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Dangers of elevated radon gas concentration in surface and ground waters in Al-Haydaria agricultural areas, Al-Najaf, Iraq

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ABSTRACT

Background and Purpose: Water is essential element of life, therefore watching water quality is of high necessity. The research in front of us dealing with measurement of ^{222}Rn concentrations in 40 water samples, of two sources: (20 samples of surface water, and another 20 samples of ground water).

Methods: These samples are collected from different spots in agricultural areas, in Al-hayderiah, Al-Najaf governorate, Iraq. This experimental study is done by measuring ^{222}Rn levels in surface and in ground waters using RAD-7 detectors.

Results: The average value of ^{222}Rn concentrations, in Bq/L, for the two types of water (surface and ground water) samples were: extended from 0.036±0.072 Bq/L to 0.144±0.051 Bq/L and the average value is 0.077±0.042 Bq/L for surface water, while for the ground water samples the concentrations were started from a value of 0.036±0.072 Bq/L to a value of 0.433±0.273 Bq/L and the average value is 0.207±0.125 Bq/L.

Conclusion: For both instances the levels were found to be within the internationally acceptable limits, that are complied with the recommendations advised by several notable international organizations and committees, including the EPA, WHO, UNSCEAR, and ICRP. Based on the study's findings, it seems safe to assume that the alpha emitter found in the majority of the water samples in this investigation poses no threat to human health.

Keywords. RAD-7 detector, Annual effective dose, Surface Water and Ground Water in Al-Hayderiah

INTRODUCTION

Radon is one of the rarest radioactive noble gases, usually found in the nature as one of the products of uranium-238 decay process. Radon owns nor odor and is tasteless, as well as it has no colour. This noble radioactive gas undergoes decaying process by emitting alpha particles that are distinguished by having characteristic chunks of energy, leading to formation of a set of briefly-lived radionuclides (for example polonium-218 and polonium-214). The half-life of Radon is (3.82 days), relatively long compared to some of its progenies, and it is sufficiently enough to be detected and measured. The surface of the soil is considered as the most important source of radon gas in the atmosphere. In addition to that, secondary sources contribute to the total concentration of Radon in the nature, like the ground and surface water, natural gases and volcanic eruptions, and other resources [1].

Natural radionuclides in water can be traced to their point of origin and to human activity in certain regions where fertilizers are utilized for agricultural purposes [2]. A number of trace elements found in fertilization products, including radon gas, have the ability to increase the amount of these naturally occurring radionuclides in the soil. Radiation exposure in surface and/or groundwater may increase as a result of industrial activities and processes that include the purification and processing of earth minerals or their by-products.

The surrounding rocks or lithological solid aquifers, which serve as reservoirs for groundwater that is accessed by wells and boreholes, may contain radionuclides. It is well knowledge that geological materials like solid aquifers and rocks contain trace levels of radioactive elements like radon gas. This element dissolves into groundwater due to the interaction of rocks, water, and soil[3-5].

Therefore, in contrast to other parts of the province of Al-Najaf, some chemicals and pesticides are utilized more frequently in these agricultural areas. As such, the measurement of radon levels has risen to prominence as one of the most pressing concerns related to the protection of human health from radioactive sources.

Radon exposure is likely to occur as a result of using contaminated water for common home activities like showering, dishwashing, cooking, and drinking. To measure the radon concentrations, Water samples are handled with the RAD-7 and RAD H20 accessories [6]. Recently, numerous nations have begun to use various procedures for measuring radionuclide amounts in water sources across their territory [7-11].

Radon levels in ground and surface water samples collected in the Al -Hadariah area were analyzed in the current investigation using a RAD-7 detector. In addition, the effective annual dose was determined for each of the water samples in relation to various age groups and lifetime cancer risk.

To that end, this research aims to assess radon concentrations in both groundwater and surface water samples from the Al -Haydariah district in the Najaf Governorate.

