Egypt. J. Chem. **Vol. 64,** No. 4 pp. 1889 - 1895 (2021)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Age-Dependent Health Risk Assessment for Radon Concentrations from Drinking Water Available in the Iraqi Markets

Nabeel A. Kadhim[a], Abdullah S.i Mdekil[b], Hawraa H. abbas[c] and Ali A. Abojassim[d]*

[a]*Ministry of Education, Najaf Education Office, Najaf, Iraq*

[b]*Ministry of Education, General Directorate for Wasit Education, Wasit, Iraq*

[c]*Physics Department, Collage of Science, Baghdad University, Baghdad, Iraq*

[d]*Physics Department, Faculty of Science, University of Kufa, Najaf, Iraq*

Abstract

Radon is occurring naturally, odourless, colourless, radioactive, tasteless, and a noble gas. It is the second most important cause of lung cancer after smoking in many countries. The rate of lung cancers attributable to radon is estimated to range from 3 to 14%. The dose exposure relation is linear, i.e. the risk of lung cancer increases proportionally with increasing radon exposure. So, it is necessary to measure radon concentrations in the drinking water that is of direct contact with human life and health. The study included measurement of radon (^{222}Rn) concentrations in some selected samples of drinking water (bottled water) are available in the Iraqi market. ^{222}Rn concentrations have been measured the usage of alpha spectroscopy (RAD-7). The RAD-7 measuring process is based on detecting alpha particles produced from the disintegration of radon and its products using a solid-state alpha detector (usually silicon), and then converting alpha radiation directly to an electrical signal. The annual effective dose and lifetime cancer risk in six age groups (3 months, 1 year, 5 years, 10 years, 15 years and adult) associated with the exposure due to an annual intake of ^{222}Rn were calculated. Results show that the average value of radon concentrations in drinking water samples was ranged from 28.4±2.7 mBq/L to 283±0.34 mBq/L. Also, it is found the average value of annual effective dose in unit µSv/y for six age groups were 0.48±0.08, 0.62±0.11, 0.18±0.03, 0.22±0.04, 0.37±0.06, and 0.27±0.05,respectively. The average value of lifetime cancer risk in same age groups were (17.99±3.26, 31.13±5.65, 46±8.37, 107.33±19.41, 276.5±50, and 926.33±168)$\times10^{-9}$ respectively. The results of ^{222}Rn concentrations in present study were found lower than the data of the recommended reference WHO 2008 (500 mBq/L or Bq/m3). Also, the results showed that the annual effective dose from drinking water exhaustion in six age groups were found lower than the permitted limit of (1mSv) suggested by UNSCEAR 2000. As well as, values of lifetime cancer risk were within the accepted level (10^{-3}). Therefore, there are no indications of significant threat from radon concentrations in bottled water brands, and it is safe as far as a health risk is concerned.

Keywords: Radon concentrations, annual effective dose, excess cancer risk, drinking water and Iraq.

1. Introduction

All humans acquire publicity from clearly going on radioactivity in soil, water, air, and food. The largest natural source of radiation exposure to humans is radon gas, that exists on air, water, and soil [1]. Radon is a mobile, chemically inert radioactive element, a colorless and odorless mono-atomic gas, boiling temperature is - 61.8ºC and its density is 9.73 kg/m^3[2]. It dissolves with water at a temperature of 20ºC. It is a noble gas that is chemically and atomically unreacted at normal temperatures due to its atomic number equal to 86 [2]. Radon is a radioactive gas decays by the emitting alpha particle to give a series of radionuclides that disintegrate also by emitting alpha particles, as well as beta and gamma radiation. Radon gas has of a significant health hazard which leads to radon monitoring in different environments around the world. It is contributes by over 50% of the total natural radiation that human received. Radon (^{222}Rn) is the most important isotope because of his long half-life relative to the other isotopes and due to the health risk that caused by exposure to its radioactive daughters. It is formed by the alpha decay of Radium

*Corresponding author e-mail: ali.alhameedawi@uokufa.edu.iq.
Receive Date: 24 December 2020, Revise Date: 29 December 2020, Accept Date: 26 January 2021
DOI: 10.21608/EJCHEM.2021.55039.3150

