ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
Research Article
www.ijptonline.com

ASSESSMENT OF CONCENTRATION OF RADON 222 AND EFFECTIVE DOSE; BANDAR ABBAS CITY (IRAN) CITIZENS EXPOSED THROUGH DRINKING TAP WATER

Yadolah Fakhri[1], Gea Oliveri Conti[2], Margherita Ferrante[2], Abotaleb Bay[3], Moayed Avazpour[4], Bigard Moradi[5],Yahya Zandsalimi[6], Leila Rasouli Amirhajeloo[7], Ghazaleh Langarizadeh[8], Hassan Keramati [9,10]*

[1]Social Determinants in Health Promotion Research Center, Hormozgan University of Medical Sciences, Bandar Abbas, Iran.

[2]Environmental and Food Hygiene Laboratories (LIAA),"G.F. Ingrassia" Department, Hygiene and Public Health, University of Catania, Catania, Italy.

[3]Environmental Health Research Center, School of Public Health, Golstan University of Medical Sciences, Golstan, Iran.

[4]Department of Environmental Health Engineering, School of Public Health, Ilam University of Medical Sciences, Ilam, Iran.

[5]Department of Health Public, Kermanshah University of Medical Sciences, Kermanshah, Iran.

[6]Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran.

[7]Department of Environmental Health Engineering, School of Public Health, Qom University of Medical Sciences, Qom, Iran.

[8]Food and Drugs Research Center, Bam University of Medical Sciences, Bam, Iran.

[9]Students research office,Department of Environmental Health Engineering, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

[10]Department of environmental health engineering, school of public health, Semnan University of Medical Sciences, Semnan, Iran.

*Correspondence; Hassan Keramati, Email: Hkramatee@gmail.com, Phone:+989128497093

Received on 10-02-2016 *Accepted on 15-03-2016*

Abstract

Radon 222 is a natural radioactive element with 3.825 days half-life. ^{222}Rnis colorless and odorless with high solubility in water. The presence of ^{222}Rnin drinking water can lead to lung or stomach cancers through chronic exposure per inhalation or ingestion. Different age groups have different sensitivity to the health effects of ^{222}Radon. In this cross-sectional study, the concentration of ^{222}Rnin the 8 regions of Bandar Abbas city in 48 samples of tap water was measured by portable Radon meter RTM1688-2 model on June 2015. The effective dose by tap water was also calculated in different age groups through UNSCEAR equation. The range and mean concentration of ^{222}Rnis 0.87-0.384 Bq/l and 0.232±0.7 Bq/l, respectively. The mean of the effective dose of exposure for the age groups was 0.0024±0.0007, 0.0018±0.0005, 0.0007±0.0002 and 0.001±0.0003 m Sv/y, respectively for adult males, adult females, children and infants. The magnitude's order of measured doses of studied age groups was: adult males>adult females>infants>children. The effective doses, ingested by all groups, are less than the standard limits particularly for children (p value<0.001).The results of this research shows that ^{222}Rn concentration in the tap water of Bandar Abbas city is lower than WHO, EU and EPA standard limits (p value<0.001). Also the effective ^{222}Rn doses in the all age groups are much lower than standard limits. Given the daily high consumption of water, adult males between the Bandar Abbas citizens showed the highest sensitivity to the ^{222}Rn health hazard.

Keywords: ^{222}Rn, tap drinking water, effective dose, age groups, Bandar Abbas City, Iran

1. Introduction

Radon 222 (^{222}Rn) is a natural radioactive element with 3.825 days half-life and is colorless and odorless. The chronic exposure to ^{222}Rn can lead to lung, blood and stomach cancers through alpha emission during the decay[3-1]. Rn has a high solubility in water (Refractive index of moles; 1.25×10^{-5} at 37ºC), ^{222}Rnhas 90 times more solubility than Neon and Helium [4].^{222}Rnis one of the main and final decay products of ^{238}Uranium and can be released from different sources such as surface and ground waters, soil, igneous and sedimentary rocks (granites) [6 ,5]. Humans are constantly exposed to ^{222}Rnboth outdoor and indoor air inhalation or drinking water's ingestion [8 ,7]. Alpha radiation's emission is the first health risk respect to other radiation types for its high ionization power [9]. When a human consumes water containing ^{222}Rn, the emitted alpha radiation during its decay can cause damage to the DNA of stomach cells. ^{222}Rncan be distributed to, also, other districts or organs through the blood perfusion of stomach wall [12-10]. For prolonged exposures, as is the case for ingestion of drinking water containing radio nuclides over extended periods of time, evidence of an increased cancer risk in humans is available at doses above 100 mSv[10, 13].It is estimated that 89% and 11% of the cancer risk is related to the inhalation or ingestion of water containing ^{222}Rn, respectively [11].

