Environmental Radioactivity evaluation and its health-related effects using gamma spectrometry in Delanta-Dawunt, Wollo District, Ethiopia

Mekuanint Lemlem Legasu (meki4emu@gmail.com)
Addis Ababa University https://orcid.org/0000-0002-2492-7471
Ashok K Chaubey
Addis Ababa University

Research Article

Keywords: Natural radioactivity, HPGe, Soil & Rock, Radiological hazards, Gemstones, Delanta-Dawunt

Posted Date: June 18th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-623756/v1

Environmental Radioactivity evaluation and its health-related effects using gamma spectrometry in Delanta-Dawunt, Wollo District, Ethiopia.

Mekuanint Lemlem[*], A.K Chaubey.

Addis Ababa University, Addis Ababa, Ethiopia
Mobile 251912297570
Email: mekuanint.lemlem@aau.edu.et
: meki4emu@gmail.com

K e y w o r d s

Natural radioactivity
HPGe
Soil & Rock
Radiological hazards
Gemstones
Delanta-Dawunt

A b s t r a c t

Background & Methodology *: The specific activity concentration of naturally occurring radionuclides ^{226}Ra, ^{232}Th, ^{40}K and their health related effects were determined in different environmental samples(gemstones) collected from Delanta-Dawunt. Which is one of the mining place in Ethiopia to extract mainly opals (gemstones). Sample collection and the gamma spectroscopic analysis followed the recommended international procedures for such type of research. Gamma-ray spectrometry was applied using HPGe gamma-ray detector and PC-based MCA.*

The Purpose of this research*: to determine the activity concentrations of the radionuclides U/Th series and K of gemstones(opals), to determine life time cancer risk of radionuclide in the environment , to assess the hazard and risk to the public associated with these dose values , to conduct the geochemical studies by quantifying the levels of trace gemstones as well as the physical parameters in soil samples within and around it, and To determine the radiation doses from these activity concentrations and compare with international recommended dose limits.*

Results*: The results of the activity concentration on our research work showed significant variations from 11.97 ± 2.46 to 62.44 ± 14.99 Bq kg^{-1} for ^{226}Ra, 25.69 ± 3.69 to 137.84 ± 13.23 Bq kg^{-1} for ^{232}Th and 184.84 ± 3.59 to 969.56 ±18.16 Bq kg^{-1} for ^{40}K. The mean radioactivity concentration of ^{226}Ra, ^{232}Th, and ^{40}K was found to be around 29.84 ± 6.53, 68.44 ± 18.94, 390.87 ± 6.09 Bk kg^{-1} respectively.*

Conculsion*: The mean values of Radium equivalent activity (Raeq), absorbed dose, annual effective dose equivalent, external and internal radiation hazard (Hex and Hin) index ,and activity utilization index is 151.68±19.46 Bq kg^{-1}, 72.19 ± 8.48 nGy h^{-1}, 0.07 ± 0.01mSv y^{-1},0.43, 0.51, 0.57 ± 0.08 and 0.29 ± 0.03 respectively. The specific activity of ^{232}Th is higher than the world mean value and ^{40}K is the same as the world mean value. The radiation hazard indices, ELCR values found in this study are lower than the world mean values. However, the absorbed dose is higher than the world means value. This is due to the reason of high thorium concentration existence and opal mining is highly explored on such study areas.*

1 Introduction

Heat and light are the types of radiation that peoples can feel and see, and therefore the two have been recognized as “elements” of the universe for a long time. Contrary to this, its prime “element”, radioactivity, which results in radiation that human sense cannot detect, was been discovered only a century ago.

Although radiation has found applications in almost all aspects of human activities, most of the ionizing radiation that people are exposed to still comes from natural sources. The health effects of radiation are relatively well understood and can be effectively minimized through careful safety measures and practices.

Radioactivity is a part of nature in the process of element formation by the nuclear reaction taking place in stars, both stable and radioactive isotopes of elements are formed. The earth and atmosphere contain varying levels of radiation from naturally occurring radionuclides. Soil features, geological formations, and human practices resulting in radiation emissions are important factors enhancing the levels of background natural radiation [1,2].

Natural radioactivity present in soil produces gamma radiations in the environment and changes the background radiation level. Everyone on the planet is exposed to these background levels of ionizing radiation. External exposure occurs as a result of irradiation and internal exposure because of inhalation and ingestion [3].

Mining activities and the processing of natural resources have impacted considerably on human being and the environment [4,5]. Mining operations are associated with environmental degradation, destruction of ecosystems and and general pollution of the environment [5,6]. Huge amounts of top soils are removed during mining which results in the production of considerable amount of mining wastes (tailings) with enhanced radioactivity [7]. These large quantities of mine tailings are disposed of on the surface in the vicinity of the mine where they are subjected to continuous physical, chemical and biological processes that concentrates radioactivity in the environment, resulting in significant radiation dose to the public [8]. Mine tailings consists of relatively loose non-compacted debris that easily contaminate the surrounding soils through atmospheric dispersion. The dust particles suspended in the air can also be inhaled directly, thus contributingto human radiation exposure [9,10].

The isotopic composition of elements is characterized by properties of nuclear reactions that led to the formation of the elements. The elemental composition of the planet earth thought to be about 4.5×10^{9} years old, although not yet in chemical equilibrium, reflects the composition of the material from which it was formed. Therefore, several radionuclides occur in nature, having long half-lives (longer than the age of the earth) [11].

