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Simultaneous Measurement of Groundwater Radon in a Large Area: First Results

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Authors' contributions

This work was carried out in collaboration between all authors. Author IA designed the study in Turkey region. Author IN designed the study in Russia region and wrote the first draft of the manuscript. Author TT done analyses of the study and the literature searches. Authors FK and BS had carry out experimental process. All authors read and approved the final manuscript.

Short Research Article

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ABSTRACT

Aims: Simultaneous measurement of groundwater ^{222}Rn concentrations in Krasnodar territory (South Russia) and in southwest Turkey for seismological application (earthquake predict) was began.
Study Design: Simultaneous measurement of ^{222}Rn concentration in groundwater samples on the large area can be taken for the study of earthquake precursors.
Place and Duration of Study: Research Centre of Natural Radioactivity (South Russia, Krasnodar region, well in the set. of Kholmsky and well in the set. of Spokoinaya), Suleyman Demirel University (Southwest Turkey, two springs in Pamukkale geothermal region), between 2012 and 2013.
Methodology: Sampling was carried out at 9-00 GMT daily. The usual method of definition of alpha - activity in the scintillation chamber for fast measurement of ^{222}Rn in water with minimally registered concentration 0.1 Bq L^{-1} was applied. Atmospheric air, taking ^{222}Rn, is passing through the glass with volume of 0.5 L with a researched sample. The obtained ^{222}Rn data was compared with seismic data.
Results: Simultaneous increase of ^{222}Rn concentration in all sources was observed before regional earthquakes. The results show changes of ^{222}Rn in water of different wells

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and springs depending on different removal of an epicenter of the earthquake in researched area.
Conclusion: Results of simultaneous measurement of ^{222}Rn concentration in groundwater on a large area can be used to determine of the epicenter of future earthquakes.

Keywords: Radon; groundwater; earthquake.

1. INTRODUCTION

Measurement of environmental radio-activity in South Russia will be carried out for many years for seismological application. This region concerns to seismically dangerous zone (e.g., [1]). Therefore the big interest causes researches of an opportunity of forecasting of earthquakes by nuclear methods. Variations of the background gamma levels in galleries have been investigated since 1999 (e.g., [2]). Large-scale measurements of soil ^{222}Rn in the galleries, caves and at the Earth's surface in South Russia began later [3,4,5]. Tsvetkova et al. [4] have done the measurement on monthly, daily and hourly variations of soil ^{222}Rn concentration in galleries and caves in the Northern Caucasus. The daily variation of soil ^{222}Rn concentration increased several days prior to the earthquakes. At the Earth's surface, using maps of average daily ^{222}Rn data, a stable daily picture and smooth movement within several days were observed earlier [5]. Such movement was observed for all the earthquakes with epicenters in the territory of ^{222}Rn network during large-scale measurements of ^{222}Rn [5].

It was necessary to extend this type of research by adopting new methods for Western Caucasus and new area of measurements. Researches of soil ^{222}Rn were added to measurements of ^{222}Rn in ground water. In the North Caucasus groundwater ^{222}Rn was measured in the Eastern Caucasus for seismological application [6] and in the Central Caucasus for the control of water quality [7]. Variations of water ^{222}Rn in Western Caucasus us have been investigated for seismological application since 2010. Further these measurements were connected with simultaneous measurements of water ^{222}Rn in Southwest Turkey.

Measurements of environmental radio-activity in Turkey for the present study area are also begin out for many years [8,9,10,11]. ^{222}Rn and ^{226}Ra were measured in the ground waters. A gamma background was investigated for methodological application. ^{238}U, ^{232}Th and ^{40}K were measured in very interesting areas of Turkey for geological researches.

So, in South Russia and Southwest Turkey researchers have wide experience of measurement of natural radio-activity. Continuation of these works as the common measurements will allow finding out new interesting regularities of changes of ^{222}Rn in the large area. Preliminary results are presented in this paper.

