Sumerianz Journal of Scientific Research, 2023, Vol. 6, No. 3, pp. 61-69
ISSN(e): 2617-6955, ISSN(p): 2617-765X
Website: https://www.sumerianz.com
DOI: https://doi.org/10.47752/sjsr.63.61.69

Original Article Open Access

Estimation of Background Radiation from A Soil Sample from A Barley Farm Area and Malt Factory in East Arsi, Ethiopia

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Article History

Received: 5 September, 2023

Revised: 7 November, 2023

Accepted: 10 November, 2023

Published: 11 November, 2023

How to Cite

T. Y. Haile, B. S. Goshu, E. Mengistu., 2023. Estimation of Background Radiation from A Soil Sample from A Barley Farm Area and Malt Factory in East Arsi, Ethiopia. *Sumerianz Journal of Scientific Research, Vol. 6, No. 3, pp. 61-69.*

Abstract

The aim of this work is to estimate the background radiation of a soil sample from the barley farm area and Malt factory in East Arsi, Ethiopia. The technique of gamma-ray spectrometry with a high-purity germanium (HPGe) gamma-ray detector and a PC-based MCA was used. The activity concentration levels due to 40K, 137Cs, 238U, and 232Th were measured within the study area at a depth of 30 cm. The soils of the study region are used as construction material by many farmers. The measured specific activity of those radionuclides was compared with the data reported worldwide. The specific activity of radionuclides was estimated in both study locations. The specific activity 238U of soil samples ranged from 41.0 Bq kg^{-1} to 30.7 Bq kg^{-1} in the barley farm, with a mean value of 37.7 Bq kg^{-1}, and for malt ranged from 23.8 Bq kg^{-1} to 40.6 Bq kg^{-1}, with a mean value of 32.5 Bq kg^{-1}. The specific activity of ^{232}Th in soil samples ranged from 89.9 Bq kg^{-1} to 156.0 Bq kg-1, with a mean value of 118.6 Bq kg-1, whereas for the Malt factory ranged from 121.0 Bq kg^{-1} to 128.0 Bq kg^{-1}, with a mean value of 123.7 Bq kg^{-1}. In barley soil samples, the specific activity of 40K ranged from 401.0 Bq kg^{-1} to 530.0 Bq kg^{-1} with a mean value at the Malt plant ranged from 518 Bq kg^{-1} to 598.0 Bq kg^{-1}, with a mean value of 553.6 Bq kg^{-1}. Similarly, the specific activity of ^{137}Cs was determined in both the barley farm and the malt Factory. In barley farm soil samples, it ranged from 3.3 $\pm$0.6 Bq kg^{-1} to 5.34$\pm$0.6 Bq kg^{-1}, and with a mean value of 4.3 Bq kg^{-1} whereas, in the Malt factory it varied from 3.1 $\pm$0.7 Bq kg^{-1} to 5.3 $\pm$0.7 Bq kg^{-1}, and with a mean value of 4.5 Bq kg^{-1}. The absorbed dose rate within the barley farm ranged from 24.6 $\pm$2.9 $nGyh^{-1}$ to 34.1 $\pm$2.9 nGy h^{-1}, and with a mean value of 30.6 $nGyh^{-1}$, whereas, in the Malt factory, it varied from 31.3 $\pm$1.3 nGy h^{-1} to 35.5 $\pm$1.3 $nGyh^{-1,}$ and with a mean value of 33.5 nGy h^{-1}. The annual effective radiation dose for BSS and MFSS was calculated to be 37.6 mSv $y^{-1}$and 41.1mSv y^{-1}. This study revealed that this region lies within a medium radiation background when compared with the world's average. The marginal value of dose is higher within the Malt factory area because of fertilizer consumption for cultivation. Since these estimated background and radiological impact factors are below the recommended values, it seems that there is no potential radiological health hazard related to the soils from both BSS and MFSS in Arsi Asella, Oromia, Ethiopia.

Keywords: HPGE; Specific activity; Soil; Absorbed dose; Radiological hazard.

1. Introduction

Soil is a food source for humans and a major source of radiation exposure. It is necessary to understand the distribution of radioactivity in the soil. NORM stands for present stuff and refers to items containing naturally occurring radioactive elements and nuclides produced using methods described in [1].

According to, soil is the basis of natural resources. It depends on life support systems and socioeconomic growth. Natural radiation from the environment is always present in every human body to varying degrees. Radiation dosimetry of radionuclides is therefore of critical importance, and natural radiation is reported to be the largest contributor to the external exposure for the world's population [2, 3].