Numerous sources of ionizing radiation can lead to human exposure: natural sources, nuclear explosions, nuclear power generation, use of radiation in medical, industrial, and research purposes, and radiation-emitting consumer products [12].

The sources of radiation that contribute to this rate are of natural origin (cosmic radiation, radionuclides of the U and Th series, Radon and Thoron and K-40) and artificial (fall-out of nuclear explosions in the earth crust, Chernobyl accident, the release of radioisotopes in nuclear facilities, use of radioactive sources in industries and nuclear medicine radiopharmaceuticals). Another source, which may be growing in recent years, is TENORM also contributes to the increase in dose in occupationally exposed workers [13]. ^{238}U is present in traces in most soil and rocks and it decays to ^{226}Ra, which is the parent of ^{222}Rn. The radium content of soil and rocks is responsible for the radon concentration in the ground [14,15]. Before assessing the radiation dose to the population, one requires precise knowledge of the activity of several radionuclides. Radioactive nuclei that are found in air, soil, and water either naturally, or as a result of human activities make up what is called background radiation. According to UNSCEAR estimates the global average human exposure from natural radiation sources is 2.4 mSv $y^{-}1$, and 82 % of this amount is attributed to the natural sources of terrestrial and cosmic origin [15].

Furthermore, radiation exists everywhere on the earth's crust and exposure from natural background radiation is the largest component of total radiation exposure received by most people. The measurement of gamma radiation dose from environmental sources is of significance because the radiation of natural origin is the principal contributing factor to the non-internal dose globally. The activity concentrations of radionuclides in the environment vary according to the geological formation; radionuclides in rocks are easily mobilized into the environment through natural and human processes [16].

2 Methodology and method

2.1 Sample collection and preparation

In this paper, the natural radioactivity levels in the gemstone soil samples of Delant-Dawunt areas are calculated by gamma-ray spectroscopy using an HPGe detector. The work in the study area has been carried out for the first time and will be of general interest to the inhabitants as the knowledge of radioactivity levels in the gemstones soil samples will provide awareness among them about the radiological effects on their health. Each gemstone's soil and rock sample were collected from different areas and was marked carefully cleared of debris, organic residue, and stone fragments to a few centimeters' depths. Each gemstone soil and rock sample was packed in a plastic bag and labeled according to the geographical coordinates of the sampling area.

The collected gemstones soil/rock sample were weighted and dried for 24 hours in an oven at 105 ^{0}C in the polymer laboratory at Addis Ababa University. Then the dried sample was crushed in an automatic grinder in the geology laboratory in this university. And then, they were sieved with a 0.25mm mesh to keep uniform grain size and obtain a fine-grained homogeneous gemstones soil/rock sample for measurements. About 500g of the homogenized gemstones soil/rock samples were packed and sealed in an airtight Marinelli beaker and stored for one month to reach secular equilibrium among the daughter product of ^{226}Ra, and their short-lived decay products. The gamma analysis was done at the Ethiopian Radiation Protection Agency laboratory.