(^{226}Ra) which belongs to the decay chain of ^{238}U [3]. The second leading cause of lung cancer deaths in the United States is exposure to ionizing radiation from radon. The Environmental Protection Agency estimates that radon is in charge of for about 21,000 lung cancer deaths per year, and 2,900 of these deaths happen in patients who were non-smokers [4]. The risk of lung cancer increases significantly by 16% per 100 Bq/m^3 increase in radon concentration. Water is one such natural source that is fundamental for life. The principal health necessity for any developing country is a plentiful stockpile of clean water. Water is the most essential and valuable regular asset that is assumed to be released from pollution, specially pollution by radon. The direct route involves for drinking water, while the indirect route requires the ingestion of polluted water or cattle fed by contaminated fodder. Indirect intake, however, is commonly considered to be non-hazardous to health because of the small dose received. The EPA and the WHO recommended guidelines (separately) for the concentration of isotopes in drinking water, based on estimates of the person annual radiation and the type of radiation [5]. Drinking water in Iraqi markets were selected to measure ^{222}Rn concentrations for several reasons, the lack of radiation environmental studies around it, it is possible to effect drinking water in geological form of such regions, the source of water in these samples such as rain water that penetrates into the ground through its rock layers, or geological water originating from rocks between fresh water or seas that store water between its rocks, and its exposure to bombardment and environmental neglect more than the other countries. The human in Iraq may be exposed to radon gas during the drinking of contaminated water. So, the measurement of radon concentrations in drinking water samples provides an obvious picture of radioactive and chemical contamination of the exposed persons. Measurement of the radon levels and environmental safety were scrutinized by several recently studies in countries around Iraq and other countries in the world [6-11]. Recently, it has been observed that many harmful radioactive elements are present in drinking water which adversely affects the exposed living beings. So, the study focuses on the evolution of ^{222}Rn concentrations in drinking water samples in Iraqi markets using RAD-7 detector which is available in the nuclear laboratory of Physics department. The device used in this research is a RAD-7 detector, it is a versatile detector that is useful for detecting radon gas, and it includes a number of special features that distinguish it from other reagents, as well as it is an advanced measuring instrument that is widely used in laboratories and researches all over the world for all purposes various for example continuous monitoring in the air, radon or thorn inhalation, radon gas measurement in water, soil gas testing and radon and throne emissions from materials and surfaces.

2. Materials and Method

60 samples (4 samples for one sample) of different types of drinking water (product in Iraq) were obtained from the local markets in Iraqi for January 2020 to measure the radon levels. In the present study, the concentrations of drinking samples of water were estimated using the RAD-7 device (Durridge company, Inc.- Bedford, MA, U.S.A) as can be seen in Figure.1. To conduct the above measurements, the Rad-7 was provided with accessories specified for water detection, namely RADH2O(11-13). These accessories allow the detection of a wide range of radioactivity in water samples (i.e. 3.7 mBq/ L up to 3 kBq/ L [14]. The accuracy of its reading can be reached within 30 min acquisition runs. The total duration of the test was half an hour for one sample at (4) cycles per five-minute session, the arithmetic average for radon concentration and effective dose was calculated. It can be calculated the annual effective dose (E_d) in six age groups based on current age-specific (ICRP 1996) [15] that received from ingestion of water containing radon to different age groups using the equation [11,16]:

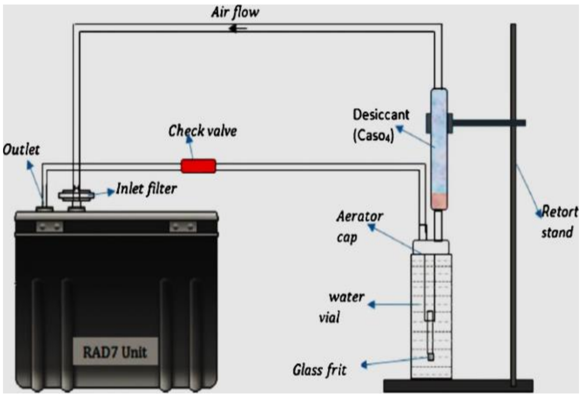
$$E_d = A_c\, A_i\, C_f \qquad (1)$$

where, A_c is the ^{222}Rn concentrations, A_i is the annual water consumption and C_f is the dose conversion factor. It is 23, 5.9 and 3.5 (nSv/Bq) for different age groups infants, children and adults respectively [17]. The values of Ai for in six age groups based on the public (IAEA 1996) [18].

