

Research Article

The Research on the Influence of Degassing Temperatures of Water Samples on Radon Observations

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Received 11 May 2022; Revised 27 June 2022; Accepted 30 June 2022; Published 19 July 2022

Academic Editor: Naeem Jan

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Radon is a naturally emitted gas that is observed in soils, subsoils, air, and all types of water. Because there is a statistically significant association observed between seismic activity and active concentration levels of radon readings, a dissolved form of radon in water near-fault locations such as wells or springs, has significant observational value. Furthermore, as the temperature of the water rises, the dissolved radon in the water might transfer to the air, a process known as degassing. Thus, radon measurements in all types of water such as groundwater, tap waters, and bottled drinking waters have been investigated by covering several aspects of the degassing process, namely, health issues, monitoring volcanic activities, and predicting seismic activities by employing various methods. In this paper, radon measurements of sampled waters removed from the well located at Yishui Seismic Station in China are utilized to monitor the degassing temperature and predict earthquakes. For this purpose, an experiment is devised to collect water samples manually. Then, the amount of radon dissolved in the water samples is examined to find a stable degassing temperature range at Yishui Seismic Station. An experimental setup is constructed to collect data for 20 days. The most important findings found regarding this research can be expressed as follows. (1) When the degassing temperature is observed to be higher than 5°C, the influence on radon value changes greatly. (2) The observations of the radon degassing temperatures in the Yishui well are found to be stable between 18°C and 23°C.

1. Introduction

Radon (Rn-222) is a naturally occurring radioactive gas found in all kinds of water. While the largest concentrations of radon are found in underground waters, wells, and springs, where granites and phosphates with high uranium content are found in fragmented porous rocks, the lowest concentrations are found in surface waters, lakes, rivers, and seas. Radon, whose concentration amounts carry a great value, providing cheap, solid, and precise measurement, is also used as one of the radioactive tracers that display solitary features and uses. Even though radon is generally observed in soils, subsoils, air, and all types of water, radon in all types of water is paid more attention to by researchers since alterations of radon concentration amounts have a practical significance to monitor some events especially seismic activities along fault zones.

Besides, when drinking water could have a high concentration amount of radon, it may pose health issues for drinkers [1]. Moreover, the transportation of underground water can be surveilled per radon and radium concentration amounts to observe how the aquifer behaves. Since radon is dissolved and degassed quickly in all types of water, there exist several measurement methods to pinpoint radon concentration activity levels, namely, alpha scintillation, an ionization chamber, or a silicon detector. Therefore, the alterations of radon concentration levels have been investigated for almost three decades to be utilized in the prediction of earthquakes or volcanic blowups, detect active faults or geothermal belts, or research water masses deposited underground [2–4].

Radon is a naturally produced radioactive gas that is the daughter output of Ra-226 and its half-life is approximately 3.8 days, which is short-lived gas. Before decaying

completely, it travels quite long distances within the soil or subsoil. Its easily detectable properties help radon be measured with high precision. Besides, radon is interacted with a large quantity of water, resulting in the dissolved form of radon [5–7]. On the contrary, the degassing phase can be realized easily too due to alterations in the pressure or the availability of the other gases in water, namely, CO_2 , air, or H_2S . Thus, as expressed previously, the relationship between alterations of radon concentration levels and earthquakes near seismically active regions is a key indicator that has been recorded and analyzed so far by researchers [8]. Despite the fact that monitoring changes in radon concentration levels has not been found to be a significant attribute for accurately predicting earthquakes, researchers have discovered a substantial link between earthquake activity and radon emission [9]. Since radon was assessed as a significant indicator that has been utilized across the globe, water radon observation has been officially carried out in China since 1969. For example, the observations of radon concentrations are important items of precursor observation in earthquake monitoring and prediction and have a crucial tool in earthquake prediction, especially in short-term and imminent forecasts [10].