Due to the more prolonged contact of groundwater with igneous rocks (granites) and sediments, the dose of radioactive substances in this water are higher respect to the surface waters[16-14]. For this reason, the ^{222}Rn concentration in groundwater resources is 2 to 3 times greater than surface waters [17]. EPA Standard and WHO Guideline for concentration of ^{222}Rn in drinking water are 100 Bq/l and 11 Bq/l [10, 18]. The WHO (2008) and the EU Council (Council Directive 98/83/EC, 1998) recommend the determination of the reference level of an effective dose from drinking water consumption at 0.1 mSv /year[19, 20]. This value excludes the effective doses from ^{3}H, ^{40}K and ^{226}Rn[21]. Many studies have measured the concentration of ^{222}Rnboth in drinking tap water and bottled water [24-22 ,4]. Per capita consumption of drinking water for residents of Bandar Abbas city is high due to warm and humid weather conditions. Therefore, aim of our study was to measure the concentration of ^{222}Rn and calculate the effective dose in the infant, children, adult male and adult female of Bandar Abbas citizen consumers of tap water and to compare with the standard limits and other studies.

2. Materials and Methods

1.2 Studied Area: Bandar Abbas city is located at the south of Iran (27º11'53" N and 54º 22'7" E) and at the height of 9 meters above the sea level(Figure 1) .The weather of this city is warm and humid and its population is increasing day to day thank to economic growth [25].

2.2 Sample collection

Our study is a cross-sectional type.48 samples of 1.5 liter tap drinking wate rwere gathered in June 2015 from 8 site of Bandar Abbas city (6 samples for each site and in two different places). Finally according to standard methods instructions, samples were maintained to 4-6ºCuntil arrival to the laboratory of Tehran University of Medical Sciences for measurement[26].

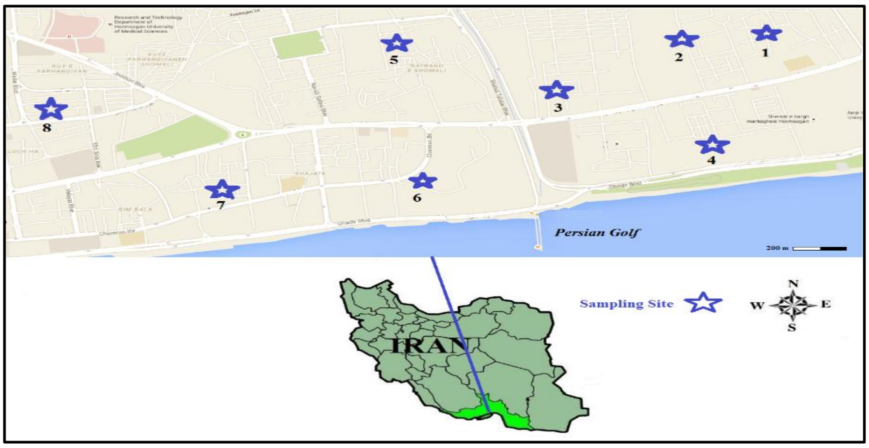

Figure-1: Sites of water samples collection from the distribution network in Bandar Abbas city.

3.2 Measurement of ^{222}Rn concentration

Temperature of all samples were alike and brought to 12ºC before measuring of ^{222}Rn[28 ,27]. Measurement of ^{222}Rn concentrations was carried out using a Sarad radon meter, model RTM1688-2, Germany. The sensitivity of this device in 150 minutes of continuous measurements is 6.5 counts/min×KBm^{-3}[29].High sensitivity associated with alpha spectroscopy analysis are resulted in short time to response even in low concentration.. The 2-hour mean ^{222}Rn concentration for all samples was registered and analyzed [30].

