Volume 18, No 2 | International Journal of Radiation Research, April 2020

Radioecological research of some water resources in central region of Azerbaijan

A.A. Garibov[1*], A.C. Mikayilova[2], F.Y. Humbatov[2], M.R. Ghahramani[2], J.A. Nagiyev[1]

[1]*National Nuclear Research Center, Baku, Azerbaijan*
[2]*Institute of Radiation Problems of ANAS, Baku, Azerbaijan*

▶ ***Original article***

***Corresponding authors:**
Adil A. Garibov, Ph.D.,
***E-mail:** nukl@box.az*

Revised: April 2019
Accepted: August 2019

Int. J. Radiat. Res., April 2020; 18(2): xx-xx

DOI:

ABSTRACT

Background: In this proposed work, the products of ^{238}U radioactive decomposition: ^{226}Ra, which has a comparatively great decomposition period and ^{228}Ra intermediate product of ^{232}Th were examined, which were more prevalent in water samples of the territories investigated. Natural radionuclides are usually observed more in artesian well waters than in river and canal waters, and less in comparison with groundwater. ***Materials and Methods:*** For studying the concentration of radionuclides in drinking and agricultural water, samples were collected from Kura River, Yukhari Garabakh and Yukhari Shirvan channels and from artesian wells in different regions. For measurement of radioactivity, gamma spectrometer with high-sensitivity Ge-detector was used, controlled by the software Genie 2000 (manufactured by CANBERRA firm). ***Results:*** The obtained results for well waters showed high activity concentrations; the total effective doses for all radionuclides were 2.54, 4.27, and 0.66 mSv for infants, children, and adults, respectively. ***Conclusion:*** From these results, it can be concluded that the investigated water is not acceptable for life-long human consumption.

Keywords: *Radionuclide, groundwater, marinelly, qamma-spectrometr.*

INTRODUCTION

The human population is exposed to a natural background radiation level originating from three components viz., cosmic rays, terrestrial radioactivity, and internal radioactivity. The contribution of these components varies with location and altitude. The terrestrial component is due to the radioactivity of uranium (^{238}U), thorium (^{232}Th), and their progeny radio isotopes as well as potassium-40 (^{40}K) that is present in environmental materials like rocks, soils, sediments, buildings, rivers, and ground water. Although these materials contain low-level radioactivity (LLR), the accumulated dose can be high. In this regard, measurements of the radiation exposure and radiation levels have been developed recently [1, 2].

Terrestrial radiations with different values in waters, foods, soils, etc [3]. Accumulate in the human body and in the environment, which radiate naturally from radioactive elements. Higher radioactivity in the surroundings is associated with the risk of damage to different parts of the body including kidney damage, mutagenicity, and leukemia as well as cancer of the bladder, kidney, testis, and lung [4, 5].

Increased concern for the radiological quality of drinking water has led to stricter quality control on our drinking water. The total dose for radiological contents basically corresponds to the recommendations given in the World Health Organization (WHO) guidelines for drinking water quality. In the WHO guidelines, the recommended reference dose level (RDL) of committed effective dose is 100 µSv for 1 year

[DOI: 10.18869/acadpub.ijrr.18.2.323]

consumption of drinking water. Meanwhile, gamma rays entering through the skin interact with human tissues. On the other hand, other elements such as uranium and radium are also found in water while not emitting strong gamma radiations; so showering and bathing do not pose a significant risk. However, with direct inhalation or ingestion of these radionuclides, sensitive tissues come into direct contact with these emissions. Uranium radionuclide enters water through dissolution from minerals and soils, elevating the level of radionuclides in ground waters, and eventually causing toxic effects to different parts of the body such as kidney leading to cancer [6,7].

The United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) has reported that the average worldwide exposure to natural sources in foods and drinking water (ingestion exposure) is 0.29 mSv y-1 (about 0.17 mSv y-1 from ^{40}K and about 0.12 mSv y-1 from Uranium and Thorium) [8].

It is estimated that on a global average, the ingestion dose due to intake of food containing ^{238}U and ^{232}Th series nuclide has proved to be 0.140 mSv/y, while the value due to ^{40}K is 0.170 mSv/y. The total dose received through ingestion and dietary intake of long-lived radionuclide of ^{238}U and ^{232}Th series as well as ^{40}K has been found to be 0.310 mSv/y globally [9].