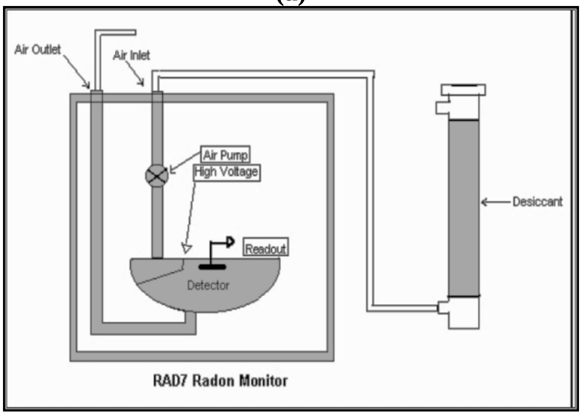
While, the lifetime cancer risk due to radon concentrations in drinking water can be found, using the equation [19]:

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

where, average lifespan in six age groups[18] and the risk coefficient is 0.055 Sv^{-1} based on the public (ICRP,2007) [20].



(a)



(b)

Fig. 1. Schematic representation: (a) RAD-7 (RADH$_2$O), (b) RAD-7 device diagram [14]

3. Results and Discussions

Our attention in this study focused on the nuclear radiation that was represented by the alpha particles emitted from ^{222}Rn gas in the drinking water, as it constitutes a good percentage of the radiation background that can be exposed to the human or the organism, and the human skin is considered a barrier to radon in the event of external exposure to it the only way to enter it into the body is either by inhalation or ingestion, that is, to drink water or the substances involved in its composition. The results of ^{222}Rn concentrations in 15 samples name of drinking water (bottled water) using RAD-7 are indicated in Table 21. Generally, from Table 1 radon concentrations in mBq/L unite ranged from 28.4±2.7 (sample H1, Aquafina, Baghdad) to 283±8.4 (sample H6, Live, Duhok) with an average mean of 104.14±18.91. From Table 1. And Figure 2, it can be seen that all results of the ^{222}Rn concentrations of drinking water (bottled water) were lower than the allowed limits of the world (0.5 Bq/L or 500 Bq/m^3) for ^{222}Rn concentrations in drinking water for human conception given by the as reported in world health organization WHO [21, 22]. The variation or difference in ^{222}Rn concentrations values for drinking water samples in the present study to many reasons such as the source of water that used to produce bottled water, climate factor and time made of bottled water. Also, It is found that, the average value of ^{222}Rn concentration in samples that product in Baghdad, Kirkuk, Duhok, Babylon, and Najaf were 109.9 mBq/L, 56.5 mBq/L, 158.5 mBq/L, 106 mBq/L, and 98.4 mBq/L, respectively, as shown in Figure 3. Figure 3 presents a comparison for the radon concentrations according to the origin that is product in Iraq Baghdad, Kirkuk, Duhok, Babylon and Najaf. The Duhok samples were characterized by the highest value of ^{222}Rn, while the lowest value was in Kirkuk samples, this reason may be attributed to the geological structure of an area.

Table 1: Results of Radon concentrations for drinking water samples in this study

No.	Sample Name	Origin	Sample Code	Radon concentrations (mBq/L)
1	Aquafina		H1	28.4±2.7
2	Ganaen	Baghdad	H2	88.7±4.7
3	Venezia		H3	212.5±7.3
4	Mona	Kirkuk	H4	33±2.9
5	Crown		H5	80±4.5
6	Live	Duhok	H6	283±8.4
7	Zalal		H7	34±2.9
8	Waha	Babylon	H8	70±4.2
9	Sawa		H9	142±6.0
10	Saqe		H10	141.5±5.9
11	Paratha		H11	189±6.9
12	Mazya	Najaf	H12	47.3±3.4
13	Tour		H13	106.3±5.2
14	Sanam		H14	71±4.2
15	Noire		H15	35.4±3.0
		Average±S.E		104.14±18.91

