Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 22, S. 347-351, Ocak 2021

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 22, pp. 347-351, January 2021

Research Article

Determination of Radon Exposure during the Geothermal Bath Therapies

Feride Kulalı[1*]

[1*] Vocational School of Health Services. Nuclear Technology and Radiation Safety, Üsküdar University, Istanbul-TURKEY, (ORCID: 0000-0002-7211-4336), feride.kulali@uskudar.edu.tr

(First received December 2020 and in final form January 2021)

(**DOI:** 10.31590/ejosat.840730)

ATIF/REFERENCE: Kulalı, F. (2021). Determination of Radon Exposure during the Geothermal Bath Therapies. *European Journal of Science and Technology*, (22), 347-351.

Abstract

Radon gas is the widest and primary origin of radiation exposure due to natural radiation sources. Radon and its short-term decay products may adhere to small particles in the air and inhalation of these particles cause an increase in lung cancer risk by irradiating lung tissues by alpha radiation. Radon can reach living spaces by diffusion in air or dissolving in water and also it is well known that radon readily soluble in water and the solubility of radon increases quickly while the temperature of the water is decreasing. For this reason, investigation of radon activity concentration levels in drinking water, groundwater and geothermal waters is necessary to avoid exposure to radiation due to water use. In this study, dissolved radon concentrations in geothermal water samples and the indoor radon levels during the treatment in thermal bath facilities, were measured by using AlphaGUARD PQ2000Pro. The indoor measurements were performed at three facilities which contain bathrooms using geothermal waters in September 2019. Radon levels in the geothermal waters of the region were determined by collecting water samples from nine locations in the geothermal fields in the Büyük Menderes Graben. The annual effective doses received by residents and visitors due to indoor radon concentrations between 753-186 Bq/m^3 was calculated.

Keywords: Radon exposure, Geothermal Bath Treatment, SPA.

Jeotermal Banyo Tedavileri Sırasında Radon Maruziyetinin Belirlenmesi

Öz

Radon gazı, doğal radyasyon kaynakları nedeniyle oluşan radyasyon maruziyetinin en yaygın ve birincil kaynağıdır. Radon ve kısa süreli bozunma ürünleri havadaki küçük partiküllere yapışabilmekte ve bu partiküllerin solunması akciğer dokularını alfa radyasyonu ile ışınlayarak akciğer kanseri riskinde artışa neden olmaktadır. Radon, havada difüzyonla veya suda çözünerek yaşam alanlarına ulaşabilmektedir ve ayrıca radonun suda kolaylıkla çözünebildiği ve azalan sıcaklıkla çözünürlüğünün hızla arttığı iyi bilinmektedir. Bu nedenle, içme suyu, yeraltı suları ve jeotermal sularda radon aktivite seviyelerinin incelenmesi, su kullanımına bağlı olarak maruz kalınan radyasyonun belirlenmesi için çok önemlidir. Bu çalışmada, jeotermal su örneklerinde çözünmüş radon konsantrasyonları ve termal banyo tesislerinde tedavi sırasındaki bina içi radon seviyeleri AlphaGUARD PQ2000Pro kullanılarak ölçülmüştür. Jeotermal suların kullanıldığı banyoların bulunduğu üç tesiste bina içi radon ölçümleri Eylül 2019'da gerçekleştirilmiştir. Büyük Menderes Grabeni'nde yer alan jeotermal sahalarda bulunan dokuz lokasyondan su örnekleri toplanarak bölgeye ait jeotermal sulardaki radon seviyeleri belirlenmiştir. 753-186 Bq / m^3 arasındaki bina içi radon konsantrasyonları nedeniyle bölge sakinleri ve ziyaretçiler tarafından alınan yıllık etkin dozlar hesaplanmıştır.

Anahtar Kelimeler: Radon maruziyeti, Jeotermal Banyo Tedavisi, SPA.