The radium concentration ranges from 0.01 to 0.1 Bq/l in surface waters [10], with the high levels originating from the sites containing uranium which are close to these waters [11]. In groundwater, the radium concentrations can reach values up to 38 Bq/l, depending on factors such as type of aquifer rock as well as physiochemical characteristics of water [12]. Then, through ingestion, the internal exposure and received dose grows appreciably in the body [13].

Therefore, the entrance of radium into the human body should be prevented by blocking its entrance through the ingestion of foods or drinking water [13]. The present study attempts to understand the occurrence and distribution of natural radionuclides ^{226}Ra and ^{228}Ra in ground waters in central regions of Azerbaijan, which are sometimes used by the public as drinking water. Another aim is to assess the concentrations of ^{226}Ra and ^{228}Ra exceeding the recommended values for ^{226}Ra and ^{228}Ra in these areas. The third goal is to estimate the radiation doses received by adults living in these areas.

MATERIALS AND METHODS

For studying the concentration of radionuclides in drinking and agricultural water, samples were collected from Kura River, Yukhari Garabakh and Yukhari Shirvan channels, and from aartesian wells in different regions.

The Kura River is the main water system which flows through the central regions of Azerbaijan (figure 1) and is used as a source of drinking and agricultural water. Kura River represents the main water-supply system of the South Caucasus. This river has remained the main source of drinking water for 70% of the population of Azerbaijan, including the main cities – Baku, Ganja, and Sumgayit. So, the quality of Kura river water resources is one of most important issues for the country.

The total groundwater resource is estimated to be 24 million m^3 per day. At present, 5 million m3/day or 20% is exploited. Groundwater is mainly used for irrigation (78%), 3% is used by the industry, and 19% is claimed by water supply to provincial towns and rural areas.

Sampling, sample preparation, and radionuclide content measurement of water samples were performed according to international methods and standards.

After filtration, the water samples were placed in Marinelli beaker. To create radioactive equilibrium, samples were kept in closed Marinelli beaker for about three days, after which the gamma-spectrum of each sample was accumulated. To measure the radioactivity, gamma spectrometer with high-sensitivity Ge-detector was used, controlled by the software Genie 2000 (manufactured by CANBERRA firm). For all samples, an identical mode of measurement was chosen, where the duration of accumulation of a sample's spectrum was 24 h.

The annual effective doses were calculated

[DOI: 10.18869/acadpub.ijrr.18.2.323]

according to the equation (1) introduced by EPA and by Meltem and Gursel [19].

$$DR_W = A_W \times IR_W \times ID_F \qquad (1)$$

Where, DR_W, A_W, IR_W, and ID_F are the effective dose (mSv y^{-1}), activity (Bql^{-1}), intake of water for person in one year, and effective dose equivalent conversion factor (mSv Bq^{-1}), respectively.

The dose rates of drinking water (150, 350, and 500 l yr^{-1}) [14] were estimated based on consumption for infants, children, and adults, respectively. The conversion factors for ^{226}Ra and ^{228}Ra as reported by ICRP [15], IAEA [16], and WHO [17] are (9.6×10^{-7} and 5.7×10^{-6}Sv Bq^{-1}) for infants, (8×10^{-7} and 3.9×10^{-6}Sv Bq^{-1}) for children, and (2.8×10^{-7} and 6.9×10^{-7}Sv Bq^{-1}) for adults.

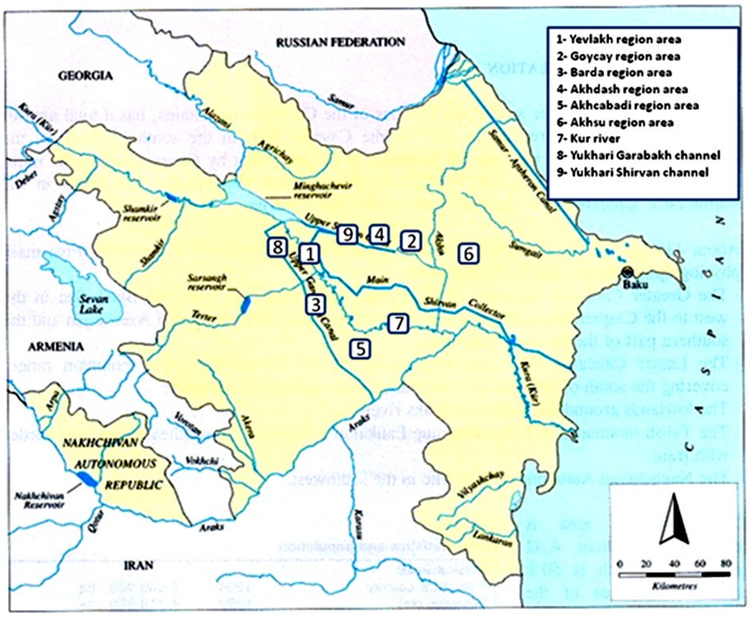

Figure 1. Reverse Map of Azerbaijan.