The reasons this area was selected for research were:

- First: how underground water has altered the region's rock structure.
- Second: the lack of environmental radiation revisions for this region.
- Third: this location's agricultural significance

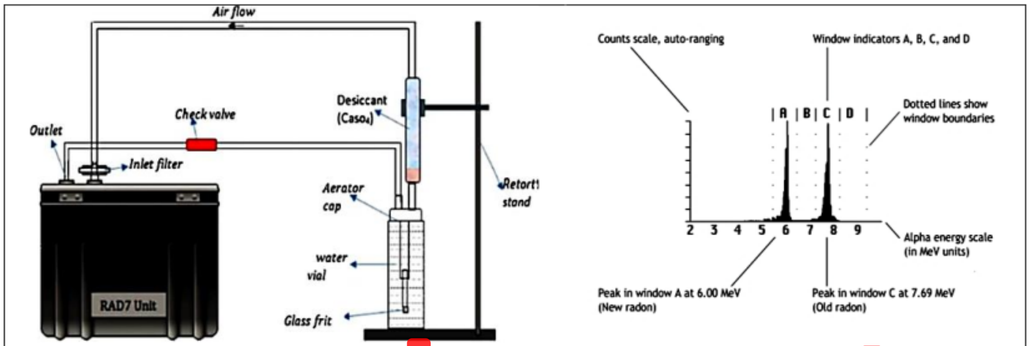
METHODS

The detector of the solid state RAD7 is a very helpful apparatus for this study. Figure(1) reveals a detector of solid-state which is manufactured from a material that has conductivity value lies between a conductor and an insulator (semiconductor silicon substance) that changes the energy of alpha particle radiation emitted because of the decomposition of a radioactive molecule ^{218}Po or ^{214}Po and it can distinguish between the two isotopes: the RAD7 can select the type of the isotope passing by the means of the recognition between them, by filtering of different electronic energy corresponding By means of an electrical signal, directly to alpha particles. Radon isotopes, specifically ^{218}Po*, a noble gas, release alpha energy at 6 MeV as* ^{214}*Po* or 7.97 MeV [12]. The radon gas isotopes ^{218}Po propel alpha particles with an energy ranging from 6 MeV to 7.97 MeV. The RAD7 cell has a size of 0.7 liters, and may be in the shape of a hemisphere as we can see it in the down image. In the figure (2), it is shown that the specially painted electric connector is supplied with elevated voltage supplier equipment, that exerts the starting high level voltage of about (2000 to 2500) volts all over the half ball shape (hemisphere). This initiates a field of electricity throughout the place. Because of the charged particles it contains, the detector cell produces a positive electrical field. Inside the cell, as ^{222}Rn atoms decay, a positive charge ^{218}Po is produced and interacts with the counter (detector), the detector's innermost core. The degrading atoms, ^{222}Rn , in the inner side of the cell and creating a positive charge ^{218}Po has a relatively short lifespan, and upon decomposition, it has an equal probability of 50% to impact the detector. This impact results in the generation of an electrical pulse current in the device along with alpha particle energies [13].

A RAD7 add-on that consistently tests for radon at different levels in water used for household purposes is the RAD H2O. After collecting a water sample, it can provide a radon concentration reading in as little as one hour [14].

The RAD H2O employs the standard protocols previously established for the RAD7 to accurately measure the concentration of Radon in the water samples being investigated. Thanks to a consistent conversion coefficient, the quantity or concentration of radon in a water sample can be determined by twice the amount of radon per unit size present in the air loop.