[*] Corresponding Author: feride.kulali@uskudar.edu.tr

1. Introduction

Radon gas is an important source of irradiation with natural radiation. The reactivity of radon is poor, so it does not chemically bind to tissues when inhaled. However, radon decay products, which irradiate lung tissue and increase the risk of lung cancer, adhere to dust and other particles to form radioactive aerosols. Inhalation of radon gas does not cause acute effects such as respiratory failure, headache and cough (Keith et al. 2012). However, in order to prevent stochastic effects that may occur, it is essential to examine especially indoor radon levels (Yarar et al. 2015; Günay et al 2018; Yalım et al. 2018; İçhedef 2019; Günay et al 2019).

The production of Rn depends on the existence of Ra in the earth's crust, in soil, rocks and groundwater. Radon emanates from solid grains and transports in pores occupied with air and water and then transported by diffusion and advection through this space in order to exhale into the atmosphere. If water is present in these pores, it is easier for the radon atoms to remain here, but if it is dry, the radon atoms can be embedded in another particle where they cannot move through the gap. For most soils, only 10 to 50 percent of the radon actually escapes from the mineral grains and enters the pores. The seasonal variation of radon concentration varies from sea level to elevation. In mountainous regions, fluctuations in concentration are observed due to temperature and wind changes. It is spreading to the environment closely related to the geological structure of the geographical region. Radon concentrations on the earth surface vary according to the permeability of soil, fractured structure of the crust and generally higher the faults (Nazaroff, 1992).

The medical use of geothermal waters, spa pools and mineral baths especially for arthritis treatment is known as balneotherapy. Balneology is the science that studies the healing effects of natural thermal waters and their use in the treatment of diseases. Thermal water treatments have been practiced since ancient times, spread all over the world and are part of the traditional therapies of ancient and modern cultures. Healing thermal waters are used not only as bathing, but also in the form of inhalation, irrigation, drinking cure or mud (Davinelli et al. 2019). There are different regional studies on radon exposure during thermal applications. (Vogiannis et al. 2004; Walczak et al. 2015; Műllerová et al. 2016; Yıldız et al. 2018)

In the current study, radon activity concentrations in groundwater and geothermal water have been measured in some parts of Büyük Menderes Graben where active fault lines are spread over a wide area. In addition, indoor radon concentrations were measured during thermal treatments and effective doses were calculated.

2. Material and Method

2.1. Monitoring Site

Many general geological and geothermal studies have been carried out on the Büyük Menderes Graben (Western Anatolia). Turkey's high enthalpy geothermal fields are located in the Büyük Menderes Graben. Büyük Menderes graben is the result of N–S extension which commenced by the Early Pliocene. Geophysical studies and drilling have shown a normal fault structure, resulting in stepwise graben formation, which is also characteristic of the Germencik, Salavatlı and Kızıldere geothermal fields in the Büyük Menderes Graben (Fig.1) (Simsek, 2003).

