Al-Nahrain Journal of Science
ANJS, Vol. 26 (4), December, 2023, pp. 67-72

Radioactivity Levels Determination and Radiological Hazards in the Drink and Well Water Samples in Baghdad

Athraa Naji Jameel

Physics Department, College of Education, Mustansiriyah University, Baghdad, Iraq

Article's Information

Received: 06.10.2022
Accepted:23.10.2023
Published: 01.12.2023

Keywords:
Radioactivity Levels
Drink and well water
HPGe detector

Abstract

Samples have been collected from two sources of water: drinking water and well water, for various depths for the Al- Bayaa region in Baghdad using a gamma spectrometer with the Germanium HPGe detector. The results of the analysis show that the average activity concentrations were 1.19±0.5 for 238U, 0.96±0.2 for 232Th, and 10.5±0.5 $Bq/$L for 40K in drinking water samples, and1.77±0.5 for 238U, 1.03±0.2 for 232Th, and 12.6± 0.5Bq/L for 40K in well water samples, respectively. The results were less than their recommended. The study also calculated the radiation hazards represented by the radium equivalent activity, Gamma index, Hazard Index, Absorbed gamma dose rate, Annual effective dose equivalent, and Lifetime cancer risk. All the radiological parameters in water drinking and well samples were within the range of the global limit; thus the water drinking and well water was Safe and free from radioactive contamination in that area.

DOI: 10.22401/ANJS.26.4.10
*Corresponding author: athraanaje@yahoo.com

1. Introduction.

Water is important elements for life and environment. Water must be free from pollution. Water is one of the necessities for all plant and animal life, and there are two primary natural sources from which it can be obtained: surface water from freshwater lakes, rivers, and streams and ground water from boreholes and wells [1,2]. Groundwater from artesian wells (pump) is defined as the groundwater layer that get from deeper drilling or subsoil far below the surface; the depth of ground wells water ranges between 7 and 10 meters from ground level [3,4]. The possibility of increased radioactivity in groundwater is increased by the existence of chemical industrial facilities, etc. [5]. The ingestion of human body to this type of radiation, through consumed and inhaled or drinking water [6,7]. Additionally, contamination from naturally occurring radionuclides brought on by human activity through non-nuclear industrial processes (e.g. mining, coal combustion, fertilizer production, etc.) [8]. The radionuclide exposes the individual to both internal and exterior radiation risks. Gamma radiation, which is released by each radionuclide and poses an external radiation risk, is more dangerous than internal radiation. The Monitoring the level of natural radioactivity in our The external environment shows how much Radiation exposure-related pollution [9,10]. The purpose of this study get to know the radioactivity in a sample of drinking water and well water, followed by the assessment of the radioactivity's internal and external hazard index in this samples.

2. Materials and methods

Twelve samples were collected from Al-Bayaa region in Baghdad; six drinking water samples were from the tap and six samples well water from the same homes that collected drinking water from it as shown in Table 1. Filter paper the suspended sample minutes from the water samples. Each sample was washed with diluted hydrochloric acid and the sample weight was also calculated and then put into plastic containers designed to collect water samples and closed completely for four weeks for a secular equilibrium. The detector in the using (HPGe) spectroscopy, operates at voltages of (+4000V), with crystal dimension 3"x3". The detector is surrounded by a lead shield . Inside the detector, there is a voltage regulator is used to reduce the variation voltages . A standard source of Marinelli beaker of 152Eu with energies was used to calibrate the energy (411.1, 444.6, 964.0, 1408.0, 344.3, 778.9, 121.8, 1112.0, 1085.8 and 244.7 keV).

3. Calculations

3.1. Specific activity

An Equation was used to determine the radionuclide concentration in the drinking water and well samples [11, 12].

$$\boldsymbol{A} = \frac{N}{\mathcal{E} \times \boldsymbol{I_\gamma} \times \boldsymbol{T} \times \boldsymbol{V}} \quad \ldots (1)$$

where; N is the net peak area of the radionuclide of interest, ε is the detector efficiency, V; is the volume of the water sample, and T is the time of measurements .

3.2 Radium equivalent activity

The following equation represents the radium equivalent activity [13].

$$Ra_{eq.}(Bq./kg) = A_{Ra} + 1.43\, A_{Th} + 0.077\, A_k \ldots (2)$$

where AU, ATh and AK are the activity concentration of 238U, 232Th and 40K.