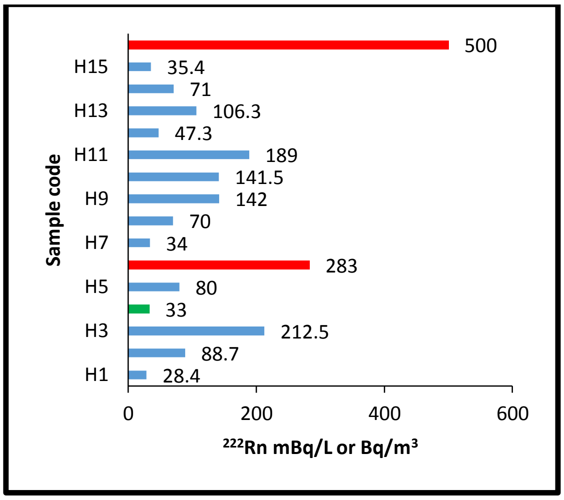


Fig. 2. Comparison of radon concentration with world limit by WHO

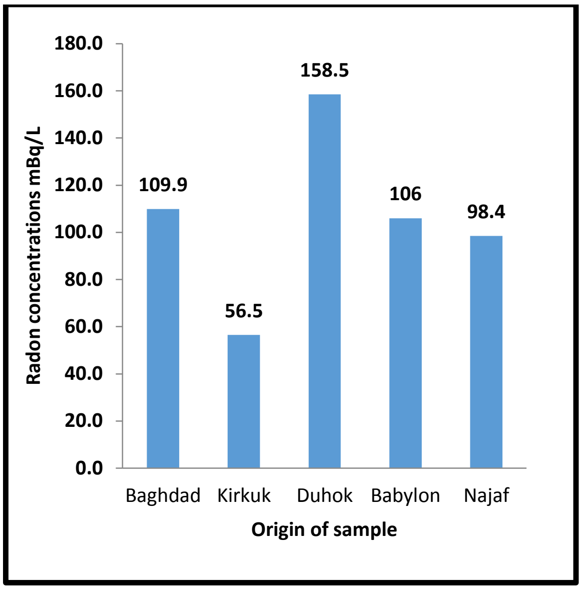


Fig. 3. Comparison of radon concentration in different origin samples

The results of the annual effective dose (E_d) in six age groups (3 months, 1 year, 5 years, 10 years, 15 years and adult) based on ^{222}Rn concentrations in drinking water (bottled water) are shown in Table 2. From Table 2, it can be seen the values of E_d for 3 months age were ranged from 0.13 to 1.30 µSv/y, for 1 year age group were ranged from 0.17 to 1.69 µSv/y, for 5 years age groups were ranged from 0.05 to 0.50 µSv/y, for 10 years age groups were ranged from 0.06 to 0.58 µSv/y, for 15 years age groups were ranged from 0.10 to 1.00 µSv/y, and for adult age groups were ranged from 0.07 to 0.72 µSv/y. Also, from Table 2 it is found that the average value of annual effective dose in µSv/y for six age groups were 0.48±0.08, 0.62±0.11, 0.18±0.03, 0.22±0.04, 0.37±0.06 and 0.27±0.05 respectively. All values of annual effective dose for six age groups of the present study was less than the natural limits for the public (1 mSv/y) given by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [23], then average values of annual effective dose for age groups were lower than value of WHO (See Figure 4). Figure 5 includes comparisons of annual effective dose due to ^{222}Rn concentrations in drinking water under study for main age groups (infinite, children and adult). It is found that the annual effective doses consumption by infants is larger than the dose from consumption by adults and children (1-15 years old). This larger value for infants is due to the high sensitivity of tissues of infants' body.

Table 2: Results of annual effective dose in six age groups for drinking water samples in this study

No.	Sample code	Annual effective Dose (µSv/y) 3 months	1 year	5 year	10 year	15 year	Adult
1	H1	0.13	0.17	0.05	0.06	0.10	0.07
2	H2	0.41	0.53	0.16	0.18	0.31	0.23
3	H3	0.98	1.27	0.38	0.44	0.75	0.54
4	H4	0.15	0.20	0.06	0.07	0.12	0.08
5	H5	0.37	0.48	0.14	0.17	0.28	0.20
6	H6	1.30	1.69	0.50	0.58	1.00	0.72
7	H7	0.16	0.20	0.06	0.07	0.12	0.09
8	H8	0.32	0.42	0.12	0.14	0.25	0.18
9	H9	0.65	0.85	0.25	0.29	0.50	0.36
10	H10	0.65	0.85	0.25	0.29	0.50	0.36
11	H11	0.87	1.13	0.33	0.39	0.67	0.48
12	H12	0.22	0.28	0.08	0.10	0.17	0.12
13	H13	0.49	0.64	0.19	0.22	0.38	0.27
14	H14	0.33	0.42	0.13	0.15	0.25	0.18
15	H15	0.16	0.21	0.06	0.07	0.13	0.09
Average±S.E		0.48±0.08	0.62±0.11	0.18±0.03	0.22±0.04	0.37±0.06	0.27±0.05