2. STUDY AREA

The study area in the South Russia (Krasnodar region) and the locations of water ^{222}Rn measurements are shown in Fig. 1a. Measurements of soil ^{222}Rn were performed in the settlement of Kholmsky. The primary seismic zones are located in the southern part of the Krasnodar region. The southern area was therefore chosen to research changes in water ^{222}Rn concentration during earthquakes. The settlement of Kholmsky (in Fig. 1a above

stations of water sampling are shown by black ellipses) with a research laboratory is located in Kuban inclined plain, which merges with foothills of the Western Caucasus in the south. This area concerns to a southern steppe damp province. The climate around this region is soft winter, moderately hot summer and uniform distribution of atmospheric precipitation during a year. The hydrological network includes the Abin River that is the left inflow of the Kuban River. The Abin River feeds by atmospheric precipitation and subsoil waters. Subsoil waters are located in the depths of 0.4 - 6.0 m. The basic direction of a stream of underground waters is to the north and northwest. Below in Fig. 1a the gorge near to the settlement of Kholmsky is shown where selection of water samples from the source is made. The second region of sampling is located at the distance of 200 km from Kholmsky to the east (Fig. 1a) in the settlement of Spokoinaya. This settlement is located in a foothill area of the Central Caucasus. Well in the depth of 10 m was used for sampling by the pump.

The research region in Turkey is shown in Fig. 1b. ^{222}Rn concentrations have been measured at two points of Pamukkale geothermal region in water. The temperature of water is 34ºC (Karahayıt – spring) and 52ºC (Pamukkale - spring). Measurement points (yellow pins for soil gas; red pins for water sampling) are shown below in Fig. 1b.

The chemical compound of analysed waters samples are shown in Table 1. The error of data is 10%.

Table 1. The chemical compound of water samples (mg L^{-1})

Spring\ elements	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SO_4^{-2}	Cl^{-}	NO_3^{-}	NO_2^{-}	HCO_3	F^{-}
Pamukkale	425.05	68.20	46.50	14.45	620.65	12.25	0.47	<0.01	1128.5	1.32
Karahayıt	508.30	114.75	121.50	24.40	862.03	25.24	0.03	<0.01	1189.5	1.71
Kholmsky	257.20	0.30	1.46	1.15	170.00	16.00	0.38	0.20		0.10

3. INSTRUMENTATION AND METHODS

A large number of methods for measuring of water radon concentration for predict of earthquake by the authors from different countries is described (e.g., [12,13,14]). But simultaneous measurement of ^{222}Rn at large distances (several thousand km) are not described. In our research sampling of water was carried out simultaneously each day at 9-00 GMT (12-00 Moscow winter time) in Turkey and Southern Russia.

The usual method (Fig. 1c) of definition of alpha - activity in the scintillation chamber for fast measurement of ^{222}Rn in water with minimally registered concentration 0.1 Bq L^{-1} was applied in South Russia [7]. Atmospheric air, taking ^{222}Rn, is passing through the glass with volume of 0.5 L with a studied sample 1. Further air with ^{222}Rn through the driers 2, 3 is going to the scintillation chamber 6 with vol. 0.4 L. Walls of the chamber were covered by ZnS coated detector. Scintillation chambers and photomultiplier from industrial device RGA-01 (Russia) were used. Flash of radiation was registered by the photomultiplier through a glass window. The tiny pump 5 was applied for air circulation. The device might be used in a field. Extraction of ^{222}Rn by air (circulating method) lasted for 30 minutes. After 2 hours (for achievement of balance of ^{222}Rn with daughters) in the scintillation chamber activity of ^{222}Rn was measured within 30 minutes for achievement of statistic reliable results. Three chambers were used. The background was in an interval 1.5 - 2.2 cpm. The calibration factor of the device was 1cpm = 4.12×10^{-2} Bq L^{-1} = 1.12×10^{-12} gRa L^{-1}. Various liquid radium standard samples (liquid radium standart samples EB-8 with concentration of ^{226}Ra

in 10 × 10^{-9} g g^{-1}) were used for calibration of the device. For water CO_2 measuring device (5) PGA-7 (Russia) was applied.