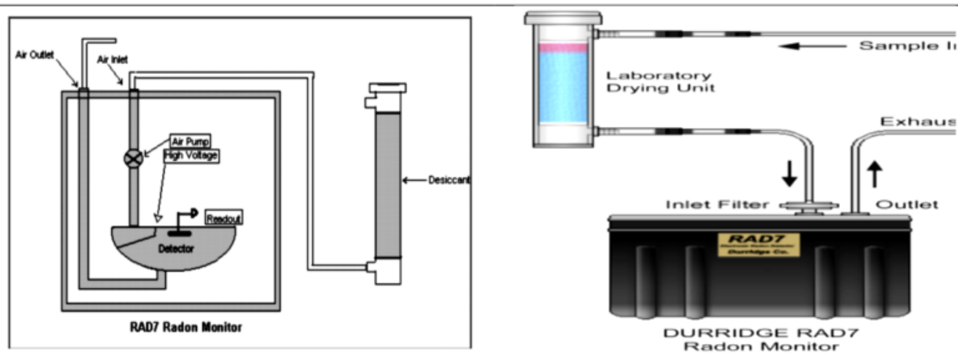
A coefficient of conversion to 4 of a 250 ml water sample vial is calculated by applying the volumes of the air circulation, the sample, and the radon distribution equilibrium coefficient at the usual ambient temperature. A system of closed circulation of air system (closed-loop aeration system) is applied during the procedure. The method in which the liquids (air and water) volumes are preserved at the starting level and unaltered by the flow rate. The Wet 250 water protocol check lasts nearly for half an hour to finish. At the start of the assessment, the RAD7's internal pump initiates automatically, running for a duration of 300 seconds (5 minutes). This process aerates the sample and conveys radon gas, free of other gases, to the RAD7 measurement cell. During the entire 300-second cycle, over 94 percent of the accessible radon is extracted from the water. The pump spontaneously stops working after a 5-minute cycle, then the machine holds on for another 5 minutes. Next, the machine restarts working and counting again. Therefore, the apparatus briefly reports the results in 5 minute cycles. The cycles continue for 30 minutes; Same the race continues for half an hour (half an hour it started operating). After four five-minute measurement cycles, the RAD7 produces a summary that includes the average radon concentration per unit size, or concentration. A cumulative spectrum, as shown in figure (1a), and a bar chart displaying the measurements from the four cycles are included in this summary [15]. The Radon concentration per unit volume of water (calculated automatically by the RAD7) is depicted in Figure (1b) [16].



(a) A visual representation displaying the spectrum of alpha particles and both elements ^{218}Po and ^{214}Po in channels A and C, respectively.

(b) Illustration demonstrating the procedure for assessing a water sample with RAD7 and its RADH2O derivatives.

Figure 1. Two images presenting the cumulative operational spectrum and measurement of a water sample utilizing the RAD7.



(a) The figure displays the internal RAD7.

(b) The figure displays the diagram in Part a.

Figure 2. The external and internal features of the RAD7 are shown in the image and the schematic

Site of Study

The city of Al-Haydariyah is situated in the northern part of Al Najaf governorate in Iraq, 40 km away from the governorate center, and on the road linking the two sacred cities of Karbala and Najaf. Al-Hydariyah is an administrative sub-district of the Najaf district. Astronomically, it is located between two latitudes (32°18' .28"- 32°20' .25") north and longitudes (44°14' .30" - 44°17' .13") east ,Figure(3).

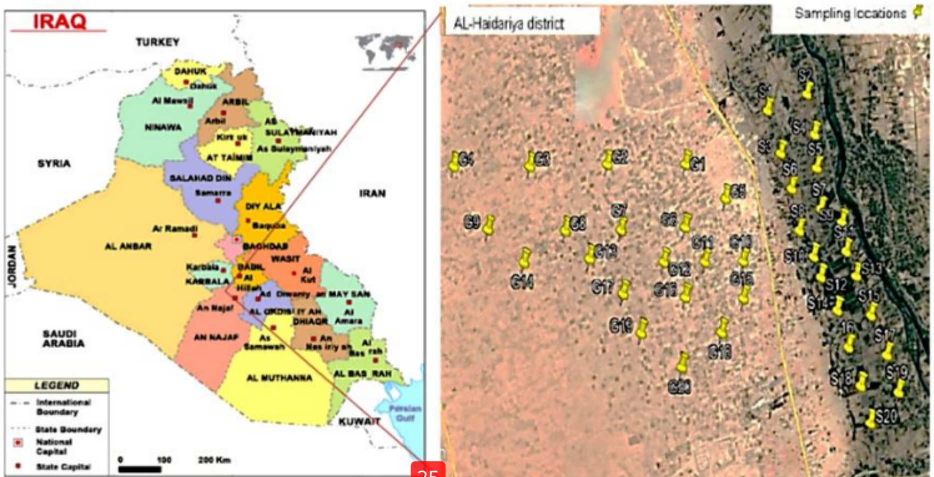


Figure 3. Map of the study area.

