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EVALUATION OF RADON CONCENTRATIONS AND ASSOCIATED ANNUAL EFFECTIVE DOSE FROM DRINKING WATER IN SAMAWA CITY, SOUTH OF IRAQ

RUSSEL S. MOHAMMED AND ABDULAMEER K. FARHOOD*

Department of Physics, College of Science, Al-Muthanna University, Iraq

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ABSTRACT

Radon and itsr adioactive progenies in the indoor environment have been identified as the main sources of public radiation dose. The presence of radon in drinking tap water and other household uses can increase the indoor radon level andcauses radiation-related health hazards both through inhalation and ingestion. In the present research, radon concentrations are measured in 167 tap water samples collected from 32 different districts in the city of Samawa, the center of AL-Muthanna Province-Iraq, using the active electronic radon detector RAD7. The results show that radon concentrations were varied from (0.015± 0.13Bq/l) to (1.01± 0.38Bq/l) with a mean value of (0.174 ± 0.13) Bq/l. The annual effective dose due to ingestion and inhalation for child and adult was calculated. Also, the mean of the total annual effective dose for adults and children is calculated and found to be (1.282) µSv/y and (1.923) µSv/y respectively. The measured values of radon gas activity concentrations and annual effective dose in all samples are lower than that of the save limit prescribed by the USEPA, UNSCEAR, and WHO, which indicates that no significant radiological hazards for the inhabitants in the study area.

KEY WORDS : Drinking water, Radon concentration, Annual effective does, Samawa city, Iraq.

INTRODUCTION

Radon (Rn^{222}), is generated from the decay of uranium-238, which is formed during radium-226(Ra^{226}) disintegration, is a naturally occurring radioactive element, an odorless, tasteless, and colorless noble gas that provides the largest contribution to the effective dose absorbed by the population. It has a half-life of 3.825 days, decays by emitting 5.49 MeV alpha particles, and generates radioactive progeny. Two of the Rn^{222} decay products, Po^{214} and Po^{218}, are alpha emitters, and they contribute over 90% to the total radiation dose received due to radon exposure,and or according to the International Commission on Radiological Protection 40%-75% of the exposure of human by natural radioactive sources comes from radon and its daughter nucleus, which represents a significant health risk to the human being in case ingested or inhaled (WHO, 2011).

The main source of water in the city of Samawa is surface water (Euphrates river), where the water is pumped after being purified through a network of pipes for households. The quality of water is one of the most important parameters of environmental studies (Patil *et al.,* 2012). The existence of Rn^{222} in drinking water gives rise to internalexposure, directly via their decay processes,when directly taken into the body through ingestion and inhalation, and indirectly when they are combined as part of the food chain (WHO, 1985). Measurement of radioactivity in drinking water helps to determine the risk of radiation exposure from daily consumption of water.

MATERIALS AND METHODS

Study Area

The present study was carried out in Samawa city, Al-Muthanna province, Iraq. Samawa is the largest city in Al-Muthanna province which has an area of (680 km^2), with a population of approximately (221.743) people. Is located in geographic coordinates 31° 192 03 N, and 45° 172 03 E, at an elevation of 9 m (29 ft) above the sea level. It is built on both sides of the Euphrates river; and is surrounded by hundreds of palm groves that give it a tropical feel, especially in the southern and northern suburbs. There are six bridges in the center of town for crossing between the two sides. The west bank of the city contains the commercial heart of it. The most famous attraction of Samawa is the ruins of the ancient Sumerian city of Uruk which dates to 4000BC, and a large salt lake called Sawa Lake.

The city is located at 280 km southwest of Baghdad the capital of the Republic of Iraq, in the hot region during the summer season and nearly cold during winter. In the late winter and spring, Samawa city can be affected by the strong southerly winds, which may give rise to dust storms. On the contrary, during the long summer months, a moderate northwesterly wind, very hot and dry, which may cause rapid dehydration, and when its more intense, it can raise dust or sand. The water consumption was high and the only water resources in this city are the surface water (Euphrates river), the water of which is pumped out with the purification process. The climate of the city is marked by a large variation of temperature, extreme dryness, and scanty rainfall. The minimum and maximum temperatures are 5 ^{o}C and 50^{o}C respectively. Whereas The average annual temperature is 23.8 °C (74.8 °F). About 106 mm (4.17 in) of precipitation falls annually. The soil of Samawa districts is yellowish-brown in color, clay to silty clay,and calcareous which vary in their characteristics at long distance,and in many places they are intermixed with sandy material (Ajayash, 2019).

