SIASAT
Journal of Religion, Social, Cultural and Political Sciences

Evaluation of Natural Radioactivity Levels in Drinking Water Sources: A Case Study from Gambella Town, Ethiopia

Nega Cheruashebir[1], Bikila Merga Derese[2], Belay Sitotaw Goshu[3]
[1,2]*Department of Physics, Gambella University, Ethiopia*
[3]*Department of Physics, Dire Dawa University, Dire Dawa, Ethiopia*
negacheru2020@gmail.com, bikilaphy.2019@gmail.com belaysitotaw@gmail.com

Abstract

Environmental materials containing radioactive elements derived from natural sources are referred to as naturally occurring radioactive materials (NORM). These substances are widely distributed and can be found in the world's ocean, atmosphere, and crust. Using high-purity germanium (HPGe) gamma spectroscopy, this study evaluated the specific activity concentrations of three naturally occurring radionuclides: 40K, 232Th, and 238U, in five drinking water samples. These materials' characteristics for radiation danger were also computed. In the water samples, the mean specific activity concentrations of 238U, 232Th, and 40K were determined to be 11.3990.276 Bq L-1, 17.2830.759 BqL-1, and 123.630 BqL-1, respectively. Within safe global limits, the average radium equivalent activity and absorbed dose were 43.759 BqL-1 and 21.24 BqL-1, respectively. The mean values of the gamma index, internal hazard index, external hazard index, and yearly effective dose equivalent were 0.165, 0.122, 0.149, and 0.103, respectively, all below the global safety criteria. As a result, the town of Glabella's water resources are safe and do not provide any health hazards to the locals.

Keywords
Specific activity; water; gamma spectroscopy; radiation hazard; hazard index

I. Introduction

Naturally occurring radionuclides are radioactive elements in the environment without human intervention. They are part of the Earth's primordial material found in various natural sources, including rocks, soil, water, and the atmosphere. These radionuclides have been present since the formation of the Earth, and their radioactivity is due to unstable nuclei that decay, emitting radiation. The most common naturally occurring radionuclides include uranium-238, thorium-232, potassium-40, and their progeny daughter nuclides [13].

Naturally occurring radionuclides (NORM) can expose humans to ionizing radiation through different pathways, such as ingestion, inhalation, and external exposure. These environmental radionuclides add to background radiation and can enter the body through several openings, harming numerous organs and tissues. After being consumed, radionuclides can build up in particular organs (radium in bones, for example), which increases the risk of internal radiation exposure and many health problems, including cancer. [1]

Water is a significant element in environmental studies due to its daily use by humans, and the possibility of water-related infections [1]. Ground water contains natural radionuclides, such as 40K, as well as natural decay chains of 235U, 238U, and 232Th, the dissolution of uranium and thorium salt enters rocks and sediment layers in the soil and pollutes the groundwater [11]. Because water or the food chain can allow radionuclides

DOI: *https://doi.org/10.33258/siasat.v9i4.186*

and the byproducts of their decay to enter the human body. They pose a concern to public health and have the potential to accumulate in the ecosystem [11].

Radionuclides gradually spread throughout the body when they are absorbed by the skin, inhaled, or consumed in water. Transmitted radiation energy results in permanent damage, such as infertility, blood vessel damage, bone cancer, leukemia, genetic problems, and cataracts in the eyes [14].

Uranium isotopes (238U, 234U, and 235U) have non-negligible radiotoxicity; In addition, several radionuclides in the radioactive decay chain starting from 238U and 235U are highly radiotoxic. Radium is the most radiotoxic and known carcinogen, with various isotope forms. With an alpha half-life of 1600 years and a beta half-life of 5.8 years, 226Ra and 228Ra are the most prevalent radium isotopes in groundwater. Given the significant radiotoxicity of 226Ra and 228Ra, special consideration needs to be given to their presence in water and the health hazards that come with it. It is well recognized that breathing in or ingesting radiation can have a major negative impact on one's health, and that even minute quantities of radioactive material can have detrimental biological effects. People who are exposed to extremely high doses of radium over an extended period may develop nasal cavities and bone cancer [14].

There had never been any research done on radionuclides in the groundwater of Gambella town's resources before the current study. The precise activity concentration of naturally occurring radionuclides in the city's groundwater is not well-documented. Thus, the purpose of this study is to evaluate the naturally occurring radionuclide levels and the corresponding radiological dangers in Gambella City, Ethiopia's drinking water sources.

II. Review of Literature

Natural radionuclides often infiltrate water sources through geological formations in the surrounding environment. These radionuclides are released from uranium, thorium, and potassium-containing rocks and soils and dissolve in groundwater and surface water [15]. Gamma and alpha spectroscopy, and liquid scintillation counting, are the principal methods for quantifying these radionuclides in water.