Barley can grow at any altitude and be cultivated by smallholder farmers throughout in Ethiopia. Northern and central parts of the country have high productivity rates. It is key meal crop on the Ethiopian plateau. As described in [4], the harvest is used in the preparation of various traditional dishes such as kita, koro, beso, injera, jatto, and wolfberry (shakeka).

Natural radionuclides present in soil belong to the thorium and uranium series. Exposure to natural radionuclide radiation relies upon electromagnetic radiation. It relies upon the geological and geographical factors of the environment. Radionuclides are different in different parts of the world, as reviewed in [2, 3].

Dose rates vary by location. They are affected by the concentration of naturally occurring radionuclides such as ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K in soil. These concerns about exposure to radionuclides are caused not only by radon and its alpha-producing daughters but by gamma-ray emissions [5, 6]. Potassium (^{40} K), Uranium (^{238} U), and Thorium (^{226} Th) are naturally occurring radionuclides in the terrestrial environment. Radon, a radioactive gas, is produced when naturally occurring radioactive isotopes decay.

As noted in [4, 5, 7, 8], this background radiation level varies around the world due to different amounts of each NORM type in different parts of the world. Radionuclide concentrations are normal in most parts of the world. According to Mussa, *et al.* [9]; Saleh, *et al.* [7], it has no adverse effects on human health or the environment. High levels of the NORM can be detrimental in some parts of the world.

Therefore, it is vital to know the amount of background radiation. It is used to distinguish between safe and harmful levels of radiation and to assess the sources of each type of radiation described in Ayalew, *et al.* [5]. Because of the health effects of radiation (chronic lung disease, malignant disease, etc.) mentioned in Ayalew, *et al.* [5]; Ayesha, *et al.* [10], people should be careful about the natural environment.

In most parts of the world, the concentrations of radionuclides are at normal levels. It does not have any health effects on humans or the environment as reported in Mussa, *et al.* [9]; Saleh, *et al.* [7]. In some parts of the world, high concentrations of NORMs can have detrimental effects.

Natural radioactivity arises from primordial radionuclides. These are ^{40}K and the radionuclides from the ^{232}Th and ^{238}U series. They occur in trace amounts in all terrestrial forms [5, 7, 11]. Other types of ionizing radiation are responsible for 10% of the average annual radiation dosage to the human body [5]. In addition, recent studies conducted in the sites of Dire Dawa and Halal, as reported in, show that humans are exposed to primordial radionuclides.

Therefore, this study was focused on the estimation of background radiation exposure in soil samples from the barley farms area and the Malt factory of Asella, Oromia, Ethiopia, using a high-purity germanium detector for gamma-ray spectrometry.

2. Material and Methods

2.1. Study Area

Soil samples were randomly collected from different locations (barley farm area and Malt factory) of fertile soil in Arsi Asella, in the southeast part of Oromia, Ethiopia (159km from Addis Ababa). The study area is located between longitude 7^{o} 57′ N and latitude 39^{o} 7′ E with an elevation of 2430m and a complete population of 110,088 in line with the 2012 census. The study was carried out near Assela town, which is found near Chilalo Mountain in Oromia regional state, as shown in Figure 1. The most economic resources of this area are derived from agriculture, as food, and input to the Malt factory. The mainland has a relative high mountain range and is widely used to crop barley and wheat.

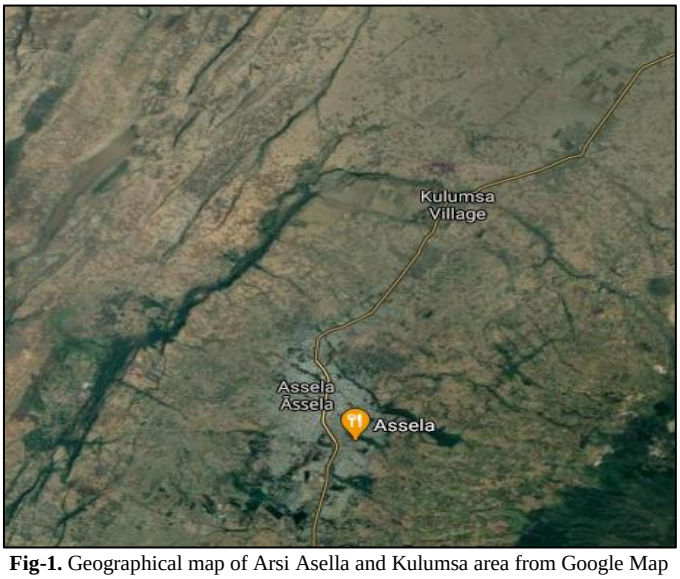

Fig-1. Geographical map of Arsi Asella and Kulumsa area from Google Map

2.2. Materials

Plastic paper or adhesive tape, balance, plastic glass (500 ml), 50cm ruler, plastic container, paper, soil blender, soil sample, and gamma-ray spectroscopy (High Purity Germanium (HPGe)) detectors, and others were used.

