Radiological Health Effects from Uranium Deposits in Tanzania

Hilali Hussein Ramadhan and Juyoul Kim*
Department of NPP Engineering, KEPCO International Nuclear Graduate School,
658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014
**Corresponding author: jykim@kings.ac.kr*

1. Introduction

Humans are continuously exposed to ionizing radiation due to the presence of natural radionuclides originated from the earth crust and high cosmic ray particles incident on the earth's atmosphere [1]. The exposure is due to internal by ingestion and inhalation and external by gamma radiation emitted from natural radionuclides such as ^{232}Th, ^{40}K and ^{238}U and their decay products. The radiation dose from these natural sources is very low and generally regarded as negligible, however, radiological assessment of their health effect must be considered as far as human health is a concern. Moreover, a high level of radioactivity has been reported worldwide in phosphate and uranium deposits. The elevated level of radioactivity concentration of ^{232}Th, ^{40}K and ^{226}Ra has also been reported in granites rich in uranium and thorium. Minjingu and Mkuju are areas with phosphates and uranium deposits reported to have high background radiation respectively in Tanzania [2]. Furthermore, Bahi district of Dodoma capital city has also been discovered with viable uranium deposits at a shallow surface. The area of the district is geographically wetlands and agricultural and economic activities conducted by the indigenous society include paddy farming, fishing, grazing ground and traditional salt production [3]. This area is a serious concern due to high radioactivity level reported in other regions with uranium deposits as well as uranium mining activities expected to commence in the nearby future. Therefore, an assessment of risk to the public become necessary as far as human health and environmental protection are concerned. This study was intended to estimate radiation dose and risk to the general public due to continuous exposure to radionuclides from uranium deposits in Bahi district using RESRAD-OFFSITE. The Total Effective Dose Equivalent (TEDE) have been estimated and discussed.

2. Materials and Methods

2.1 Description of Study area

Bahi wetland falls between latitudes 05º51′S and 06º20′S and longitudes 34º59′E and 35º21′E east. The wetland is 60 km north-west of the capital Dodoma, covering an area of about 2000 km^2 with an estimated population of about 270,000. The wetlands offer a wide range of livelihood options to communities as compared to the surrounding dry. The Study location is shown in Fig. 1.

2.2. Sampling and Measurement

As shown in Fig. 2, a total of 25 undisturbed soil samples of about 2 kg were randomly collected at a depth level of 0-15 cm from 8 identified points using standard sampling procedure. The area was also divided into three zones; northern zone (NZ) central zone (CN) and southern zone (SN) and selection of sampling locations within each zone were based on the accessibility of the station to the public as shown in Fig. 1. Sample analysis was conducted at the Laboratory of Tanzania Atomic Energy Commission (TAEC) and activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were measured using a P-type coaxial high purity germanium detector (HPGe) with the relative efficiency of 51.0% and resolution of 1.80 keV at 1332 keV energy of ^{60}Co. The detector chamber is shielded with three layers of copper, cadmium and lead of 30 mm, 3 mm and 100 mm thick respectively. Energy and efficiency calibration was performed using the multi-nuclide standard packed in a 500 ml Marinelli beaker [4]. The maximum activity concentration of ^{226}Ra ^{232}Th and ^{40}K for NZ, CN and SN was obtained and used for the worthiest case of analysis of this study as shown in Table. I.

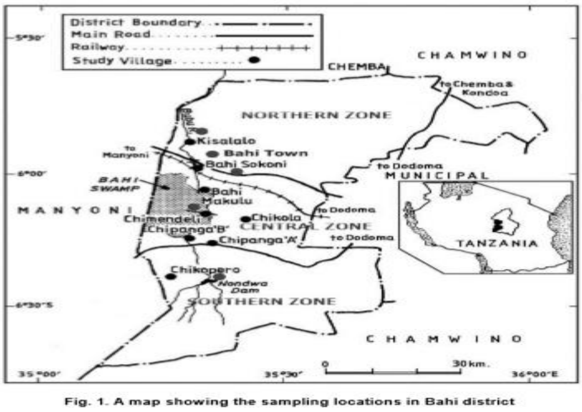


Fig. 1. Map of Bahi district showing sampling locations [4].