Two different ways of observing radon concentration level activities in all types of water have been realized. While the first type is called a sampling procedure that automatically and continuously collects measurement, which is titled the digitized measurement of radon gas, the second one is called the manual sampling procedure that simulates measurements of water radon observations. For the sampling based on the digitized measurement, the combined form of water and gas is sampled from a well. Then, this mixture is moved into a degasser and a device in charge of collecting gas; finally, the measurement of the radon concentration level is assessed by a ZnS (Ag) detector system. Measurement precision is defined by 0.1 Bq/L by the SD-3A emanometer.

On the contrary, the sampled water from a well is degassed by utilizing a bubbling process and then transferred into an ion chamber or ZnS (Ag) detector, where the radon concentration level is gauged by an ionization or scintillation approach utilizing a radon-thorium analyzer or electrometer, called FD-125 or FD-105K (105), respectively. The same precision is also reached, which is 0.1 Bq/L. A device, called emanometry, is based on transferring dissolved radon from water to air by bubbling or circulating air to degas, which transfers Rn-222 to a system that realizes measurements.

Several factors, such as the method of taking samples, the container types used to keep samples, and the distance travelled to bring samples to the laboratory, have been found to be sensitive to measurement outcomes in a laboratory context [11]. The findings suggest that polylactic biopolymer and polyethylene terephthalate are found to be better than polyethylene. Moreover, glass or steel containers are practically usable when the experiments are conducted.

In the literature, the factors playing roles that lead to variations of radon being emitted are called a crustal strain, temperature, air pressure, and rainfall.

Besides, the air temperature has been found to present a significant impact on radon emanation. Garavaglia et al. [12] suggested that there exists a statistically significant correlation between the air temperature and the radon measurements concerning the observations taken for a short period, which was between 10 and 20 days. Moreover, while this correlation is oppositely related in the summer, it is positively correlated in the winter. Therefore, it was concluded that when radon emanation is under consideration, the temperature is determined as one of the factors. Miklyaev et al. [13] found that altering air temperature values is determined to be a more important attribute having an impact on seasonal radon alterations than precipitations. Seminsky and Seminsky recommended [14] that air temperatures cause an indirect effect on radon measurements in groundwater since the relatively cold weather decreases water temperatures. Then, the solubility of radon increases. Similar findings were presented in [15, 16]. Tayebi et al. [17] projected that the amount of released radon out of water is merely related to two conditions, which are called temperature and contact with the area. Battino [18] discussed the solvability coefficient of radon based on their interrelations and limitations.

In daily observation, it is found that water radon samples are degassed when the water temperature is relatively high, and the measured value of water radon is also relatively high.

When degassing at different water temperatures is under consideration, the influence on radon measurement is found to be different. Hence, degassing of water samples is the main link when radon observation is under a consideration. To reduce the influence of water temperature on radon value, a relatively suitable degassing temperature must be found. Therefore, it is of great practical significance to study the current degassing temperature of radon in the water.

Observing radon levels of water samples based on a technological perspective usually refers to a complete set of observational processes consisting of manual sampling, automatic observation, automatic computations, and manual submission of observational results.

The observations of water radon measurements in seismic stations have been still conducted extensively by manual operations, and investigating degassing processes of water radon measurements grows significantly, which is highly related to the whole process of observing radon measurements of sampled waters.

For this purpose, the negative pressure sampling method of the diffuser has been employed to observe radon measurement levels in the sampled waters. We use a glass container. The procedure entails vacuuming the glass diffuser before sampling, connecting the diffuser's water inlet to the sampling pipe when sampling occurs, sucking a water sample into the diffuser under negative pressure, and connecting the diffuser's air outlet to the vacuum scintillation chamber to obtain measurements, connecting the water inlet to the glass-air inlet control valve, slowly opening the air inlet valve, and bringing the radon emanation and its components into the vacuum scintillation chamber. This process is usually called degassing process [10], which is depicted in Figure 1.