3.3 Gamma-index

The gamma-index was determined in this study using a formula recommended by the European Commission [14, 15].

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad \ldots (3)$$

3-4 Hazard Index

The following two hazard indices are calculated using the given relations to determine the gamma ray radiation dangers caused by the indicated radioactive components in water samples [16, 17].

$$H_{ex} = \frac{A_{Ra}}{370\, Bq/kg} + \frac{A_{Th}}{259\, Bq/kg} + \frac{A_K}{4810\, Bq/kg} \ldots (4)$$

$$H_{ex} = \frac{A_{Ra}}{185\, Bq/kg} + \frac{A_{Th}}{259\, Bq/kg} + \frac{A_K}{4810\, Bq/kg} \quad \ldots (5)$$

3.5 Absorbed gamma Dose Rate

The absorbed dose rate due to gamma-ray emission from the radionuclides (238U, 232Th and 40K) in air. The absorbed dose of radiation is the energy imparted per unit mass of the irradiated material [18, 19].

$$D_{out}(nGy/h) = 0.462\ \mathrm{A}_U + 0.621\mathrm{A}_{Th} + 0.0417\ \mathrm{A}_K \quad \ldots (6)$$

$$D_{in}(nGy/h) = 0.92\ \mathrm{A}_U + 1.1\ \mathrm{A}_{Th} + 0.081\ \mathrm{A}_K \quad \ldots (7)$$

3.6 Annual Effective Dose Equivalent

The annual effective dose equivalent (AEDE) Which was determined using the relations as follows [20].

$$AEDE_{\ in}\left(\frac{\mu Sy}{Gy}\right) = D_{in} \times 10^{-6} \times 0.8 \times 8760\ \frac{h}{y} \times 0.7\ \frac{Sy}{Gy} \quad \ldots (8)$$

$$AEDE_{out}\left(\frac{\mu Sy}{Gy}\right) = D_{out} \times 10^{-6} \times 0.2 \times 8760\ \frac{h}{y} \times 0.7\ \frac{Sy}{Gy} \quad \ldots (9)$$

The occupancy factor for indoor and outdoor is 0.8 and 0.2, respectively, and the conversion coefficient from the absorbed dose in the air to the effective dose received by humans is 0.7 Sv/Gy.

3.7 Life-time cancer risk

The excess lifetime cancer risk is used to quantify the likelihood or additional the risk of developing lung cancer as a result of indoor exposure to radionuclides. The ELCR was determined using the following formula based on calculated values of the annual effective dose [21, 22].

$$ELCR_{in} = AEDE_{in} \times DL \times RF \quad \ldots (10)$$

$$ELCR_{out} = AEDE_{out} \times DL \times RF \quad \ldots (11)$$

where AEDE is the Annual effective dose equivalent, DL is the duration of life (70yrs), and RF is risk factor (0.05 Sv-1). For stochastic effects, ICRP 60 uses values of 0.05/Sv .

4. Results and discussion

The activity concentrations of 238U, 232Th, and 40K radionuclides in the drinking water and well water samples are shown in Table 1. The an average concentrations of 238U, 232Th, and 40K were 1.19±0.5, 0.96±0.2, and 10.5±0.5 Bq/L in drinking water samples. The average

Al-Nahrain Journal of Science
ANJS, Vol. 26 (4), December, 2023, pp. 67-72

concentrations of 238U, 232Th, and 40K were 1.77±0.5, 1.03±0.2 and 12.6±0.5 *Bq/L* in well water samples, as shown in Figure 1. These results were less than the allowed limit of UNSCEAR, 2000[23]. The concentration of 238 U, 232Th, and 40K in drinking water samples was lower than in well water samples because the operations of Purification and removal of contaminants from drinking water and treatment.

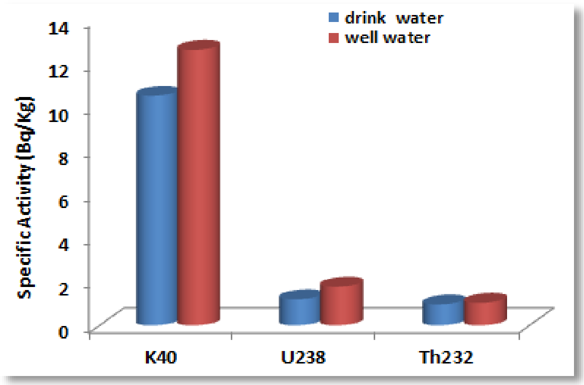

Figure 1. Specific activities for drinking and well water samples.