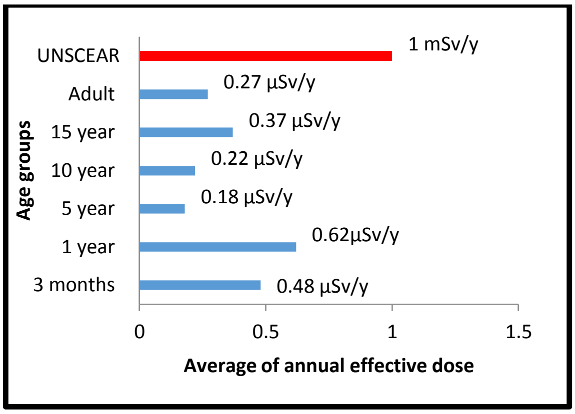


Fig. 4. Comparison of average of annual effective dose in six age groups with world limit by UNSCEAR

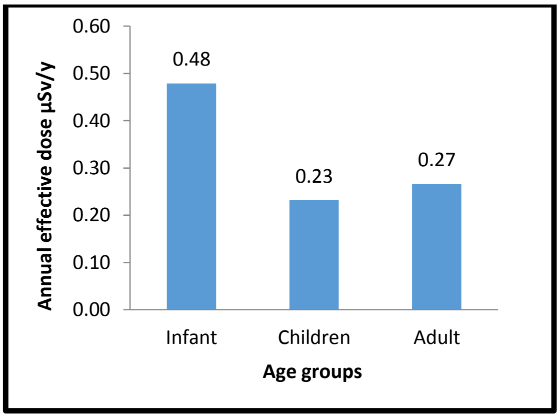


Fig. 5. Comparison of annual effective dose in main age groups

The results of lifetime cancer risk in the same six age groups were shown in Table 3. From Table 3., it can be seen lifetime cancer risk ($\times 10^{-9}$) for 3 months, 1 year, 5 years, 10 years, 15 years and adult age groups were ranged from 4.9 to 48.8, from 8.5 to 84.5, from 12.5 to 125, from 30 to 290, from 75 to 750, and from 245 to 2520, respectively. As well as, from Table 3. the average lifetime cancer risk in Nano unit for all age groups was 17.99±3.26, 31.13±5.65, 46±8.37, 107.33±19.41, 276.5±50 and 926.33±168 respectively. While, the average value of lifetime cancer risk in main age groups were (18.0, 115.2 and 926.3)$\times 10^{-9}$ respectively. The results of lifetime cancer risk for the collected drinking water samples understudy in six age groups were lower than the acceptable level of cancer risk that it is equal to 10^{-3} [19,24], therefore the cancer risk of cancer is negligible.

Table 3: Results of lifetime cancer risk in six age groups for drinking water samples in this study

No.	Sample code	Lifetime cancer risk$\times 10^{-9}$ 3 months	1 year	5 year	10 year	15 year	Adult
1	H1	4.9	8.5	12.5	30	75	245
2	H2	15.4	26.5	40	90	232.5	805
3	H3	36.8	63.5	95	220	562.5	1890
4	H4	5.6	10	15	35	90	280
5	H5	13.9	24	35	85	210	700
6	H6	48.8	84.5	125	290	750	2520
7	H7	6.0	10	15	35	90	315
8	H8	12.0	21	30	70	187.5	630
9	H9	24.4	42.5	62.5	145	375	1260
10	H10	24.4	42.5	62.5	145	375	1260
11	H11	32.6	56.5	82.5	195	502.5	1680
12	H12	8.3	14	20	50	127.5	420
13	H13	18.4	32	47.5	110	285	945
14	H14	12.4	21	32.5	75	187.5	630
15	H15	6.0	10.5	15	35	97.5	315
	Average±S.E	17.99±3.26	31.13±5.65	46±8.37	107.33±19.41	276.5±50	926.33±168

The results of the current study were compared with the results of other studies in different countries of world, which were conducted to measure ^{222}Rn concentration in drinking water as shown in the Table 4. This Table reveals that the highest ^{222}Rn concentrations values are observed in Jamaica [28] and lowest was in Saudi Arabia[29]. The values of ^{222}Rn in the current study are lower than the results of Malaysia [8], India[25], Pakistan[26], Iran[27], Jamaica [28], and Egypt[30].

Table 4. Comparison of ^{222}Rn concentration in drinking water of present study to other research.