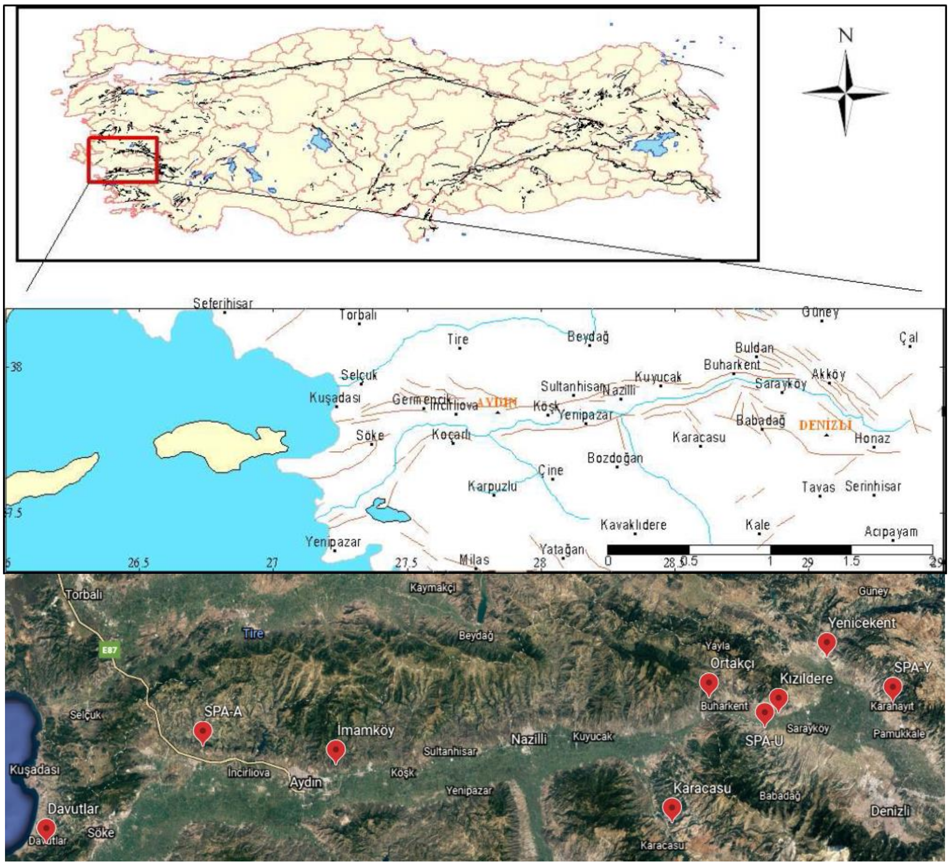

Figure 1. Active faults of Büyük Menderes graben system and measurement points (Eravcı 2006)

2.2. Measurement Technique

Measurements were carried out with AlphaGuard PQ 2000PRO, a portable radon monitor produced for long-term radon survey. AlphaGuard is an ionizing chamber which determines radon via alpha spectrometric techniques. The AlphaGuard device has a variety of equipment for different applications. AquaKIT was used for the determination of radon activity concentration in water (Fig.2). For measurement with Aquakit, water samples were circulated in a radon sealed assembly consisting of two glass containers and an Alpha Guard unit. The water temperatures were measured by thermometer during the sampling. Indoor radon measurements was performed on diffusion mode of the AlphaGuard monitor during the thermal treatments. The device was left in the treatment room for an hour, allowing it to operate in 10-minute data sampling cycles and at the end of process mean value obtained for per treatment.

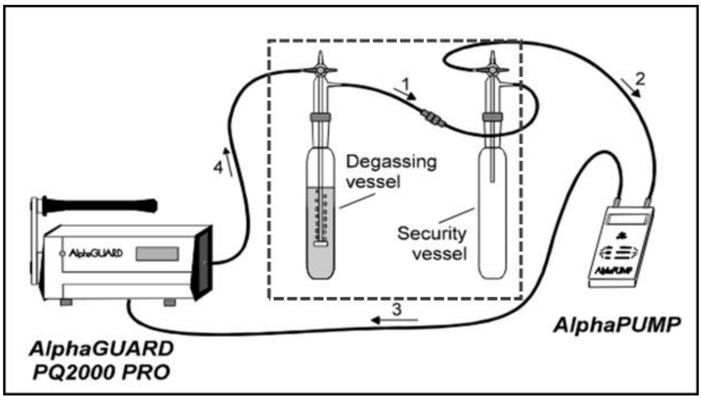

Figure 2. AquaKIT scheme.

AlphaEXPERT is the software of the monitoring system and it was used for the imaging, processing and storage of the measurement data. Radon concentrations in the water samples (C_{water}) were calculated using the following equation

$$\mathbf{C_{water}} = \frac{\mathbf{C_{air}} \times \left(\frac{\mathbf{V_{system}} - \mathbf{V_{sample}}}{\mathbf{V_{sample}}} + \mathbf{k} \right) - \mathbf{C_0}}{\mathbf{1000}} \quad (1)$$

Where C_{air} is the radon activity concentration [Bq/m³] in the measuring set-up after expelling the radon. C0 is the radon activity concentration in the measuring set-up before sampling and V is the volume (Genitron Instruments, 2000).