Sampling and Sample analysis

Water samples were collected directly from the tap after 15 min of opening the water to ensure that the sample collected served as a representative sample, quality-wise. The samples were collected in a clean 0.5 L bottle previously rinsed with distilled water. During water collection, a conscious effort was taken to prevent bubbling of the water, and sealed with a cap underwater immediately, so as not to allow the escape of dissolved radon in the water. All bottles were labeled with the date and time of sample collection, as well as the district name. Five to seven samples were taken at each district depending on the area of it, and the collected samples were immediately transported at a minimal possible time to the laboratory at the Department of physics for radon analysis. The latitude and longitude of sampling points were recorded by using the GPS device and documented by using google earth software. A total of 167 samples of tap water were collected from 32 districts in the study area in two months extending from December 1st, 2019 to January 31th, 2020. A calibrated portable continuous radon monitor, RAD7 (Durridge Company, USA) was used for measurements. Figure 1 shows the schematic diagram of the RAD7 setup for radon in water measurements (Rad, 2018). In the RAD-H_2O setup, a 250 ml sample bottle was connected to the RAD7 detector viaa bubbling kit and desiccant tube to establish a closed air loop. To ensure the quality of the sample measurements, each sample was measured in 4 cycles of 5 min each, with an initial aeration time of 5 min. This means that RAD7 is capable of accurately measuring radon concentration in a water sample within 20 min which is a very short time compared with 3.825 days half-life of radon, thereby making RAD7 very good detectors for evaluation of radon in water (Sharrad and Farhood, 2019). At the end of the run, the RAD7 prints out automatically the mean radon concentration from the four cycles counted, or it can be saved the results on the computer memory using RAD7 capture software that presided by the manufacturer which allows displaying Rn^{222} concentration for each cycle.

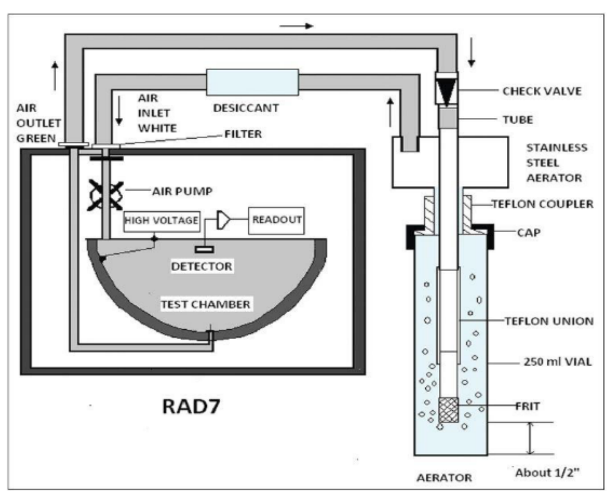

Fig. 1. Schematic diagram of RAD-H_2O assembly.

Annual effective dose calculation

The annual effective dose due to the ingestion of radon from drinking water (H_{ing}), was calculated according (UNSCEAR, 1993):

$$H_{ing}(mSv/yr) = C_{Rn} \times D_{ing} \times L \qquad .. (1)$$

Where: C_{Rn}: mean radon concentration in drinking water (Bq/L)

D_{ing}: The conversion factor for ingestion, (1×10^{-8} Sv/Bq or 1×10^{-5} mSv/Bq for an adult and 2×10^{-8} Sv/Bq or 2×10^{-5} nmSv/Bq for a child)(Christensen *et al.*, 2014).

L: annual drinking water consumption in liters.