4.2.^{222}Rn concentration assessment

Since there was a time gap between sampling and measurement of ^{222}Rn concentration in sample, so it is needed to adjust the ^{222}Rn concentration at the sampling time due to continuous decay of it. The ^{222}Rn concentration in sampling time can be calculated through equation1;

Equation1: $C_t=C_0e^{-\lambda t/60}$

In this equation, C_t is ^{222}Rn concentrationin measurement time (Bq/m^3), C_0 is ^{222}Rn concentration in sampling time, λ is the constant of ^{222}Rndecay (0.007542 h^-) and t is the time difference between sampling and measuring times (h) [31].

5.2. Determination of the annual effective dose

To determine the annual effective dose of exposure resulting from drinking water containing ^{222}Rn , the equation of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was used [32];

Equation 2: $E=K\times G\times C\times T\times 1000$

In this equation, E is the annual effective dose of exposure by mSv/y, K is the conversion coefficient of ^{222}Rn concentration to the effective dose (Sv/Bq), G is daily water intake (l/d), C is ^{222}Rn concentration measured (Bq/l), T is duration of tap water consumption (365 days) and 1000 is the conversion coefficient of Sv vs mSv. K sensitivity coefficient for adult males and females (17-65 years old), children (4-14 years old) and infants (<2 years) is 18×10^{-9} Sv/Bq, 26×10^{-9} Sv/Bq and 35×10^{-9} Sv/Bq, respectively [34 ,33]. Many studies have shown that the amount of consumed drinking water by humans is less than 2 liters per day but this consumption varies with the different age groups. The daily water intake by humans is dependent on weather conditions, physical activity, culture, economy and etc. Since there were no data or information available about the exact amount of drinking water daily consumption in different age groups in Bandar Abbas city, we have chosen to use the EPA Estimated Per Capita Water Ingestion in hot and humid weather regions (percentile 95%). The daily water intake in age groups of adults males, adults females, children and infants is 2.723, 2.129, 0.431 and 0.327 l/p-d, respectively [35].

6.2. Statistical Analysis

Used to one sample t test for compare ^{222}Rn concentration of tap water with standard limits. Since the prerequisite for t test analysis is normal distribution, we have done kolmogorov-smirnov analysis in the SPSS 16.0.lnk.Also, p value<0.05 was selected as the significant level (α=5%).

3. Results

Kolmogorov-Smirnov analysis has showed that data is Normal distributed (p value = 0.8). Hence we used to statistical Analysis one sample t test for compare concentration of ^{222}Rn with WHO guideline(100 Bq/l) and EPA standard limit (11 Bq/l). Statistical analysis showed that ^{222}Rn concentration in tap water is lower than WHO Guideline and EPA standard significantly (p value<0.001). Range concentration of ^{222}Rn 0.225-0.25 Bq/l (n=12) and

0.35-0.375 Bq/l (n=0) are samples with higher and lower frequency respectively (figure 2). The mean of ^{222}Rn in 48 tap water samples of Bandar Abbas city has been shown in Table 1. The range and mean concentration of ^{222}Rn measured was 0.087-0.384 Bq/l and 0.232±0.7 Bq/l, respectively.