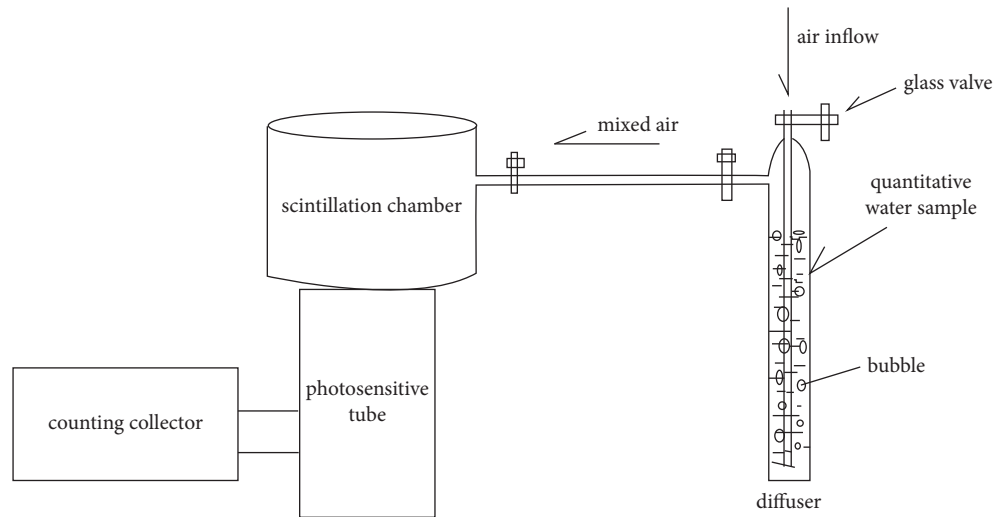


FIGURE 1: The schematic diagram of the degassing process of water radon observations.

The core motivation of the lead experiment is to observe radon values of sampled waters at different degassing temperatures by employing the temperature regulator device, so the influence of the degassing temperatures on the measurements of radon value is determined.

The rest of the manuscript is structured as follows: Section 2 describes the stages of the experiment such as the collection of data and analysis of data. Section 3 is allocated to discuss the results of the conducted experiment. Finally, Section 4 concludes the research.

2. Conducting the Experiment

To utilize the radon measurements of the daily water samples collected from the Yishui well to extract insights related to seismic activities, a device is employed to take measurements of dissolved radon values in the daily sampled waters. The concentration levels of the radon measurements in the samples of groundwater are gauged automatically. Those measurements are denoted by Rn1. Then, a temperature control treatment is implemented by increasing 2.0°C on the first day starting at 20°C and continues to increase the temperature up to 58°C on the 20th day since the average degassing temperature from the daily observational data is found to be around 18°C . Thus, the radon measurements of the collected samples after conducting the temperature control treatment at different degassing temperatures are recorded. Those measurements are denoted by Rn2. By doing so, the influence of degassing temperatures on the measurements of radon concentrations is attained. The experiment was conducted in the hydrochemistry laboratory at the Yishui Seismic Station. The experimenters of the Yishui Seismic Station were listed as follows: Cheng Shuqi, Wang Xibao, and Liu Haigang.

2.1. Temperature Control Device. Figure 2 depicts a water bath thermostat. A water sample of 100 ml is taken, and the treatments of the temperature controls for the sampled water are conducted five minutes before the degassing occurs. In



FIGURE 2: The control device of the water temperatures to observe the degassing processes of radon measurements.

the experiment, a heater is placed horizontally in the thermostatic device, and an aluminum plate with holes is placed inside the water tank. The upper cover is equipped with combined ferrules with different diameters, which can adapt to the installation of diffusers with different diameters. The temperature control range of the device is set the room temperature to 100°C . The temperature control accuracy is set to 0.5°C . The temperature control system of the device adopts electronic components, and the device can uniformly control the temperature of the water samples.

2.2. Measurement of the Sampled Water Temperature. Because the diffuser is in a sealed state, the ordinary thermometer cannot be utilized to measure the temperature of the sampled water. Instead, a digital infrared thermometer is utilized to gauge the temperature present in Figure 3. The model of this equipment is called TA8201 whose measurement range is between -50°C and $+380^{\circ}\text{C}$, and the resolution is assigned to 0.1°C , which meets the specific requirements of this research project.

2.3. Process of the Experiment. The constraints of the experiment are expressed as follows:

- (1) The experimental data were chosen based on the following criteria: to reduce the temperature



FIGURE 3: A digital infrared thermometer.

differential between room and water, the trial period was determined between September 1 and September 20 in 2017. As a result, there are 20 observations.