Table 1. The activity concentration of ^{238}U, ^{232}Th, and ^{40}K in drinking water and well water samples.

Sample No	Water type	^{238}U	^{232}Th	^{40}K
D1	drink	3.0	1. 6	12.5
D2	drink	1.2	1.09	10.3
D3	drink	2.08	1	12.1
D4	drink	0.99	0.88	8.54
D5	drink	2.06	1.28	11
D6	drink	1	0.95	9
Average ±SD		**1.19±0.5**	**0. 96±0.2**	**10.5±0.5**
W1	well	2	1.23	14.81
W2	well	3.2	1.93	13.3
W3	well	2.1	1	12
W4	well	2.03	0.95	10.91
W5	well	2.39	1.09	13.2
W6	well	3.0	1.08	11.6
Average± SD		**1.77±0.5**	**1.03±0.2**	**12.6±0.5**

Table 2 showed the values of radium equivalent activity, gamma-index, internal and external hazard index. The values of radium equivalent activity in drinking water samples were range from 0.022 to 0.008 with average of 0.013±0.002, from 0.025 to 0.006 with average of 0.013 ±0.002 and from 0.017 to 0.06 with average of 0.01±0.001 respectively. The radium equivalent activity was between from 2.206 to 6.251*Bq*/L with an average value 3.5±0.5*Bq*/L in drinking water samples. And the an ranged from 2.35 to 6.984*Bq*/L with mean value 4.5±0.6 *Bq*/L in well water samples, see figure 2.

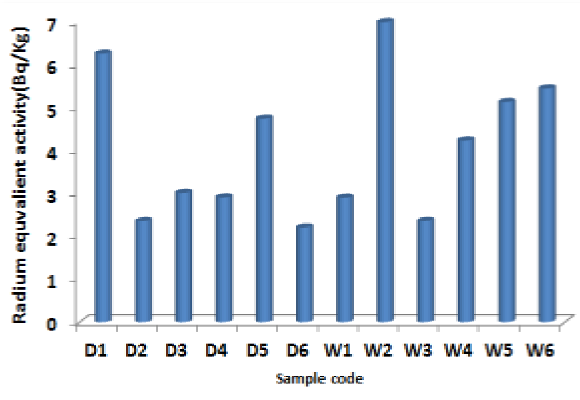

Figure 2. Radium equivalent activity for drinking and well water samples.

The values of $I\gamma$, Hin and Hex in drinking water sample ranged from 0.022 to 0.008 with an average of 0.013±0.002, from 0.025 to 0.006 with an average of 0.013 ±0.002 and from 0.017 to 0.06 with an average of 0.01±0.001 respectively. The an values of $I\gamma$, Hin and Hex in well water samples range from 0.025 to 0.009 with average of 0.016±0.002, from 0.028 to 0.006 with average of 0.017 ±0.003 and from 0.019 to 0.006 with an average of 0.01±0.002 as shown in Figure 3. These results were lower than the allowed limit.

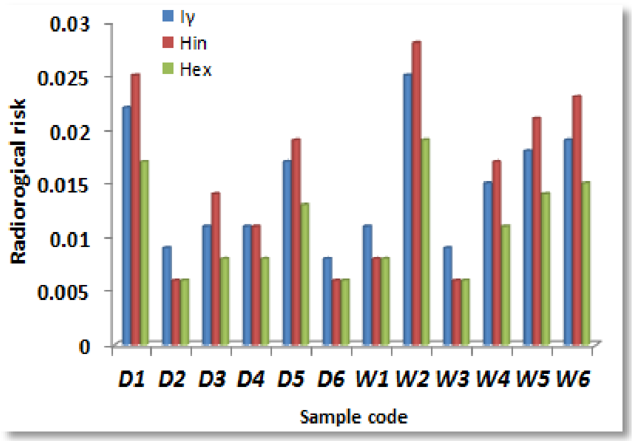

Figure 3. The gamma-index, internal and external hazard index for drinking and well water samples.