There have been controversies over the amount of annual water intake in a year. The value of (60 L/y) for the weighted direct annual consumption of tap water has been proposed by UNSCEAR (UNSCEAR, 2013). The total annual water intake for the so-called ''ICRP Standard Man'' equals to (2L/d) or (730 L/y) for adults and for children the average water consumption rate (ACR) was (1.5L/d) or (547.5 L/y) (H. Bem *et al.,* 2014). Because the south-western area of Iraq has a desert climate, and it's the driest area of the country, in addition to the high temperature in the city of Samawa most days of the year which means that to consume a large quantity of water, and for consistency with most international drinking water guidelines, the ICRP amount has been applied for calculations of ingestion dose in this study.

The annual effective dose due to the inhalation of radon (H_{inh}), resulting from the radon concentration in drinking water, was calculated using the following relation (UNSCEAR, 1993):

$$H_{inh}(nSv/yr) = C_{Rn} \times R \times F \times T \times D \ldots\ldots\ldots\ldots\ldots(2)$$

Where: C_{Rn}:meanradon concentration in drinking water, (Bq/m^3).

***R*:** air to water concentration (10^{-4}).

***F*:** Equilibrium factor between indoor radon and its progeny (0.4).

***T*:** Exposure time in hours (7000 hr/yr) for adults and children.

***D*:** Dose conversion factor (9 nSv/(Bq hr/m^3)) or (9×10^{-6} mSv/(Bq hr/m^3).

RESULTS AND DISCUSSION

The radon activity concentration in the residential drinking tap water was analyzed for 167 samples in Samawa city-Iraq. In the study area, residential tap water is obtained from the surface water of the Euphrates river. The result for 167 samples reported in Table 1. As shown from the table, the radon activity concentrations from each district of the study area were found to range from (0.238±0.62 Bq/L) to (0.387±0.83Bq/L) with a mean concentration of (0.174±0.13 Bq/L). Figure 2 shows the frequency distribution of mean radon concentration in the studied districts. The figure reveals that the most concentrations were within the first category which contains the lower values (lower than or equal to 0.176Bq/L) which indicates that the most analyzed samples of different regions in the city pose low concentrations as compared to other samples in the rest of categories.However, these recorded values of radon concentration in the drinking tap water were below the permissible value of 11 Bq/L recommended by the USEPA and 100Bq/L recommended by the EU and WHO, or the UNSCEAR value of 4 to 40 Bq/L (UNSCEAR, 2008), (WHO), 2011), (European Commission, 2001), and or within or lower than ICRP suggested maximum contamination level of radon concentration in water samples as 0.6 Bq/L(Ravikumar and Somashekar, 2014). As seen in Figure 3 and Table 1, the measured radon concentration in the Al-qasabahdistrict is higher than that of measured activity in other districts. The reason for this may be due to the soil and rock structure where the water pipes pass through it,and or the water network that provides this district with water is the oldest in the city (where the district represents the old city). In addition, the network pipes are made from concrete, and as known the radon content within concrete pipes is higher than PVC or iron pipes. On the other hand, these pipes contain a significant number of fractures and cracks which allow the ground water

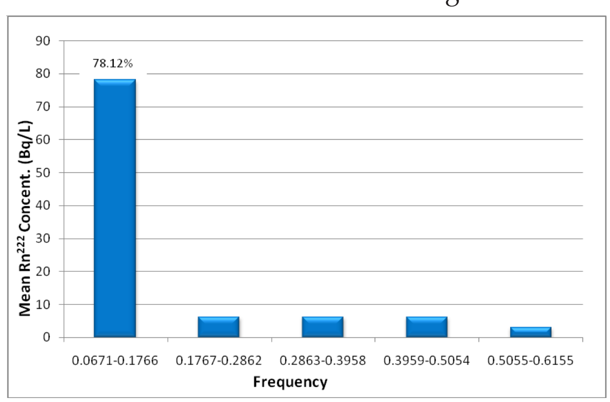

Fig. 2. Frequency distribution of mean radon concentrationin the drinking water for different districts.

to be mixed with transported water which increase the radon level within pipes. Hence, The materials that pipes made from, as well as the nature of the ground, will affect the concentration of radon gas in drinking water. The value of the lowest radon activity concentration was measured in the water samples taken from Al-Risalahdistrict, this low value is could be due the district is close to the processing stations or back to that the water network has been newly created, and hence, its transportation lines are devoid of any cracks or fissures which help to avoid any additional contamination. In the scope of our results, the values of the measured radon activity concentration in the water sample are marginally lower than or within the limit value of 0.6 Bq/L given by the ICRP(Ravikumar and Somashekar, 2014).