2.3. Sample Preparation

Letters and numbers are used to assign soil samples in two areas (BSS1, BSS2, BSS3… & BSS10) for soil samples from barley farm areas and (MFSS1, MFSS2, MFSS3… & MFSS10) for soil samples from the Malt factory shown in Table 1with geographical position.

Table-1. Samples code and Geographical position

Areas	Soil samples code	Geographical position		Altitude (m) above sea level
		Latitude N(deg)	Longitude E(deg)	
Farm	BSS1	7.9875	39.1855	3350
	BSS2	7.9874	39.1854	
	BSS3	7.9875	39.1855	
	BSS4	7.9875	39.1856	
	BSS5	7.9868	39.1854	
	BSS5	7.9875	39.1852	
	BSS6	7.9875	39.1852	
	BSS7	7.9874	39.1854	
	BSS8	7.9875	39.1851	
	BSS9	7.9870	39.1853	
	BSS10	7.9874	39.1851	
Malt	MFSS1	8.0058	39.1549	2234
	MFSS2	8.0023	39.1593	
	MFSS3	8.0050	39.1549	
	MFSS4	8.0058	39.1549	
	MFSS5	8.0024	39.1590	
	MFSS6	8.0068	39.1569	
	MFSS7	8.0033	39.1598	
	MFSS9	8.0054	39.1569	
	MFSS9	8.0078	39.1599	
	MFSS10	8.0073	39.1596	

The soil sample collected from the study areas is determined using GPS, which is found by the geographical position of the latitude and longitude ranges mentioned in Table 1 to estimate the concentration of background radiation. Ten soil samples were gathered randomly from barley farm areas by digging the bottom at a depth of 30 cm, and ten soil samples were collected inside the Asella Malt factory.

The samples were packed and submitted to the laboratory of the Ethiopian radiation protection authority. The sample dried until it reached a constant mass in the laboratory. Air-dried samples were then crushed into fine powder by using a soil blender to keep a uniform size and sieved through a 0.2-mm sieve.

Approximately 500 g of uniform soil samples were packaged and sealed in a 500 ml airtight plastic container and left for a month before counting by gamma-ray spectrometry. The homogenized soil samples were dried, and then weighted by an electrical balance before counting by gamma-ray spectrometry, as reported by [3, 6, 18, 20]. This allowed for secular equilibrium between ^{226}Ra and thus the chemical element radon (^{222}Rn) and its decay products.

Gamma-ray spectroscopy was used to measure (determine) the concentrations of rubidium (^{226}Ra), uranium (U), thorium (^{232}Th), and potassium (^{40}K) with the help of High Purity Germanium (HPGe) detectors. The spectroscopy was used to measure (determine) the concentrations of rubidium (^{226}Ra), uranium (U), thorium (^{232}Th), and potassium (^{40}K) with the assistance of High Purity Germanium (HPGe) detectors.

2.4. Gamma-ray Detection System

The gamma spectrometer was used to measure emitted gamma rays from soil samples. The gamma spectrometer was an n-type coaxial CANBERRA high-purity germanium detector with a crystal with a diameter and thickness of 72.5mm (Prague, Czech Republic). The detector has a relative efficiency of 70. A three-layer, copper shield of 6mm in thickness and a lead shield of 4cm in thickness surround this spectrometer to cut back the background of gamma radiation to a minimum value. For the measurement of low-level radioactivity, a well-shielded counting system is essentially, as reported in Abojassim [1]; Ayalew, *et al.* [5]; Mussa, *et al.* [9].

The gamma spectrometry detector is shielded by lead, iron, and aluminum with thicknesses of 5cm, 1cm, and 1cm, respectively. They provide an efficient suppression of the background gamma radiation present at the laboratory site.

The energy-dependent detection photopeak efficiency has been determined using a calibrated 152 Eu gamma reference source sealed in a standard Marinelli beaker with an 85 mm bore diameter, a full-of-life volume of 1000

ml, and an average density of 1 gcm^{-3}. It's characterized by an initial activity of 10.1k Bq kg^{-1}. Given a 3% uncertainty in the source activity, the calculated efficiency's mean uncertainty is expected to be around 5%.