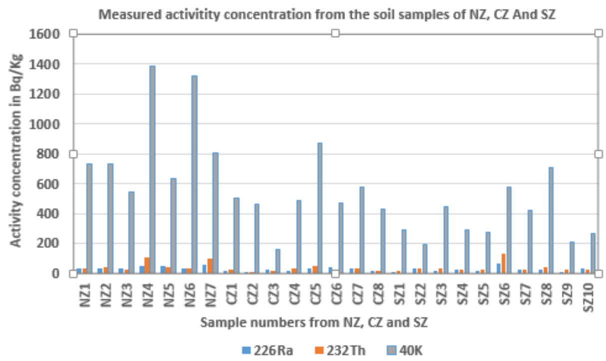


Fig. 2. Activity concentration from soil samples around the Bahi district area [4].

Table I: The maximum activity concentration (Bq/kg) in Nouthen(NZ), Central(CZ) and Southern zone (SZ).

Surveyed area	Maximum activity concentration (Bq/kg)		
	^{226}Ra	^{232}Th	^{40}K
NZ	60.09±1.19 1,384.75±14.92		107.36±1.79
CN	42.75±0.85	47.74±0.81	874.77±9.43
SZ	69.38±1.38	132.11±2.25	706.67±7.64

2.3. Description of RESRAD Code

Mathematical models play an important role in radiological risk assessment. They are used to evaluate the dispersion and transfer of radionuclides in the environment and exposure of radiation dose to humans, hence become very crucial in estimating risk to the public concerning radiation facility or activity. RESRAD code is one of the modelling software tool developed by the Argonne National Laboratory under the United State Department of Energy (DOE) and the United State Nuclear Regulatory Commission (NRC) as a multifunctional tool to assist in developing criteria for evaluating human radiation doses and risks associated with exposure to radiological contamination [5]. RESRAD also uses U.S. Federal Guidance Report No. 12 and the ICRP-38 and 70 radionuclide database in this evaluation procedure. The software allows users to specify the features of their site and to predict the dose received by an individual at any time interval and modelling a site through the use of more than 150 variables. Each parameter has a default value assigned by the developers at Argonne, but can be changed to suit site-specific needs. RESRAD-OFFSITE is an extension of the RESRAD-ONSITE computer code that was developed to estimate the radiological consequences for an individual's located onsite or offsite the area of primary contamination. The code considers the release of radionuclides from the primary contamination source to the atmosphere, surface runoff, and groundwater. In this study, five exposure pathways were considered in RESRAD-OFFSITE such as direct exposure from contamination in soil, inhalation of dust/radon, ingestion of plant foods, meat and milk, ingestion of water (borehole water) and f, and incidental ingestion of soil. RESRAD can be used to model the resident exposure scenario through a selection of different pathways.

3. Results and Discussion

The result from Table 2, 3 & 4 and Figure 3, 4, & 5 were calculated by RESRAD-OFFSITE for Tanzania to estimate the total effective dose equivalent (TEDE) and radiological health effect to the public due to continuous exposure from uranium deposits in Northen zone, Central Zone and Southern Zone of Bahi district. The results indicated that the TEDE received to the public over 100 years in all the three zones is below the public dose limit of 1mSv/year recommended by International Commission on Radiological Protection (ICRP) and Tanzania Atomic Energy Commission (TAEC), a regulatory authority. Furthermore, Radon and direct radiation from soil (direct and airborne) are the major pathways contributing more to the received dose and cancer risk from all the pathways summed over 100 years for Northen zone (NZ) while fish ingestion and direct radiation from soil (direct and airborne) contributing more in Central Zone (CN) and Southern Zone (SZ).

Table II: TEDE for individual nuclides for all pathways over a duration of 100 years for Nortern Zone (NZ).

Year	Total Effective Dose Equivalent (mSv/year)		
	^{226}Ra	^{232}Th	^{40}K
0	6.4E-03	3.4E-05	1.0E-03
1	6.4E-03	3.4E-05	1.0E-03
10	6.3E-03	3.4E-05	7.7E-04
20	6.1E-03	3.4E-05	5.7E-04
30	5.9E-03	3.4E-05	4.3E-04
40	5.8E-03	3.4E-05	3.2E-04
60	5.4E-03	3.4E-05	1.8E-04
80	5.1E-03	3.4E-05	9.9E-05
100	4.9E-04	3.4E-05	5.6E-05

Table III: TEDE for individual nuclides for all pathways over a duration of 100 years for Central Zone(CZ).

Year	Total Effective Dose Equivalent (mSv/year)		
	^{226}Ra	^{232}Th	^{40}K
0	3.4E-04	1.5E-05	6.5E-04
1	3.4E-04	1.5E-05	6.5E-04
10	3.3E-04	1.5E-05	4.9E-04
20	3.2E-04	1.5E-05	3.6E-04
30	3.1E-04	1.5E-05	2.7E-04
40	3.0E-04	1.5E-05	2.0E-04
60	2.8E-04	1.5E-05	1.1E-04
80	2.7E-04	1.5E-05	6.3E-05
100	2.5E-04	1.5E-05	3.5E-05

Table IV: TEDE for individual nuclides for all pathways over a duration of 100 years for Souther Zone (SZ).