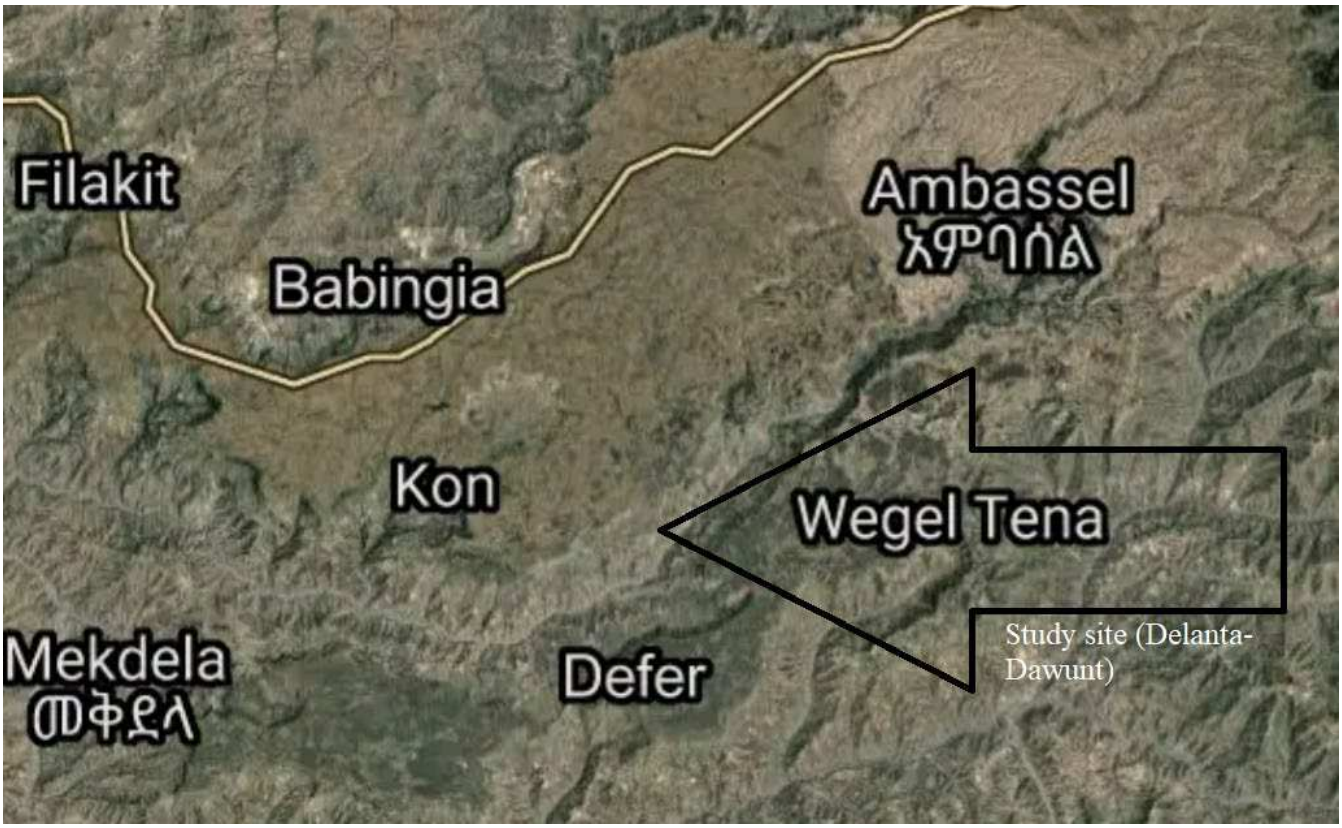

Fig1. sampling areas are taken from a satellite image of a google map

2.2 Calibration and Gamma Spectrometry Measurements

The gamma-ray system (Canberra coaxial hyper pure germanium detector) has a photopeak efficiency of 30% and energy resolution of 1.8 keV full-width at half maximum (FWHM) for the 1332 keV gamma-ray line of ^{60}Co. A model B13010 detector was a shield with lead has a 0.040 in and 0.062 in the copper graded liner to prevent interference by lead X-rays. The detector operating voltages around 3499V and Genie 2000 software from Canberra were used to analyze the spectra. The calibration of the spectrometer was carried out by using standard point sources (Co^{60}, ^{137}Cs). An empty bottle with the same geometry was measured for subtracting the background. The counting time was about 28,800 s to obtain the gamma spectrum with good statistics. The gamma-ray transitions of energies 295.21and 351.92 keV (^{214}Pb), 609.31 keV, 1120.29 keV, and 1764.49 keV (^{214}Bi) and were used to determine the concentration of the ^{238}U/^{226}Ra series. The gamma-ray transitions of energies 338.4 keV, 911.21keV,and 968.97 keV (^{228}Ac), 583.3 keV (^{208}Tl), were used to determine the concentration of the (^{232}Th) series. The 1460.81 keV gamma-ray transition ^{40}K was used to determine the concentration of ^{40}K in different samples.

3 Radiological Parameters

The calculated activity of thorium, uranium, and potassium of 8 samples collected from in Delanta-dawunt on different lithological units of the study are plotted in figure 1 (sample area). From the collected samples of such area radionuclides detected mostly belong to the ^{232}Th, ^{238}U/^{226}Ra decay series, though the most prominent gamma-ray energy peak, observed corresponding to ^{232}Th.

3.1 Natural radionuclides in environmental samples

Using the dry weight of the samples, the net counts (N_c), detector photo-peak efficiency (ε_γ) of the peak under consideration, the probability of the transition of the radionuclide of interest at the respective gamma energy (P_γ) the mass (m) of the sample in kg and the sample counting time (s) using Equation (1) [17, 18 , 19, 20]. their respective specific activity of NORM could be expressed (Bq kg^{-1})

$$A = \frac{N_C}{M\varepsilon_\gamma I_\gamma t} \quad (1)$$

The calculated specific activity of ^{232}Th, ^{226}Ra, and ^{40}K are indicated in Table 1.

Sample Code	Activities (Bq kg^{-1})			Radium equivalent (Bq kg^{-1})	Absorbed Dose (nGyh^{-1})	Annual effective dose equivalent(mSv y^{-1})
	^{226}Ra	^{232}Th	^{40}K	Ra_{eq}	D	AEDE
ABBS	62.44±14.99	137.84±13.23	374.31+5.96	262.44±34.36	128.64±14.89	0.16±0.01
AGS	18.25±4.08	45.43±5.98	280.81±5.48	104.83±13.05	48.17±5.70	0.06±0.01
BBS	61.58±11.29	115.99±18.03	398.85±0.12	258.08±37.09	115.67±16.06	0.14±0.02
GOS	16.03±2.77	25.69±3.69	969.59±18.16	127.44±9.45	64.55±4.26	0.08±0.01
KOK	11.97±2.46	27.31±3.94	184.8±3.59	65.26±8.36	30.08±3.66	0.04±0.01

ROS	15.50±4.89	40.13±5.34	231.48±4.05	72.96±12.84	41.57±5.59	0.05±0.01
CWS	23.14±5.20	86.66±10.79	296.93±5.33	169.93±21.05	76.64±9.17	0.09±0.01
Mean value	29.84±6.53	68.44±18.94	390.87±6.09	151.68±19.46	72.19±8.48	0.07±0.01

[1]**Table 1**. Results of specific activity, radium equivalent activity, and radiological hazards in different soil and rock samples of the Delanta-Dawunt area.

Radium Equivalent activity (Ra_{eq})

The exposure due to gamma radiation is usually defined in terms of radium equivalent activity Raeq is given by equation (2) [21, 22]

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.0077A_K \quad (2)$$

The above equation is based on the assumption 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th, 4810 Bq kg^{-1} of ^{40}K produce the same gamma-ray dose rate. The radium equivalent is related to both the external gamma dose and the internal alpha dose from radon and its progeny. The permissible maximum value of the radium equivalent activity is 370 Bq kg^{-1} which corresponds to an effective dose of 1mSv yr^{-1} for the inhabitants of the dwelling [15].