The energy peak efficiency of a high-purity Germanium (HpGe) detector depends on the number of γ- rays detected by the number of photons emitted by the source for specific energy, which is defined by Eq. (1) shown in [1, 5, 9, 12].

$$\varepsilon(E) = \frac{n(E)}{AxI_\gamma} \quad (1)$$

where $n(E)$ is the net count rate of the photopeak for the corresponding energy E, I_γ is the intensity of the gamma energy, and A is the present activity of the quality reference source.

The specific activity for the natural radionuclides in the measured samples was computed using the following Eq. (2) reported in [3, 13, 14]

$$C_{\mathrm{f}} = \frac{C_o}{\varepsilon P_\gamma M} \quad (2)$$

where C_f is the net counting rate of γ-ray (counts per second), ε is the detector efficiency of the specific γ-ray, P_γ the absolute transition probability of γ-decay, and M is the mass of the sample (kg).

Depending on the prepared samples, each was placed in the device one by one and counted for about 50,400 s. The traditional Genie 2000 package software from Canberra is used for the environmental analysis of the sample spectra.

The specific activity of ^{238}U, ^{232}Th, and ^{40}K in $BqKg^{-1}$ soil samples was determined. The ^{232}Th specific activity was determined using photo peaks ^{228}Ac at 911.21 keV and 968.97 keV. We use the 1460.81 keV photo-peak, directly for ^{40}K, and the ^{238}U activity was determined by taking the mean activity of the two separate photo peaks of the daughter nuclides: ^{214}Pb at 295.21 keV and 351,92keV and ^{214}Bi at 609.3 keV and 1120.29 keV [1, 5, 9, 15][2, 3, 6, 18].

The radium equivalent activity (*Raeq*) is defined in terms of the actual specific activity of the elements containing different amounts of ^{238}U, ^{232}Th, and ^{40}K. Eq. (3) described in [1, 5, 9, 15] gives it.

$$Ra_{eq} = A_{\mathrm{U}} + 1.43A_{\mathrm{Th}} + 0.077A_{\mathrm{K}} \quad (3)$$

where A_{U}, A_{Th}, and A_{K} are the specific activities of ^{238}U, ^{232}Th, and ^{40}K in $Bqkg^{-1}$, respectively.

The absorbed dose rates (D_R) due to gamma radiation within the air at 1m above the bottom surface for the uniform distribution of the present radionuclides (^{238}U, ^{232}Th, and ^{40}K) were calculated using the guidelines provided by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [8]; UNSCEAR [16]; UNSCEAR [11] and shown in Eq. (4).

$$D_R(\mathrm{nGyh^{-1}}) = 0.462A_{\mathrm{U}} + 0.621A_{\mathrm{Th}} + 0.417A_{\mathrm{K}} \quad (4)$$

The absorbed dose rate was translated into an annual effective dose equivalent using the conversion factors published in Najam, *et al.* [17]; Saeed, *et al.* [12]; Saleh, *et al.* [7] [19-21] of 0.7 $SvGy^{-1}$ for the outdoors and 0.2 for the indoors. The annual effective dose rate for outdoor and indoor use can be calculated by Eqs. (5) and (6), respectively, reported in [1, 5, 9, 15]

$$AEDR_{outdoor} = D(\mathrm{nGyh^{-1}}) \times 8670\mathrm{hy^{-1}} \times 0.7 \times 10^{-3}\mathrm{SvGy^{-1}} \quad (5)$$

$$AEDR_{indoor} = D(\mathrm{nGyh^{-1}}) \times 8670\mathrm{hy^{-1}} \times 0.2 \times 10^{-3}\mathrm{SvGy^{-1}} \quad (6)$$

The people who live around this area have used soil for building their local houses. These soils will contribute to the exposure to radiation. The external hazard index (Hex) is the indoor radiation dose rate due to the external exposure to gamma radiation in the construction materials of the residence, which was calculated by Eq. (7) reported in [1, 2, 5, 9, 15][2-4, 6, 18].

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (7)$$

The external hazard index, radon, and its short-lived products are hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index (*Hin*), which is given by Eq. (8) reported in [1, 2, 5, 15, 18].

$$H_{ex} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (8)$$

The values of the indices (*Hex, Hin*) must be less than unity, and dimensionless quantities.

The gamma index I_γ was evaluated with Eq. (9) to estimate the radiation hazard associated with the natural radionuclide given by Eq. (9), shown in [5, 15].