RESULTS

In the central regions of Azerbaijan, the ground water has a high level, which contains naturally occurring dissolved radioactive materials (NORMs). These norms can influence the water quality in Kur River. The river water has been polluted by the impact of human factors.Further, is response to drainage of salty underground waters in plain areas, the salinity has increased, the chemical structure has become complicated, and the water type has changed. These conditions are observed in Shirvan, in the streams of Kur River flowing from Mil-Garabagh lowland, in Kur itself, and in Aras River.

Radium is more soluble in groundwater than its thorium (^{228}Ra from thorium-232) and uranium (^{226}Ra from uranium-238) precursors. The solubility of radium is enhanced by the common-ion effect (when the content of dissolved solids is high), oxygen-poor environment, and fragmentation of uranium-bearing minerals [20].

Radiologically, the Ra-isotopes in environmental samples should be determined. Due to their radiotoxicity, especially that of ^{226}Ra and ^{228}Ra, the contamination hazard is potentially dangerous to human beings even at low concentration levels. The principal health risks associated with the use of mineral waters containing elevated concentrations of dissolved radium are carcinomas of the head and sarcoma of bone. An excess of 2% above the background cancer incidence rate was estimated due to ingestion of mineral spring waters [21].

[DOI: 10.18869/acadpub.ijrr.18.2.323]

Table 1 presents the results of radionuclide analysis of natural radionuclides in artisan water samples, which were collected fromtheinvestigated area.

Table 2 reports the results of the specific activity of radionuclide analysis of water samples, collected from Kur River as well as from Yukhari Garabakh and Yukhari Shirvan channels.

Table 1. The results of radionuclide analysis in artisan water samples

Artezan water samples	Specific activity, Bq/l	
	^{226}Ra(Bq/l)	^{228}Ra
Yevlakh region area	0.48±0.12	0.183±0.22
Goycay region area	0.34±0.04	0.151±0.05
Barda region area	0.39±0.07	0.172±0.03
Akhdash region area	0.47±0.08	MDA=0.77
Akhcabadi region area	MDA=0.44	0.138±0.010
Akhsu region area	0.38±0.06	0.161±0.09

Table 2. The results of the specific activity of radionuclide analysis in rivers and channels.

River and cannels water samples,	Specific activity, Bq/l	
	^{226}Ra	^{228}Ra
Kur river	0.36±0.12	0.178±0.25
Yukhari Garabakh channel	0.48±0.03	0.154±0.06
Yukhari Shirvan channel	0.39±0.07	0.143±0.04

Studies of radionuclide transport in geologic systems based on naturally-occurring decay-series disequilibria such as the multiple – tracer approach of the present study, have the advantage of obtaining *in-situ* hydrologic information integrated over a range of time scales. This study provides a clearer picture of the physical and chemical hydrology of the Central region of Azerbaijan as an example to be applied to other areas around Kura River.

Radiation dose estimation

For proper dose evaluation, several factors such as the weighted average activity concentration in (Bq l^{-1}), amount of water intake by person in one year, and dose coefficient for ingestion of radionuclides by humans (mSv Bq^{-1}) should be addressed considering the radionuclides in drinking water.

Effective doses calculated by the above equation for different age groups including infants, children, and adults are presented in table 3. Note that the doses ranged from 1.78-7.26 mSv y^{-1} for infants, 3.04- 11.83 mSv y^{-1} for children, and 0.53-0.92 mSv y^{-1} for adults. Table 3 shows that the children, adults, and infants received a higher dose, respectively.

The doses obtained for well (artesian) waters in our study were higher than the recommended reference levels of 0.26, 0.2, and 0.1 mSv yr^{-1} for effective doses of infants, children, and adults, respectively as published by IAEA [22], WHO [17], and UNSCEAR, from one-year consumption of drinking water. Thus, it can be concluded that the investigated waters are not suitable for life-long human consumption.

Comparison of results with findings of other countries

^{226}Ra and ^{228}Ra concentrations in the present work were compared with other countries' values, as presented in table 4. (In the next two pages)

According to the results, the values of ^{226}Ra concentrations found in this work are far higher than those reported from other countries, though they are lower than the values obtained in Yemen.