Country	samples	^{226}Ra/ ^{238}U (Bq kg^{-1})	^{232}Th(Bq kg^{-1})	^{40}K(Bq kg^{-1})	Ra_{eq}(Bq kg^{-1})	Reference
Ghana	Medicinal plant	31.8±2.8	56.2±2.3	839.8±11.9	No information	[17]
Sapin	Soil	25	31	615	No Information	[18]
Qatar	Soil & building materials	17.22 ±1.55	6.38 ±0.26	169 ±5	40.6±7.4	[19]
Nigeria	Rock	13.1±1.6-129± 38	42.4±4.5-150 23	64.5±6.3-882± 298	83-391	[16]
Egypt	Granitic rock	5.26 - 336.70	3.12 -64.43	160.22-774.16	40.26-465.26	[23]
Ethiopia	Soil	19.97±2.42	56.38±4.50	716.59±68.43	No information	[24]

[1] The activity of a radioactive source or radionuclide sample is, by definition, its strength or intensity, or in other words, the number of nuclei decaying per unit time. The activity of a given radionuclide in a sample is proportional to the number of radioactive atoms present in that sample.

Ethiopia	Flouri culture soil	142.29±.27.67	7.82 ± 0.54	259.62 ± 44.9	140.42±9.81	[25]
India	Flooring materials	25.48	42.82	560.69	130.29	[26]
Brazil(Mambucaba)	Sand	169	963	824	669	[27]
Iraq	Soil	34.8	18.8	289.2	83.95	[22]
Turkey	Soil	27.1	34.3	370.5	No information	[28]
Turkey	Soil	167	44	404	258	[29]
Malaysia	Soil	3798±419	12896±1533	2521±298	No information	[30]
Cyprus	Soil & rock	14.2±5.7	10.6±5.1	153±5.6	No information	[31]
Nigeria	Soil	47.06±14.01	75.97±9.11	216.02±62.37	172.33	[12]
Ethiopia	Gemston Soil/rock	29.84±6.53	68.44±18.94	390.87±6.09	151.68±19.46	Present Study
World average		35	30	400	370	[15]

Table 2 comparison of activity concentration and radium equivalent of different samples from different countries of the world

Dose rate and annual outdoor effective dose

External absorbed dose rate (D) in the air is defined for terrestrial gamma radiation at a height of about 1m above the ground [27] .

$$D(nGy/h) = 0.427A_{Ra} + 0.623A_{Th} + 0.043A_K \quad (3)$$

In the present study, the absorbed dose for the different locations of gemstone soil and rock samples varied from 30.08 ± 3.66 to 128.64 ± 14.89 with a mean value of 72.19 ± 8.48, which is higher than the world mean value of 57nGy/h [32].

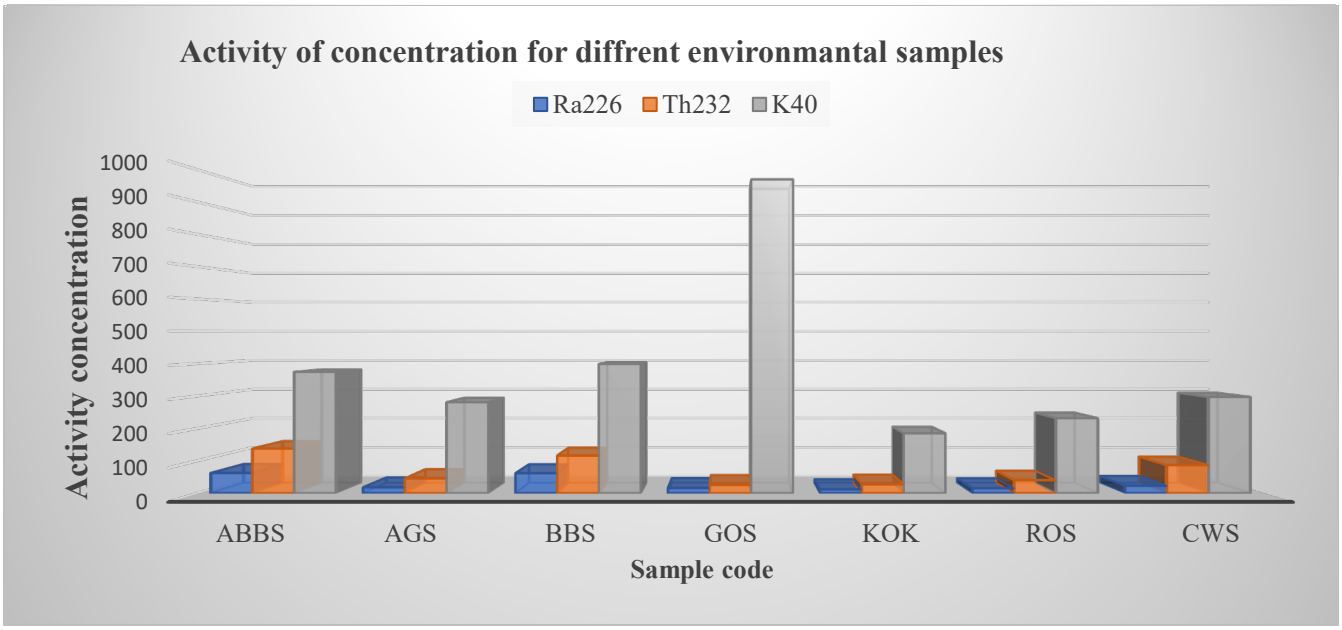

Fig 2: Activity of concentration for different environmental samples

Annual outdoor effective dose (AEDE)