Natural radioactivity levels in Ethiopian drinking water fluctuate, according to studies. For instance, research carried out in several regions of Ethiopia has demonstrated that the local geology can have a significant impact on radionuclide concentrations [1, 8]. The high starting levels of uranium and thorium found in bottled and sachet water in Dire Dawa, Ethiopia, emphasize the need for continuous observation and assessment.

Researchers from Ethiopia have shown the naturally occurring radioactivity in drinking water. In Addis Ababa, for instance, a study looked at the activity concentrations of natural radionuclides in several different mineral waters and found significant variations that would be harmful if consumed over time [6]. Analogous research conducted in other regions of Ethiopia has underscored the importance of comprehensive evaluations and consistent observation to guarantee the safety of water [1, 8].

The annual effective dosage that individuals who drink water receive is used to calculate the radiological risk associated with it. Maximum levels of specific radionuclides have been set by the World Health Organization (WHO) [5, 16]. Over time, drinking water tainted with radioactive elements can raise your risk of developing cancer and other illnesses.

The consumption of water with significant quantities of natural radionuclides can result in internal exposure to alpha, beta, and gamma radiation. This exposure is linked to an increased risk of cancer and other health concerns. The WHO's drinking water quality guidelines contain limitations for radionuclides and are intended to reduce these health hazards [16]. Long-term research is critical for understanding the cumulative consequences of low-dose radiation exposure through drinking water [18].

There is a rare chance to look into naturally occurring radioactivity in drinking water in the Gambella region of western Ethiopia. The geological features of the area suggest that there may be significant radioactive contamination in the water supplies. To ascertain the precise activity concentrations of radionuclides like potassium, uranium, and thorium, preliminary surveys and investigations are necessary. Comprehending these thresholds will aid in evaluating radioactive risks and guiding public health initiatives.

III. Research Methods

3.1 Study area

The study was conducted in the town of Gambella. It is situated in the southwest of Ethiopia and borders Sudan to the west, Western Ethiopia Regional State to the south, and Oromia to the north and east. The geographical coordinates are 8.25° N and 34.58° E. Temperatures range from 21 to 36 degrees Celsius at minimum and maximum, respectively, with an average annual rainfall of 600 millimeters.

3.2 Sample collection and preparation

In Gambella town, five kebeles provided five liters of water. To lessen precipitation and absorption on the container walls, the samples were moved to polyethylene Marinelli beakers with pH numbers W01, W02, W03, W04, and W05 after their GPS locations were noted. Each sample received 20 milliliters of diluted hydrochloric acid. After that, the container was filled and the opening was tightly sealed. The samples were stored for four weeks or one month. The purpose of doing this was to preserve the secular equilibrium between the daughters of radium isotopes. Finally, a high-purity germanium gamma spectrometer was used to assess the samples' radioactive concentration.

Table 1. Geographic locations of water samples

Samples No.	Sample codes	Geographical locations	
		Lat	Lon
1	W01	8.263	34.587
2	W02	8.249	34.596
3	W03	8.241	34.577
4	W04	8.259	34.574
5	W05	8.234	34.599

3.3 Experimental setups

The tests were carried out with a gamma-ray spectrometer equipped with a 70% relative efficiency P-type coaxial HPGe detector (Ortec). The resolution of the 2000-channel MCA and the 1332.5 keV ^{60}Co gamma line is 1.9 keV. An analytical method for identifying and quantifying gamma-emitting isotopes in various matrices is gamma-ray spectrometry. The measurement yields a spectrum of lines, where the energy of the

radionuclide is represented by its position on the horizontal axis, and its activity is shown by its amplitude. This system is made up of a computer running specialized software, a multichannel analyzer (MCA), and several preamplifiers and amplifiers.

3.4 Sample counting and specific activity measurement

The use of gamma spectrometry in conjunction with an HPGe detector (Ortec) with 70% relative efficiency and 1.9 keV resolution for the 1332.5 keV ^{60}Co gamma line and 2000 channel MCA allowed for the determination of the activity concentrations of 238U, 232Th, and 40K in the samples. After being placed inside the Marinelli beaker, 36,000 samples were tallied.

Using the energy peak of ^{214}Bi and ^{214}Pb at 352.0 keV at 609.31 keV, the specific activity content of ^{238}U in the samples was calculated. Similarly, photopeaks of ^{212}Pb at 583.1 keV and ^{228}Ac at 911.1 keV were used to determine the activity ^{232}Th. It was possible to calculate the activity concentration of ^{40}K using the energy of 1460.83 keV [4].

