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Evaluation of Dose and Risk to the Public around Uranium Mining Area in Mongolia

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1. Introduction

The uranium mining and the inappropriate management of residues have had a harmful impact on the environment. Naturally-occurring radioactive materials (NORMs) are a common occurrence in our environment since the formation of the Earth. This eventually affects humans through different radiation exposure pathways, either external or internal [2, 5, 6]. ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs provide significant sources of human exposure to ionizing radiation. Internal exposure from ^{226}Ra and ^{232}Th, since they are alpha emitters. Alpha particles have a high energy, but are harmful only inside the body, especially if associated with dose concentrated at a specific site. In the case of ^{226}Ra and ^{232}Th, they can enter the bloodstream and accumulate in bones, where they may remain for many years. ^{40}K is a beta emitter and contributes to both external and internal dose. Internal sources, such as radioactive materials that enter the body through the ingestion of contaminated plant and animal's meat and milk are an essential dose pathway for the consideration of residential exposure scenarios [8]. The aim of this study to calculate the radiation exposure from the surface soil to public certain area of Janchivlan uranium exploration area in Mongolia using the RESRAD code.

2. Study Area

The Janchivlan uranium exploration region is 70 km southeast from Ulaanbaatar city and eastern part of the Tov province in Mongolia. The study area is covers about 100 m2 part of the Erdene Soum. The altitude ranges from 1800 to 2044 m. There are around 3736 residents and 186,474 animals in Erdene soum [7]. This region has a continental climate with a warm summer and cold winter. The average annual precipitation is less than 200-250 mm. The sampling was carried out in May 2008 prior to the uranium exploration activities. The map of the mining area and sampling locations are shown in Fig. 1. A Global Positioning System (GPS) receiver was used to locate the sampling points.

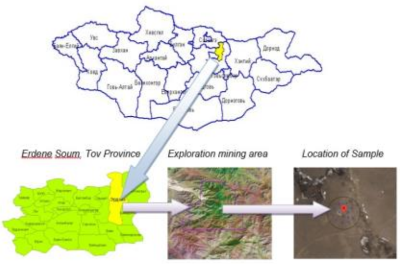

Fig. 1. The map of the Janchivlan uranium exploration mining area and sampling locations.

3. Sampling and Measurements

As shown in Fig. 1, a total of 12 surface soil samples were collected each sample was around 1.3 kg within about a 400 m^2 from the after drilling area. At sampling location, a square area of 20 x 20 cm was marked out. Then samples were collected from the surface layer. In the laboratory, each sample was grinded by machine before further gamma-ray measurement. The concentrations of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs were determined by a HPGe γ-ray spectrometry system (Nuclear Research Center of National University of Mongolia). Shown in the Table I, results of measurements for concentration of radionuclides in soil samples around the Janchivlan uranium exploration mining.

Table I: The contents of radionuclides (Bq/kg) in surface soil samples around the Janchivlan exploration uranium mining area.

Item	Activity of Isotopes (Bq/kg)			
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
Soil sample 1	43.7	30.5	838	17.3
Soil sample 2	51.4	31.5	784	17.5
Soil sample 3	49.6	31.7	829	13.0
Soil sample 4	39.9	29.1	914	13.7
Soil sample 5	44.7	29.2	887	16.0
Soil sample 6	47.3	34.2	906	13.9
Soil sample 7	37.5	36.5	876	13.2
Soil sample 8	36.8	38.1	761	17.8
Soil sample 9	38.8	34.3	789	19.9
Soil sample 10	47.6	31.0	811	17.4
Soil sample 11	50.5	31.6	807	15.2
Soil sample 12	44.7	30.4	871	13.3
Min	**37.5**	**29.1**	**761**	**13.0**
Max	**51.4**	**38.1**	**914**	**19.9**
Mean	**44.4**	**32.3**	**839.4**	**15.7**

HPGe γ-ray spectrometry system employed to carry out the radioactivity measurements was based on a high-purity germanium detector. The activity concentrations of ^{232}Th, ^{226}Ra, ^{40}K, ^{137}Cs in the soil samples were determined in Bq/kg. The minimum detectable activity for each radionuclide was determined from the HPGe γ-ray spectrometry system and samples for the counting time was 3,600 s [4, 8, 9].

4. Simulation

One of the most frequently used modelling software for dose and risk is RESRAD code. It was developed by the Argonne National Laboratory under the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission as a multifunctional tool to assist in developing criteria for evaluating human radiation doses and risks associated with exposure to radiological contamination. RESRAD allows users to specify the features of their site and to predict the dose received by an individual at any time. The code considers the release of radionuclides from the primary contamination source to the atmosphere, to surface runoff, and to groundwater. It calculates the radiation dose and excess cancer risk with the radionuclide concentrations in the environment. In this study, four exposure pathways were considered in RESRAD Offsite: direct exposure from contamination in soil, ingestion of meat and milk. By selecting the different pathways, RESRAD Offsite can be used to model the resident exposure scenario. [1, 8].