The measurement of the concentrations of radionuclides in the environment due to terrestrial gamma radiation from $^{238}U/^{226}Ra$, ^{232}Th, and ^{40}K, can be estimated by the average outdoor conversion coefficient from absorbed dose rate in the air and the environmental gamma dose conversion factor (CC) to be 0.7 Sv/Gy to convert the absorbed dose ratio to the annual effective dose equivalent. Besides, when a person spent 20% outdoor occupancy factor (OOF) of 0.2 and the time was exposed to gamma rays during a year (T) is 8760 h / y [28, 29, 33].

$$AEDE(\mu Sv/y) = D \times CC \times OOF \times T \quad (4)$$

The world average annual effective dose equivalent to outdoor terrestrial gamma radiation is 70 (μSv y^{-1}). From Table (1), the annual effective dose equivalent ($mSvy^{-1}$) range from 0.04 ± 0.01 to 0.16 ± 0.01 with a mean value of 0.07 ± 0.01 $mSvy^{-1}$. It is the same as the world average value.

External Hazard Index (Hex)

Every human being is continuously exposed to an external radiation field produced by natural radionuclide coming from soil, sediments, and rocks. To assess this issue, the external radiation hazard index is defined on the basis that the radiation exposure due to natural radionuclides should not surpass the permissible dose equivalent limit [16, 30, 34]

$$H_{ext} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (5)$$

The value of this index must be less than unity to keep the radiation hazard insignificant. The prime objective of this index is to limit the radiation dose to the accepted dose limit of 1mSv/y [35].

Internal hazard index (H_{int})

Inhalation of alpha particles emitted from the short-lived radionuclides (radon, ^{222}Rn, the daughter product of ^{226}Ra) and thoron (^{220}Rn, the daughter product of ^{224}Ra) is also hazardous to the respiratory organs. This hazard can be controlled by the internal hazard index (H_{int}) which is given by [31]

$$H_{int} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (6)$$

For the safe use of certain building material in the construction of dwellings, the index (H_{int}) should less than unity.

External (γ *radioactivity*) level index (I_γ)

This index is also known as a representative level index and was calculated from the following relation [26,36]

$$I_\gamma = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \leq 1 \quad (7)$$

The OECD group of experts suggested some criteria for a definition of different levels of to be (representative, first enhanced, secondly enhanced).

I_γ =1 as an upper limit, $I_\gamma \leq 1$ corresponds to 0.3mSv/y, $I_\gamma \leq 3$ corresponds to 1mSv/y.

Internal (α *radioactivity*) level index I_α

The excess alpha radiation due to radon inhalation originating from building materials is estimated using the relation below [37]

$$\boldsymbol{I_\alpha} = \frac{A_{Ra}}{200} \leq 1 \qquad (8)$$

It should be lower than the maximum permissible value of $\boldsymbol{I_\alpha} \leq 1$, which corresponding to 200Bqkg^{-1}.

For alpha radiation and taking into consideration that a building material with ^{226}Ra concentration less low than 200 Bqkg^{-1} could not cause indoor radon concentration higher than 200Bqm^{-3}.

Samples	H_{ext}	H_{int}	$\boldsymbol{I_\gamma}$	$\boldsymbol{I_\alpha}$	ELCR(mSv y^{-1})
ABBS	0.78	0.95	1.02±0.12	0.31±0.08	0.51±0.03
AGS	0.28	0.33	0.38±0.14	0.09±0.02	0.19±0.02
BBS	0.69	0.86	0.92±0.13	0.31±0.06	0.46±0.06
GOS	0.34	0.39	0.51±0.03	0.08±0.01	0.26±0.02
KOK	0.18	0.21	0.24±0.03	0.06±0.01	0.12±0.02
ROS	0.25	0.29	0.33±0.04	0.08±0.02	0.17±0.02
CWS	0.46	0.52	0.61±0.07	0.12±0.03	0.31±0.04
Mean value	0.43	0.51	0.57±0.08	0.15±0.03	0.29±0.03

[2]**Table 3** result of radiological hazards index for different soil and rock samples of Delanta-Dawunt

[2] Any radiation exposure might have negative effects on health. This can be considered as the basic principle of radiation protection. The biological effect of ionizing radiation is a consequence of the energy transfer by ionization and excitation to body cells. The radiosensitivity of tissue is directly proportional to the reproductivity of cells it is made of (mitosis) and inversely proportional to the differentiation of the cells.

Excess lifetime cancer risk (ELCR)

Here, the AEDE is the annual effective dose equivalent, the average life expectancy of DL (average 67 years), and the risk factor for RF, and for stochastic effects, ICRP risk factors for lethal cancer in the whole population, respectively (1/Sv), RF ICRP 103, BEIR VII [23] (NRC, 2006) and for ICRP 60, 0.057, 0.064 and 0.072 are used [38, 39]

$$ELCR\ (mSv/y) = AEDE \times DL \times RF \quad (9)$$

Here, the AEDE is the annual effective dose equivalent, the average life expectancy of DL (average 67 years), and the risk factor for RF, and for stochastic effects, ICRP risk factors for lethal cancer in the whole population, respectively (1/Sv), RF ICRP 60, 0.072 are used.