Each radio-nuclide daughter peak's net count rate under the well-known photo peaks was determined by deducting the corresponding count rate from the background spectrum acquired for the same counting time. Next, the radionuclide's specific activity is computed using the known gamma-ray energies' removed background region.

The equation [1] was utilized to compute the radionuclide's specific activity in every water sample.

$$A = \frac{N}{\varepsilon(E)\times P\times t\times m} \qquad (1)$$

where A is the specific activity of the radionuclide in BqL^{-1}, N is the net area count under the photo-peak of each radionuclide, m is the mass of the water sample, t is the counting time, P is gamma yield or absolute probability of the specific gamma ray, and $\varepsilon(E)$ is the efficiency of specific gamma-ray energy in BqL^{-1}.

3.5 Radiation Hazard Indices

Radioactive hazard variables are essential for evaluating the risk radioactive materials provide to the environment and human health. These parameters have significant aspects of radiological hazards and help to the extent of radiation exposure and its possible biological effects [3].

Radium Equivalent Activity (Raeq): Defined as the weighted sum of ^{238}U, ^{232}Th, and ^{40}K activity concentrations, based on the assumption that 370 Bq. L^{-1} of ^{226}Ra, 259 Bq. L-1 of ^{232}Th, and 4810 Bq. L^{-1} of ^{40}K produces the same gamma-ray dose rate. The radium equivalent is given by

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

The received dose from radiation emitted from radioactive concentrations in water in the open air is expressed as the absorbed dose rate (*DR*) in air one meter above the ground surface. When radiation is dangerous to a biosystem, this is an important quantity to assess. Eq. (3) [3] can be used to calculate the absorbed dosage rate, which is given by

$$DR = 0.462A_U + 0.604A_{Th} + 0.0417A_K \qquad (3)$$

From the computed values of DR, the annual effective dose equivalent (*AEDE*) received by each individual was determined by applying the dose rate conversion factor of 0.7 Sv Gy^{-1} and the occupancy factors of 0.2 (5/24) for outdoor and 0.8 (19/24) for indoor environments, respectively [2]. Consequently, the annual effective dose rate (mSvy^{-1}) was calculated using Equation 4.

$$AEDE(\text{msvy}^{-1}) = DR(\text{nGyh}^{-1}) \times 8760(\text{hy}^{-1}) \times 0.7(\text{Sv.Gy}^{-1} \times 0.8 \times 10^{-6} \qquad (4)$$

3.6 Hazard index

The external hazard index is a commonly used hazard index that measures external exposure. Hex is defined as [1-2, 8].

$$H_{ex} = \frac{A_U}{370\ Bq.L^{-1}} + \frac{A_{Th}}{259\ Bq.L^{-1}} + \frac{A_K}{4810\ Bq.L^{-1}} \quad (5)$$

Where are the particular activities of ^{238}U, ^{232}Th, and ^{40}K in Bq. L^{-1} and the H_{ex} value must be less than one for the radiation threat to be safe for humans.

The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and its short-lived progeny. To account for this threat, the maximum permissible concentration of ^{226}Ra must be reduced to half of the normal limit (185 Bq L^{-1}) and is given by the following [4].

$$H_{in} = \frac{A_U}{185\ Bq.L^{-1}} + \frac{A_{Th}}{259\ Bq.L^{-1}} + \frac{A_K}{4810\ Bq.L^{-1}} \quad (6)$$

To have negligible dangerous effects on respiratory organs from radon and its short-lived progeny, the values of H_{ex} and H_{in} must be less than unity.

3.7 Excess lifetime cancer risk

Excess lifetime cancer risk (*ELCR*) is the probability of developing cancer over a lifetime at a given exposure level. A higher *ELCR* value implies a higher chance of cancer in the individual exposed. It can be calculated using Eq. 7 [1-2, 4, 13].

$$ELCR = AEDE \times DL \times RF \quad (7)$$

Where *AEDE* is the annual effective dose equivalent, the duration of life (*DL*) is the duration of life (estimated to be 70 years), and the risk factor (*RF*) is in Sv^{-1}. The International Commission on Radiological Protection (ICRP) sets *RF* at 0.05 for the general population to account for stochastic effects.