The radon activity concentration observed in the drinking water of this study region has been compared with the outcomes of similar studies

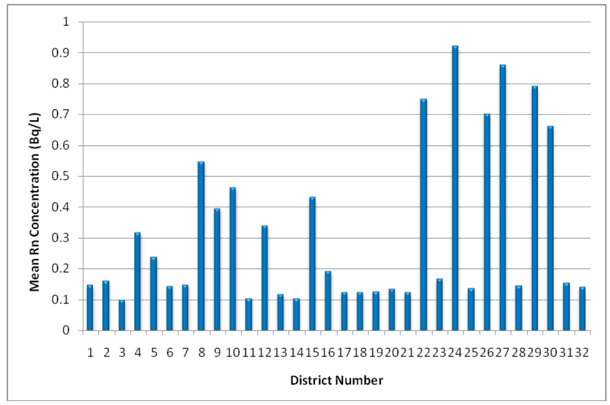

Fig. 3. Radon Concentration distribution for the studied districts.

Table 1. Radon activity concentrations in drinking water used in different districts (locations) in theSamawaCity area.

No.	District Name	Rn Concentration (Bq/L)		Mean
		Min	Max	
1.	AL-Hussein	0.00 ± 0.6	0.557 ± 0.9	0.147667
2.	AL-Mualimin	0.00 ± 0.6	0.542 ± 0.9	0.1606
3.	AL-Muealimin 2	0.00 ± 0.6	0.721 ± 1	0.11064
4.	AL-Orouba	0.00 ± 0.6	0.721 ± 1	0.146183
5.	AL-Sader	0.00 ± 0.6	0.729 ± 1	0.2398
6.	AL-Shuhada 2	0.00 ± 0.6	0.561 ± 0.9	0.15694
7.	AL-Gharbi 2	0.00 ± 0.6	0.547 ± 0.9	0.148657
8.	AL-qasabah	0.00 ± 0.6	1.69 ± 1.3	0.6152
9.	AL- jadidah	0.00 ± 0.6	1.81 ± 1.3	0.3944
10.	B.S AL-sharqayh	0.00 ± 0.6	1.44 ± 1.2	0.4212
11.	9 Nisan	0.00 ± 0.6	0.466 ± 0.9	0.10498
12.	AL-Haydariah	0.00 ± 0.6	0.947 ± 1.1	0.339167
13.	AL-Nahdah	0.00 ± 0.6	0.390 ± 0.8	0.11692
14.	AL-Jumhuriah	0.00 ± 0.6	0.399 ± 0.8	0.104567
15.	AL-Askari	0.00 ± 0.6	0.854 ± 1	0.4234
16.	AL-Hakim	0.00 ± 0.6	0.939 ± 1.1	0.1926
17.	AL-Thryr	0.00 ± 0.6	0.619 ± 1	0.1238
18.	AL-Iielam	0.00 ± 0.6	0.461 ± 0.9	0.12348
19.	AL-Amir	0.00 ± 0.6	0.391 ± 0.8	0.12576
20.	AL-Hassan	0.00 ± 0.6	0.461 ± 0.9	0.13608
21.	AL-Mujybil	0.00 ± 0.6	0.466 ± 0.9	0.12376
22.	AL-Sinaeiah	0.00 ± 0.6	0.373 ± 0.8	0.07588
23.	AL-Jahil	0.00 ± 0.6	0.619 ± 1	0.1671
24.	AL-Eatshan	0.00 ± 0.6	0.308 ± 0.8	0.09266
25.	AL-Qushlah	0.00 ± 0.6	0.464 ± 0.9	0.13638
26.	AL-Jihad	0.00 ± 0.6	0.313 ± 0.9	0.0711
27.	AL-Taamim	0.00 ± 0.6	0.157 ± 0.8	0.08642
28.	AL-Siagh	0.00 ± 0.6	0.391 ± 0.8	0.14656
29.	AL-Entisar	0.00 ± 0.6	0.308 ± 0.8	0.0802
30.	AL-Sisalah	0.00 ± 0.6	0.311 ± 0.8	0.067117
31.	AL-Nasr	0.00 ± 0.6	0.466 ± 0.9	0.09882
32.	B.S Algharbiah	0.00 ± 0.6	0.557 ± 0.10	0.14102
	Mean Value	0.00 ± 0.2	0.387 ± 0.83	0.175596