- (2) The selection criteria of the temperature gradient are as follows: the degassing temperature is about 18°C when the daily observation temperatures are composed. Hence, the experimenters chose to increase the temperature by 2°C every day by utilizing the temperature control device set to 20°C. Then, a comparison is conducted between the observations taken daily and the controlled observations generated by increasing the temperature by 2°C. The gradient span of the temperature is set to 2°C, and the total span is set to 40°C for the whole experiment.

- (3) The data are collected on a regular basis and are kept at room temperature. Rn1 signifies a corresponding daily observed radon value, whereas T1 denotes the degassing temperature of the reported daily data. According to the outcomes present in Table 1, the average value of the Rn1 is found to be 30.1 Bq/L for 20 days of the observations. Figure 4 depicts the trends of both T1 and Rn1 for 20 days of the observations. The formula to measure the radon amount in sampled water is expressed by equation (1) as follows:

$$C_{\text{WATER}} = \frac{c_{\text{AIR}} \left((V_{\text{SYSTEM}} - V_{\text{SAMPLE}}/V_{\text{SYSTEM}}) + k \right) - C_0 \left((V_{\text{SYSTEM}} - V_{\text{SAMPLE}}/V_{\text{SYSTEM}}) + k \right)}{1000}, \quad (1)$$

where C_{WATER} denotes radon concentration in water sample (Bq/L), C_{AIR} denotes radon concentration (Bq/m³) in the measuring setup after expelling radon, C_0 denotes radon concentration in the measuring setup before sampling, V_{SYSTEM} denotes the interior volume of the measurement setup (ml), V_{SAMPLE} denotes the volume of the water sample (ml), and k denotes the radon distribution coefficient of water/air.

When the graph in Figure 4 is investigated, the trends of both T1 and Rn1 have almost parallel and steadily similar patterns except for measurements no. 3 and no. 14, which implies that an increase and a decrease randomly occur at the 3rd and 14th daily observations, respectively, in temperature values.

2.4. Observational Data Assessed by the Temperature Control Devise. The temperature control treatment of the daily observed samples using the diffuser is used to obtain this collection of data. While T2 represents the daily recorded degassing temperatures, Rn2 represents the corresponding radon values when the temperature control treatment is

used. The temperatures of the sampled waters are increased by 2°C on the first day starting from 20°C, and the corresponding radon measurements are recorded. Then, the mean value of the Rn2 present in Table 2 is found to be 35.9 Bq/L.

Figure 5 depicts the relationships between water samples and the temperatures and between radon measurements and temperature values. It can be seen that while the temperature steadily increases, the corresponding radon measurements fluctuate between 31.4 and 42. Therefore, there is no clear implication to comprehend the relationship.

2.5. Data Analysis. Table 3 presents the differences between temperatures of daily observations and the control treatment observations and the radon measurements of daily observations and the radon measurements of the control treatment observations. The findings imply that when the temperature difference increases from 1.52°C to 39.22°C, the difference between radon measurements increases. However, the maximum difference between radon measurements is observed in the 19th sample water, which is 11.2 Bq/L. On the contrary, the difference between radon measurements

TABLE 1: The daily observed measurements for both T1 and Rn1.

Date	1	2	3	4	5	6	7	8	9	10
T1 (°C)	18.5	18.6	18.7	18.6	18.5	18.5	18.5	18.5	18.5	18.6
Rn1 (Bq/L)	33.6	32.8	27.7	31.1	28.5	29.3	29.7	30.6	30.3	28.6
Date	11	12	13	14	15	16	17	18	19	20
T1 (°C)	18.5	18.5	18.5	18.0	18.5	18.6	18.7	18.8	18.8	18.8
Rn1 (Bq/L)	27.3	28.9	30.0	29.5	30.8	29.7	31.8	31.6	30.8	30.0