The Ostwald coefficient (k) in the equation explains the solubility of radon in water and is defined as the ratio of radon concentration in the water phase to that in the gas phase. The value of k changes with temperature and there is an inverse correlation between the increase in temperature and the solubility of radon in water.

3. Results and Discussion

In this study, samples of nine geothermal sources located in the Büyük Menderes Graben, including Kızıldere, Germencik and Karahayıt geothermal fields, were collected and radon concentrations in these waters were determined (Table 1). Radon dissolved in water can enter indoor air when water is used. In 1993, the concentration ratio in air and water was taken as 10-4 by Unscear. This value was also suggested in a national review of experimental and model study results in the United States (National Research Council 1998). Considering the measured values, it is clear that their contribution to indoor radon values and to the effective dose due to inhalation will be very low.

The Commission of the European Communities (2001) recommended a reference level for the radon in drinking water of 100 Bq /1, while the USEPA (2000) proposed a MCL (maximum contaminant level) of 11 Bq/1 and an AMCL (alternative maximum contaminant level) of 148 Bq /1 for radon. Sources are rarely used for drinking, but are often below recommended levels.

Three of the locations were SPA facilities with personal treatment rooms. All SPA facilities have a small pool in the rooms and this pool is filled with geothermal water before the therapy. Before filling the pool, background radon levels were measured and determined as 131 Bq/m3 for SPA-Y, 98 Bq/m3 for SPA-U and 146 Bq/m3 for SPA-A, respectively. The mean values were determined by measuring one hour for an average of one hour treatment period after filling. Effective doses were calculated by measuring the exposed indoor radon concentrations during the treatments performed in these rooms (Table 2-3). Occupancy factor changes for residents of the facilities and visitors for annual effective doses. Visitors stated that they visit the thermal facilities for one week to ten days a year and use the indoor geothermal pools twice a day, while those who live here stated that they use it at least once a week.

Table 1. Rn activity concentrations in geothermal waters

	Location	Temperature(ºC)	Rn (Bq/l)	Rn Error (Bq/l)
1	*SPA-Y (Karahayıt)*	42.5 (59) *	10.634	±1.33
2	*Yenicekent*	45.1	3.143	±0.93
3	*SPA-U (Sarayköy)*	89	1.772	±0.22
4	*Kızıldere*	86 (242) *	2.036	±0.25
5	*Ortakçı*	30.6	39.340	±4.90
6	*Karacasu*	25	9.315	±1.16
7	*İmamköy*	41	4.631	±0.57
8	*SPA-A (Alangüllü/Germencik)*	61.7 (232) *	1.392	±0.21
9	*Davutlar*	54	1.899	±0.23
	Recommended reference levels			
	USEPA		11	
	EURATOM		100	

* reservoir temperatures (Simsek 2003)

Table 2. Indoor Rn activity concentrations

Location	Temperature (°C)	Rn (Bq/m^3)	Rn Error (Bq/ m^3)
SPA-Y (Karahayıt)	42.5	753	±94
SPA-U (Sarayköy)	89	186	±24
SPA-A (Alangüllü/Germencik)	61.7	243	±60

Table 3. Effective doses

Location	Effective dose (µSv) (per treatment)	Annual Effective dose (µSv) (for residents)	Annual Effective dose (µSv) (for visitors)
SPA-Y (Karahayıt)	2.7	140.4	37.8-54
SPA-U (Sarayköy)	0.66	34.32	9.24-13.2
SPA-A (Alangüllü/Germencik)	0.87	45.24	12.18-17.4