Country	^{222}Rn concentrations (Bq/L)	Reference
Malaysia	5.7±0.68	[8]
India	3.75	[25]
Pakistan	5.67 ± 1.34	[26]
Iran	9.02	[27]
Jamaica	18±2	[28]
Saudi Arabia	0.10 ± 0.02	[29]
Egypt	0.125	[30]
Iraq	0.104±0.018	This Study

4. Conclusions

In this research, ^{222}Rn concentrations were estimated using RAD-7 (RADH$_2$O), in drinking water (bottled water) samples produced in Iraq. Also, the annual effective dose (E_d) was calculated in six age groups (3 months, 1 year, 5 years, 10 years, 15 years, and adult) in this study. The average value of ^{222}Rn concentrations was 0.104±0.018 Bq/L, on the other hand; the average values of Ed for six age groups in the drinking water samples were 0.48±0.08, 0.62±0.11, 0.18±0.03, 0.22±0.04, 0.37±0.06, and 0.27±0.05 respectively. The findings demonstrate that the levels of ^{222}Rn concentrations and E_d in drinking water samples from a six age group lower than in the acceptable limits according to WHO 2008 and UNSCEAR 2000. It is found annual effective dose from drinking water consumption by infants is larger than the dose from consumption by adults and children. Also, it is found lifetime cancer risk due to radon concentrations in six age groups is very little, therefore, it may be decided that the risk of cancer is negligible. There are no health hazards when drinking water samples under this study. This study gives a sensitive and reliable procedure for determining the levels of ^{222}Rn concentrations for drinking water in Iraq that are consumed daily. Certainly, this study was conducted to provide a health-oriented radon concentration assessment of drinking water in Iraq, address long term management goals, especially from the environmental point of view. The results provide a framework for future studies that should include a large and broader survey of radon concentration in Iraq.

Conflicts of interest

There are no conflicts to declare.

Formatting of funding sources

By the authors themselves.

Acknowledgments

The authors are thankful to university of Kufa for their help in this work.

.

References

[1] Baskaran, M. (2016). Radon measurement techniques. In Radon: A tracer for geological, geophysical and geochemical studies (pp. 15-35). Springer, Cham.

[2] Carroll, Q. B. (2018). Radiography in the Digital Age: Physics-exposure-radiation biology. Charles C Thomas Publisher.

[3] Rubin, B. (2015). Introduction to Radon transforms (Vol. 160). Cambridge University Press.

[4] Baskaran, M. (2016). Physical, Chemical and Nuclear Properties of Radon: An Introduction. In Radon: A Tracer for Geological, Geophysical and Geochemical Studies (pp. 1-14). Springer, Cham.

[5] Ting, D. S. K. (2010). WHO handbook on indoor radon: a public health perspective.

[6] Roudi, A. M., Kamyab, H., Chelliapan, S., Ashokkumar, V., Kumar, A., Yadav, K. K., & Gupta, N. (2020). Application of response surface method for Total organic carbon reduction in leachate treatment using Fenton process. Environmental Technology & Innovation, 19, 101009.

[7] Yadav, K. K., Kumar, S., Pham, Q. B., Gupta, N., Rezania, S., Kamyab, H., ... & Talaiekhozani, A. (2019). Fluoride contamination, health problems and remediation methods in Asian groundwater: A comprehensive review. Ecotoxicology and environmental safety, 182, 109362.

[8] Ahmad, N., Rehman, J. U., Rafique, M., & Nasir, T. (2018). Age-dependent annual effective dose estimations of 226Ra, 232Th, 40K and 222Rn from drinking water in Baling, Malaysia. Water Science and Technology: Water Supply, 18(1), 32-39.

[9] Velu, M., Balasubramanian, B., Velmurugan, P., Kamyab, H., Ravi, A. V., Chelliapan, S., ... & Palaniyappan, J. (2020). Fabrication of nanocomposites mediated from aluminium nanoparticles/Moringa oleifera gum activated carbon for effective photocatalytic removal of nitrate and phosphate in aqueous solution. Journal of Cleaner Production, 124553.

[10] Abojassim, A. A., Mohammed, H. A. U., Najam, L. A., & El-Taher, A. (2019). Uranium isotopes concentrations in surface water samples for Al-Manathera and Al-Heerra regions of An-Najaf, Iraq. Environmental earth sciences, 78(5), 132.