Year	Total Effective Dose Equivalent (mSv/year)		
	^{226}Ra	^{232}Th	^{40}K
0	5.5E-04	4.2E-05	5.3E-04
1	5.4E-04	4.2E-05	5.1E-04
10	5.3E-04	4.2E-05	3.9E-04
20	5.2E-04	4.2E-05	2.9E-04
30	5.0E-04	4.2E-05	2.2E-04
40	4.9E-04	4.2E-05	1.6E-04
60	4.6E-04	4.2E-05	9.1E-05
80	4.4E-04	4.2E-05	5.1E-05
100	4.1E-05	4.2E-05	2.8E-05

Fig. 3. Excess cancer risk for all nuclides and components pathways for Northern Zone (NZ).

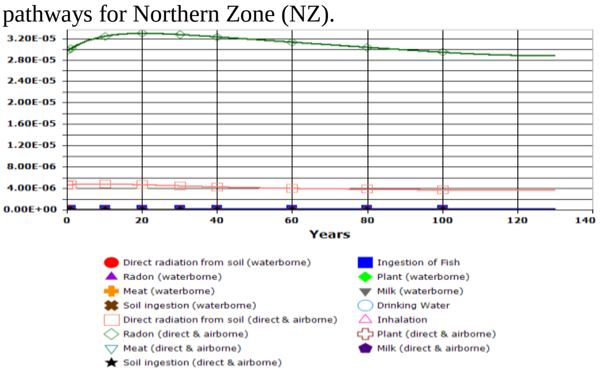


Fig. 4. Excess cancer risk for all nuclides and components pathways for Central Zone (CZ).

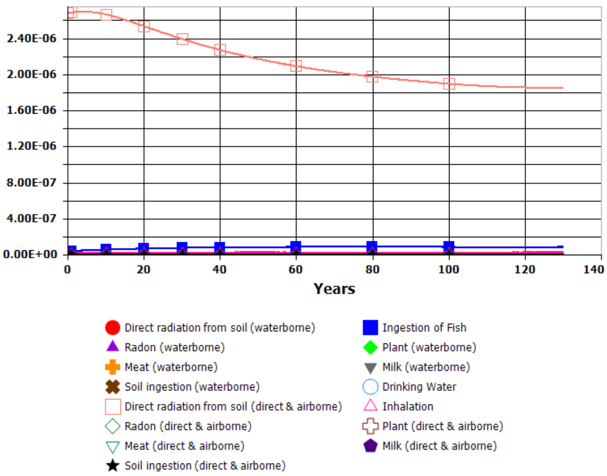
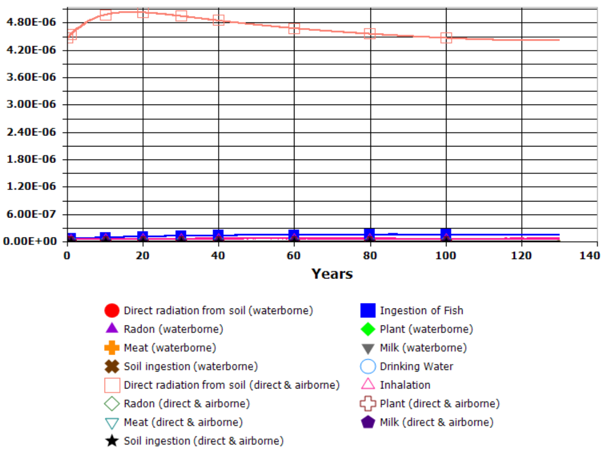


Fig. 5. Excess cancer risk for all nuclides and components pathways for Southern Zone (SZ).



4. Conclusion

RESRAD-OFFSITE was employed to evaluate radiation dose and risk to the public due to continuous exposure to radionuclides from uranium deposits in Tanzania using the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K for 25 soil samples over 100 years to determine the most dormant pathway to public dose. The results of this study are below the public dose limit of 1mSv/year recommended by ICRP and TAEC. The total effective dose equivalent (TEDE) and Excessive Life Cancer Risk (ELCR) is mostly contributed by Radon gas and direct radiation from soil (direct and airborne) as dominant pathway among all the pathways for Northen Zone (NZ), while fish ingestion and direct radiation from soil (direct and airborne) contributing more in Central Zone (CN) and Southern Zone (SZ) for this study.

Acknowledgement

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