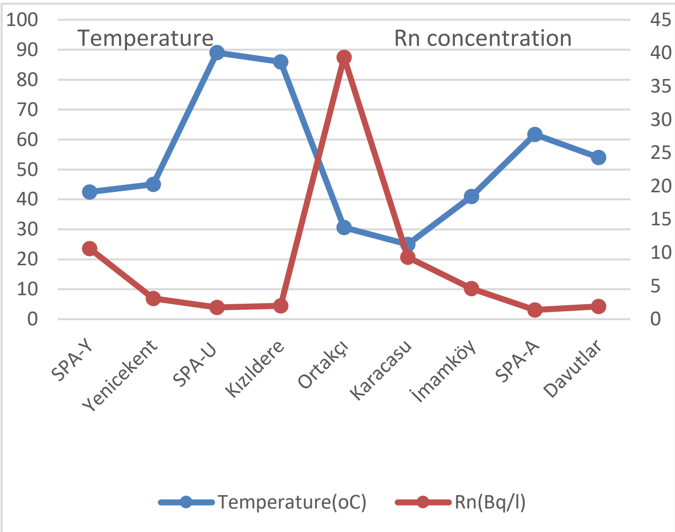

Figure 3. Temperature&Rn concentration graph

It is clear that the radon values dissolved in water are consistent with the oswald coefficient at high temperature differences, but this situation changes at some close values. Because the radon values are not only related to temperature, but are also affected by factors such as the natural radioactivity levels of the region, the proximity of the location to the fault lines and the flow rate of the water (Fig 3).

4. Conclusions and Recommendations

The geothermal water resources of the Büyük Menderes Graben are utilized for varied purposes, such as geothermal treatments in SPAs, swimming in natural and artificial geothermal pools, irrigation and rarely drinking. Ortakçı sample has a radon concentration level that exceeds the maximum pollutant level (MCL) of 11 Bq / l as recommended by the United States Environmental Protection Agency (USEPA 2000) and is significantly higher than at other locations. However, Ortakçı resource is far from settlements and is not used for any special purpose. Karacasu spring is generally used in irrigation and it was determined that radon activity concentrations in Imamköy, Kızıldere, Davutlar and Yenicekent samples are well below the reference values.

Indoor radon levels are below the 400 Bq.m^{-3} recommended for indoor radon concentration in dwellings by the Turkish Atomic Energy Authority during the treatmens at SPA-U and SPA-A, however SPA-Y exceeds the limit (TAEA 2012). As seen from Table 3, the annual effective doses changed from 9.24 µSv to 37.8 µSv for visitors and from 34.32 µSv to 140.4 µSv for residents. The reason why SPA-Y has a higher radon concentration compared to other facilities can be thought to be due to the lower water temperature and higher radon solubility in this water. It is also known that the proximity of active fault lines affects the radon level in geothermal waters. In addition, since the source temperature is very high in SPA-U and SPA-A, the geothermal waters are first taken to the tanks and then served to the rooms, which causes the radon density to decrease. In SPA-Y, on the other hand, water directly reaches the rooms from the source, so gas discharge from the taps is observed along with the water. For this reason, it may be recommended to ventilate the room while filling the pools in the rooms. The effective doses people receive from SPA facilities are restricted by the short exposure time and remains below level of 1.2 mSv the average worldwide exposure due to radon sources. (Unscear 2000). It can be concluded that the use of geothermal water in balneotherapy will not pose a radiological hazard if the room is ventilated and the treatment times are not exceeded.

References

Davinelli, S., Bassetto, F., Vitale, M., & Scapagnini, G. (2019). Thermal Waters and the Hormetic Effects of Hydrogen Sulfide on Inflammatory Arthritis and Wound Healing. The Science of Hormesis in Health and Longevity, 121-126. doi:10.1016/b978-0-12-814253-0.00010-3

Eravcı B (2006) Geology and Paleoseismilogy of Active Faults in Büyük Menderes Graben. Dissertation, Ankara University

Genitron Instruments, 2000. Alpha Guard PQ2000 PRO Multiparameter Radon Monitor. Genitron Instruments Ltd, Frankfurt.