Table 2. Radiological Hazards (Ra_{eq}, I_γ, H_{in} and H_{ex}) in drinking water and well water samples.

sample	Ra_{eq} (Bq/L)	I_γ	H_{in}	H_{ex}
D1	6.251	0.022	0.025	0.017
D2	2.352	0.009	0.006	0.006
D3	3.012	0.011	0.014	0.008
D4	2.906	0.011	0.011	0.008
D5	4.737	0.017	0.019	0.013
D6	2.206	0.008	0.006	0.006
Average ±SD	**3.5 ±0.5**	**0.013 ±0.002**	**0.013 ±0.002**	**0.01 ±0.001**
W1	2.899	0.011	0.008	0.008
W2	6.984	0.025	0.028	0.019
W3	2.354	0.009	0.006	0.006
W4	4.229	0.015	0.017	0.011
W5	5.122	0.018	0.021	0.014
W6	5.438	0.019	0.023	0.015
Average± SD	**4.5 ±0.6**	**0.016 ±0.002**	**0.017 ±0.003**	**0.01 ±0.002**

Table 3 displays Radiological Hazards (Din, Dout, AEDEin , AEDEout , ELCRin and ELCRout)) in drinking water and well water samples. The values of absorbed gamma dose rate Din range from 5.533 to 1.936 nGy/h with an average of 3.5±0.5, the value of *Dout* range from 2.865 to 1.025 nGy/h with an average value of 1.6±0.2 nGy/h in drinking water samples and the values of the *Din* range from 6.144 to 2.072 nGy/h with an average 4.0± 0.5, the values of the *Dout* range from 3.189 to 1.096 nGy/h with an average value of 2.0±0.2 nGy/h in well water sample Figure 4.

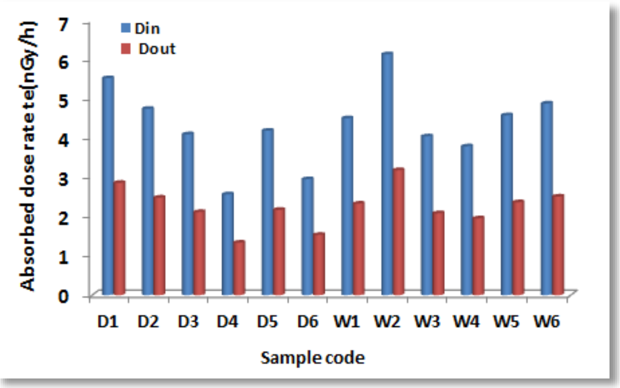

Figure 4. Absorbed Dose Rate for drinking and well water samples.

The values of outdoor and indoor annual effective dose equivalent ranged from 3.514 to 1.257 µ*Sv*/*y* with Average 2±0.3µ*Sv*/*y* , from 27.143 to 9.497 µ*Sv*/*y* with average 15±2.5 µ*Sv*/*y* in drinking water samples and The values of outdoor and indoor annual effective dose equivalent ranged from 3.911 to 1.344 µ*Sv*/*y* with Average 2.5±0.3µ*Sv*/*y* , from 30.14 to 10.164 µ*Sv*/*y* with average 19.6±2.7 µ*Sv*/*y* in well water samples. see Figure 5.

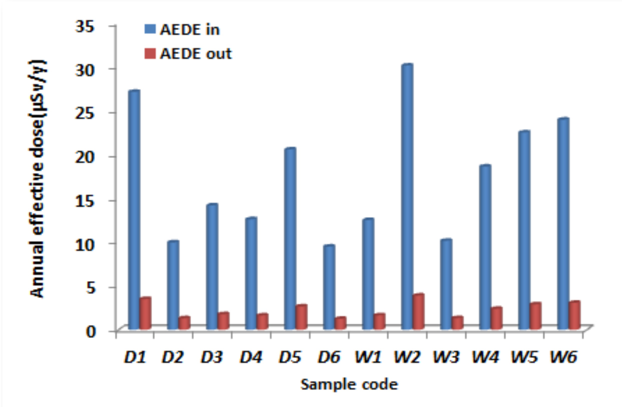

Figure 5. Annual effective dose equivalent for drinking and well water samples.

The values of *ELCR*in ,and *ELCRout* range from 95.001 to 33.24 with an average of 54.8±8.9, from 12.299 to 4.4 with an average of 7.1±1.1 in drinking water samples and from 105.49 to 35.574 with an average of 68.7±9.7, from 13.689 to 4.704 with an average of 8.9±1.2 in well water samples. All the obtained results which is less than the worldwide limit UNSCER 2000 [23].