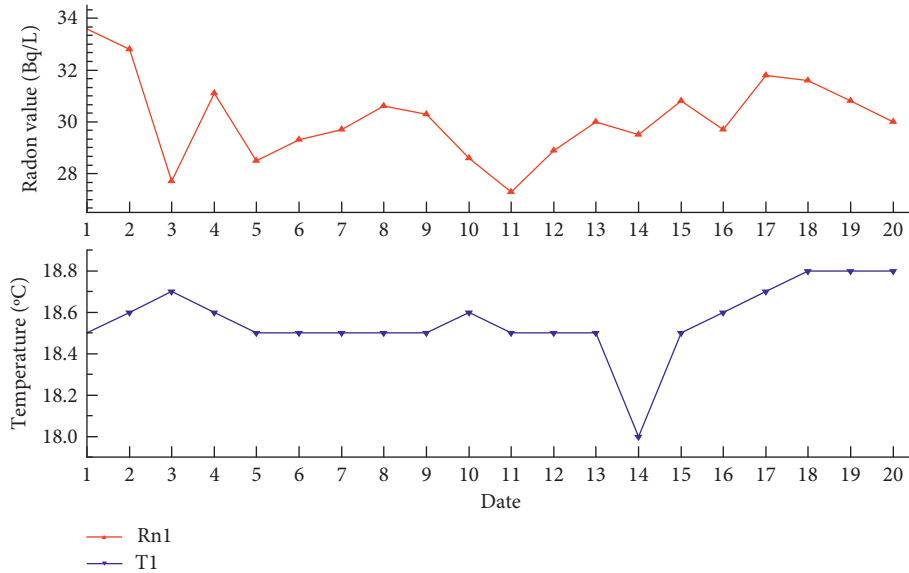


FIGURE 4: The relationship between the daily degassing temperature and radon measurements.

TABLE 2: The data set of running temperature control treatment.

Date	1	2	3	4	5	6	7	8	9	10
T2 (°C)	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0
Rn2 (Bq/L)	35.2	34.5	31.4	35.0	34.2	36.0	34.5	36.8	36.0	37.2
Date	11	12	13	14	15	16	17	18	19	20
T2 (°C)	40.0	42.0	44.0	46.0	48.0	50.0	52.0	54.0	56.0	58.0
Rn2 (Bq/L)	34.2	34.5	36.0	35.2	37.8	34.0	38.9	40.2	42.0	39.5

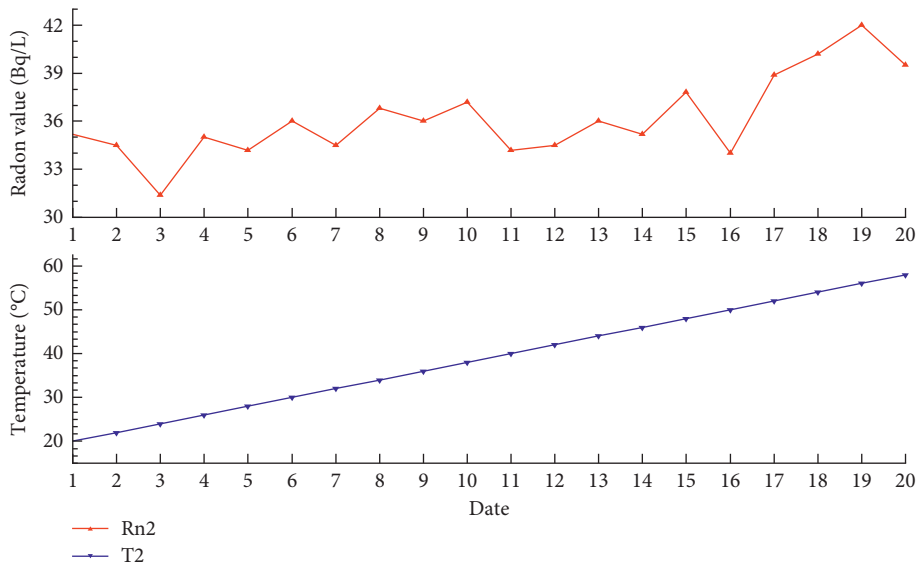


FIGURE 5: The relationship between radon values and temperature values in the temperature control treatment.

TABLE 3: The comparative analysis of the data.