5. Results

Shown in Table I are the activity concentration values of radionuclides in the soil samples collected from the study area. The measured activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs was between 914 to 19.9 Bq/kg. Highest values are 51.4, 38.1, 914 and 19.9 Bq/kg, respectively. The activity concentrations of ^{40}K are higher than the other radionuclides. RESRAD Off-site code to calculate the Total Effective Dose Equivalent (TEDE). TEDE from the Janchivlan uranium exploration mining area for all of the pathways summed over a duration of 1000 years were calculated as shown in Table II. According to RESRAD, the maximum TEDE from exploration mining area during 1000 years was found that 0.2240 mSv/year in the 473 years. The results have showed within to a basic radiation dose limit value of 0.2500 mSv/year. Shows in Table II ^{40}K contributed the most to TEDE, while ^{226}Ra, ^{232}Th had lesser effect [1, 4, 8].

Table II: Total effective dose equivalent (mSv/year) drilling area for all the pathways summed over a duration of 40 years.

Year	Total Effective Dose Equivalent (mSv/Year)				
	Nuclides				Total
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs	
0	4.03E-04	1.12E-05	6.83E-04	5.30E-05	1.15E-03
1	4.02E-04	3.72E-05	6.75E-04	5.18E-05	1.17E-03
10	3.98E-04	2.70E-04	6.08E-04	4.22E-05	1.32E-03
50	3.78E-04	4.21E-04	3.81E-04	1.69E-05	1.20E-03
100	3.54E-04	4.24E-04	2.12E-04	5.37E-06	9.95E-04
200	3.09E-04	4.28E-04	4.52E-04	5.44E-07	1.19E-03
300	2.69E-04	4.32E-04	4.92E-02	5.50E-08	4.99E-02
400	2.34E-04	4.35E-04	1.82E-01	5.57E-09	1.83E-01
500	2.04E-04	4.39E-04	2.18E-01	5.64E-10	2.19E-01
1000	1.02E-04	4.57E-04	1.85E-03	5.96E-15	2.41E-03

As expected in the pathways, most of the total effective dose equivalent is caused by milk and meat and followed by soil ingestion. Figure 2 shows the radiation doses over a duration of 1000 years following contamination [8, 9].

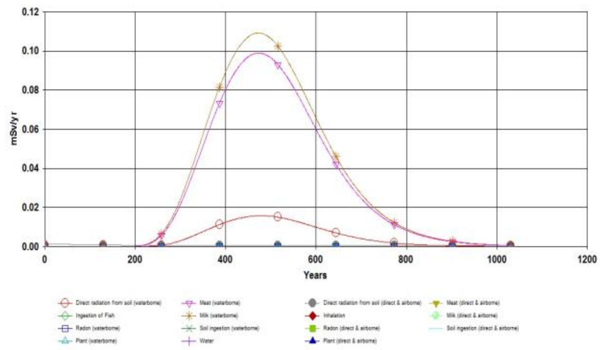

Fig. 2. Total effective dose equivalent from the all nuclides summed based on component pathways.

RESRAD Offsite computer code to calculate the excess cancer morbidity risks from for all of the pathways summed over a duration of 1000 years. Figure 3 clearly shows the excess cancer morbidity risk from certain area of uranium exploration mining. The results of cancer morbidity risk from the all nuclides ^{226}Ra, ^{232}Th, ^{40K} and ^{137}Cs based on component pathways. The cancer morbidity risks from exposure to ^{40}K is significantly greater than from exposure to ^{226}Ra, ^{232}Th and ^{137}Cs. The assessed cancer morbidity risk for ^{40}K indicated a 7.30 x 10−4 at the 480 years. This is expected due to the high levels of ^{40}K activity concentration in the soil samples collected from the study area.

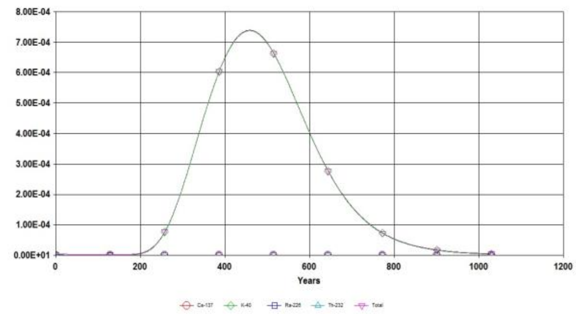

Fig. 3. Excess cancer morbidity risk from the all nuclides summed based on component pathways.

6. Conclusions

Natural radionuclides in soil were measured using gamma-ray spectrometry to determine the cancer morbidity risk and TEDE in the Janchivlan area of Erdene Soum. The results indicated the highest activity concentration was ^{40}K. According to the RESRAD calculations, the maximum total effective dose equivalent from ^{137}Cs ^{40}K, ^{232}Th, and ^{226}Ra was 0.2240 mSv/year in 473 years, respectively. Also total cancer morbidity risk from ^{40}K was 7.3 x 10−4 in the 480 years. From the other radionuclides cancer risk was compartivlity lower than ^{40}K.

Acknowledgement

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