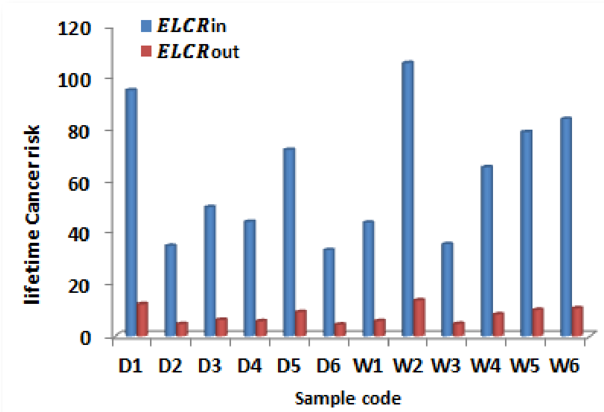

Figure 6. Lifetime cancer risk for drinking and well water samples.

Table 3. Radiological hazards (D_{in}, D_{out}, $AEDE_{in}$, $AEDE_{out}$, $ELCR_{in}$ and $ELCR_{out}$)) in drinking water and well water samples.

Sample Code	D_{in} (nGy/h)	D_{out} (nGy/h)	$AEDE_{in}$ (μSv/y)	$AEDE_{out}$ (μSv/y)	$ELCR_{in}$	$ELCR_{out}$
D1	5.533	2.865	27.143	3.514	95.001	12.299
D2	2.033	1.081	9.973	1.326	34.906	4.641
D3	2.894	1.457	14.197	1.787	49.69	6.255
D4	2.571	1.339	12.612	1.642	44.142	5.747
D5	4.194	2.176	20.574	2.669	72.009	9.342
D6	1.936	1.025	9.497	1.257	33.24	4.4
Average±SD	**3.5±0.5**	**1.6±0.2**	**15±2.5**	**2±0.3**	**54.8±8.9**	**7.1±1.1**
W1	2.553	1.35	12.524	1.656	43.834	5.796
W2	6.144	3.189	30.14	3.911	105.49	13.689
W3	2.072	1.096	10.164	1.344	35.574	4.704
W4	3.796	1.959	18.622	2.403	65.177	8.411
W5	4.588	2.37	22.507	2.907	78.775	10.175
W6	4.888	2.514	23.979	3.083	83.927	10.791
Average±SD	**4.0±0.5**	**2.0±0.2**	**19.6±2.7**	**2.5±0.3**	**68.7±9.7**	**8.9±1.2**

5. Conclusions

The activity concentrations and radiological of radionuclides 238U, 232Th, and 40K and hazard indicators were determined in drinking water and well water samples collected from the Al- Bayaa region of Baghdad city. The results of the activity concentrations and the radiological parameters such as Raeq, Iγ, Hin, Hex, Din, Dout, AEDEin, and AEDEout, as ELCRin and ELCRout were lower than the permissible limit recommended by UNSCEAR. When comparing the results were found to be in good compatibility with Alaboodi, A et al., 2020 results [24]. Through this study, it was found that drinking water is suitable for drinking and well water is suitable for domestic use.

References

[1] Vanloon, G.W.; Duffy, S.J.; “The Hydrosphere in Environmental Chemistry”: A Global Perspective (second edition), Oxford university press, New york, 197-211, 2005.

[2] Mendie, U.; “The nature of water The Theory and Practice of Clean water Production for Domestic and Industrial Use in Lagos, Lacto-Medals Publishers ”, 1-21, 2005.

[3] Rohanda, J.; Hamzah, A.; Rokhmadi.; “Analisis Kandungan Radionuklida Pada Inventori Bahan Bakar Bekas Reaktor Pwr 1000 Mwe Dengan Menggunakan Origen-Arp”, Jurnal Teknologi Pengelolaan Limbah, ISSN 1410-9565, 2013.

[4] Shohda, A.M.; Draz, W.M.; Ali, F.A.; Yassien, M.A.; “Natural radioactivity levels and evaluation of radiological hazards in some Egyptian ornamental stones”, J. Rad. Res. Appl. Sci.: 2018.