carried out in Iraq and different parts of the world as shown in Table 2. The average radon concentration reported in this study were in the range of those reported in other parts of Iraq. On the other hand, annual effective dose due to ingestion and inhalation from exposure of Rn^{222} in water for adults and children has been calculated using equation (1) and (2). The calculated total annual effective dose of children ranged from (0.735μSv/yr) at Al-Risalah district (sample no.30) to (6.737μSv/yr) at Al-qasabah district (sample no. 8), with an average value of (1.923 μSv/yr), while for adults the total annual effective dose ranged from (0.4901μSv/yr) at Al-Risalahdistrict (sample no.30) to (4.492 μSv/yr)

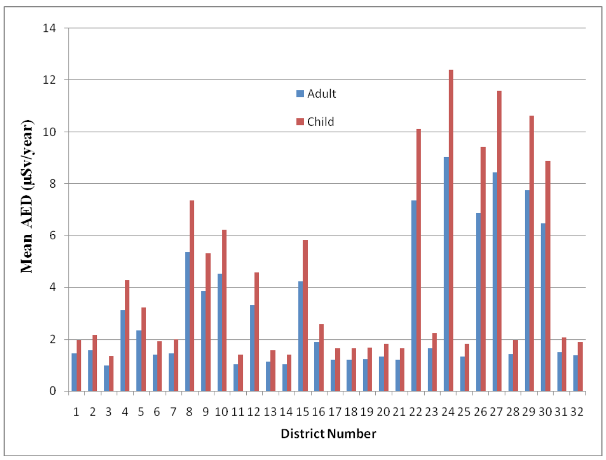

Fig. 4. Mean annual effective dose for adults and children of the studied districts

at Al-qasabah district (sample no. 8) with an average value of (1.282 μSv/yr). In the scope of our results, it was found that the total annual effective dose of child higher than of total annual dose for an adult, which is maybe due to the ingesting dose conversion factor, or this biggest value for children is due to the high sensitivity of tissues of children body (Abojassim, 2017). Figure 4, shows the relation between the district number and the annual effective dose for children and adults.

The World Health Organization (WHO)((WHO), 2011) and the EU Council (European Council, 2020) recommended the action level for annual ingestion dose received from water consumption of 100 μSv/yr. According to WHO, if the total annual effective dose is less than 100 μSv/yr, the water is appropriate for consumption purposes and no further remedial action is necessary. The results of the total annual effective dose from all locations of the studied area were well below the reference level of 100 μSv/yr of WHO, and hence do not cause any health hazards from Rn^{222} dose received by water in the study region.

CONCLUSION

The radon activity concentration in drinking water was analyzed for 167 samples in 32 different districts in Samawa city area, Iraq, using the continuous radon monitoring device RAD7. The

Table 2. Comparison between our results and the published data by other investigators in the neighbouring countries.