3.8 Annual gonad equivalent dose

The annual gonadal equivalent dose (AGED) represents the dose received by those organs which include the reproductive organs (gonads), bone marrows, and bone cells. The gonads, the bone marrow, and the bone surface cells are considered organs of interest because of their sensitivity to radiation.

$$AGED(\text{msvy}^{-1}) = 3.09\ A_U + 4.18\ A_{Th} + 0.314 A_K \quad (8)$$

3.9 gonad equivalent

Gamma index I_γ was calculated using the following formula, this is used to estimate the I_γ radiation hazard associated with the natural radionuclide in specific investigated samples. Values of $I_\gamma \leq 1$ BqL^{-1} correspond to an annual effective dose of less than or equal to 1 mSv

$$I_\gamma = \frac{A_U}{300\ Bq.L^{-1}} + \frac{A_{Th}}{200\ Bq.L^{-1}} + \frac{A_K}{3000\ Bq.L^{-1}} \quad (9)$$

IV. Results and Discussion

4.1 Results

The primary goals of this study were to determine the levels of natural radioactivity in drinking water sources in Gambella Town, Ethiopia, and the associated radiological dangers. This entailed determining the quantities of radionuclides such as uranium-238, thorium-232, and potassium-40 in water samples obtained from the area. The study also aimed to determine the annual effective dose received by those who drank this water and

compare it to global safety requirements established by organizations such as the World Health Organization (WHO).

a. The specific activity of the detected radionuclides in water samples

The specific activity of the samples used on the lead isotope (214Pb) at energies of 295.21 and 351.92 keV and bismuth (214Bi) at energies of 609.31, 1120.29, and 1764.49 is equivalent to the specific activity of uranium (238U) by selecting the maximum value of their activities. The activity used on the lead isotope (212Pb) at energies of 77.1 and 238.63 keV and actinium (228Ac) at energies of 911.21 and 968.97 keV, respectively, is similar to the specific activity of thorium (232Th) by selecting the maximum value of their activities, The specific activity of radionuclide concentrations at 40K was estimated using energy of 1460.81 keV. The activity of radionuclide concentrations can also be calculated using Eq. (1).

The results of the measured values of specific activity concentrations of natural radionuclides in water samples are tabulated in Table 1.

Table1. The measured value of activity concentration of radionuclides in drinking water samples collected from five kebeles in Gambella town

Samples codes	Specific activities [Bq L^{-1}]		
	A_U	A_{Th}	A_K
W01	4.00 ± 0.72	10.21 ± 0.81	86.50 ± 0.24
W02	6.30 ± 0.37	13.15 ± 0.50	97.13 ± 0.57
W03	3.12 ± 0.53	8.32 ± 0.62	79.7 ± 0.14
W04	2.20 ± 0.12	11.05 ± 0.34	74.31 ± 0.73
W05	2.70 ± 0.85	10.57 ± 0.76	81.65 ± 0.15
Mean	3.66 ± 0.51	10.66 ± 0.60	83.86 ± 0.36
World average	30	35	400

The specific activity of 238U, 232Th, and 40K in water samples ranged from 2.2 ± 0.12 to 6.3 ± 0.37 Bq.L-1, 8.32 ± 0.62 to 13.15 ± 0.12 Bq.L-1, and 74.31 ± 0.73 to 97.13 ± 0.57 Bq.L-1, respectively, with a mean of 3.66 ± 0.51, 10.66 ± 0.6 Bq.L-1, and 83.86 ± 0.36 Bq.L-1 for 238U, 232Th, and 40K.

Many observations about the distinct activities of AU, ATh, and AK throughout the different samples may be made based on the data obtained from the Gambella water samples, as illustrated in Figure 1. Sample W02 had the greatest specific activity of AK of all the samples, measuring 97.13 BqL-1. In a similar vein, the highest-ever recorded activity of AU in W02 was 6.30 BqL-1. W02 had the greatest specific activity of ATh among the samples, with 13.15 BqL-1.

The specific activity of AU in sample W04 was 2.20 BqL-1, the lowest of the samples. Similarly, the AK activity in W04 was 74.31 BqL-1, the lowest recorded number, while the ATh activity in W04 was 11.05 BqL-1, greater than W03 but lower than W01, W02, and W05.