Date	1	2	3	4	5	6	7	8	9	10
Δt ($^{\circ}\text{C}$)	1.5	3.4	5.3	7.4	9.5	11.5	13.5	15.5	17.5	19.4
ΔR_n (Bq/L)	1.6	1.7	3.7	3.9	5.7	6.7	4.8	6.2	5.7	8.6
Date	11	12	13	14	15	16	17	18	19	20
Δt ($^{\circ}\text{C}$)	21.5	23.5	25.5	28.0	29.5	31.4	33.3	35.2	37.2	39.2
ΔR_n (Bq/L)	6.9	5.6	6.0	5.7	7.0	4.3	7.1	8.6	11.2	9.5

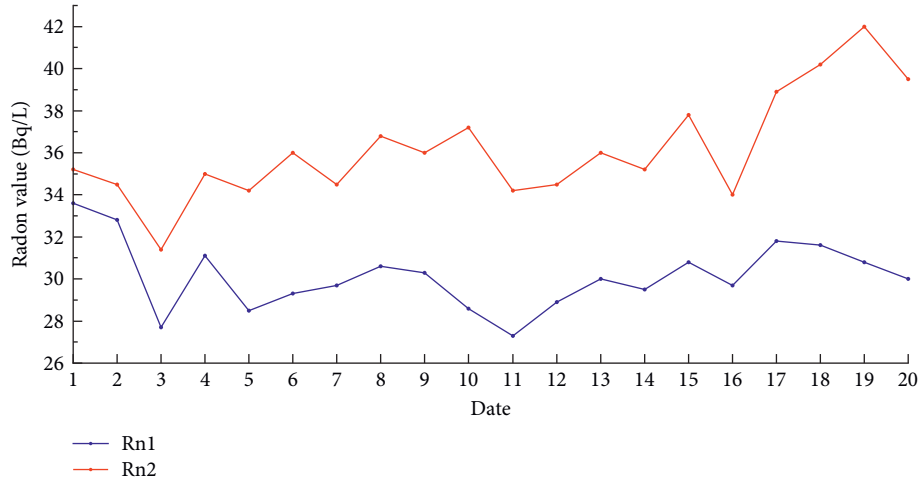


FIGURE 6: The comparison of the radon values between temperature control values and the daily observations.

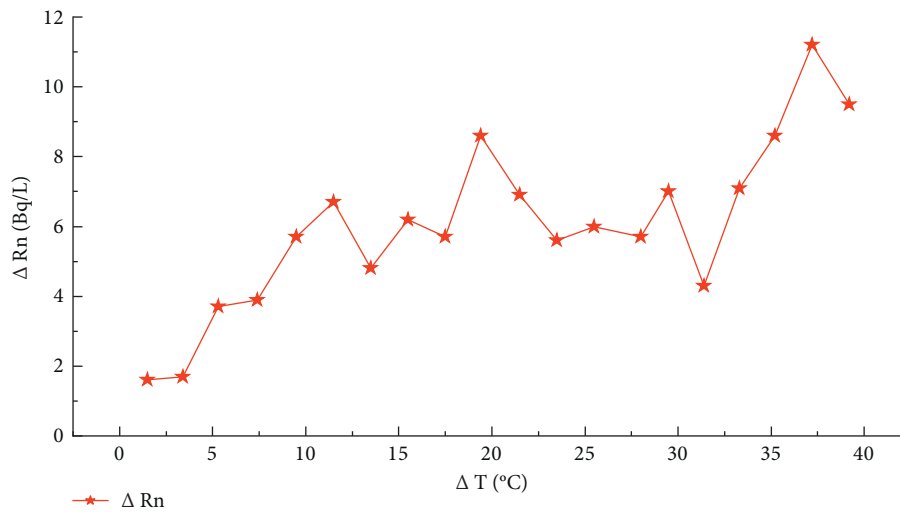


FIGURE 7: The relationship between the differences in the radon values and the difference in the temperatures.

follows a steady increment trend with fewer fluctuations. Figure 6 suggests that when a steady increase in the temperature occurs, an increase could be subsequently observed in the measurements of radon concentrations. Besides, when the difference in radon measurements is plotted, an upward trend can be seen in Figure 7.