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad (9)$$

3. Results and Discussions

3.1. Results

3.2. Radionuclides Concentration in Soil Sample from Malt Factory

The specific activity concentrations of the ^{238}U series (^{226}Ra), ^{232}Th, and ^{40}K, expressed in $Bqkg^{-1}$, for soil samples obtained from the Arusi, and Asella barley farm areas are presented in Table 2.

Table-2. ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs Specific activity in barley soil samples

Barley farm soil sample codes	Specific Activity			
	A_U (Bq kg^{-1})	A_{Th} (Bq kg^{-1})	A_K (Bq kg^{-1})	A_{Cs} (Bq kg^{-1})
BSS1	40.7	133.0	512.0	4.1
BSS2	30.7	89.9	401.0	3.3
BSS3	38.3	156.0	512.0	4.4
BSS4	37.5	108.0	477.0	4.2
BSS5	41.0	137.0	520.0	4.0
BSS6	37.0	135.3	530.0	4.2
BSS7	37.8	106.0	488.0	3.9
BSS8	37.9	107.0	480.0	4.9
BSS9	38.8	107.0	492.0	4.6
BSS10	37.2	107.0	480.0	5.3
Average	37.7	118.6	489.2	4.3
Max	41.0	156.0	530.0	5.3
Min	30.7	89.9	401.0	3.3
Std	2.8	20.3	36.2	0.6

The results obtained in Table 2 show that the highest value of the specific activity of ^{238}U found in BSS5 was 41±2.8 Bq kg^{-1}. Similarly, the all-time low value of the specific activity of ^{238}U found in BSS2 was 30.7 ±2.8 Bq kg^{-1} with a mean value of 37.7 Bq kg^{-1}.

The maximum value of the specific activity of ^{232}Th found in BSS3 was 156.0 ± 20.3 Bq kg^{-1} and its minimum value was found 89.9 ± 20.33 Bq kg^{-1} in BSS2, with a mean value of 118.6 Bq kg^{-1}.

The maximum value of the specific activity of ^{40}K found in BSS6 was 530 ±36.2 Bq kg^{-1}, and the minimum value of was 401± 36.2 Bq kg^{-1} in BSS2, with a mean value of 489.2 Bq kg^{-1}.

The maximum value of the specific activity of ^{137}Cs found in BSS10 was 5.34±0.6 Bq kg^{-1}, and the minimum value was 3.3 ±0.6 Bq kg^{-1} in BSS2, with a mean value of 4.3 Bq kg^{-1}.

The radium equivalent, the dose rate (D_R), annual effective dose (*AED*), internal hazard, external hazard indices (H_{in}, H_{ex}), and gamma index I_γ are shown in Table 3.

Table-3. Radium equivalent activity (Raeq), absorbed dose rate, outside and inner yearly effective dose, and external and internal hazard index of samples collected from the Barley farm area (BSS) were all calculated

Soil samples code	Radium equivalent activity Raeq (Bq kg^{-1})	Dose rate (D_R) (nGy h^{-1})	Annual effective dose (AED) (msv y^{-1})		Internal hazard index (Hin)	external hazard index (Hex)	Gamma index I_γ
			Outdoor	Indoor			
BSS1	270.3	32.7	40.1	196.8	0.84	0.73	0.97
BSS2	190.1	24.6	30.2	148.2	0.60	0.51	0.69
BSS3	300.8	34.1	41.8	205.3	0.92	0.81	1.10
BSS4	228.6	29.4	36.0	176.9	0.72	0.62	0.82
BSS5	277.0	33.3	40.9	200.5	0.86	0.75	0.99
BSS6	271.3	33.4	41.0	201.4	0.83	0.73	0.98
BSS7	226.9	29.7	36.5	179.0	0.71	0.61	0.82
BSS8	227.9	29.4	36.1	177.4	0.72	0.62	0.82
BSS9	229.7	30.0	36.8	180.7	0.73	0.62	0.83
BSS10	227.1	29.4	36.1	177.2	0.71	0.61	0.82
Average	245.0	30.6	37.6	184.3	0.76	0.66	0.88
Max	300.8	34.1	41.8	205.3	0.92	0.81	1.10
Min	190.1	24.6	30.2	148.1	0.60	0.51	0.69
Std	33.2	2.9	3.50	17.2	0.09	0.09	0.12

The radium equivalent activity was calculated, and the values were shown in Table 3 column 2. The mean value of radium equivalent activity in the barley farm area is 245.0 Bq kg^{-1}, and ranged from 190.1 ± 33.2 Bq kg^{-1} to 300.8± 33.2 Bq kg^{-1}.