Günay O, Aközcan S, Kulalı F (2018) Bina İçi Radon Konsantrasyonlarının Belirlenmesi. European Journal of Science and Technology 13: 91-97.

Günay O, Aközcan S, Kulalı F (2019). Measurement of indoor radon concentration and annual effective dose estimation for a university campus in Istanbul. Arabian Journal of Geosciences, 12(5), 171-178., Doi: 10.1007/s12517-019-4344-x

İçhedef M (2019) Measurement of Rn-222 and Ra-226 in municipal supply tap water to evaluate their radiological impacts," International Journal of Environmental Analytical Chemistry, vol.99, 1069-1077. DOI: 10.1080/03067319.2019.1609461

Keith S, Doyle JR, Harper C, et al. Toxicological Profile for Radon. Atlanta (GA): Agency for Toxic Substances and Disease Registry (US); 2012 May.

Műllerová, M., Mazur, J., Blahušiak, P., Grządziel, D., Holý, K., Kovács, T., Shahrokhi, A. (2016). Preliminary results of radon survey in thermal spas in V4 countries. Nukleonika, 61(3), 303-306. doi:10.1515/nuka-2016-0050

Nazaroff, W. W. (1992), Radon transport from soil to air, Rev. Geophys., 30(2), 137– 160, doi:10.1029/92RG00055.

National Research Council (1998) Risk Assessment of Radon in Drinking Water. National Academy Press, Washington.

Simsek, S. (2003). Hydrogeological and isotopic survey of geothermal fields in the Buyuk Menderes graben, Turkey. Geothermics, 32(4-6), 669-678. doi:10.1016/s0375-6505(03)00072-5

The Commission of the European Communities (2001) Commission Recommendation of 20 December 2001 on the protection of the public against exposure to radon in drinking water supplies. C(2001)/4580/01/928/EURATOM.

Turkish Atomic Energy Authority-TAEA (2012) Radon gas in the indoor environment. Technical report 2012/3, Ankara.

UNSCEAR (1993) United Nations Scientific Committee on the Effects of Atomic Radiation. 1993 Report to the General Assembly, with scientific annexes. United Nations sales publication E.94.IX.2. United Nations, New York.

UNSCEAR (2000) United Nation Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation, United Nations Publications, New York.

USEPA Office of Ground Water and Drinking Water (2000) Radionuclides Notice of Data Availability, Technical Support Document, The United States Environmental Protection Agency Publications, March 2000, EPA Number: 815R00007

Vogiannis, E., Niaounakis, M., & Halvadakis, C. (2004). Contribution of 222Rn-bearing water to the occupational exposure in thermal baths. Environment International, 30(5), 621-629. doi:10.1016/j.envint.2003.11.004

Walczak, K., Olszewski, J., & Zmyślony, M. (2015). Estimate of radon exposure in geothermal SPAs in Poland. International Journal of Occupational Medicine and Environmental Health, 29(1), 161-166. doi:10.13075/ijomeh.1896.00404

Yalım HA, Gümüş A, Başaran C, Bağcı M, Yıldız A, Açil D, Özçelik M, İlhan MZ, Ünal R (2018) Comparison of radon concentrations in soil gas and indoor environment of Afyonkarahisar Province. Arab J Geosci 11, 246. https://doi.org/10.1007/s12517-018-3546-y

Yarar Z, Taşköprü C, Içhedef M, Saç MM, Kumru MN, Bolca M (2015). Ra-222 and Ra-226 in geothermal waters of Bayindir-Izmir (Turkey). Environmental Earth Sciences, vol.74, 6943-6949. DOI: 10.1007/s12665-015-4701-3

Yıldız A, Başaran C, Bağcı M, Gümüş A, Çonkar FE, Ulutürk Y, Yalım HA (2018) The measurement of soil gases and shallow temperature for determination of active faults in a geothermal area: a case study from Ömer–Gecek, Afyonkarahisar (West Anatolia). Arab J Geosci 11, 175. https://doi.org/10.1007/s12517-018-3520-8