[11] El-Taher, A. M., Abojassim, A. A., Najam, L. A., & Mraity, H. (2020). Assessment of Annual effective Dose for Different Age Groups based on Radon Concentrations in the Groundwater of Qassim, Saudi Arabia. Iranian Journal of Medical Physics, 17(1), 15-20.

[12] Alzurfi, S. K. L., Abojassim, A. A., & Mraity, H. A. A. (2018). Monthly Monitoring of Physicochemical and Radiation Properties of Kufa River, Iraq. Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences, 61(1), 43-51.

[13]] Abojassim, A. A., Kadhim, S. H., Mraity, H. A. A., & Munim, R. R. (2017). Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets. Water Science and Technology: Water Supply, 17(1), 206-211.

[14] Durridge Company Inc. (2010), Reference Manual version 6.0.1, RAD-7™ Electronic Radon Detector.

[15] ICRP (1996) International Commission on Radiological Protection Age-dependent doses to members of the public from intake of radionuclides: part 5 compilation of ingestion and inhalation
dose coefficients. ICRP Publication 72. Ann ICRP 26(1)

[16] Alam, M. N., Chowdhury, M. I., Kamal, M., Ghose, S., Islam, M. N., & Anwaruddin, M. (1999). Radiological assessment of drinking water of the Chittagong region of Bangladesh. Radiation protection dosimetry, 82(3), 207-214.

[17] UNSCEAR., 1993 United Nations Scientific Committee on the Effects of Atomic Radiation Sources and Effect of Ionizing Radiation, New York, United Nations.

[18] IAEA (1996) International Atomic Energy Agency—international basic safety standards for protection against ionizing radiation and for the safety of radiation sources. Vienna, Safety Series-115.

[19] Mathews, G., Nagaiah, N., Kumar, M. K., & Ambika, M. R. (2015). Radiological and chemical toxicity due to ingestion of uranium through drinking water in the environment of Bangalore, India. Journal of Radiological Protection, 35(2), 447.

[20] Valentin, J. (2007). The 2007 recommendations of the international commission on radiological protection (Vol. 37, No. 2-4, pp. 1-133). Oxford: Elsevier.

[21] World Health Organization. WHO (2008) Guidelines for drinking water quality. World Health Organization Recommendations. 4th Ed. Geneva, 1-6.

[22] Abojassim, A. A., Kadhim, S. H., Ali Mraity, H. A., & Munim, R. R. (2017). Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets. Water Science and Technology: Water Supply, 17(1), 206-211.

[23] United Nations Scientific Committee on the Effects of Atomic Radiation, & Annex, B. (2000). Exposures from natural radiation sources. United Nations, New York.

[24] Kim, Y.S., Park, H.S., Kim, J.Y., Park, S.K., Cho, B.W., Sung, I.H. & Shin, D.C. (2004). Health risk assessment for uranium in Korean groundwater. Journal of environmental radioactivity, 77, 77-85.

[25] Kumar, A., Kaur, M., Sharma, S., & Mehra, R. (2016). A study of radon concentration in drinking water samples of Amritsar city of Punjab (India). Radiation Protection and Environment, 39(1), 13.

[26] Ahmad, N., Uddin, Z., Rehman, J. U., Bakhsh, M., & Ullah, H. (2020). Evaluation of radon concentration and heavy metals in drinking water and their health implications to the population of Quetta, Balochistan, Pakistan. International Journal of Environmental Analytical Chemistry, 100(1), 32-41.

[27] Shamsaddini, M., Negarestani, A., Malakootian, M., & Javid, N. (2020). Study of radon concentration of drinking water sources in adjacent areas of Sabzevaran fault. Journal of Radioanalytical and Nuclear Chemistry, 326(2), 1437-1446.

[28] Smith, L., & Voutchkov, M. (2017). Assessment of radon levels in drinking water wells in St. Catherine, Jamaica. Journal of Health and Pollution, 7(16), 31-37.

[29] Abuelhia, E. (2019). Assessment of radiation dose from radon ingestion and inhalation in commercially bottled drinking water and its annual effective dose in Eastern Province, Saudi Arabia. International journal of environmental health research, 29(2), 164-172.

[30] Khaled, S. D., Khaled, A. M., Shaban, R. H., & Baset, A. A. (2020). Measurement of 222Rn concentration levels in drinking water samples from Qena city (Egypt) and evaluation of the annual effective doses. International Journal of Radiation Research, 18(2), 227-233.