Country	Rn^{222} (Bq /L)	Reference
Turkey, Adýyaman (drinking water)	0.39 – 0.51	(Mehmet Fatih Aydin, 2019)
Turkey, Kastamonu (drinking water)	0.50 – 5.78	(Yalcin *et al.*, 2011)
Saudi Arabia, Qassim (groundwater)	1.20 – 15.43	(Najam *et al.*, 2019)
Saudi Arabia, Jazan (drinking water)	1.65 – 3.82	(El-Araby *et al.*, 2019)
Iran, Kerman (drinking water)	1.2 – 9.88	(Malakootian and Soltani Nejhad, 2017)
Iran, Taft Township (drinking water)	0.881 – 20.36	(Malakootian *et al.*, 2016)
Iran, Borujerd County (water supplies)	1.339 – 4.032	(Adinehvand *et al.*, 2019)
Iran, Mashhad city (drinking water)	0.064 - 46.088	(Binesh *et al.*, 2010)
Jordan (drinking water)	3.9 -117	(Al-Kazwini and Hasan, 2003)
Lebanon (well and spring water)	0.91 – 49.6	(Duggal, Mehra and Rani, 2013)
Kuwait (drinking water)	1.02 – 6.05	(Kumar *et al.*, 2016)
Palestine (residential tap water)	1.0	(Al Zabadi *et al.*, 2012)
Iraq, Baghdad Government (tap Water)	0.012 – 0.283	(Abid Abojassim *et al.*, 2015)
Iraq, Erbil Governorate (drinking Water)	0.069 – 13.062	(Ezzulddin, 2008)
Iraq, Baghdad, Al-Mustansiriyah (tap Water)	0.073 – 0.190	(Tawfiq, Mansour and Karim, 2015)
Iraq, Hilla City (drinking water)	0.0361 – 0.193	(Al-jnaby, 2016)
USEPA	11.1	(USEPA (1991), no date)
UNSCEAR	10	(UNSCEAR, 1993)
WHO	100	((WHO), 2011)
Iraq, Samawa city	0.067 – 0.615	Present Study

radon level in drinking water is lower than the safe limits reported by national organizations. Also, the use of drinking water that has been investigated in this study show that the total annual effective doses from ingestion and inhalation are lower than the safe limit of 0.1 mSv/yr suggested by WHO and EU council, and 1.0 mSv/yr of ICRP reference limit, or 0.12 mSv/yr the UNSCEAR world average value.

It can be concluded that the estimated annual ingestion dose exposure from Rn^{222} in drinking water is on average low relative to that from inhalation of radon present in indoor air. This means that the risk due to inhaled radon and its daughter radionuclides from the water is still effective, which is maybe due to the great household water usage such as showers, baths, dishwashers, laundries, and toilets which all provide adequate aeration to release a high percentage of the waterborne radon into the household air. However, from the results discussed above, it can be concluded that drinking water in all studied districts is safe to use, and therefore any necessary action is not required to reduce the radon concentration in water resources in studied districts.

REFERENCES

Abid Abojassim, A. 2015. Radon Concentrations in Selected Samples of Tap Water in Baghdad Government/Iraq. *Research Journal of Applied Sciences, Engineering and Technology*. 11 (12) : 1358-1364.

Abojassim, A. A. 2017. Annual effective dose of gamma emitters in infants, children and adults for frozen chicken samples consumed in Iraq. *Current Pediatric Research*. 21 (3) : 520-525.

Adinehvand, K., Azadbakht, B. and Fallahi Yekta, M. 2019. Dose assessment and measurement of radon concentration in water supplies of Borujerd County in Iran. *International Journal of Radiation Research*. 17(3) : 507-511.

Al-jnaby, M. K. M. 2016. Radon Concentration in Drinking Water Samples at Hilla city, Iraq. *World Scientific News*. 52 (52) : 130-142.

Al-Kazwini, A. T. and Hasan, M. A. 2003. Radon concentration in Jordanian drinking water and hot springs. *Journal of Radiological Protection*. 23(4): 439-448.

Binesh, A. 2010. Evaluation of the radiation dose from radon ingestion and inhalation in drinking water sources of Mashhad. *Research Journal of Applied Sciences*, pp. 221-225.

Christensen, D.M., Iddins, C.J. and Sugarman, S. L. 2014. Ionizing radiation injuries and illnesses. 32 : 245-265.

Duggal, V., Mehra, R. and Rani, M. 2013. Analysis of radon concentration in drinking water in Hanumangarh district of Rajasthan, India. *Radiation Protection and Environment*. 36 (2) : 65.

El-Araby, E. H., Soliman, H. A. and Abo-Elmagd, M. 2019. Measurement of radon levels in water and the associated health hazards in Jazan, Saudi Arabia. *Journal of Radiation Research and Applied Sciences*. Taylor & Francis, 12(1) : 31-36.

