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Investigation of the Radon Levels in Groundwater and Thermal Springs of Pamukkale Region

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Radon, which is the largest source of natural ionizing radiation, reaches surface as gas form or solvated in the ground water. Emanation of radon can has a profile which is disposed to increase or decrease depending on the effects of meteorological events or crust movements. Pamukkale, which was involved previously in the world heritage list of UNESCO, and the surrounding area have many groundwater and thermal springs that carry dissolved radon to surface. The aim of this study was to investigate the variations of radon in the water samples of the region.

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1. Introduction

Radon is a chemical element with symbol Rn and atomic number 86. It is a radioactive, colourless, odourless, tasteless noble gas, occurring naturally as the decay product of uranium or thorium. Its most stable isotope, ^{222}Rn, has a half-life of 3.8 days. Radon is one of the densest substances that remains a gas under normal conditions and is considered a health hazard due to its radioactivity.

The hot springs of Pamukkale (group) are located at the intersection of the Büyük Menderes and Gediz grabens. Their temperature is in the range of 28–59 °C. In this area the thickness of travertine reaches 85 m. The Pamukkale springs, which have a temperature of 36 °C, deposit white travertine, whereas the Karahayıt spring deposits red travertine due to high iron concentrations in the fluid. Pamukkale and Karahayit are tourist attractions, visited by 1.5 million tourists every year [1]. The thermal fluid from the wells is used for swimming, bath and spa.

As the radon is important for health the radon measurements are studied largely by researchers [2–4].

In this work radon levels have been measured in ground water and thermal spring in Pamukkale region (Turkey).

2. Methods

2.1. Hydrogeological structure

The Pamukkale area is one of the UNESCO-sponsored world cultural heritage sites. The travertine and thermal springs emerging in the area are sited in the Çürüksu graben, which belongs to the extensive Büyük Menderes graben system (Fig. 1). There are two fields with manifestations, Pamukkale (36 °C) and Karahayıt (59 °C). The main aquifer supplying hot and mineralized water to the Pamukkale thermal springs is the paleozoic and mesozoic limestone [5].

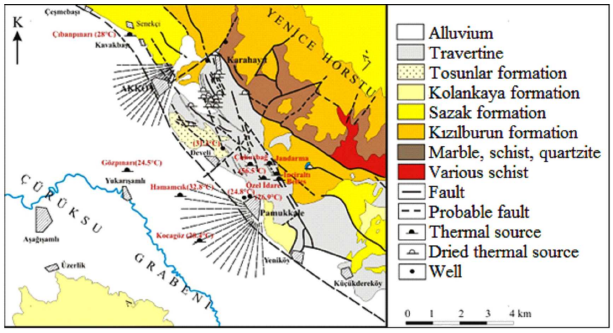

Fig. 1. Hydrogeological map of the region [6].

2.2. Measuring system

The measurement has been performed by a portable device, AlphaGUARD PQ 2000PRO, which is designed for long-term monitoring of radon gas concentration. AlphaGUARD is an ionizing chamber which measures radon via alpha spectrometric techniques. The AlphaGUARD has several components for different applications. AquaKIT is used for the determination of radon in water (Fig. 2).

AlphaEXPERT software was used for the analysis and storage of the measurement results. Radon concentrations in the water samples (C_{water}) were determined using the following equation [7]:

$$C_{\text{water}} = \frac{C_{\text{air}}\left(\frac{V_{\text{system}} - V_{\text{sample}}}{V_{\text{sample}}} + k\right) - C_0}{1000}, \qquad (1)$$

where C_{air} is the radon concentration [Bq/m^3] in the measuring setup after expelling the radon, C_0 is the radon concentration in the measuring setup before sampling and V is the volume.

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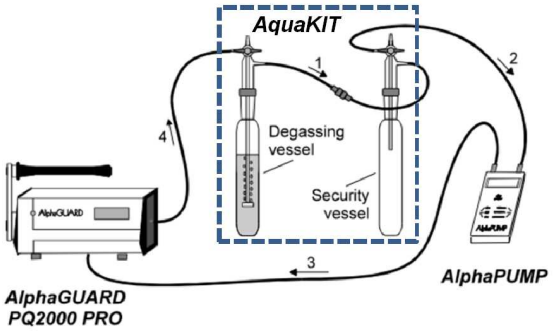

Fig. 2. Measuring setup for water samples.

The Ostwald coefficient (k) in Eq. (1) accounts for radon solubility in water and is defined as the ratio of radon concentration in the water phase to that in the gaseous phase. The value of k decreases with increasing temperature (Fig. 3). In other words the solubility of radon in water decreases with temperature [8].

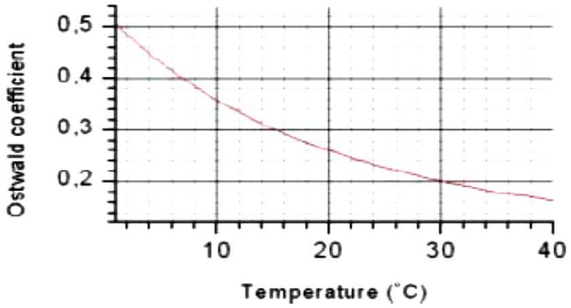

Fig. 3. Radon solubility vs. temperature [7].

3. Results

The measurements have been performed at seven points of the region (two locations at Pamukkale, Akköy and Karahayıt, one location at Develiköy) and the results are given in Table I. Radon concentrations and temperature variations for seven locations are shown in Fig. 4.

TABLE I

Rn concentrations of water samples.

Location	T [°C]	A_{Rn} [Bq/l]
Pamukkale özel idare source	34.8	19.96
Pamukkale jandarma source	34	10.00
Karahayıt spa	42	9.20
Karahayıt well	52	3.20
Akköy spring 1	20	6.45
Akköy spring 2	22	9.86
Develiköy source	30	23.80

The concentrations of radon in water may range over several orders of magnitude, generally being highest in well water, intermediate in ground water, and lowest in surface water [9].

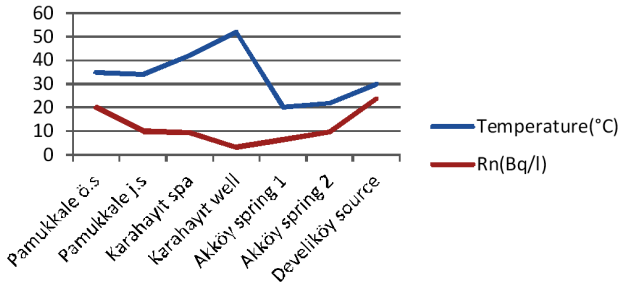

Fig. 4. Variations of Rn and temperature.

4. Conclusion

The results obtained from the present study have shown that radon concentration in groundwater and thermal springs of Pamukkale region varies between 3 and 25 Bq/l. It is observed that the radon concentration is high in ground water which has relatively low temperature and flow rate. The water sources of the region are used for various purposes, such as thermal treatments, swimming, irrigation and drinking. The Pamukkale and Develiköy water samples show higher level of ^{222}Rn concentrations, which exceeds the MCL 11 Bq/l as recommended by USEPA [10]. The Develiköy source is not used for any purpose and the Pamukkale source is usually used for swimming only by the visitors. Therefore the effective dose that a person receives from Pamukkale pool is limited by the short exposure time.

Acknowledgments

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