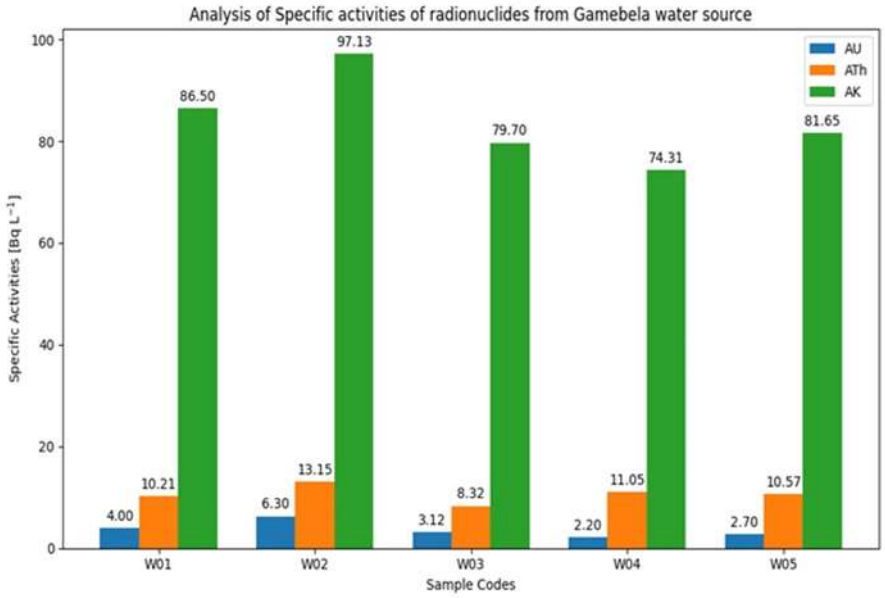


Figure1. *The specific activities of radionuclides from water samples in Gambella, Ethiopia*

b. Radiological hazard parameters in water samples

Radiation dose calculations and evaluations of the biological effects on people are based on the specific activity of radionuclides in an environmental sample. Using Eqs. (3–8) from 226Ra, 232Th, and 40K-specific activity, radiation hazard parameters such as radium equivalent activity (Raeq), absorbed dose rate (DR), effective dose rates (AED), external hazard index (Hex), internal hazard index (Hin.), annual gonad dose, excess lifetime cancer risk, and gamma index were calculated. The results of the radioactive danger parameter indices in soil samples are shown in Table 3.

Table 2. Radiological hazard parameters in water samples

Sample code	Ra_{eq} [Bq. L^{-1}]	DR [nGy. h^{-1}]	$AEDE$ [msv. y^{-1}]	H_{ex}	H_{in}	I_{γ}	$ELCER$ (10^{-3})
w01	25.68	11.61	0.0056	0.066	0.078	0.093	0.019
w02	32.6	14.90	0.0073	0.087	0.104	0.110	0.025
w03	21.14	9.81	0.0048	0.057	0.064	0.078	0.017
w04	23.72	10.78	0.0052	0.063	0.069	0.087	0.018
w05	24.04	11.02	0.0054	0.064	0.072	0.089	0.019
Min	21.14	9.81	0.0048	0.057	0.064	0.078	0.017
Max	32.6	14.90	0.0073	0.087	0.104	0.110	0.025
Mean	25.44	11.62	0.0056	0.067	0.077	0.091	0.020
World average	370.0	60.00	1.000	1.000	1.00	1.000	0.290

Table 2, Column 2 presents the values of radium equivalent (Raeq). The water samples from the research area have radium equivalents ranging from 21.14 to 32.6 BqL-1, with a mean of 25.44 BqL-1. Table 3 displays the average value of 11.62 nGyh-1 for the absorbed dose rates caused by radionuclides in water samples, which range from 9.81 to 14.90 nGyh-1. With an average of 0.0056 mSvy-1, the computed yearly effective dosage equivalent varied from 0.0048 mSvy-1 to 0.0073 mSvy-1. With an average of 0.091 and

the increased lifetime cancer risk fluctuated from 0.078 to 0.11 (dimensionless). This result is below the global average of 0.29 and increased lifetime cancer risk. The internal and exterior hazard indices were 0.057 to 0.087 and 0.064 to 0.104, with mean values of 0.067 and 0.077, respectively.

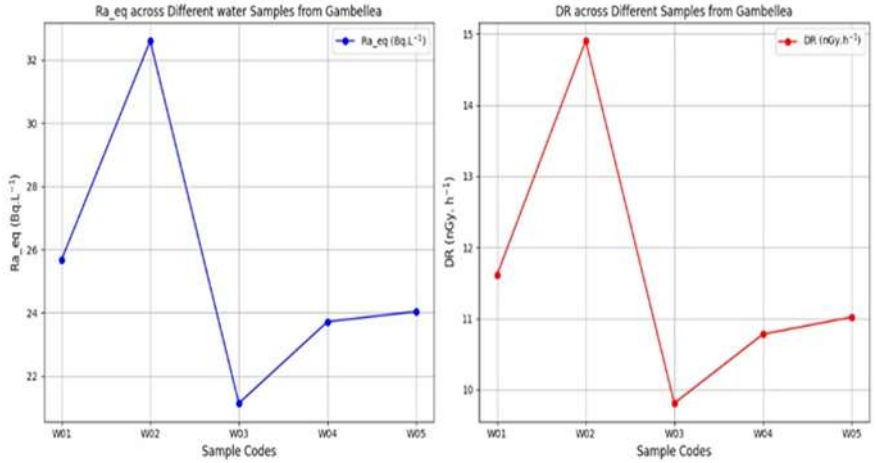


Figure 2. *The radium equivalent and the absorbed dose rate produced by the water collected from Gambella.*

The analysis of Gambella water samples showed significant variations in the specific activity of several radionuclides depicted in Figure 3. Raeq and absorbed dose rate (DR) in sample W02 are notably higher than in the other samples. Raeq's specific activity in sample W02 is the highest of all samples at 32.6 BqL-1. A weighted total of the activities of 226Ra, 232Th, and 40K, taking into account their risks, is referred to as the "radium equivalent activity," or Raeq. A higher concentration of these radionuclides is suggested by the higher Raeq in W02.