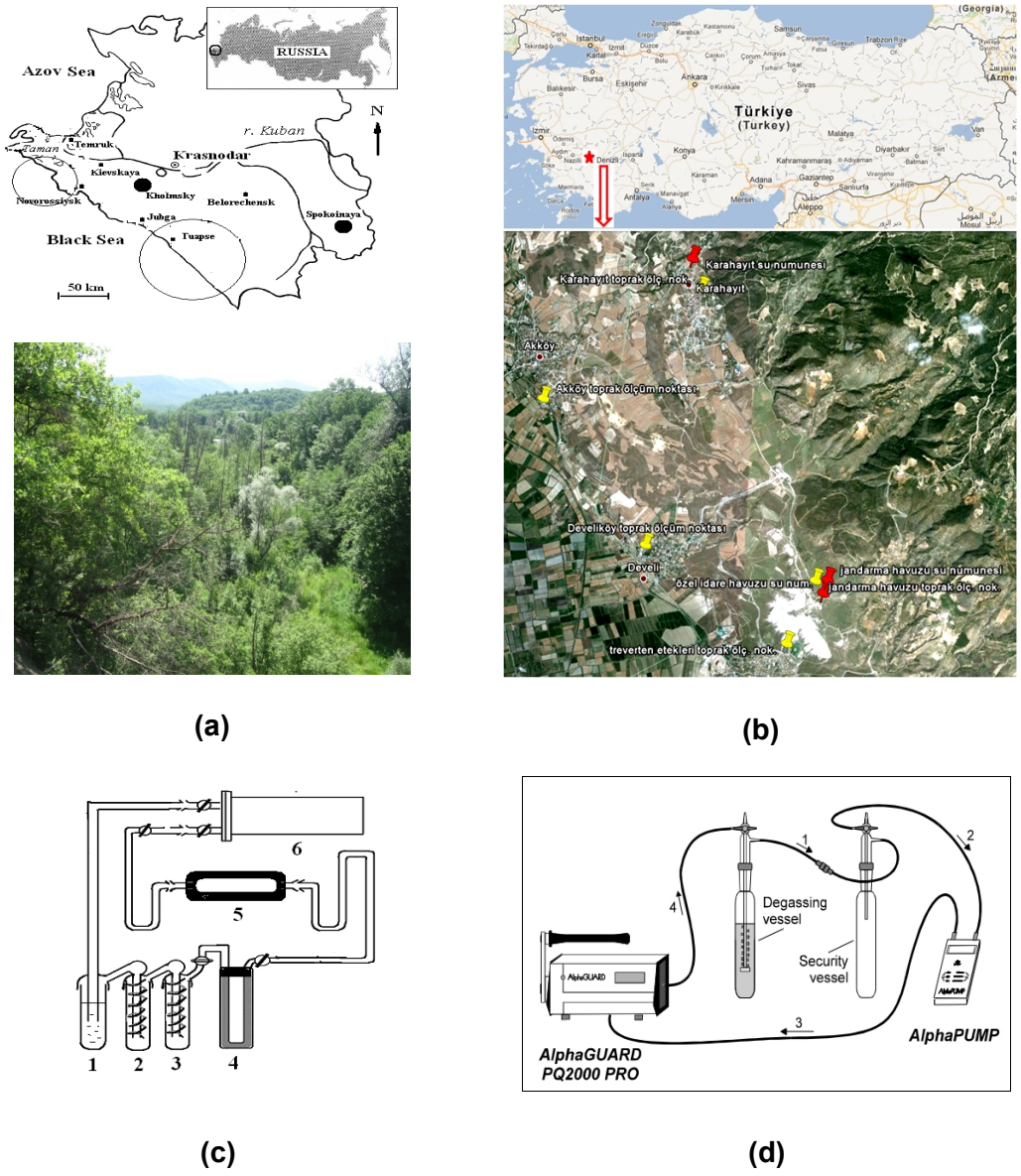

Fig. 1. Study area in Russia (a) and Turkey (b) and devices used for the measurement of radon in Russia (c) and Turkey (d)

In the Pamukkale geothermal region ^{222}Rn concentration in water samples are measuring with Alpha GUARD and Aquakit components (Fig. 1d above). Degassing method was used also. Sample was put into the degassing vessel. The Alpha PUMP has a performance level of a flow rate of air in 0,03 L min^{-1}. Air movement with radon shown by numbers 1 - 4 in Fig. 1d Extraction of ^{222}Rn by air lasted for 10 minutes. Activity of ^{222}Rn was measured in

Alpha GUARD within 60 minutes. For the determination of the ^{222}Rn concentration in the water samples was used the following formula:

$$C_{water} = C_{air} \times (((V_{system} - V_{Sample}) \times (V_{Sample})^{-1} + k) - C_o) \times 10^{-3} \quad (1)$$