Materials and Methods

In this study, 40 water samples were meticulously chosen for examination from two agricultural areas within the Al-Haydariah region. This selection aimed to provide a comprehensive analysis of the ground and surface waters in the specified area. The sampling techniques employed were as follows: Initially, 20 groundwater samples were obtained from wells at each site, and an additional 20 samples were procured from surface water. Subsequently, each sample was carefully preserved in a 250-ml plastic container.

Moving forward, the radon levels in each sample were measured utilizing a handheld RAD-7 detector. The RAD H2O, serving as a companion kit for the RAD-7 reagent, facilitated the measurement of radon in water at concentrations less than 10 pCi/L [17]. This lightweight detector, powered by batteries, delivered precise readings in a short timeframe. The radon content in a water sample could be accurately gauged with this equipment in approximately 60 minutes. Its sensitivity is noteworthy; after about 30 minutes of testing, it can be used to obtain a single reading, matching or even exceeding that of liquid scintillation techniques [18]. After 5 minutes of aeration, the water had removed almost 95% of the radon that was present. RAD-7's inner cell's radon concentration was determined by using the following differential equations:

The following formula was used to estimate an individual's effective dosage (Ed) in (Sv/y) from ^{222}Rn in groundwater taken as drinking water[19]:

$$Ed = Ac\ Ai\ Cf \qquad (1)$$

Where Ai is the yearly intake of sachet drinking water in liters, Cf is the ingested dosage conversion factor for radionuclides in Sieverts per Becquerel, and Ac is the radioactive activity content in Bq/l of sachet water. In 2000, the United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) determined that the respective levels for adults, children, and newborns were 3.5 nSv/Bq, 5.9 nSv/Bq, and 23 nSv/Bq [20].

For the age groups of < 1, 2–17, and ≥ 17 years, the yearly consumption of sachet drinking water was recorded as 230, 330, and 730 liters, respectively [21]. The lifetime cancer risk attributable to radon concentrations in drinking water can be calculated using the following equation [22]:

$$lifetime\ cancer\ risk = Annual\ effective\ dose \times Average\ lifespan \times Risk\ coefficient \quad (2)$$

where six age groups' average lifespans were determined [23], and the risk coefficient was determined to be 0.055 Sv^{-1} based on public data (ICRP, 2007) [24]. The designated level of cancer risk is set at 10^{-3} [25].

The average radon concentration in the groundwater samples was found to be below what relevant international health organizations or specialized institutions consider to be the acceptable upper limit after the data was analyzed.

Results

The findings of the radon levels in each of the 20 surface water tests and the 20 ground water samples in these farming areas, which, because they make up a sizable portion of the radiation background, can irradiate a living thing, including humans, and cause a variety of diseases and disorders. When exposed to radon radioisotopes outside of the body, the human skin is thought to act as a barrier, with just two possible entry points inside the body: first by inhalation, or second by ingestion, i.e by drinking polluted water or eating polluted fruits and vegetables that are irrigated by polluted water (so that radon becomes one of the substances involved in the structure position of the fruits and vegetables.

The outcomes of ^{222}Rn concentrations in this research of the 40 samples (groundwater and surface water) using RAD-7) are shown in Table (1,3), and figure (4,7). Generally speaking, the prevailed results of radon concentration ranges of ground water (0.109 - 0.399) Bq/L with the mean of 0.235 Bq/L and the results of surface water (0.036 - 0.144) Bq/L with the mean of 0.074 Bq/L. The results exposed that radon concentration in the ground water samples have values below than the maximum globally permissible for the heath of animals and human beings. The range of total yearly effective doses that are transferred to babies through ingesting or drinking polluted ground water is (0.031-0.144) µSv/y, as indicated by Table (2,4) and Figure (5,7). The groundwater's radon content for children fell between 0.13 and 2.11 µSv/y. Additionally, the results obtained for adults varied from 3.07 to 39.42 µSv/y, with the corresponding mean values being 27.41±2.06, 10.08±0.76, and 13.23±0.99 µSv/y, respectively. Table (2,4) shows that the results show substantial differences in the dosage rate between the age groups. According to reports from the World Health Organization (WHO), all of the results for ^{222}Rn concentrations in water were found to be below the permitted limits set by the organization (0.5 Bq/L or 500 Bq/m3) for ^{222}Rn concentrations in drinking water for human consumption [27, 28]. The present study's groundwater and surface water samples' ^{222}Rn concentration values varied for a variety of reasons, including the water source used for collection.