Eq 4 was used to compute the absorbed dose rate of barley soil samples outcome is shown in Table 3, column 3. This absorbed dose rate due to terrestrial gamma-ray at one meter above the earth ranged from 24.6± 2.9 nGy h^{-1} to 34.1 ± 2.9 nGy h^{-1} within an average value of 30.6 nGy h^{-1}.

The annual effective dose equivalent was calculated from the air-absorbed dose (outdoor and indoor) using the relation given by Eqs. (5) and (6) are shown in Table 3, column 4. The values varied from 38.4± 3.5 mSv y^{-1} to 43.6± 3.5 mSv y^{-1} and 188.3 ± 17.2 mSv y^{-1} to 213.9± 17.18 mSv y^{-1} for outdoor and indoor respectively, with a mean value of 37.55 mSvy^{-1} and 184.32 mSvy^{-1} for outdoor and indoors, respectively.

The hazard index (external and internal) for soil samples were calculated by Eqs. (8) and (9) and are shown in Table 3, columns 5 and 6, respectively. The internal hazard index (Hin) ranges from 0.6± 0.09 to 0.92± 0.09, with a mean of 0.76.

Our findings show that $I\gamma$ of the study area for the soil samples ranged from 0.69±0.12 to 1.10±0.12 with a mean value of 0.88. The values are all within the safe limit for gamma radiation.

3.3. Radionuclides Concentration in Soil Sample from Malt Factory

The specific activity concentrations of the ^{238}U series (^{226}Ra), ^{232}Th, and ^{40}K, expressed in Bq kg^{-1} for soil samples obtained from Arsi, and Asella inside the Malt factory are presented in Table 4.

Table-4. Activity concentrations of 226Ra, 232Th, 40K, and 137C for soil samples in MFSS

Malt factory soil sample (MFSS)	Specific Activity			
	A_U (Bq kg^{-1})	A_{Th} (Bq kg^{-1})	A_K (Bq kg^{-1})	A_{Cs} (Bqkg^{-1})
MFSS1	26.4	121.0	557.0	4.4
MFSS2	23.3	119.0	518.0	5.3
MFSS3	26.8	122.0	564.0	3.1
MFSS4	26.2	126.0	580.0	3.6
MFSS5	27.9	128.0	598.0	5.3
MFSS6	38.8	123.0	565.0	4.7
MFSS7	38.3	125.0	578.0	4.6
MFSS8	40.6	122.0	519.0	4.9
MFSS9	36.9	127.0	525.0	4.4
MFSS10	39.4	124.0	532.0	5.1
Average	32.5	123.7	553.6	4.5
Max	40.6	128.0	598.0	5.3
Min	23.3	121.0	518.0	3.1
Std	6.8	2.8	28.4	0.7

One can notice from Table 4 that the highest specific activity of ^{238}U was 40.6± 6.8 Bq kg^{-1} in MFSS3, and the lowest was 23.3± 6.8 Bq kg^{-1} in MFSS8, with an average value of 32.5 Bq kg^{-1}.

The highest value of the specific activity of ^{232}Th was 128.0± 2.8 Bq kg^{-1} in MFSS10, the lowest value was 121.0± 2.8 Bq kg^{-1} in MFSS3, with an average value of 123.7 Bq kg^{-1}.

The highest value of the specific activity of ^{40}K was found in MFSS5 598.0± 28.4 Bq kg^{-1}, the lowest value was 518.0 ± 28.4 Bq kg^{-1} in MFSS1, with an average value of 553.6 Bq kg^{-1}.

The highest value of the specific activity of ^{137}Cs was 5.3± 0.7 Bq kg^{-1}in MFSS5, and the lowest value was 3.1 ± 0.7 Bq kg^{-1} in MFSS3, with an average value of 4.5 Bq kg^{-1}.

The radium equivalent (Raeq), the dose rate (D_R), the annual effective dose rate (AED), and Hazard indices are shown in Table 5.