Similarly, sample W02, at 14.90 nGyh-1, had the highest absorbed dose rate (DR). The amount of radiation energy absorbed per unit mass per unit of time is known as the absorbed dose rate, and it provides information on potential radiological effects on the environment and public health.

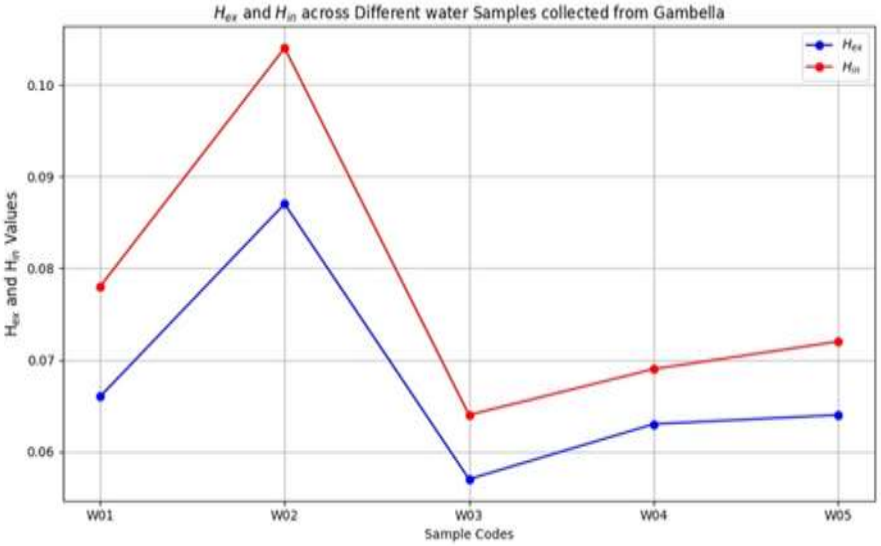


Figure 3. *The water samples that were taken from Gambella have both internal and exterior danger indexes.*

The results of the Gambella water samples reveal notable variations in the internal and external hazard indices, with the samples displayed in Figure 3 exhibiting higher internal hazard indices (Hin) than external hazard indices (Hex). Additionally, the highest values for both indices were provided by the second sample (W02).

The potential radiological risk to human health from breathing in or consuming radionuclides found in water is evaluated using the internal hazard index. The available data consistently showed that Hin was higher than Hex, suggesting a higher possible risk of internal radiation. For instance, among all the samples displayed in Table 3 and Figure 3, sample W02 had the highest Hin of 0.104.

The external hazard index evaluates the radiological risk associated with external radionuclide exposure. Hex were often lower than those of Hin. In sample W02, Hex was 0.087, the highest of the samples but still lower than the matching Hin value.

4.2 Discussion

The average specific activity of 238U, 232Th, and 40K was less than the required global average value. The global permitted average levels for 226Ra, 232Th, and 40K in drinking water are 30 Bq L-1, 35 Bq L-1, and 400 Bq L-1, respectively [18].

The measured values for the specific activity concentrations of 238U and 232Th in water samples from the research region are marginally higher than the radionuclide activity concentrations of 4.30-6.01 and 3.75-12.74, respectively, in the water resources of Dire Dawa city. However, compared to 40K in Dire Dawa City, which ranges between 3.04 and 122.48, the specific activity concentration of 40K in the research water samples is lower [1, 9]. The discovered radionuclides' specific activity concentrations, which are 18.20 Bq. L-1, 16.40 BqL-1, and 375.44 BqL-1 for 238U, 232Th, and 40K, respectively, are also lower than the water resources in Al-Sader City, Baghdad, Iraq [3].