Table 1. Radon concentrations of ground water.

No.	Sample Code	Radon Concentrations (Bq/L)
1	G1	0.203
2	G2	0.399
3	G3	0.199
4	G4	0.12
5	G5	0.181
6	G6	0.302
7	G7	0.211
8	G8	0.355
9	G9	0.195
10	G10	0.13
11	G11	0.217
12	G12	0.254
13	G13	0.362
14	G14	0.326
15	G15	0.31
16	G16	0.145
17	G17	0.29
18	G18	0.188
19	G19	0.109
20	G20	0.217
	Average	0.235±0.02
	WHO	0.5

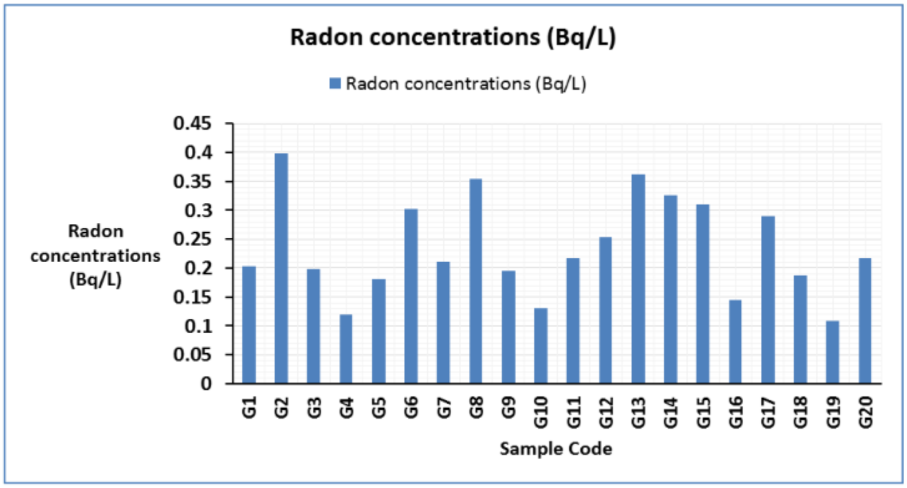


Figure 4. Radon concentration of ground water.

Table 2. Annual effective dose of ground water in three age groups.

No.	Sample Code	Annual effective dose (μSv/y)		
		≤ 1 y	**(2-17)y**	**≥ 17 y**
1	G1	1.074	0.395	0.519
2	G2	2.111	0.777	1.019
3	G3	1.053	0.387	0.508
4	G4	0.635	0.234	0.307
5	G5	0.957	0.352	0.462
6	G6	1.598	0.588	0.772
7	G7	1.116	0.411	0.539
8	G8	1.878	0.691	0.907
9	G9	1.032	0.380	0.498
10	G10	0.688	0.253	0.332
11	G11	1.148	0.422	0.554
12	G12	1.344	0.495	0.649
13	G13	1.915	0.705	0.925
14	G14	1.725	0.635	0.833
15	G15	1.640	0.604	0.792
16	G16	0.767	0.282	0.370
17	G17	1.534	0.565	0.741
18	G18	0.995	0.366	0.480
19	G19	0.577	0.212	0.278
20	G20	1.148	0.422	0.554
	Average	1.247±0.103	0.459±0.038	0.602±0.05
	UNSCEAR		1m Sv/y	