Table-5. Radium equivalent activity (Raeq), absorbed dose rate, outdoor and inner annual effective dose, and external and internal hazard index of the samples collected inside the Malt factory area (MFSS)

Soil samples code	Radium equivalent activity Raeq (Bq kg^{-1})	Dose rate (D_R) (nGy h^{-1})	Annual effective dose (AED) (msv y^{-1})		Internal hazard index (*Hin*)	External hazard index (*Hex*)	Gamma index I_γ
			Outdoor	Indoor			
MFSS1	242.3	33.2	40.7	200.0	0.73	0.65	0.72
MFSS2	233.4	31.3	38.4	188.3	0.69	0.63	0.69
MFSS3	244.7	33.6	41.2	202.3	0.73	0.66	0.73
MFSS4	251.0	34.5	42.4	207.9	0.75	0.68	0.74
MFSS5	257.0	35.5	43.6	213.9	0.77	0.69	0.77
MFSS6	258.2	34.2	42.0	206.1	0.80	0.70	0.79
MFSS7	261.6	34.9	42.8	210.1	0.81	0.71	0.80
MFSS8	255.0	32.2	39.6	194.2	0.80	0.69	0.78
MFSS9	259.0	32.7	40.1	196.8	0.80	0.70	0.78
MFSS10	257.7	32.9	40.3	198.1	0.80	0.70	0.79
Average	252.0	33.5	41.1	201.8	0.77	0.68	0.76
Max	261.6	35.5	43.6	213.9	0.81	0.71	0.80
Min	233.4	31.3	38.4	188.3	0.69	0.63	0.69
Std	9.1	1.3	1.6	7.9	0.04	0.02	0.04

The radium equivalent activity was computed using Eq. (3), and the maximum value is 261.6 9.1 Bq kg^{-1}, is shown in Table 5. The highest value is 261.6 ± 9.1 Bq kg^{-1}. The average of the radium equivalent activity within the Malt factory area is 252.0 Bq kg^{-1}, and it varies from 233.4 ± 9.1 Bq kg^{-1}at MFSS to 261.56 ± 9.1 Bq kg^{-1} at MFSS2 and MFSS7 for these ten samples, as shown in Table 6, column 1.

The absorbed dose rate in Malt factory soil samples was calculated using Eq. 4, and the result of the calculation is shown in Table 6, column 3. This absorbed dose rate due to terrestrial gamma-ray at 1m above the earth varying from 31.3± 1.3 nGy h^{-1} to 35.5± 1.3 nGy h^{-1} with an average value of 33.5 nGy h^{-1}.

The annual effective dose equivalent was calculated from the air absorbed dose using Eqs. (5) and (6) for outdoor and indoor, respectively and shown in Table 6, column 4. The values varied from 38.4± 1.6 mSv y^{-1} to 43.6 ± 7.9 mSv y^{-1}, and with a mean value of 41.1 mSv y^{-1}.

The hazard indices (external and internal) for soil samples from the Malt factory were calculated according to Eqs. (8) and (9) respectively. The results were shown in Table 6, columns 4 and 5, respectively. The value of the internal hazard index (*Hin*) ranges from 0.7± 0.04 to 0.8± 0.04, with a mean value of 0.77. The highest value of the internal hazard index was 0.81 in MSS7.

The value of the external hazard index (*Hex*) ranges from 0.63± 0.02 to 0.71± 0.02, with mean value of 0.63 as shown in Table 6, column 5 above. The highest value of the external the hazard index 0.71, was measured in MFSS7 for the Malt factory.

Our findings show that *Iγ* of the study area for the Malt factory soil samples ranged from 0.69±0.04 to 0.80±0.04 with a mean value of 0.80. These values are all within the safe limit for gamma radiation.

4. Discussions

The present study has shown that the values of specific activities of ^{238}U are less than the results obtained in Qatar reported in Ayalew, *et al.* [5] and the USA (Texas) province [1, 13]. Similarly, the results of the specific activity of ^{232}Th obtained in this work are lower than the result in Dire Dawa city by Ayalew, *et al.* [5] and the global limit reported with United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [8]; UNSCEAR [16]; UNSCEAR [11]. Whereas, the specific activities of ^{40}K obtained during this work are lower than the work that was reported in [19] and the global limit reported in UNSCEAR [11].

The radium equivalent obtained during this work is below the results obtained in Dire Dawa reported in [5, 9, 15] and the global limit reported in Saleh, *et al.* [7]; United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [8]; UNSCEAR [16]. The absorbed dose rate obtained during this work is higher than the work that was obtained in Dire Dawa and Harar cities reported by Abas, *et al.* [15]; Ayalew, *et al.* [5]; Mussa, *et al.* [9]. Whereas, the highest limit of the absorbed dose rate obtained during this work is slightly under the work that was reported in Mehraa and Singhb [18].