Table 3. *Comparing the distinct natural radioactive activity found in groundwater and bottled water across several regions*

Country	Types	Specific activities [Bq. L^{-1}]			References
		^{238}U	^{232}Th	^{40}K	
Iran	Groundwater	0.67	1.65	4.72	[10]
Nigeria	Well water	3.61	2.26	60.84	[17]
Iraq	groundwater	18.20	16.40	375.44	[2]
Egypt	groundwater	1.99-3.01	1.33-1.44	5.07-12.04	[7]
	Nile water	1.09-2.56	1.29-1.46	8.01-8.16	
	Canal water	0.98-3.0	0.81-1.84	3.71-10.50	
Iran	groundwater (deep)	0.11	0.65	4.32	[11]
	Groundwater(shallow)	0.14	0.47	0.76	
Ethiopia (Dire Dawa)	Groundwater	4.36	7.81	131.26	[1]
Ethiopia (Dire Dawa)	Bottled water	3.26	11.31	106.40	[8]
Ethiopia	Groundwater	3.66	10.66	83.36	Present

(Gambella)					study

The evaluation of natural radioactivity levels in different nations finds significant variations in radioactive concentrations in groundwater and surface water sources as shown in Table 4. Groundwater samples in Iran include lower levels of 238U (0.11–0.67 Bq. L-1), 232Th (0.47–1.65 Bq. L-1), and 40K (0.76–4.72 Bq. L-1) [10]. In contrast, Nigeria reported significantly greater amounts of well water, with 40K reaching up to 60.84 Bq. L-1 [17]. Iraq has the greatest amounts found, notably in groundwater, where 226Ra can reach 18.20 Bq. L-1, 232Th can reach 16.40 Bq. L-1 and 40K can reach 375.44 Bq. L-1 [2].

The levels of radioactivity in different water sources in Egypt differ considerably. Concentrations of 238U, 232Th, and 40K in groundwater vary from 1.99 to 3.0 Bq. L-1, 1.44 to 1.44 Bq. L-1, and 5.07 to 12.4 Bq. L-1, respectively [7]. Similarly, 226Ra, 232Th, and 40K are found in Nile and canal water, indicating local geological influences [7].

Groundwater concentrations in Ethiopia have increased from 238U to 4.36 BqL-1, 232Th to 7.81 Bq.L-1, and 40K to 131.26 Bq.L-1, especially in Dire Dawa [1]. Lower but significant concentrations of 238U at 3.26 Bq. L-1, 232Th at 11.31 Bq. L-1, and 40K at 106.40 Bq. L-1 is found in bottled water from the same region [8]. The moderate concentrations of 238U at 3.66 Bq. L-1, 10.66 Bq. L-1, and 40K at 83.36 Bq. L-1 found in groundwater samples from Gambella, Ethiopia, indicates regional geological heterogeneity.

The wide range of radioactive amounts realized in these places underscores the importance of ongoing monitoring and assessment of water quality. Elevated amounts have been recorded in certain regions, such as Iraq and portions of Ethiopia, indicating potential health problems connected with increased radiation exposure through drinking water sources. In contrast, places with lower quantities, such as Iran and some parts of Egypt, may pose a lower risk to human health from natural radioactivity. Effective management methods and regulatory measures are required to reduce potential health risks and ensure safe drinking water for communities worldwide.

V. Conclusions

The activity of naturally existing radionuclide concentrations in drinking water samples taken from the study area was examined in this investigation. Furthermore, the parameters of health danger associated with specific radionuclides are established. The study samples yielded concentrations of 238U, 232Th, and 40K below the world average limit. The worldwide allowed threshold is not met by radiological hazard measurements such as radium equivalent activity, absorbed dose rate, annual effective dose equivalent, gamma index, internal and external hazard index, or excess lifetime cancer risk. Therefore, our study indicates that drinking water in Gambella town won't hurt residents' health and is safe from a radiation protection perspective. The results of this study will offer a strong basis for determining present and future drinking.

The higher exterior and internal hazard indices in sample W02 highlight the need to thoroughly evaluate water sources radiologically, especially in areas where geological or human influences may be present. The results underscore the importance of consistent monitoring and suitable mitigation strategies in mitigating potential radiation risks to human well-being and the ecosystem.

References

ABAS, E. B. SITOTAW, E MENGISTU, E., Evaluation of radionuclides specific activity of groundwater resources. A case of Dire Dawa City, Ethiopia, *Romanian J. Biophys*., 2021, **31**(1), 1–11.

ABDULHAMEED, N., M.H. NASSIR, N.H. AMEEN, M.M. HUSSIEN, Assessment of natural radioactivity levels and radiological hazards for Tigris River Basin. *Journal of Madenat Alelem College*, 2019, 11(2), 16-22.

AL-MASHHADANI, A.M., Assessment of radioactivity and associated hazards in drinking water in Al-Sadar city, Baghdad, *International Journal of Geology, Agriculture and Environmental Sciences*, 2014, **2**(4), 28-33.