Therefore, monitoring the natural radioactivity in drinking water is crucial for public health studies, allowing the assessment of population exposure to radiation with consumption of water. The occurrence of radionuclides in drinking water poseshealth hazards due to human internal exposure from the decay of radionuclides absorbed into the body through ingestion. This study was conducted to examinethe presence of natural radioactivity elements in drinking and mineral water using gamma spectrometry technique and to compare the concentration of radioactive elements; ^{238}U, ^{232}Th, and ^{40}K found in water samples as well as to test its safety for humans.

When the representative sampling shows that

[DOI: 10.18869/acadpub.ijrr.18.2.323]

the parametric indicator value of 0.1 mSv/year is exceeded, necessary measures should be taken (35).

The activity concentration of ^{226}Ra &^{228}Ra in 9 drinking water samples collected from different locations ranged from the lower limit of detection LLD (0.36±0.12 Bq l^{-1} to 0.48±0.03 Bql^{-1}) with a mean of 0.12 mBq l^{-1} and (0.138±0.01 Bq l^{-1} to 0.183±0.22 Bql^{-1}) with a mean of 0.46 mBq l^{-1}, respectively as reported in tables 1 and 2.

The cancer risk coefficients of ^{226}Ra &^{228}Ra for morbidity and mortality cases have been (1.04×10^{-8} and 7.17×10^{-9} Bq^{-1}) and (2.81×10^{-8} and 2.00×10^{-8} Bq^{-1}), for ^{226}Ra &^{228}Rarespectively [36]. So, the cancer morbidity and mortality risk due to ^{226}Ra &^{228}Ra in drinking water during the life (70 y) could be estimated and presented in Tables 4 and 5. The results indicate that the cancer morbidity risk ranged from 7.3×10^{-5} to 9.8×10^{-5} with a mean value of 8.4×10^{-5} and 2.8×10^{-4} to 3.7×10^{-4} with a mean value of 3.2×10^{-4} for ^{226}Ra &^{228}Ra,respectively, while the cancer mortality risk ranged from 1.1×10^{-4} to 1.40×10^{-4} and 3.9×10^{-4} to 5.3×$10^{-4}$with an average of 4.6×10^{-4} for ^{226}Ra &^{228}Ra, respectively.

Table 3. Estimates of annual effective doses in mSv y^{-1} in terms of ingestion of ^{226}Ra and ^{228}Ra for different age groups.

Sample code	^{226}Ra			^{228}Ra			Total doses		
	Infants	Children	Adults	Infants	Children	Adults	Infants	Children	Adults
Yevlakh region area	69*10^{-2}	134*10^{-2}	67*10^{-2}	156*10^{-2}	25*10^{-2}	6*10^{-2}	226*10^{-2}	384*10^{-2}	74*10^{-2}
Goycay region area	49*10^{-2}	95*10^{-2}	48*10^{-2}	129*10^{-2}	206*10^{-2}	5*10^{-2}	178*10^{-2}	301*10^{-2}	53*10^{-2}
Barda region area	56*10^{-2}	109*10^{-2}	55*10^{-2}	147*10^{-2}	235*10^{-2}	6*10^{-2}	203*10^{-2}	344*10^{-2}	61*10^{-2}
Akhdash region area	68*10^{-2}	132*10^{-2}	66*10^{-2}	658*10^{-2}	1051*10^{-2}	27*10^{-2}	726*10^{-2}	1183*10^{-2}	92*10^{-2}
Akhcabadi region area	63*10^{-2}	123*10^{-2}	62*10^{-2}	118*10^{-2}	188*10^{-2}	5*10^{-2}	181*10^{-2}	312*10^{-2}	66*10^{-2}
Akhsu region area	55*10^{-2}	106*10^{-2}	53*10^{-2}	138*10^{-2}	220*10^{-2}	5*10^{-2}	192*10^{-2}	326*10^{-2}	59*10^{-2}
Kur river	52*10^{-2}	101*10^{-2}	50*10^{-2}	152*10^{-2}	243*10^{-2}	6*10^{-2}	204*10^{-2}	344*10^{-2}	57*10^{-2}
Yukhari Garabakh channel	69*10^{-2}	134*10^{-2}	67*10^{-2}	132*10^{-2}	210*10^{-2}	5*10^{-2}	201*10^{-2}	345*10^{-2}	73*10^{-2}
Yukhari Shirvan channel	56*10^{-2}	109*10^{-2}	55*10^{-2}	122*10^{-2}	195*10^{-2}	5*10^{-2}	178*10^{-2}	304*10^{-2}	60*10^{-2}
Mean	60*10^{-2}	116*10^{-2}	58*10^{-2}	195*10^{-2}	311*10^{-2}	8*10^{-2}	254*10^{-2}	427*10^{-2}	66*10^{-2}