The results obtained for the specific activity of ^{137}Cs were very small compared to the specific activities of the other radionuclides. It is well known that ^{137}Cs do not exist naturally within the soil, but the manmade radionuclide deposited in the soil was presumably a result of a nuclear energy plant accident and atmospheric nuclear weapon tests around the world [10]. The ^{137}Cs are readily mixed with the soil by rain or wind. However, the potential radiological impact on humans from such a low level of concentration of ^{137}Cs is insignificant [10].

The annual effective dose equivalent shown in Table 6 is less than the world average value of 55 nGy h^{-1} [5, 8, 9, 11, 16]. The highest absorbed dose rate was detected at MFSS5 is less than the standard limit that is in reference [11].

The present results have shown that the values of specific activity concentrations for uranium reported in the USA (Texas) 33.7 Bq kg^{-1} province was higher than the activity of ^{238}U in MFSS (32.46 Bq kg^{-1}) [18].

The present results have shown that the values of activity concentrations in the studied districts in Kars, Turkey 67.1±13.8 Bq kg^{-1} were lower than the value of ^{232}Th in MFSS (mean 123.7 Bq kg^{-1}). It is over the global limit, which is capable (45 Bq kg^{-1}) [11, 20].

The value of specific activity of ^{40}K in MFSS (mean 553.6 Bq kg^{-1}) was not up to this result as shown in the studied districts in Kars, Turkey (mean 574.7 ±7.4 Bq kg^{-1}). It is better than the global limit (420 Bq kg^{-1}) [11, 20].

The present results have shown that the values of activity concentrations within the studied districts in Kars, Turkey (8.1±1.4 Bq kg^{-1}) were below the value of activity concentration of ^{137}Cs in MFSS, which is 4.53 Bq kg^{-1} [20][10]. These results were small compared to the specific activities of the other radionuclides in MFSS. It is known that ^{137}Cs does not naturally exist in soil. The manmade radionuclide deposited in it was presumably the result of a nuclear power plant accident and nuclear atmospheric weapon tests. ^{137}Cs were found in organic matter, and its soil PH value was lowered. Low PH more 137Cs detected, and high total organic carbon in soil contain a high value of ^{137}Cs [10][7]. The ^{137}Cs are readily mixed with and by rain or wind. However, the potential for a radiological impact on humans from such low levels of concentration of 137Cs is insignificant. Notably, ^{137}Cs do not exist in soil, as reported in Ahmad, *et al.* [2]; [4].

This study's data show that all values of hazard indices from the site were less than one, and their value agrees with the suggested global average [4, 5, 21].

The gamma index is determined using Eq. (2), according to Abdel-Rahman, *et al.* [22]. The $I\gamma \leq 2$ values correspond to an annual dose rate of 0.3 mSv y^{-1}, while $I\gamma \leq 6$ values correspond to a dose rate of 1 mSv y^{-1}. However, $I\gamma \geq 6$ values correlate to annual exposure rates that exceed the regulatory limit [11]. It is deemed dangerous for the general public. As a result, our findings demonstrate that the readings for both soil samples are under the safe gamma radiation limit.

5. Conclusions and Recommendations

5.1. Conclusions

The average values for the annual effective dose were evaluated, for 15 samples randomly collected in East Arsi. The activity concentration of naturally occurring radionuclides in soil from the barley farm area and measured

in East Arsi, ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs specific activity in soil are listed in Tables 2 and 4 for the barley farm area and the Malt factory soil samples, respectively. The result from this study indicates that the mean estimated radium equivalent is 244.96 Bq kg^{-1} for BSS and 251.98 Bq kg^{-1} for MFSS. These values were below the world average value.

Because the radionuclides studied are radiologically important to humans living in the barley farm region, the Arsi Asella Malt Factory determined the radiological internal and external danger index. The dosage rate and yearly effective dose rate averages are lower than the global average. The hazard indexes calculated in this study were less than one. The study area was deemed safe for human occupancy because no significant radioactive dangers were detected.

Recommendations

Based on the findings of this work, we will recommend the following point. Thus, all data gathered from this study contributes to the creation of a reference database on this critical topic, allowing for any future changes in this regard as a result of the nuclear phenomenon and other proven radiation safety measurements to be taken into account.

Acknowledgments. We sincerely acknowledge the Ethiopian Radiation and Protection Agency for the opportunity to utilize one of their laboratories, the low background counting laboratory, and also the research facilities therein. The corresponding author appreciates the Department of Physics, Dire Dawa University, acknowledging the resource to finish this research in time.

Source of Fund

This project was funded by the Dire Dawa University research office

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