European Commission 2001. Commission recommendation of 20 December 2001 on the protection of the public against exposure to radon in drinking water supplies L344/85. *Official Journal of the European Communities*. 4(2001/928/Euratom), p. 4.

European Council 2020. Special meeting of the European Council Conclusions. 2020(EUCO 10/20), pp. 1-68.

Ezzulddin, S. K. 2008. *Radon-222 and Radium-226 Activity Concentration Measurement in Erbil Governorate Drinking Water Resources Using Active and Passive Detection Methods Supervised by*.

Ajayash, F.L. 2019. *The Cartographic Represrntation of Classification of Agricultural Land Using in Al-Muthanna Province Using Remote Sensing and GIS techniques*. University of Basrah.

Bem, H., Plota, U., Staniszewska, M. and Bem, M.D. M. 2014. 'Radon (222Rn) in underground drinking water supplies of the Southern Greater Poland Region', 299(p.p.1312).

Kumar, A. 2016. A study of radon concentration in drinking water samples of Amritsar city of Punjab (India). *Radiation Protection and Environment*. 39(1) : 13.

Malakootian, M. 2016. Determination of radon concentration in drinking water of Taft Township and evaluation of the annual effective dose. *Internatuinal Journal of Radiation Research*. 14(1): 39-46.

Malakootian, M. and Soltani Nejhad, Y. 2017. 'Determination of radon concentration in drinking water of Bam villages and evaluation of the annual effective dose. *International Journal of Radiation Research*. 15(1) : 81-89.

Mehmet Fatih Aydin, Ö. S. 2019. Measurement of radon gas activity concentrations in drinking water in the city center of Adýyaman, Turkey. *Radiation Protection and Environment*. (June), pp. 59-60.

Najam, L. A. 2019. Assessment of Annual effective Dose for Different Age Groups Due to Radon Concentrations in Groundwater Samples at Qassim, Saudi Arabia. *Iranian Journal of Medical Physics*. 0(Apr).

Patil, P. N., Sawant, D. V. and Deshmukh, R. N. 2012. Physico-chemical parameters for testing of water – A review. 3 (3) : 1194-1207.

Rad, H. O. 2018. Durridge RAD H_2O User Manual. pp. 1-33.

Ravikumar, P. and Somashekar, R. K. 2014. Determination of the radiation dose due to radon ingestion and inhalation. *International Journal of Environmental Science and Technology*. 11 (2) : 493-508.

Sharrad, A. A. and Farhood, A. K. 2019. Radon concentration measurements and physiochemical parameters of Sawa Lake water-Samawa city, south of Iraq. *Journal of Global Pharma Technology*. 11(5) : 532-543.

Tawfiq, N. F., Mansour, H. L. and Karim, M. S. 2015. Measurement of Radon Gas Concentrations in Tap Water for Baghdad Governorate by Using Nuclear Track Detector (CR-39). *International Journal of Physics*. 3(6) : 233-238.

UNSCEAR 1993. *Sources and Effects of Ionizing Radiation*. New York.

UNSCEAR 2013. 'UNSCEAR 2013 Report: Volume II. Effects of radiation exposure of children', *Unscear. Org*, II.

UNSCEAR 2008 Report (2008) *Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2008 Report*, *United Nation*.

USEPA (1991) (no date) *'National primary drinking water regulation for radionuclides'.EPA/570/9-91/700. Washington US., Governmental Printing Office.* Washington US., Governmental Printing Office.

WHO, 2011. *Guidelines for Drinking-water Quality*, *Encyclopedia of Earth Sciences Series*. doi: 10.1007/978-1-4020-4410-6_184.

(WHO), W. H. O. 2011. Guidelines for Drinking-water Quality, 4th.

World Health Organization 1985. Guidelines for drinking water Quality, Vol. 1. Recommendations', *Environmental Pollution Series A, Ecological and Biological*. 37(3) : 282.

Yalcin, S. 2011. Measurements of radon concentration in drinking water samples from Kastamonu (Turkey). *Isotopes in Environmental and Health Studies*. 47(4) : 438-445.

Al Zabadi, H. 2012. Exposure assessment of radon in the drinking water supplies: A descriptive study in Palestine. *BMC Research Notes*, 5.