ASHEBIR, N.C., B.G. GOSHU, E. MENGISTU, Assessment of natural radioactivity in soil samples and tea leaves at Gumero tea farm, Ethiopia, *Romanian J. Biophys*., 2022, **32**(2), 103–119.

BANGOTRA P., M. SHARMA, R. MEHRA, R. JAKHU, A. SINGH, A.S. GAUTAM, S. GAUTAM, A systematic study of uranium retention in human organs and quantification of radiological and chemical doses from uranium ingestion. *Environ Technol Innov*., 2021, **21**(12):101-360

ELISABET YILKAL, F. ZEWGE, B.S. CHANDRAVANSH, Assessment of the Quality of Bottled Water Marketed in Addis Ababa, Ethiopia. *Bulletin of the Chemical Society of Ethiopia, 2019,* **33**(1), 21-41.

EL-ZAYAT, M. H., M. EL-ZOHRY, The natural background activity concentration of (226Ra, 232Th, and 40K) and the annual effective dose from different water sources consumption in phosphate-polluted areas. *Egyptian Journal of Physics,* 2020, **48**(1), 19-26.

GOSHU, B.S., E. ABASA, M. WOLDEAMANUEL, Assessment of the natural radioactivity of bottled drinking water produced in Dire Dawa, Ethiopia, ROMANIAN J. BIOPHYS., 2023, **33**(3), 89–103, BUCHAREST, https://www.doi.org/10.59277/RJB.2023.3.01

HE, R., S. LIAW, M. ZHOU, X.D. ZHOU, H. LUO, Environmental evaluation of radioactivity levels and associated radiation hazards in groundwater around the WIPP site. *Ecotoxicology and Environmental Safety,* 2022, **242**, 113849. https://doi.org/10.1016/j.ecoenv.2022.113849

KABADAYI, O., H. GÜMÜŞ, Natural activity concentrations in bottled drinking water and consequent doses, *Radiation Protection Dosimetry*, 2012, **150**(4), 532–535.

KHALIFA, N., Natural Radioactivity of Ground and Drinking Water in Some Areas of Upper Egypt, *Turkish Journal of Engineering and Environmental Science*, 2004, **28**, 345–354.

MAJED, N. A., M.H. NASSIR, N.H. AMEEN, M.M. HUSSIEN, Assessment of Natural Radioactivity Levels and Radiological Hazards for Tigris River Basin. *Journal of Mesopotamian Academic Union of Chemists (JMAUC), 2019,* **11***(2), 16-22*.

MUSSA, Y., E. MENGISTU, D. AYALEW, B. SITOTAW, Assessment of natural radioactivity levels and radiation hazard in ancient Harar city, Jugal, soil, Ethiopia. *Romanian Journal of Biophysics,* 2021, **31**(2), 89-101.

POURIMANI, R., Z. NEMATI, Measurement of radionuclide concentration in some water resources in Markazi Province, Iran. *Iranian Journal of Medical Physics,* 2016, **13**(1), 49-57.

SINGH, P., P.C. SETHY, A.K. SINGH, S. SINGHAL, A.K. MAURYA, S.R. GIRI, Geochemistry and U–Pb zircon geochronology of the Jutogh thrust sheet, Himachal

Pradesh, NW-Himalaya: Implications to the petrogenesis and regional tectonic setting, *Geological Journal*, 2023, **58**(1), 131-149.

TCHOKOSSA, P., J. OLOMO, F. BALOGUN, Assessment of radionuclide concentrations and absorbed dose from consumption of community water supplies in oil and gas producing areas in Delta State, Nigeria., *World Journal of Nuclear Science and Technology*, 2011, **1**(3), 77-86. doi: 10.4236/wjnst.2011.13012.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). *Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report to the General Assembly, with Scientific Annexes*. United Nations Publications.

WORLD HEALTH ORGANIZATION (WHO). *Guidelines for Drinking-Water Quality*. 4th ed. Geneva: WHO, 2011.

YADAV, J., B. KHYALIA, N. KUMAR, N. KHATI, R.K. SINGH, V. KUMAR, M. THAKUR, Assessment of natural radioactivity in soil and water in the upper Himalayas region along the Manali–Leh highway, India. *J Radioanal Nucl Chem*, 2024, **333**, 3075–3086. https://doi.org/10.1007/s10967-023-09196-6.

YADAV, J., B. KHYALIA, N. KUMAR, N. KUMAR, R. SHARMA, Assessment of natural radioactivity in soil and water in the upper Himalayas region along the Manali–Leh highway, India. *J Radioanal Nucl Chem*, 2024, **333**, 3075–3086, https://doi.org/10.1007/s10967-023-09196-6