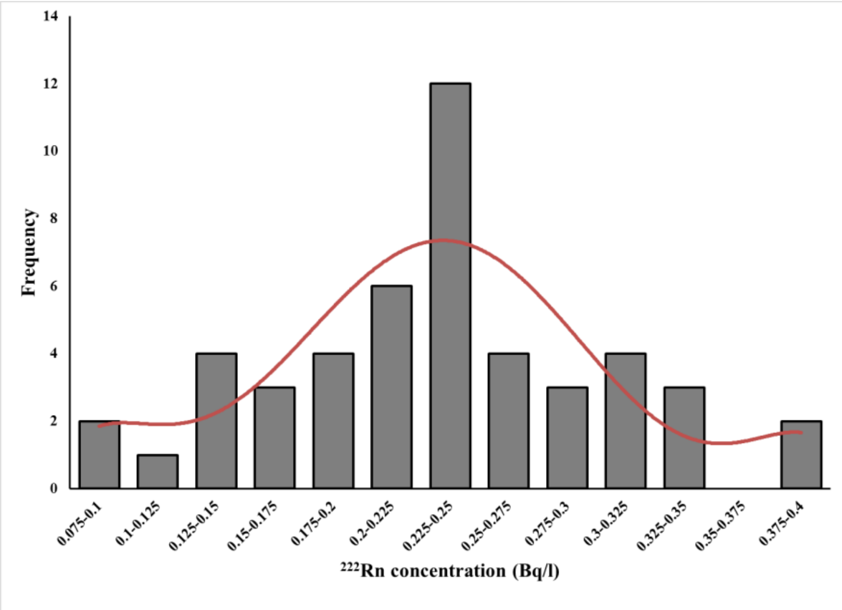

Figure-2: Normal distribution concentration of ^{222}Rn in the tap drinking water (n=48).

Table-1: Mean of ^{222}Rn concentration in 48tap water samples at sampling and measurement times

Number samples	Date Collection	Hours of collection	Date measurement	Different time (h)	Concentration laboratory	Mean	Concentration in sampling moment	Mean of region
1	2015.6.3	7:30	2015.6.6	75.6	0.157	153	0.153	0.2407
2	2015.6.3	7:30	2015.6.6	77.6	0.152			
3	2015.6.3	7:30	2015.6.6	79.6	0.15			
4	2015.6.3	8:20	2015.6.6	81.6	0.066	59	0.059	0.0978
5	2015.6.3	8:20	2015.6.6	83.6	0.061			
6	2015.6.3	8:20	2015.6.7	96.0	0.05			
7	2015.6.3	8:40	2015.6.7	98.1	0.085	83	0.083	0.1489
8	2015.6.3	8:40	2015.6.7	100.1	0.083			
9	2015.6.3	8:40	2015.6.7	102.2	0.081			
10	2015.6.3	9:15	2015.6.7	104.2	0.104	96	0.096	0.1818
11	2015.6.3	9:15	2015.6.7	106.3	0.1			
12	2015.6.3	9:15	2015.6.8	119.0	0.084			
13	2015.6.3	9:40	2015.6.8	121.1	0.118	110	0.11	0.2257
14	2015.6.3	9:40	2015.6.8	123.1	0.111			
15	2015.6.3	9:40	2015.6.8	125.2	0.101			
16	2015.6.3	10:20	2015.6.8	127.2	0.115	104	0.104	0.225
17	2015.6.3	10:20	2015.6.8	129.3	0.111			
18	2015.6.3	10:20	2015.6.9	142.0	0.086			
19	2015.6.3	11:01	2015.6.9	143.5	0.066	60	0.06	0.1399
20	2015.6.3	11:01	2015.6.9	145.0	0.059			

21	2015.6.3	11:01	2015.6.9	146.5	0.055			
22	2015.6.3	11:30	2015.6.9	149.0	0.123	109	0.109	0.2709
23	2015.6.3	11:30	2015.6.9	150.5	0.118			
24	2015.6.3	11:30	2015.6.10	172.0	0.086			
25	2015.6.4	7:40	2015.6.10	147.0	0.092	86	0.086	0.2047
26	2015.6.4	7:40	2015.6.10	148.5	0.085			
27	2015.6.4	7:40	2015.6.10	150.0	0.081			
28	2015.6.4	8:30	2015.6.10	151.5	0.124	103	0.103	0.2741
29	2015.6.4	8:30	2015.6.10	153.0	0.121			
30	2015.6.4	8:30	2015.6.13	216.0	0.064			
31	2015.6.4	8:50	2015.6.13	217.5	0.098	95	0.095	0.3414
32	2015.6.4	8:50	2015.6.13	219.0	0.095			
33	2015.6.4	8:50	2015.6.13	220.5	0.092			
34	2015.6.4	9:30	2015.6.13	222.0	0.105	96	0.096	0.3624
35	2015.6.4	9:30	2015.6.13	223.5	0.103			
36	2015.6.4	9:30	2015.6.14	239.0	0.08			
37	2015.6.4	9:50	2015.6.14	240.5	0.053	51	0.051	0.2096
38	2015.6.4	9:50	2015.6.14	242.0	0.051			
39	2015.6.4	9:50	2015.6.14	243.5	0.049			
40	2015.6.4	11:01	2015.6.14	245.0	0.06	58	0.058	0.251
41	2015.6.4	11:01	2015.6.14	246.5	0.058			
42	2015.6.4	11:01	2015.6.15	261.0	0.056			
43	2015.6.4	11:30	2015.6.15	262.5	0.057	55	0.055	0.2571
44	2015.6.4	11:30	2015.6.15	264.0	0.055			
45	2015.6.4	11:30	2015.6.15	265.5	0.053			
46	2015.6.4	12:01	2015.6.15	267.0	0.068	59	0.059	0.2874
47	2015.6.4	12:01	2015.6.15	268.5	0.064			
48	2015.6.4	12:01	2015.6.16	280.5	0.045		0.153	
Mean							0.232	
Standard Deviation							0.7	