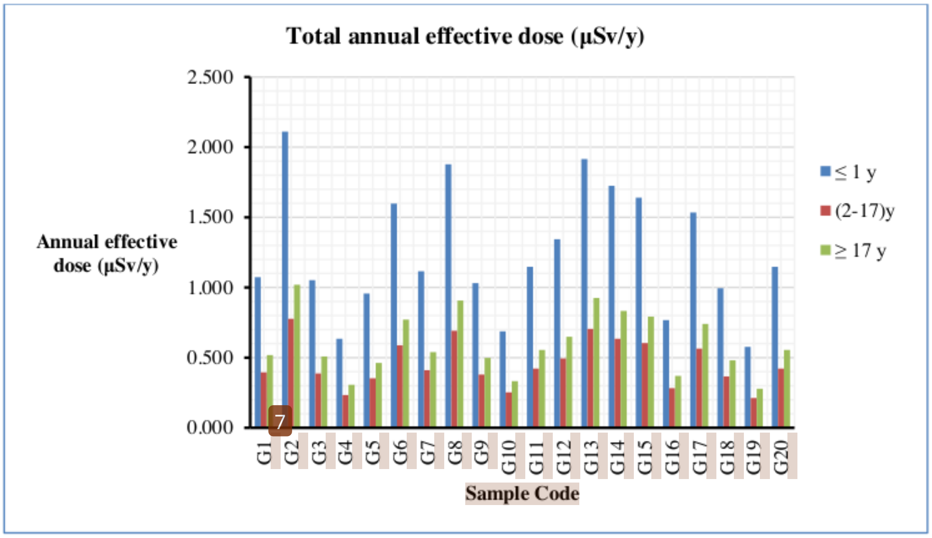


Figure 5. Annual effective dose of ground water in three age groups.

Table 3. Radon concentrations of surface water.

No.	Sample Code	Radon concentrations (Bq/L)
1	S1	0.036
2	S2	0.055
3	S3	0.039
4	S4	0.065
5	S5	0.041
6	S6	0.123
7	S7	0.077
8	S8	0.063
9	S9	0.075
10	S10	0.122
11	S11	0.072
12	S12	0.144
13	S13	0.031
14	S14	0.072
15	S15	0.044
16	S16	0.039
17	S17	0.083
18	S18	0.102
19	S19	0.096
20	S20	0.114
	Average	0.074±0.008
	WHO	0.5

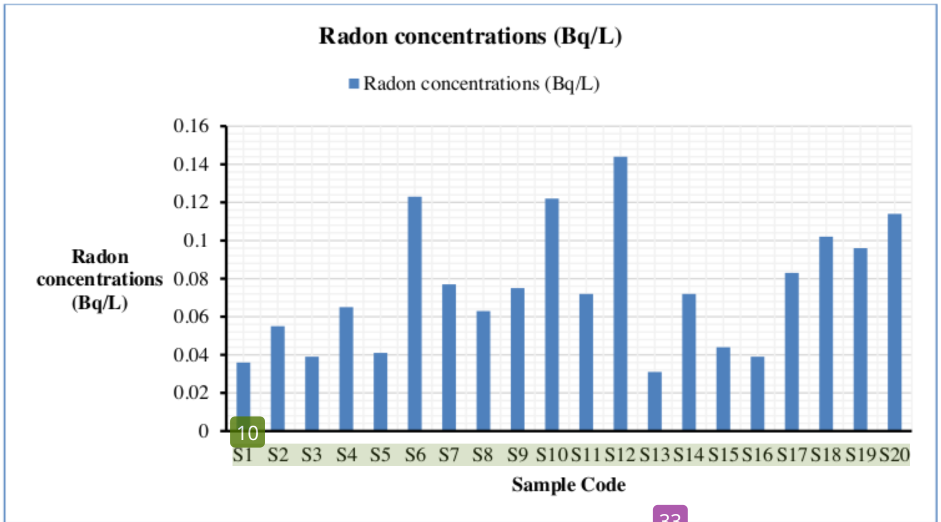


Figure 6. Radon concentration of Surface water.

Table 4. Annual effective dose of surface water in three age groups.

No.	**Sample Code**	**Annual effective dose (µSv/y)**		
		≤ 1 y	**(2-17)y**	**≥ 17 y**
1	S1	0.190	0.070	0.092
2	S2	0.291	0.107	0.141
3	S3	0.206	0.076	0.100
4	S4	0.344	0.127	0.166
5	S5	0.217	0.080	0.105
6	S6	0.651	0.239	0.314
7	S7	0.407	0.150	0.197
8	S8	0.333	0.123	0.161
9	S9	0.397	0.146	0.192
10	S10	0.645	0.238	0.312
11	S11	0.381	0.140	0.184
12	S12	0.762	0.280	0.368
13	S13	0.164	0.060	0.079
14	S14	0.381	0.140	0.184
15	S15	0.233	0.086	0.112
16	S16	0.206	0.076	0.100
17	S17	0.439	0.162	0.212
18	S18	0.540	0.199	0.261
19	S19	0.508	0.187	0.245
20	S20	0.603	0.222	0.291
	Average	0.394	0.145	0.190
	UNSCEAR		1m Sv/y	