Table 4. The activity concentration range, the cancer morbidity risk, cancer mortality risk, and lifetime average daily dose of ^{226}Ra in drinking water samples

^{226}Ra concent ration range	^{226}Ra concentration value (Bq l^{-1})a	Cancer morbidity risk	Cancer mortality risk
Maximum	0.48±0.03	9.8*10^-5	1.4*10^-4
Minimum	0.36±0.12	7.3*10^-5	1.1*10^-4
Average	0.41±0.07	8.4*10^-5	1.2*10^-4

Table 5. The activity concentration range, the cancer morbidity risk, cancer mortality risk, and lifetime average daily dose of ^{228}Ra in drinking water samples

^{228}Ra concent ration range	^{228}Ra concentration value (Bq l^{-1})a	Cancer morbidity risk	Cancer mortality risk
Maximum	0.183±0.22	3.7*10^-4	5.3*10^-4
Minimum	0.138±0.010	2.8*10^-4	3.9*10^-4
Average	0.16±0.09	3.2*10^-4	4.6*10^-4

[DOI: 10.18869/acadpub.ijrr.18.2.323]

Table 6. The activity concentration of ^{226}Ra, ^{232}Th, and 40K in Bql^{-1} of the investigated samples in comparison with other countries.

Country	Type of water	Activity Concentration in Bql^{-1}			Referenses
		^{226}Ra	^{232}Th	^{40}K	
Egypt Egypt Egypt (Qena)	-	Mean 0.20 1.83-18.53 Mean 0.08	Mean 0.13 1.47-12.78 Mean 0.04	Mean 5.29 8.09-64.48 -	[5,20]
Yemen	-	2.01-6.55	1.07-2.93		[20,23]
Sudan	-	0.007-0.014	0.001-0.039		[24]
Brazil	-	0.01-3.79			[10]
China	-	Max 0.93			[16]
Sweden	-	0.016-4.9			[25]
Finland	-	0.01-49			[5]
Denmark	-	0.55			[5]
Poland	-	0.001-0.049			[5]
China	Ground water	Min. 0.001 Max. 0.94 Mean 0.013			[26]
Finland	Ground water in bedrock (Drilled wells) Ground water in soil (Dug wells and springs)	Mean 0.11 Mean 0.01			[13]
China	Ground water	Up to 0.39	0.01		[13]
Denmark (Island of Bornholm)	Wells	0.55			[13]
India (Bombay)	Tap water		2.9×10^{-5}		[27]
Inner Mongolia	Tap water Wells Springs		1.9×10^{-4} 8.8×10^{-5} 3×10^{-4}		[27]
Germany (Erzgebirge)	Tap water		5×10^{-4}		[27]
U.S.A (New York)	Tap water		5×10^{-5}		[27]
Austria	Domestic bottle water	0.04			[27]
Tunisia	Springs	0.034-3.9			[29]
Hungary	Bottled mineral water	0.1-3			[30]
Portugal	Mineral water	0.03			[13]
Poland (Lodz)	Underground water	0.01-0.05			[13]
Qena (Egypt)	Drink water Ground water	0.05 0.079	0.027 0.041		[13]
Safaga-Quseir (Egypt)	Drink water Ground water	0.056 0.11	0.029 0.05		[13]
Pakistan	Drink water	0.011	0.005	0.141	[31]
Italy	Mineral water	0.01 – 0.052			[32]
Nigeria	Drink water			0.57 – 34.08	[7]
Iran	Drink water (Guilan)	0.038			[33]
Turkey	Drink water (Sumsun)	0.419	0.142	0.806	[34]

[DOI: 10.18869/acadpub.ijrr.18.2.323]

DISCUSSION

Radionuclide content was investigated in river and canals that flow into the Central Aran zone and bottom sediment of the territory. Rivers, crossing this zone connected to other water basins originate from the southern slope of the Greater Caucasus Mountains and from Karabakh and Murovdagh ranges. These rivers play the role of a carrier of geological and mineralogical information of the territory, where rivers have their sources. The Kur and Araz Rivers are affected by the impact of technogens and natural factors of both their sources and territories where the rivers flow. These waters are also used for irrigation in territories of the regions being investigated. Thus, the investigation of water and bottom sediments of these rivers allows characterizing their role in transport processes of their radionuclides [37,38].