C_{water} - ^{222}Rn concentration in water sample [Bq L^{-1}]
C_{air} - ^{222}Rn concentration [Bq m^{-3}] in the measuring set-up after expelling the radon
C_o - ^{222}Rn concentration in the measuring set-up before sampling (zero level) [Bq m^{-3}]
V_{system} - interior volume of the measurement set-up [ml]
V_{Sample} - volume of the water sample [ml]
k - ^{222}Rn distribution coefficient

4. RESULTS AND DISCUSSION

Results of variations of ^{222}Rn in water of two sources in Turkey and two wells Kh1, Kh2 (set. of Kholmsky, 30 and 180 m depth) in South Russia at 2012, are shown in Fig. 2a as an example. These data were compared with the seismic data. Results of the researches interval (23-30, April, 2012) when there were three earthquakes (are shown by grey vertical lines) near Kholmsky and two earthquakes (are shown by white vertical lines) near the Pamukkale geothermal region are shown in Fig. 2a. At rather stable concentration of ^{222}Rn in source 1 and ^{222}Rn in source 2 during earthquakes varied strongly. Concentration of ^{222}Rn in Kh2 has increased before earthquakes. ^{222}Rn changes in Kh1 have taken place in the day of the second earthquake.

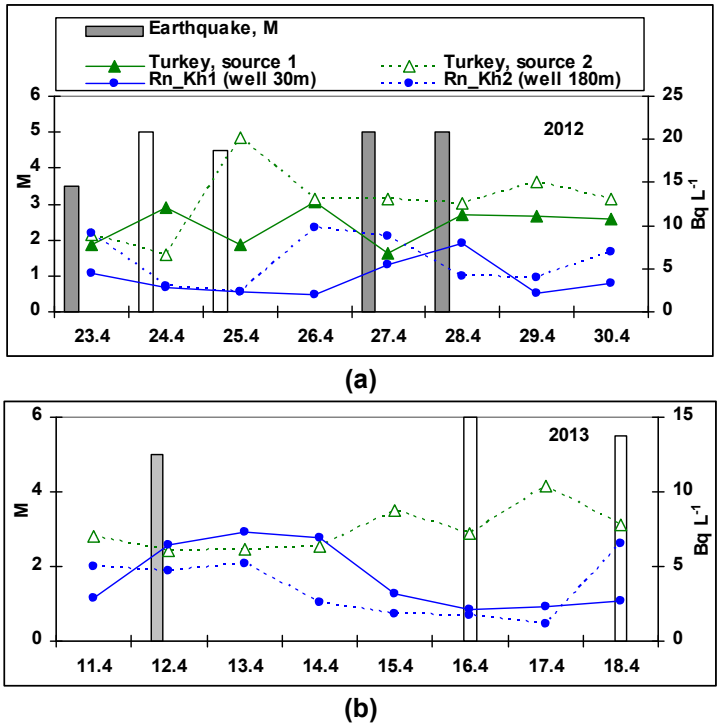

Fig. 2. Some results of the common researches of groundwater ^{222}Rn in Turkey and Russia

Some results of 2013 are shown in Fig. 2b above. Changes of ^{222}Rn in source 1 changed poorly (are not shown because of the big values). And concentration of ^{222}Rn in a source 2 has increased during earthquakes. Concentration of ^{222}Rn in Kh1 and "Spokoinaya" (the well of the depth of 10 m is shown by black circles with a dashed line) has simultaneously increased during earthquake and has gone down on April 15, 2012. The described preliminary results show changes of ^{222}Rn in water of different wells and springs depending on different removal of an epicenter of the earthquake in researched area.

5. CONCLUSION

More than 15 years of our measurements of soil ^{222}Rn concentrations in different geological structures of Northern Caucasus have shown that radiation measurements can be used to forecast of strong geophysical processes. The probability of change in the concentration of soil ^{222}Rn before regional earthquakes can approach 90%. Measurement of groundwater ^{222}Rn in Western Caucasus is made only 3 years for seismological application. But the results of changes in water ^{222}Rn concentration before earthquakes have a similar kind with a soil radon data. It was expected to receive much new regularity from common Russia-Turkey researches. The preliminary results have been described, continuation of these common studies may reveal lot of very important scientific information. Further, results of simultaneous measurement of ^{222}Rn concentration in ground water on a large area can be used to determine of the epicenter of future earthquakes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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