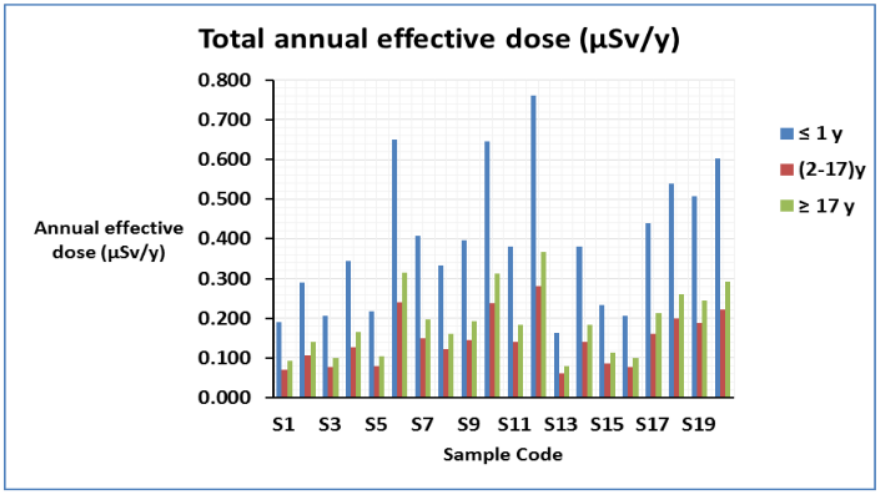


Figure 7. Annual effective dose of surface water in three age groups.

Discussion

The outcomes of the current scientific investigation, encompassing analyses and geographical areas, are presented in Table (1) and Figure (3). Each sample underwent a four-cycle analysis, during which the mean average of the three readings was calculated for all 40 locations where water samples were collected.

Table (1) reveals variations in measurements attributed to localized aqueous testing processes, indicating radon gas levels ranging from 0.120 Bq/L to 0.399 Bq/L for groundwater and 0.036 Bq/L to 0.144 Bq/L for surface water in the selected research area. The primary study conclusion indicates that the readings for groundwater and surface water in the investigated region were, on average, 0.5 Bq/L lower than the recommended levels by major health organizations such as WHO [29]. No universally accepted concentration of radon radiation for safe use by the general population has been established. While various studies on radon concentrations in water have been conducted in Iraq [28], there are currently no defined reference levels for radon gas in water. Even in neighboring countries to Iraq, safety requirements and standards have not been established, and they continue to rely on the levels set by the World Health Organization and UNSCAER.

Conclusion

The majority of the radon concentrations in the groundwater samples from Agricultural Areas in Al Hayderiah in Al-Najaf Alashraf were found to be below the levels considered to be either harmful or effective by the United States Environmental Protection Agency (EPA), the United Nations Scientific Committee on the Environment (UNSCEAR), the European Union Council (EU Council), and the World Health Organization (WHO). Consequently, it might be stated that the vast majority of samples are suitable for consumption and other household uses. For every location studied, annual effective doses were expected to be less than 100 Sv/y, regardless of age group.

References

[1] IAEA. Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM) and Technological Options for Mitigation, Technical Reports Series. 2003:419.

[2] Ghetti F, Checcucci G, Bornman JF, editors. Environmental UV Radiation: Impact on Ecosystems and Human Health and Predictive Models: Proceedings of the NATO Advanced Study Institute on Environmental UV Radiation: Impact on Ecosystems and Human Health and Predictive Models Pisa, Italy, June 2001. Springer Science & Business Media; 2006.

[3] Ahmed NK. Natural radioactivity of ground and drinking water in some areas of upper Egypt. Turkish Journal of Engineering and Environmental Sciences. 2004; 28(6):345-54.