Radionuclide content of groundwater, which is relatively shallow in close territories to the KurRiver, is compatible with each other within the waters of the Kur River, from which these canals originate. When taking groundwater from various depths, the collection of radionuclides comparatively exceeds those in the layers and waters close to the surface.

The results provided important information that clearly reveals the details of groundwater flow patterns and geochemical evolution of the aquifer as well. Using naturally-occurring uranium series nuclides, we have provided more detailed groundwater flow pathways, mixing volumes, and water/rock interaction, along with the prediction of solute migration rates. Series of zones preferential flow were identified representing pathways along which groundwater from the Kur River and main irrigation canals flows. Further, two zones of relatively stagnant groundwater were also identified [39].

The amount of radionuclides was comparatively higher in the waters of Kur and other rivers, which took their sources from the southern slope of the Greater Caucasus Mountains. This may also be explained by radionuclide content of waters contact flow time.

According to the results of the present study, Yevlakh region area had higher levels of ^{226}Ra and ^{228}Ra radiation. The average annual effective dose was calculated based on the intake of individual radionuclide ^{226}Ra and ^{228}Ra for mixed consuming water, which was obtained as 2.54 mSv y-1 for infants, 4.27 mSv y-1 for children, and 0.66 mSv y-1 for adults.

The activity concentrations of radionuclides in this study indicated higher levels of radionuclides in the drinking water of Azerbaycan in comparison with the findings in Italy [7], Austria [28], Brazil [10], Egypt[5,13,20], Yemen[20,23], Sudan[24], China[13,26]), Sweden[25], Finland([5], Denmark[5,13], Poland[5], India[27], Inner Mongolia[27], Germany[27]), U.S.A[27], Tunisia[29], Hungary[30], Portugal[13], Pakistan[31], Turkey [34], Iran [33], and Nigeria[7]. The values of ^{226}Ra concentrations presented in this work seemed to be far higher than the values reported from other countries, with the exception of Yemen which was higher than the values in the present study. According to the guidelines for drinking water of the Environmental Protection Agency (EPA), ^{226}Ra &^{228}Ra concentration in drinking water level should not exceed 0.74 Bq l^{-1}. So, the measured levels of ^{226}Ra &^{228}Ra in this research have been lower than the recommended level. Also, the level recommended by WHO in drinking water 1000 mBq l^{-1}, has been higher than our maximum concentration value. Based on the available information, it is assumed that any radiation exposure imposes a degree of risk to the public.

On the other hand, the United States Environmental Protection Agency (USEPA) has established the maximum contaminant level (MCL) for radium in public water supplies as 0.185 Bq/l (5 picocuries per liter).

According to ICRP recommendations, an effective dose of 1 mSv/y is considered as the limit for public exposure [30]. Accordingly, the doses measured in this study were significantly higher than the values recommended for all water types.

The radiological risk due to ^{226}Ra and ^{228}Ra in drinking water was calculated with obtained

[DOI: 10.18869/acadpub.ijrr.18.2.323]

results compared with the standard level of 10^{-3} for the radiological risk recommended by EPA. According to the results, the cancer mortality and morbidity risks for the study area were regarded to be negligible.

CONCLUSION

The natural radioactivity levels of ^{226}Ra and ^{228}Ra were measured in water samples by gamma ray spectroscopy. The obtained results for well waters revealed high activity concentrations, and the total effective doses due to all radionuclides were 2.54, 4.27, and 0.66 for infants, children, and adults, respectively, which were 9.77, 21.35, and 6.6 times the values of 0.26, 0.2, and 0.1 mSv for the recommended reference levels of effective dose from 1 year consumption of drinking water for infants, children, and adults, respectively. From these results, it can be concluded that the investigated water is not acceptable for life-long human consumption.

The calculated annual effective dose due to water consumption was higher than the average annual global range. Therefore, based on the findings, radionuclide intake due to the consumption of drinking water had adverse consequences for the public health in the evaluated regions.