4 Results and Discussion

The results of activity concentration of ^{238}U-series, ^{232}Th-series, and ^{40}K radionuclides in gemstone rock/soil samples from eight sites in the Delanta-Dawunt are presented in Figs. 1 and also Table 1 shows the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K respectively. The range of the measured activity of ^{226}Ra in the gemstone rock/ soil samples of 11.97 ± 2.46 to 62.44 ± 14.99 with an average value of 29.84 ± 6.53 Bq kg^{-1} which is lower than the world average value.

The minimum value of ^{226}Ra was obtained in the sample of code KOK and a maximum for the sample of code ABBS. The differences are attributable to the geochemical composition and origin of gemstone soil types in a particular area. The range of measured activity the concentration of ^{232}Th for the gemstone rock/soil samples was 25.69 ± 3.69 to 137.84 ± 13.23 Bq kg^{-1} with an average of 68.44 ± 18.94 Bq kg^{-1} which is higher than the world average values. The minimum value obtained in sample code ABBS and a maximum for the sample code GOS. The differences are significant in all samples. The range of the activity concentration of ^{40}K was in the 184.8 ± 3.59 and 969.59 ± 18.16Bq kg^{-1}, with an average value of 390.87 ± 6.09 Bq kg^{-1} which is approximately the same as the world average value. These differences are also attributable to the gemstone soil type differences in the region under investigation besides the gemstones(opals) exploration. Moreover, our obtained average values fall within the range of corresponding world values and other published results [15] mentioned in Table 2. The world average activity concentration of ^{226}Ra is 35 Bq kg^{-1} with ranges of 17 to 60 Bq kg^{-1}, ^{232}Th is 30 Bq kg^{-1} with ranges of 11to 64 Bq kg^{-1} and ^{40}K is 400 Bqkg^{-1} with ranges of 140 to 850 Bq kg^{-1} [15; 40] The observed results in some samples show that the activity concentrations for ^{226}Ra ^{232}Th and ^{40}K for the investigated sites are higher than the reported international radioactivity levels of ^{226}Ra and ^{232}Th in [15,40]. The recorded high values of the radionuclides in some soil samples may be due to the presence of radioactive rich granite, phosphate, sandstone, and quartzite. The activity concentration of thorium is higher than radium in all samples in this study as shown in Table 1 and Fig 2.

The activity concentration of ^{226}Ra in this study is higher than Spain [18] , Cyprus [31], Quatar [19], Nigeria [16], Turkey [28], Ethiopia [24], and India [26] It also lower than Ghana [17],Ethiopia [25], Brazile [27], Iraq [2], Turkey[29], Malaysia [30] and Nigeria [12] as shown in Table 2 .

The activity concentration of ^{232}Th in this study is higher than World mean value [15], Spain [18], Cyprus [31], Qatar [19], Nigeria [16], Turkey [28], Ethiopia [24], Ghana [17], Turkey [29], Ethiopia [25], Iraq [22] and India [26]. It is also lower than [27], Malaysia [30], and Nigeria [12] as shown in Table 2.

The activity concentration of ^{40}K in this study is higher than Qatar [19], Nigeria [16], Turkey [28], Ethiopia [25], Iraq [22] and It is also lower than Brazile [27], Malaysia [30], Ghana [17], India [26], Ethiopia [24], Nigeria [12], Turkey [29], Spain [[18], and Cyprus [31]as shown in Table 2. Variation in the radioactivity concentrations in soil/rock of various locations worldwide depends on the geographical and geological conditions of the region.

Table 1 & 3 shows the obtained radiological effects such as the radium equivalent (Raeq), the absorbed dose rate (D), the external (Hex) and the internal (Hin) hazard index, the radioactivity level index (Iγ) and the annual effective dose equivalent(AEDE) and excess lifetime cancer risk(ELCR) for the gemstone rock/soil samples.

The Raeq for the gemstones of rock/soil samples was between 65.26 ± 8.36. Bq kg^{-1} and 262.44 ± 34.36 Bq kg^{-1} with an average value of 151.68 ± 19.46 Bq kg^{-1}. It is inferred that for all the soil samples analyzed, the radium equivalent activity value is well within and less the permissible limits of 370 Bq kg^{-1} [Beretka & Mathew, 1985]. The obtained absorbed dose rate varied from 30.08 ± 3.66 to 128.64 ± 14.89 nGy h^{-1}, with an average value of 72.19 ± 8.48 nGy h^{-1}. Some values are higher than the international recommended value 57 nGy h^{-1} [32].

The calculated external hazard indexes (Hex) were varied from 0.18 to 0.78, with an average value of 0.43 and internal hazard indexes (Hint) 0.21 to 0.95 within the average value of 0.51. The calculated Iγ values for all the samples are presented in Table 3. The values

ranged from 0.24 ± 0.03 to 1.02 ± 0.12 with an average of 0.57 ± 0.08.

The calculated outdoor AEDE values are quoted in Table 1. The results of outdoor effective dose from range of 0.04 ± 0.01 to 0.16 ± 0.01 $mSvy^{-1}$ within an average value of 0.07 ± 0.01$mSvy^{-1}$.