[5] Alaboodi, A.S.; Kadhim, N.A.; Abojassim A.A.; Hassan A.B.; “Radiological hazards due to natural radioactivity and radon concentrations in water samples at Al-Hurrah city ”, Int. J. Rad. Res. 18(1): 2020.

[6] Jameel, A.N.; “Radiological Risk Assessment and Radioactivity Concentration in Sediment of Tigris River of the Medical City/Bab Al Muadham”. Ibn Al-Haitham J. Pur. Appl. Sci. 35(1): 28-38, 2022.

[7] Korkmaz, G.F.; Camgoz, H.; “Natural radioactivity in various water samples and radiation dose estimations in Bolu province, Turkey”. Chemosphere 112: 134-140, 2014.

[8] Cothern, C.R.; Lappenbush, W.L.; “Compliance data for the occurrence of radium and gross alpha particle activity in drinking water supplies in the US. Health Phys. 46(503): 1984.

[9] Jameel, A.N.; Evaluation of the radiological hazard in some dried fruit and grain samples in Iraqi Markets by Using of gamma ray

Spectroscopy". J. Phys., Conf. Ser. IOP Publishing, 1879, 3,2021.
[10] Pujol, L.; Sanchez-Cabeza, J.A.; "Natural and artificial radioactivity in surface waters of the Ebro river basin (Northeast Spain)". J. Environ. Radio. 51(2): 181-210, 2000.
[11] Vayalill, PK.; "Antioxidant and antimutagenic properties of aqueous extract of date fruit (Phoenix dactylifera L. Arecaceae". J. Agri. Food Chem. 50: 610-617, 2002.
[12] Al-Yahyai, Al-Kharusi R.; Al-Yahyai L,; Al-Kharusi; "Physical and chemical quality attributes of freeze-stored dates" Int. J. Agric. Biol. 14(1): 97-100, 2012.
[13] Taskin, H.; Karavus, M.; Topuzoglu, P.; Ay, A.; Hidiroglu, S.; Karahan, G.; "Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli", Tur. J. Environ. Radio. 100: 49-53, 2009.
[14] Krisiuk, E.M.; Tarasov, S.I.; Shamov, V.P.; Shalak, N.I.; Lisa chenko, E.P.; Gomelsky, L.G.; "A Study on Radioactivity in Building Materials", Research Institute for Radiation Hygiene, Leningrad, 1971.
[15] Markkanen, M.; "Radiation dose assessments for materials with elevated natural radioactivity". Report STUK-B-STO 32, Radiation and Nuclear Safety Authority STUK, 1995.
[16] Isinkaye, M.O.; Agbi, J.I.; "Natural radioactivity and associated radiation hazards of some commonly used building materials in southwest Nigeria adioprotection", 48: 355-365, 2013.
[17] Xinwei,W.; Lingqing, J.; "Xiaodan Radiometric analysis of Chinese commercial granites", J. Radio. Nucl. Chem. 267 (3): 669-673, 2006.
[18] European Commission, EC "Radiation protection 112. Radiological protection principles concerning the natural radioactivity of building materials. Directorate-General Environment", Nuclear Safety and Civil Protection, 1999.
[19] UNSCEAR, Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations Publication, New York, USA,1993.
[20] Ravisankar, R.; Sivakumar, S.; Chandrasekaran, A.; Prince, J.; Prakash Jebakumar, I.; Vijayalakshmi P., Vijayagopal, et al.; "Spatial distribution of gamma radioactivity levels and radiological hazard indices in the east coast sediment of Tamilnadu, India with statistical approach", Rad. Phys. Chem. 103: 89-98, 2014.
[21] Alam, B.M.; "Distribu- on of radionuclides in soil samples in and around Dhaka City"; Appl. Rad. Isotopes 49: 133-137,1998.
[22] Ramasamy, V.; Murugesan, S.; Mullainathan S.; "Activity concentration and radiological hazards of Palar river sediment Tamilnadu", Ind. Metero. 40: 9-23, 2006.
[23] UNSCEAR, "United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation"; Report to General Assembly. Annex B: Exposures from Natural Radiation Sources, New York, 2000.
[24] Alaboodi, A.S., Kadhim, N.A., Abojassim, A. A., Hassan, A.B.; "Radiological hazards due to natural radioactivity and radon concentrations in water samples at Al-Hurrah city", Iraq Int. J. Rad. Res. 18(1): 1-11, 2020.