hazard to the general public. These values as documented in this work are area-specific average value and are the baseline on which the assessment of the impact of the uranium mining operations should base on, rather than on country or world average values. Therefore any future increment from these values will be attributed to uranium mining and milling process.

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