The annual effective dose evaluations according to age groups indicated that infants and adult groups have the highest and lowest sensitivity to the presence of ^{226}Ra &^{228}Ra in drinking water. For these groups, the high value of dose absorption could be related to testosterone, which has significant rules to bone calcification during these life periods. The mortality and morbidity risks ranged from 7.3×10^{-5} to 9.8×10^{-5} with a mean value of 8.4×10^{-5} and from 2.8×10^{-4} to 3.7×10^{-4} with a mean value of 3.2×10^{-4} for ^{226}Ra and ^{228}Ra,respectively, while the cancer mortality risk ranged from 1.1×10^{-4} to 1.40×10^{-4} and from 3.9×10^{-4} to $5.3\times10^{-4}$with an average of 4.6×10^{-4} for ^{226}Ra and ^{228}Ra,respectively. These results were lower than the recommended level of WHO, 10^{-3}.

All calculated annual effective doses exceeded the international recommended values by several orders of magnitude leading to significant health hazards in these areas.

The high activity concentrations for ^{226}Ra and ^{228}Ra observed in well water samples explain the great impact of water infiltration from the pond to the underground water in the surrounding areas. Thus, precautionary measures should be taken when using this water in agricultural irrigation.

Conflicts of interest: *Declared none.*

REFERENCES

1. Murugesan S, Mullainathan S, Ramasamy V, *et al.* (2011) Radioactivity and radiation hazard assessment of Cauvery River, Tamilnadu, India. *Int J Radiat Res, **8(4)**: 211-222*.
2. Abbasi A and Bashiry V (2016) Measurement of radium-226 concentration and dose calculation of drinking water samples in Guilan province of Iran. *Int J Radiat Res, **14(4)**: 361-366*.
3. Njinga RL and Tshivhase VM (2017) Radio-epidemiological evaluation and remediation in water sources from two mines in South Africa. *Int J Radiat Res, **15(3)**: 307-315*.
4. Guogang J, Giancarlo T, Leandro M (2009) Concentrations of 238U, 234U, 235U, 232Th, 230Th, 228Th,226Ra, 228Ra, 224Ra,210Po, 210Pb And 212Pb in Drinking Water in Italy: Reconciling Safety Standards Based on Measurements of gross α and β. *J Environ Rad*, ***100**: 941-949*.
5. Hany El-Gamal, and Abdallah Ibrahim Abd El-Mageed (2014) Natural Radioactivity in Water Samples from Assiut City, Egypt. *Int J Pure Appl Sci Technol*, ***22(1)**: 44-52*.
6. Ajayi OS and Adesida G (2009) Radioactivity in some sa-chet drinking water samples produced in Nigeria. *Iran J Radiat Res, **7(3)**: 151 -153*.
7. Yussuf NM, Hossain I, Wagiran H (2012) Natural radioac-tivity in drinking and mineral water in Johor Bahru (Malaysia). *Scientific Research and Essays, **7(9)**: 1070-1075*.
8. Ajayi OS and Adesida G (2009) Radioactivity in some sa-chet drinking water samples produced in Nigeria. *Iran J Radiat Res, **7(3)**: 151-158*.
9. Ramachandran TV (2011) Background radiation, people and the environment. *Int J Radiat Res, **9(2)**: 63-67*.
10. Godoy JM and Godoy ML (2006) Natural radioactivity in Brazilian groundwater. *J Environ Radioact*, ***85**: 71-83*.
11. Ahmed NK (2004) Natural Radioactivity of Ground and Drinking Water in Some Areas of Upper Egypt. *Turk J Eng Env Sci, **28**: 345- 354*.