The mean of the ^{222}Rn effective dose ingested inadult males, adult females, children and infantsis 0.0024±0.0007, 0.0018±0.0005, and 0.0007±0.0002 and 0.001±0.0003 mSv/y, respectively(Table 2).

Table-2: Effective dose of ^{222}Rn in different age groups induced by ingestion of contaminated tap water.

Age Group	Concentration (Bq/l)	G (m^3/d)	K (Sv/Bq)	E(mSv/y)
Adult Males	0.232±0.7	0.002787	1×10^{-8}	0.0024±0.0007
Adult Females	0.232±0.7	0.002129	1×10^{-8}	0.0018±0.0005
Childrens	0.232±0.7	0.000431	2×10^{-8}	0.0007±0.0002
Infants	0.232±0.7	0.000327	3.5×10^{-8}	0.001±0.0003

4. Discussion

High values of radon in well water is attributed to depth of well, as the ^{222}Rn concentration in groundwater is usually higher than surface water [36]. This higher ^{222}Rn concentration can be resulted from the mixing of groundwater (Wells of Minab plain and Shamil) with surface water (Esteghlal lake of Minab). Since almost^{222}Rn concentration in surface water is less than groundwater, so, mixing of surface water with groundwater can decrease concentration in a lot of cases [37].

Table-3: Concentration of ^{222}Rn (Bq/l) in different sources of water with different parts of the world.

Sources of water	Concentration	Country	References
Tap water	3.7	Iran /Tehran	[38]
Tap water	17.99	Iran /Neyshabour	[38]
Tap water	16.23	Iran /Mashhad	[38]
Tap water	0.78±0.06	Iran /Minab	[22]
Tap water	0.019	Iran /Jask	[39]
Tap water	3.4	Iran /Ramsar	[38]
Tap water	4.63	China/ Beijing	[40]
Tap water	0.0355	Palestine/Gaza	[41]
well	12.7	Italy	[42]
well	0.02 -112.5 (15.4)	Brazil	[43]
Groundwater	0.71 -3735 (229.4)	China	[44]
Tap water	0-2	Venezuela	[45]
Tap water	10.2	Turkey/Konya	[46]
Tap water	8 -18 (12)	China	[47]
Tap water	0.4-6.4	Romania/ North-West	[48]
Tap water	0.91-12.58	Turkay	[49]
Tap water	2.5 -4.7	Jordon	[50]
Tap water	0.082±0.7	Iran /Bandar abbas	This study

The values of ^{222}Rn concentrations in tap are lower than standard limit of EPA and WHO guideline. Our data may be the reflection of both long aeration process undergone by the water in the process of treatment due to aeration of radon gas to the atmosphere, and lack of major contact with radon emanating mineral material retention time in the network distribution water.

The differences in geological structure, sensitivity measurement devices and temperature of water before measurement [51, 52],influence emanation of ^{222}Rn from water, increase of temperature of water induce decreases emanation of ^{222}Rn from water [52] and Igneous and sedimentary geological structure increase ^{222}Rn dissolved in water[51].

The results of the ^{222}Rn concentrations in wells, grond water and tap water of the studied area were compared with those reported by other authors in different countries of the world. The mean value of ^{222}Rnconcentration in tap water was lower compared to the values reported in Brazil, China(Groundwater), Turkay, China(Beijing), Romania (North-West), China (tap water), Jordon, Venezuela, Turkey (Konya), Italy, Iran (Mashhad), Iran (Neyshabour), Iran (Tehran), Iran (Ramsar) and Iran (Minab) , and was higher compared to the values reported in Iran (Jask) and Palestine/Gaza(Table3).