It can be concluded that the degassing temperature is found to be around 18.5°C and the radon value is also found to be stable. Figure 4 shows that the radon value increases with the increment in the temperature. The difference formulas regarding the temperature and the measurements of radon levels are expressed in (2) and (3):

$$\Delta t = t_2 - t_1, \quad (2)$$

$$\Delta R_n = R_{n2} - R_{n1}. \quad (3)$$

Table 3 summarizes the difference values of temperatures and radon measurements for 20 days. Hence, the average value of the differences in radon measurements denoted by ΔR_n , is found to be 5.7Bq/L . After conducting the treatment of the temperature control, the radon value of the water samples is found to be 5.7Bq/L , which is higher than that of the untreated water samples. In other terms, 18.9% higher than that of the untreated water samples is found. Thus, this

result is rendered as 20.4°C higher than that of the untreated water samples, which indicates that the degassing temperature has an obvious influence on radon levels in the water samples.

3. Discussion

The radon measurements of the sampled waters in the Yishui well are affected by the degassing temperature. This outcome is reached by running a temperature control treatment. The radon value is found to be relatively high when the degassing temperature is set to high, while the radon value is found to be relatively low when the degassing temperature is set to low. The mechanism of this phenomenon can be elucidated as follows: the different degassing temperatures of the sampled water samples change the dissolution coefficient of the radon gas in the sampled waters increasing the degassing efficiency. Thus, affecting the final results of the radon measurements is observed.

The radon value increases when the degassing temperature increases, which indicates that the higher the degassing temperature, the higher the radon value. When the degassing temperature is constantly rising, as is realized in the temperature control treatment presented in this manuscript, the radon value is found to be higher than that without conducting the temperature control treatment. The relationship between the temperature differences of the degassing and the differences between radon values is constructed. The greater the temperature difference, the greater the difference between radon values will be. It is further confirmed that the influence of the temperature on radon measurement value is observed.

On the contrary, when the temperature difference is kept within 5°C, the influence on the water radon observation is found to be less than 2.0 Bq/L, and the relative error is found to be 6.6% and is lower than 8%, which is the required specification. The influence is found to be small and meets the observation specification.

4. Conclusion

Temperature has been found to be a key factor in determining the solvability of radon amounts in groundwater, particularly in wells near seismic zones, in the literature. Furthermore, statistically strong relationships between temperature measures and radon readings are provided in several researches, confirming this major result. As a result, the primary goal of the experiment is to detect radon levels in collected waters at various degassing temperatures using a temperature control device, in order to determine the effect of degassing temperatures on radon measurements. For this purpose, the daily sampled water is collected at Yishui well for 20 days, and the degassing temperatures and radon measurements are recorded.

Similarly, it is found that the degassing temperature has an obvious influence on water radon observations and increases with the increment of a degassing temperature. If the degassing temperature changes are kept within 5°C, it has little influence on radon observation. When the degassing

temperature exceeds 5°C, the effect on radon value changes dramatically. Therefore, the bubbling temperature should be controlled by 5°C throughout the year to reduce the influence on water radon observations. The observations of the radon degassing temperatures in the Yishui well are found to be stable between 18°C and 23°C. Therefore, the degassing temperature should be controlled within this range in the daily observations.

The limitations of this research can be expressed as follows: due to the reason of having just one observation device in the station, the experiment adopts the method of regular observation in the morning and conducting experiments in the afternoon of the same day to ensure more reliability. However, a current disadvantage with this method is that the instrument observation base is high, which affects the stability of the experimental data, so there are some sudden jumps in the measurements of the experimental data.

Data Availability

Data will be provided upon request to the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This study was supported by the Shandong Earthquake Agency (Project number: 17Y13).