5 Conclusion

In this research work, gamma radiation from gemstone soil/ rock samples collected in the Delanta-dawunt was analyzed. Gamma-ray spectrometry was exploited to determine the activity concentration of natural radioactive isotopes that originated in the decay series of ^{232}Th,^{226}Ra, together ^{40}K were determined. The measured mean value of ^{226}Ra is below the world average value, but for ^{232}Th is higher than the world average value. The activities of concentration ^{40}K are the same as the world average value. The mean annual effective dose equivalent is the same as the world recommended values. These results point out that the radiation hazard due to NORM radionuclides found in gemstone soil/rock samples from the sites studied in this work is not significant. Higher values of ^{226}Ra, ^{232}Th concentration, and radiation hazard levels were for the ABBS sample code and the lower value is in the sample code of KOK. The average value of absorbed dose rate is higher the world average value and other published paper that is compared with our results in Table 2.

6 Decelaration

Ethics approval and consent to participate

Not applicable

Competing Interests

The authors declare that they have no competing interests

Consent for publication

Not applicable

Author contribution

M.L, performed the analytic calculations and performed the data analysis and interpretations. Both Mekuanint Lemlem and A.K C authors contributed to the final version of the manuscript. A.K.C supervised the project.

Availibality of data and materiasl

Additional data are available in the supplementary information file and upon request to the corresponding author.

Funding

Not Applicable

Author Information

Affiliations

Addis Ababa University, School of Computational and Natural Science, Department of Physics,, Nuclear Physics Stream, Arat Kilo, Addis Ababa,Ethiopia.

Mekuanint Lemlem Legasu, PhD student

Ashok K.Chuabey, Professor

Corresponding Author

Mekuanint Lemlem:meki4emu@gmail.com

Acknowledgments

I would like to thanks the department head of Physics Dr. Teshome, Geology department head and Mr. wendosewens from Geology laboratory AAU, Ethiopian radiation protection agency research laboratory head Mr. Eshitu and Mrs. Bogalech for their cooperative and helping to do my experimental work. Lastly, I would like to thanks Adama Science and Technology University and Addis Ababa University for supporting my research .

Reference

1. Bal, S.S.,(2018). The determination of concentrations of radioisotopes in some granite samples in Turkey and their radiation hazards. Radiat. Eff. Defect Solid 1–14.

2. .Sujo, L.C., Cabrera, M.E.M., Villalba, L., Villalobos, M.R., Moye, E.T., Leon, M.G., GarciaTenorio, R., Garcia, F.M., Peraza, E.F.H., Aroche, D.S., (2004). Uranium-238 and thorium-232 series concentrations in soil, radon-222 indoor and drinking water concentrations, and dose assessment in the city of Aldama, Chihuahua, Mexico. J. Environ. Radioact. 77, 205–219. Vlado Valković (Auth.) - Radioactivity in the Environment - libgen.lc

3. Singh, J., Singh, H., Singh, S., Bajwa, B. S., & Sonkawade, R. G. (2009). Comparative study of natural radioactivity in soil samples from the Upper Siwaliks and Punjab, India

using gamma-ray spectrometry. Journal of Environmental.

4. Ajayi O and Ibikunle S (2013) Radioacvity of surface soil from Oyo state, South-western Nigeria. Int. J Radiat Res, 11, 271-278.

5. Ibeanu IGE (2002) Tin mining and processing in Nigeria:cause for concern? Journal of environmental radioactvity,64(1): 59-66.

6. Usikalu MR, Anoka OC, Balogun FA (2011) Radioactvity Measurements of the Jos Tin Mine Tailing in Northern Nigeria. Archives of Physics Research, 2(2): 80-86.

7. Pontedeiro EM, Heilbron PFL, CoNa RM (2007) Assessement of the mineral industry NORM/TENORM disposal in hazardous landfills. Journal of Hazardous Materials, B139: 563-568.

8. Aliyu AS, Ibrahim U, Akpa CT, Garba NN, Ramli AT (2015) Health and ecological hazards due to natural radioactivity in soil from mining areas of Nasarawa State, Nigeria. Isotopes in environmental and health studies (ahead-ofprint): 1-21.

9. Isinkaye MO (2013) Natural radioactivity levels and the radiological health implications of tailing enriched soil and sediment samples around two mining sites in Southwest Nigeria. Radiation Protecon and Environment, 36(3): 122.

10. Skubacz K, Michalik B , Wysocka M (2011) Occupatonal radiation risk caused by NORM in coal mining industry. Radioprotection, 46(6): S669-S674.

11. Vlado Valković :Radioactivity in the Environment

12. M.A. Akpanowo, I. Umaru, S. Iyakwari. (2019). Assessment of radiological risk from the soils of artisanal mining areas of Anka, northwest Nigeria, Afr. J. Environ. Sci. Technol. 13 (8),303–309.

13. Souza, E.M . (2015). Environmental gamma survey: methodologies and patterns, Instituto de Radioproteção e Dosimetria Rio de Janeiro-RJ, Brasil CEP 22780-160.

14. Elzani 2015

15. UNSCEAR. (2000). Effects of atomic radiation to the general assembly, New York; United Nations Committee on the Effects of Atomic Radiation, United Nations .

16. E.O. Joshua, J.A. Ademola, M.A. Akpanowo, O.A. Oyebanjo, D.O. Olorode (2009), Natural radionuclides and hazards of rock samples collected from Southeastern Nigeria, Radiat. Meas. 44 (4), 401–404.

17. Tettey-larbi, L., Darko, E.O., Schandorf, C., Appiah, A.A. (2013). Natural radioactivity levels of some medicinal plants commonly used in Ghana. Springer Plus 2, 1–9.