The order of the ^{222}Rn effective doses ingested in different age groups was adult males>adult>females>infants>children, respectively. Per capita drinking water consumption in the children's age group is greater than infants and despite of more conversion coefficient, the effective dose in this group (children) is higher. Due to more water consumption in the adults group age (adult males 2.723 l/d and, adult females 2.129 l/d), the effective dose is higher than the infants and children group age. The effective doses of all age groups under this study are less than the standard limit set by WHO (p value<0.001) [20]. Even at the maximum^{222}Rn concentration (0.384 Bq/l), the effective dose is also much less than 0.1 mSv/y.

The mean of effective dose for the age groups of adults and children in Somlai et al. study is 20.3 μSv/y(1.13-88.7μSv/y) and 40.6 μSv/y(2.26-177μSv/y) μSv/y, respectively. The effective dose in Somlai et al. study was much higher than our study because of more ^{222}Rn concentration in the tap water[21]. The effective dose due to drinking the tap drinking water in Binesh et al. study in Mashhad city was also higher than in our study because of more ^{222}Rn concentration (0.04 mSv/y) [53].

In the study of Ahmad et al., mean of concentration of ^{222}Rn is 5.37 Bq/l and effective doses due to the ingestion of radon in drinking water varied from 0.014±0.0016 to 0.0899 ±0.0088 mSv/y, 0.0052 ±0.0006 to 0.033 ±0.0032 mSv /y and 0.0068 ±0.0007 to 0.0434±0.0042 mSv/y, for age groups <2years, 2-16years and >16 years, respectively[4]. Ratio minimum effective doses in the study of Ahmad et al. for infants, children's and adults males are 2.79, 7.4 and 14, respectively. In the same study ^{222}Rn concentration in the tap water was 65 times higher respect to our data. In both studies the conversion coefficient is almost the same, daily water intake and sensitivity coefficient are necessary to calculate the effective dose, therefore, ^{222}Rn concentration is the effective factor for this differences.

5. Conclusions

The results of this research shows that^{222}Rn concentration in the tap water of Bandar Abbas city is lower than WHO, EU and EPA standard limits. Also the effective dose of^{222}Rn in the all age groups is much lower than standard limits.

Given the daily high consumption of water, adults males are highest sensitivity to health hazards of ^{222}Rn, in particular for both stomach and lung cancer. Therefore, we recommend to remove the ^{222}Rn excess from the drinking water using a proper treatment to reducing the ^{222}Rn health hazards for the adults males.

6. Acknowledgements

Students Research office of Shahid Beheshti University of Medical Sciences (Code:8156, Date:2016/02/29) and Social Determinants in Health Promotion Research Center of Hormozgan University of Medical Sciences were supports the financial of this research (Code:93104, Date: 2014/11/24).

7. References

1. Colmenero Sujo, L., et al., Uranium-238 and thorium-232 series concentrations in soil, radon-222 indoor and drinking water concentrations and dose assessment in the city of Aldama, Chihuahua, Mexico. Journal of Environmental Radioactivity, 2004. **77**(2): p. 205-219.
2. Smith, B.J., L. Zhang, and R.W. Field, Iowa radon leukaemia study: a hierarchical population risk model for spatially correlated exposure measured with error. Statistics in medicine, 2007. **26**(25): p. 4619-4642.
3. Sciacca, S. and G.O. Conti, *Mutagens and carcinogens in drinking water.* Mediterranean Journal of Nutrition and Metabolism, 2009. **2**(3): p. 157-162.
4. Ahmad, N., M.S. Jaafar, and M.S. Alsaffar, Study of radon concentration and toxic elements in drinking and irrigated water and its implications in Sungai Petani, Kedah, Malaysia. Journal of Radiation Research and Applied Sciences, 2015.
5. Oner, F., et al., The measurements of radon concentrations in drinking water and the Yeşilırmak River water in the area of Amasya in Turkey. Radiation protection dosimetry, 2009. **133**(4): p. 223-226.
6. Kam, E. and A. Bozkurt, *Environmental radioactivity measurements in Kastamonu region of northern Turkey.* Applied Radiation and Isotopes, 2007. **65**(4): p. 440-444.
7. M.Rožmaric, et al., Natural radionuclides in bottled drinking waters produced in Croatia and their *contribution to radiation dose.* Science of the Total Environment, 2012. **437**: p. 53-60.
8. Radiation, U.N.S.C.o.t.E.o.A., *UNSCEAR 2000.* Sources and effects of ionizing radiation, 2000. **2**.
9. Hamanaka, S., et al., *Radon concentration measurement in water by means of α liquid-scintillation spectrometry with a PERALS spectrometer.* Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1998. **410**(2): p. 314-318.