References

- [1] C. Papastefanou, S. Stoulos, M. Manolopoulou, A. Ioannidou, and S. Charalambous, "Indoor radon concentrations in Greek apartment dwellings," *Health Physics*, vol. 66, no. 3, pp. 270–273, 1994.
- [2] V. Walia, F. Quattrocchi, H. S. Virk, T. F. Yang, L. Pizzino, and B. S. Bajwa, "Radon, helium and uranium survey in some thermal springs located in NW Himalayas, India: mobilization by tectonic features or by geochemical barriers?" *Journal of Environmental Monitoring*, vol. 7, no. 9, pp. 850–855, 2005.
- [3] Y. Prasad, G. Prasad, G. S. Gusain, V. M. Choubey, and R. C. Ramola, "Seasonal variation on radon emission from soil and water," *Indian Journal of Physics*, vol. 83, no. 7, pp. 1001–1010, 2009.
- [4] B. Zmazek, L. Todorovski, S. Džeroski, J. Vaupotič, and I. Kobal, "Application of decision trees to the analysis of soil radon data for earthquake prediction," *Applied radiation and isotopes*, vol. 58, no. 6, pp. 697–706, 2003.
- [5] G. Gervino, R. Bonetti, C. Cigolini, C. Marino, P. Prati, and L. Pruiti, "Environmental radon monitoring: comparing drawbacks and performances of charcoal canisters, alpha-track and E-PERM detectors," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 518, no. 1–2, pp. 452–455, 2004.
- [6] X. Zhang, "The study of different existing forms of radon in groundwater and the diversity of reflecting earthquakes," *Northwestern Seismological Journal*, vol. 4, no. 19, 1997.

- [7] Y.-W. Liu and J. Shi, "Information characteristics of ground fluid precursors of strong continental earthquakes," *Acta Seismologica Sinica (Chinese edition)*, vol. 13, no. 1, pp. 115–121, 2000.
- [8] G. Igarashi, S. Saeki, N. Takahata et al., "Ground-water radon anomaly before the Kobe earthquake in Japan," *Science*, vol. 269, no. 5220, pp. 60–61, 1995.
- [9] J. Haki, I. Hunyadi, K. Varga, and I. Csige, "Determination of radon and radium content of water samples by SSNTD technique," *Radiation Measurements*, vol. 25, no. 1–4, pp. 657–658, 1995.
- [10] Monitoring and Forecasting Department of China Earthquake Administration, *Theoretical Basis and Observation Technique of Seismic Subsurface Fluid*, Seismological Press, Beijing, China, 2007.
- [11] A. Kurnaz and M. Atif Çetiner, "Exposure assessment of the radon in residential tap water in Kastamonu," *International Journal of Radiation Research*, vol. 14, no. 3, pp. 245–250, 2016.
- [12] M. Garavaglia, G. Dal Moro, and M. Zadro, "Radon and tilt measurements in a seismic area: temperature effects," *Physics and Chemistry of the Earth - Part A: Solid Earth and Geodesy*, vol. 25, no. 3, pp. 233–237, 2000.
- [13] P. S. Miklyaev, T. B. Petrova, D. V. Shchitov et al., "The results of long-term simultaneous measurements of radon exhalation rate, radon concentrations in soil gas and groundwater in the fault zone," *Applied Radiation and Isotopes*, vol. 167, Article ID 109460, 2021.
- [14] K. Z. Seminsky and A. Seminsky, "Radon concentration in groundwater sources of the Baikal region (East Siberia, Russia)," *Applied Geochemistry*, vol. 111, Article ID 104446, 2019.
- [15] M. Erdogan and V. ErenDemirelZedef, "Determination of radon concentration levels in well water in Konya, Turkey," *Radiation Protection Dosimetry*, vol. 156, no. 4, pp. 489–494, 2013.
- [16] M. Schubert, A. Paschke, E. Lieberman, and W. C. Burnett, "Air-water partitioning of ^{222}Rn and its dependence on water temperature and salinity," *Environmental Science and Technology*, vol. 46, no. 7, pp. 3905–3911, 2012.
- [17] A. Tayebi, F. Achhima, M. Wahbi, and M. E. Maghraoui, "Instrumentation for measurement of Rn^{222} in water," *International Journal of Mechanical Engineering and Technology(IJMET)*, vol. 10, no. 11, pp. 183–191, 2019.
- [18] R. Battino, "The Ostwald coefficient of gas solubility," *Fluid Phase Equilibria*, vol. 15, no. 3, pp. 231–240, 1984.