18. Salmani-Ghabeshi, S., Palomo-Marín, M. R., Bernalte, E., RuedaHolgado, F., Miro-Rodriguez, C., Cereceda-Balic, F., Fadic, X., Vidal, V., Funes, M., & Pinilla-Gil, E. (2016). Spatial gradient of human health risk from exposure to trace elements and radioactive pollutants in soils at the Puchuncaví-Ventanas industrial complex, Chile. Environmental Pollution, 218, 322–330.

19. Al-Sulaiti, H., (2011). Determination of natural radioactivity levels in the state of Qatar using high-resolution gamma-ray spectrometry. Thesis (Ph.D.), University of Surrey.

20. El-Sayed, N., 2014. Studying naturally occurring radionuclides for some environmental samples and their hazardous effects. Thesis (MSc), Fayoum University

21. Berekt, J., & Mathew, P.J.(1985). Natural radioactivity of Australian building materials, industrial wastes, and by-products. Health and Physics,48,87-95

22. Ali H. Taqi a, Laith Abdul Aziz Al-Ani, Abbas M. Ali. (2015). Assessment of the natural radioactivity levels in Kirkuk oil field, Iraq.Journal of radiation research and applied research 9, 337-344

23. Arafa. (2004). Specific activity and hazards of granite samples collected from Eastern Desert of Egypt. Journal of environmental radioactivity,75, 315-327.

24. D. Ayalew, B. Sitotaw, E. Mengistu,(2019) Assessment of natural radioactivity levels in the soil of Dire Dawa city, Ethiopia, ROMANIAN J. BIOPHYS., Vol. 29, No. 4.

25. Hailu Geremew*, A.K.Chaubey (2019): Investigations of natural radioactivity levels and the possible radiation hazards in floriculture soil, Holeta, Shoa, Ethiopia using gamma spectrometry, International Journal of Current Research Vol. 11, Issue, 02, pp.1535-1540, February.

26. Ravisankar, R., Suganya, M., Vanasundari, K., Sivakumar, S., Senthilkumar, G., Chandramohan, J., et al. (2012b). Natural radioactivity in common building materials used in Tiruvannamalai City, Tamilnadu, India. Radiation Protection Environment, 35, 172-177.

27. R. Veiga, N. Sanches, R. M. Anjos, et al., (2006) . Measurement of natural radioactivity in Brazilian beach sands, Radiation Measurements, vol. 41, no. 2, pp. 189–196.

28. Karataşlı, M., Turhan, Ş., Varinlioğlu, A., and Yeğingil, Z. (2016). Natural and fallout radioactivity levels and radiation hazard evaluation in soil samples. Environmental Earth Science, 75, 424, 1-9.

29. U. Cevik, N. Damla, B. Koz, and S. Kaya, (2008). Radiological characterization around the Afsin-Elbistan coal-fired power plant in Turkey, Energy & Fuels, vol. 22, no. 1, pp. 428–432.

30. Hamzah Z., Ahmad S., Noor H. M., and She D. E. (2008) Surface Radiation Dose and Radionuclide Measurement in Ex-Tin Mining Area, Kg Gajah, Perak, The Malaysian Journal of Analytical Sciences, 12 (2): 419-431.

31. Svoukis, E., & Tsertos, H. (2007). Indoor and outdoor in situ high-resolution gamma radiation measurements in urban areas of Cyprus. Radiation Protection Dosimetry, 123(3), 384-390.

32. UNSCEAR. (2002). Effects of atomic radiation to the general assembly, New York; United Nations Committee on the Effects of Atomic Radiation, United Nations

33. UNSCEAR (1988). Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Sources, Effects, and Risks of Ionizing Radiation. United Nations sales publication, New York. United Nations.

34. El-Taher,(2010). “INAA and DNAA for uranium determination in geological samples from Egypt,” Applied Radiation and Isotopes, vol. 68, no. 6, pp. 1189–1192.

35. Hewammanna,R.,Sumithrarachchi,CS.,Mah awatte,P.,&Naayakkara,H.L.C.(2001). Natural radioactivity and gamma dose from Sri Lankan clay bricks used in building construction.Applied Radiation and Isotopes,54(2),365-369.

36. Nuclear Energy Agency (NEA-OECD), (1979). Exposure to Radiation from Natural Radioactivity in Building Materials. Report by NEA Group of Experts, OECD, Paris, 1979.

37. El-Galy, M.M., El Mezayn, A.M., Said, A.F., EL Mowafy, A.A., & Mohamed, M.S.(2008). Distribution and environmental impacts of some radionuclides in sedimentary rocks at Wadi Naseib area, southwest Sinai, Egypt. Journal of Environmental Radioactivity,99,1075-1082.

38. Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hidiroglu, S., and Karahan, G. (2009). Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity, 100,1, 49–53.

39. UNSCEAR (2008). Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Sources, Effects, and Risks of Ionizing Radiation. United Nations sales publication, New York. United Nations.

40. ICRP, (2007). International Commission on Radiological Protection. Recommendations of the ICRP. ICRP Publication 103. Ann. ICRP 37 (2–4).

41. NRC,(2006). National Academy of Sciences. National Research Council Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. Report of VII.

42. Orgun, Y., Altinsoy, N., Shain, S.Y., Gungor, Y., Gultekin, A.H., Karaham, G., et al.(2007) Natural and anthropogenic radionuclide in rocks and beach sands from Ezine region, Western Anatolia, Turkey.Applied and Isotopes, 65,739-747.