10. Organization, W.H., *Guidelines for drinking-water quality: recommendations*. Vol. 1. 2004: World Health Organization.
11. Oner, F., et al., The measurements of radon concentrations in drinking water and the Yeşilirmak River water in the area of Amasya in Turkey. Radiation protection dosimetry, 2009: p. ncp049.
12. Motesaddi, S., et al., Effective dose of Radon222 and thoron220 in the indoor air of Genow hot springs of Bandar Abbas. Advances in Environmental Biology, 2014. **8**: p. 453-459.
13. Brenner, D.J., et al., *Cancer risks attributable to low doses of ionizing radiation: assessing what we really know*. Proceedings of the National Academy of Sciences, 2003. **100**(24): p. 13761-13766.
14. Rangela, J.D., et al., *Radioactivity in bottled waters sold in Mexico.* Applied Radiation and Isotopes, 2002. **56**: p. 931-936.
15. Ali, N., et al., Estimation of mean annual effective dose through radon concentration in the water and indoor air of Islamabad and Murree. Radiation protection dosimetry, 2010. **141**(2): p. 183-191.
16. Akawwi, E., *Radon-222 Concentrations in the Groundwater along Eastern Jordan Rift.* Journal of Applied Sciences, 2014. **14**(4): p. 309-316.
17. Forte, M., et al., *The measurement of radioactivity in Italian drinking waters.* Microchemical Journal, 2006. **85** p. 98–102.
18. EPA (2006). Environmental Protection Agency website. *www.epa.org*.
19. Risica, S. and S. Grande, Council Directive 98/83/EC on the quality of water intended for human consumption: calculation of derived activity concentrations. 2000: Istituto Superiore di Sanità Roma.
20. WHO. (2008). Guidelines for drinking-water quality (Vol. 1, pp. 197 e209). World health Organisation Publication.
21. Somlaia, K., et al., 222Rn concentrations ofwater in the Balaton Highland and in the southern part of Hungary, and the assessment of the resulting dose. Radiation Measurements, 2006. **42**: p. 491 – 495.
22. Fakhri, Y., et al., Effective Dose of Radon 222 Bottled Water in Different Age Groups Humans: Bandar Abbas City, Iran. Global Journal of Health Science, 2015. **8**(2): p. p64.
23. Erdogan, M., K. Manisa, and F. Tel, *The Measurment of radon activity concentrations in tap water in some dwellings of konya province-Turkey.* Carpathian Journal of Earth and Environmental Sciences, 2015. **10**(1): p. 273-278.