12. Pourimani R and Nemati Z (2016) Measurement of Radionuclide Concentration in Some Water Resources in Markazi Province, Iran. *Iran J Med Phys*, ***13(1)****: 49-57*.
13. UNSCEAR (1993) Sources and Efects of Ionizing Radiation, *UN Report, New York*
14. Malakootian M and Soltani Nejhad Y (2017) Radon concentration in drinking water of Bam villages. *Int J Radiat Res,* ***15(1)****: 81-89*.
15. ICRP (1996) Age-dependent doses to members of the public from intake of radionuclides: Part 5, Compilation of Ingestion and Inhalation Dose Coefficients. *Annals of the ICRP*, ***26(1)****: 72*.
16. Zhuo W, Lida T, Yang X (2001) Occurrence of 222Rn, 226Ra, 228Ra and U in groundwater in Fujian Province China. *J Environ Radioact*, ***53****: 111-120*.
17. WHO (2017) Guidelines for Drinking Water Quality: *Radiological Aspects.*
18. Abbasov Sh M, Suleymanov BA, Hummbatov FY, Mikailova AC, Lisanova E V (2005) Radium and radon isotops monitoring as indicators for groundwater characterisation along btc pipeline. *Workshop, Environmental Impact of oil transportation, Baku-Azerbaijan November* ***22-25****: 28-29*.
19. EPA (1999) Final draft for the drinking water criteria document on radium. *US Environmental Protection Agency, Washington, DC, Tr-1241-85*.
20. El-Mageed AA, El-Kamel A, Abbady A, *et al.* (2013) Natural radioactivity of ground and hot spring water in some areas in Yemen, *Desalination,* ***321:*** *28-31.*
21. Labidi S and Gharbi S (2018) Dose assessment to members of the pulic in Tunisia from intakes of some naturally occurring radionuclides in bottled mineral water. *Int J Radiat Res,* ***16(3)****: 371-381*.
22. IAEA (1996) International basic safety standards for protection against ionizing radiation and for the safety of radiation sources, *Safety Series 15.*
23. Harb S, El-Kamel AH, Zahran AM, Abbady A, Ahmed FA (2013) Natural radioactivity of ground water in Aden governorate South of Yemen Region. *Radiat Prot Environ,* ***36(3):*** *115-121.*
24. Alfatih AA, Isam S, Ibrahim A, *et al.* (2006) Investigation of natural radioactivity levels in water around Kadugli Sudan. *Appl Radiat Isot*, ***66****: 1650-1653*.
25. Saleh MMI, Pettersson HBL, Lund E (2002) Uranium and thorium series radionuclides in drinking water from drilled bedrock wells: Correlation to geology and bedrock radioactivity and dose estimation. *Radiat Prot Dosim*, ***102(3)****: 249-285*.
26. Weihai Z, Takao I, Xiaotang Y (2001) Occurrence of Rn-222, Ra-226, Ra-228 and U in Groundwater in Fujian Province China. *J Environ Radio*, ***53****: 111-120*.
27. Fisenne I M (2000) Thorium Isotopes in Humans. *Foodstuffs and the Environment Technology*, ***7****: 397- 406*.
28. Kralik C, Friedrich M, Vojir F (2003) Natural Radionuclides in Bottled Water in Austria. *J Environ Radio,* ***65****: 233-241*.
29. Labidi S, Dochraoui M, Mahjoubi H, Lemaitre N, Ben Salah R, Mtimet S (2002) Natural Radioactive Nuclides in Some Tunisian Thermo-Mineral Springs. *J Environ Radio*, ***62****: 87-96*.
30. Somlai J, Horvath G, Kanyar B, *et al.* (2002) Concentration of Ra-226 in Hungarian Bottled Mineral Water. *J Environ Radio*, ***62****: 235-240*.
31. Fatima I, Zaidi JH, Arif M, Tahir SNA (2007) Measurement of natural radioactivity in bottled drinking water in Pakistan and consequent dose estimates. *Rad Prot Dos*, ***123 (2)****: 234-40*
32. Kehagia K, Koukouliou V, Bratakos S*, et al*. (2007) Radioactivity monitoring in drinking water of Attika, Greece. *Desalination*, ***213****: 98-103*.
33. Abbasi A, and Bashiry V (2016) Measurement of radium-226 concentration and dose calculation of drinking water samples in Guilan province of Iran. *Int J Radiat Res,* ***14(4)****: 361-366*.
34. Altıkulac A¸ Turhan S, Gumus H (2015) The natural and artificial radionuclides in drinking water samples and consequent population doses. *J Rad Res Appl Sci,* ***8****: 578-582*.
35. Hosseini SA (2007) Radioactivity monitoring in drinking water of Zahedan, Iran (2007) *Iran J Radiat Res,* ***5(2)****: 97-100*.
36. Abbasi A and Mirekhtiary F (2019) Risk assessment of Radium-226 in drinking water samples. *Int J Radiat Res,* ***17 (1)****: 163-169*.
37. Qaribov AA, Suleymanov BA, Mikayilova AC (2012) Detrmination of natural radionuclides in drinking and agricultural water. *Chemstry Problems*, ***3****: 96-99*.
38. Abbasov Sh M, Suleymanov BA, Hummbatov FY, Mikailova AC, Ahmadov MM (2008) Distribution of Radionuclides in Central Region of Azerbaijan. *The fifth Eurasian conference on nuclear science and its application. Ankara-Turkey October,* ***14-17****: 225-226*.
39. Mikailova AC (2015)The radionuclide composition of artesian well water in the central zone .*International Multidisciplinary Forum Dedicated to the 70th anniversary of Azerbaijan National Academy of Sciences*, *420-421*.