[4] Bonotto DM, Bueno TO, Tessari BW, Silva A. The natural radioactivity in water by gross alpha and beta measurements. Radiation Measurements. 2009; 44(1):92-101.
[5] Povinec P, Hirose K, Aoyama M. Fukushima accident: radioactivity impact on the environment. Newnes; 2013 Jul 9.
[6] Malik MF, Rabaiee NA, Jaafar MS. Determination of radon concentration in water using RAD-7 with RAD H2O accessories. InAIP Conference Proceedings. AIP Publishing. 2015; 1657(1): 120005.
[7] Saidu A, Bala A. Assessment of the Specific Activity of Alpha-and Beta-emitting Radionuclides in Groundwater, Anka, Nigeria. Iranian Journal of Medical Physics. 2018; 15(4): 285-94.
[8] El-Taher A, Al-Turki A. Radon activity measurements in irrigation water from Qassim Province by RAD-7. Journal of environmental biology. 2016; 37(6):1299.
[9] Pourimani R, Nemati Z. Measurement of Radionuclide Concentration in Some Water Resources in Markazi Province, Iran. Iranian Journal of Medical Physics. 2016;13(1):49-57.
[10] Abojassim AA. Natural Radioactivity and Radon Concentrations in Parenteral Nutrition Samples Utilized in Iraqi Hospitals. Iranian Journal of Medical Physics. 2019;16(1):1-7.
[11] Parhoudeh M, Khoshgard K, Zare MR, Ebrahiminia A. Natural Radioactivity Level of 226Ra, 232Th, and 40K Radionuclides in Drinking Water of Residential Areas in Kermanshah Province, Iran using Gamma Spectroscopy. Iranian Journal of Medical Physics. 2019;16(1):98-102.
[12] RAD7 Radon Detector. User Manual. (2011). Durridge Company Inc.
[13] Manual CAPTURE version 4.7.5. (2011). Durridge Company Inc.
[14] RAD7 RAD H2O (2011). Radon in Water Accessory. Owner's Manual. Durridge Company Inc.
[15] Durridge Company Inc., Reference Manual, RAD-7 Electronic Radon Detector, (2017).
[16] Durridge Company Inc. (2010), Reference Manual version 6.0.1, RAD-7 Electronic Radon Detector.
[17] Abojassim AA, Kadhim SH, Mraity A, Abid H, Munim RR. Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets. Water Science and Technology: Water Supply. 2017;17(1):206-11.
[18] Alzurfi SK, Abojassim AA, Mraity HA. Monthly Monitoring of Physicochemical and Radiation Properties of Kufa River, Iraq. Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences. 2018;61(1):43-51.
[19] [Alam MN, Chowdhury MI, Kamal M, Ghose S, Islam MN, Anwaruddin M. Radiological assessment of drinking water of the Chittagong region of Bangladesh. Radiation protection dosimetry. 1999;82(3):207-14.
[20] United Nations. Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation: sources. United Nations Publications; 2000.
[21] World Health Organization. Guidelines for drinking-water quality: second addendum. Vol. 1, Recommendations. World Health Organization; 2011.
[22] Mathews, Gladys, et al. "Radiological and chemical toxicity due to ingestion of uranium through drinking water in the environment of Bangalore, India." Journal of Radiological Protection 35.2 (2015): 447.
[23] IAEA Safety Series. "International basic safety standards for protection against ionizing radiation and for the safety of radiation sources." (1996).
[24] Valentin, J., et al. "Published on behalf of the International Commission on Radiological Protection." (2007).
[25] Salman, A.Y., et al. *Study the contamination of radioactivity levels of 226Ra, 232Th and 40K in (water) Iraq and their potential radiological risk to human population*. in *IOP Conference Series: Materials Science and Engineering*. 2020. IOP Publishing.

[26] World Health Organization, and WHO. Guidelines for drinking-water quality. Vol. 1. world health organization, 2004.
[27] United Nations Scientific Committee on the Effects of Atomic Radiation. "Sources and effects of ionizing radiation. UNSCEAR 1996 report to the General Assembly, with scientific annex." (1996).
[28] Ting, David S-K. "WHO handbook on indoor radon: a public health perspective." (2010): 100-102.
[29] Environmental Protection Agency The United States Environmental Protection Agency. (2009). A citizen’s guide to radon.