24. Fakhri, Y., et al., Determination concentration of Radon222 in Tap drinking water; Bandar Abbas City, Iran.
25. Center, I.S., *Iran Statistical Year Book*. 2000, Tehran.
26. Federation, W.E. and A.P.H. Association, *Standard methods for the examination of water and wastewater.* American Public Health Association (APHA): Washington, DC, USA, 2005.
27. Ishikawa, T., et al., *Airborne and waterborne radon concentrations in areas with use of groundwater supplies.* Journal of radioanalytical and nuclear chemistry, 2005. **267**(1): p. 85-88.
28. Somlai, K., et al., 222Rn concentrations of water in the Balaton Highland and in the southern part of Hungary, and the assessment of the resulting dose. Radiation Measurements, 2007. **42**: p. 491-495.
29. Ursulean, I., et al. ESTIMATION OF INDOOR RADON CONCENTRATIONS IN THE AIR OF RESIDENTIAL HOUSES AND MINES IN THE REPUBLIC OF MOLDOVA. in Paper presented at the First East European Radon Symposium–FERAS. 2012.
30. GmbH, S. *APPLICATION NOTE AN-003_EN: Measurement of the Radon concentration of water samples*. June 2007; Available from: www.sarad.de.
31. Jalili-Majareshin, A., A. Behtash, and D. Rezaei-Ochbelagh, *Radon concentration in hot springs of the touristic city of Sarein and methods to reduce radon in water.* Radiation Physics and Chemistry, 2012. **81**(7): p. 749-757.
32. Somlai, J., et al., *Concentration of 226Ra in Hungarian bottled mineral water.* Journal of Environmental Radioactivity 2002. **62**: p. 235-240.
33. Somlai, K., et al., 222Rn concentrations ofwater in the Balaton Highland and in the southern part of Hungary, and the assessment of the resulting dose. Radiation Measurements 2007. **42** p. 491 – 495.
34. Binesh, A., et al., Evaluation of the radiation dose from radon ingestion and inhalation in drinking water. Int J Water Resour Environ Eng, 2010. **2**(7): p. 174-178.
35. Agency, E.P., stimated Per Capita Water Ingestion and Body Weight in the United States–An Update. October, 2004. p. 40-45.
36. Nasir, T. and M. Shah, Measurement of annual effective doses of radon from drinking water and dwellings by CR-39 track detectors in Kulachi City of Pakistan. Journal of Basic & Applied Sciences, 2012. **8**: p. 528-536.
37. Rožmarić, M., et al., Natural radionuclides in bottled drinking waters produced in Croatia and their contribution to radiation dose. Science of the Total Environment, 2012. **437**: p. 53-60.

38. Mowlavi, A.A., A. Shahbahrami, and A. Binesh, *Dose evaluation and measurement of radon concentration in some drinking water sources of the Ramsar region in Iran.* Isotopes in environmental and Health Studies, 2009. **45**(3): p. 269-272.
39. Fakhri, Y. and M. Mirzaei, *Determination concentration of Radon 222 in tap drinking water, Jask City, Iran.* IOSR Journal of Environmental Science, Toxicology and Food Technology, 2015. **9**(8): p. 6-9.
40. Wu, Y.-Y., et al., *Radon Concentrations in Drinking Water in Beijing City, China and Contribution to Radiation Dose.* International journal of environmental research and public health, 2014. **11**(11): p. 11121-11131.
41. El-Ghossain, M.O. and A.A.A. Shammala, *Radioactivity measurements in tap water in Gaza Strip (Al-Naser Area).* Journal of the Association of Arab Universities for Basic and Applied Sciences, 2012. **11**(1): p. 21-26.
42. Kozłowska, B., et al., *Radioactivity in waters of Mt. Etna (Italy).* Radiation Measurements, 2009. **44**(4): p. 384-389.
43. Bonotto, D.M., *222 Rn, 220 Rn and other dissolved gases in mineral waters of southeast Brazil.* Journal of environmental radioactivity, 2014. **132**: p. 21-30.
44. Zhuo, W., T. Iida, and X. Yang, *Occurrence of 222Rn, 226Ra, 228Ra and U in groundwater in Fujian Province, China.* Journal of environmental radioactivity, 2001. **53**(1): p. 111-120.
45. Horvath, A., et al., *Radon concentrations in hot spring waters in northern Venezuela.* Journal of environmental radioactivity, 2000. **47**(2): p. 127-133.
46. Erdogan, M., K. Manisa, and F. Tel, *THE MEASUREMENT OF RADON ACTIVITY CONCENTRATIONS IN TAP WATER IN SOME DWELLINGS OF KONYA PROVINCE–TURKEY.* CARPATHIAN JOURNAL OF EARTH AND ENVIRONMENTAL SCIENCES, 2015. **10**(1): p. 273-278.
47. Xinwei, L., Analysis of radon concentration in drinking water in Baoji (China) and the associated health effects. Radiation protection dosimetry, 2006. **121**(4): p. 452-455.
48. Moldovan, M., et al., Radon and radium concentration in water from North-West of Romania and the estimated doses. Radiation protection dosimetry, 2014. **162**(1-2): p. 96-100.

Corresponding Author:

Hassan Keramati*,

Email: Hkramatee@gmail.com