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ASSESSMENT OF ^{222RN} DISTRIBUTION IN WATER AND SOIL GAS IN THE SHIDA KARTLI REGION, GEORGIA

[*]Kapanadze N., [*]Melikadze G., [*]Tchankvetadze A., [*]Jimsheladze T., [**]Gogichaishvili Sh., [*]Todadze M., [*]Chikviladze E., [*]Magradze Z., [**]Chelidze L.

[*]*M. Nodia Institute of Geophysics of the I. Javakhishvili Tbilisi State University, Georgia,*
[**]*E. Andronikashvili Institute of Physics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia*
ninokapanadze@gmail.com

Abstract. *Within the framework of the SRNSFG FN-19-22022 project "222Rn Mapping and Radon Risk Assessment in Georgia," fieldwork was carried out to quantify ^{222}Rn distribution in water and soil gas and to identify geological factors influencing ^{222}Rn concentrations in selected areas of Georgia. In Shida Kartli region, on-site ^{222}Rn measurements were performed at 78 soil gas sampling points and 90 water sources (63 springs, 27 boreholes) using the AlphaGUARD PQ2000 PRO (Saphymo GmbH) radon monitor. Measured ^{222}Rn concentrations ranged from 0.08 to 51.76 Bq/L in water and up to 46.6 kBq·m $^{-3}$ in soil gas. Basic statistical analysis and visualization revealed that most water and soil gas values fall in the low to moderate range, with occasional localized high values. All observation sites were georeferenced using GPS. The data were digitized and integrated into a GIS to illustrate ^{222}Rn distribution in water and soil gas across Shida Kartli.*
The works [8-11] present the results of our early studies of ^{222}Rn content in soil gas and water in various regions of the country.

Key words: *radon mapping, soil gas, groundwater, GIS, Shida Kartli, Georgia*

Introduction

Radon (^{222}Rn) is a naturally occurring radioactive gas produced by the decay of uranium (^{238}U) in soils and rocks. Its presence in groundwater and soil gas poses environmental and public health concerns, particularly in areas with elevated uranium or thorium content. Mapping ^{222}Rn concentrations in both water and soil gas provides a basis for understanding local geological influences, hydrogeological pathways, and potential exposure risks.

Shida Kartli, located in central Georgia, features a complex geological setting comprising sedimentary, volcanic, and carbonate formations. Previous studies indicate that radon concentrations in both water and soil gas can vary significantly depending on lithology, structural features, and groundwater flow characteristics. However, comprehensive regional datasets integrating both media have been lacking, motivating the present study.

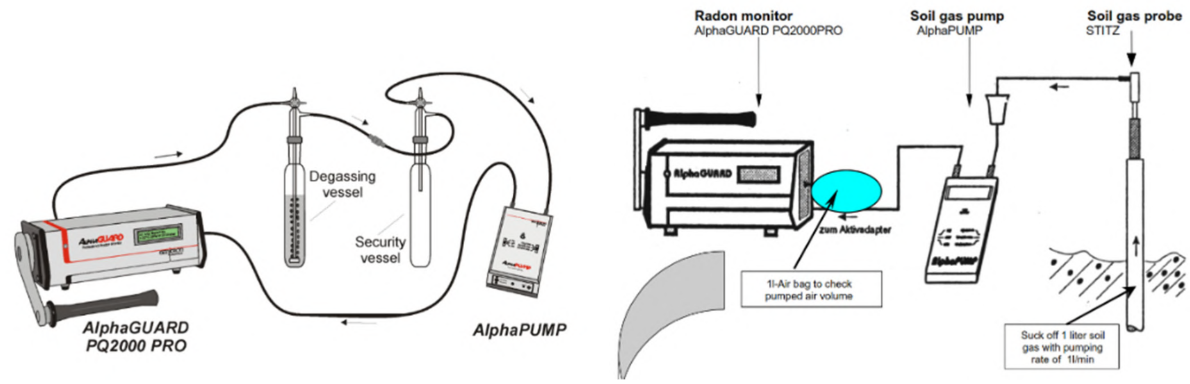
Geological and lithological data of the study area

Shida Kartli is characterized by a diverse geology, including Mesozoic and Cenozoic sedimentary sequences, volcanic deposits, and carbonate formations. Major lithologies include clay, siltstone, sand, limestone, and basaltic volcanics [1]. Structural features such as faults and fractures enhance groundwater circulation and can serve as preferential pathways for radon migration. This geological heterogeneity underlies the variability in measured ^{222}Rn concentrations across the region [2].

Measurement Methodology

Water

^{222}Rn in water sources was monitored at 90 points, including 63 springs and 27 boreholes, using the AlphaGUARD monitor and the AquaKIT [3-4] consisting of the AlphaGUARD monitor, degassing vessel, security vessel, and AlphaPUMP [5] (Fig. 1a). The components were connected in a closed circuit, and ^{222}Rn concentration was measured according to the manufacturer's protocol [4]. ^{222}Rn concentrations were calculated using established equations accounting for air-water partitioning and decay corrections.



a) b)

Fig. 1. Schematic views of AquaKIT, a) and soil gas, b) measurement set-ups

Soil Gas

^{222}Rn concentrations in soil gas were measured at 78 sampling points in the vicinity of water sources and additional locations to achieve dense spatial coverage. Measurements were conducted using the AlphaGUARD monitor coupled with a soil gas probe and the AlphaPUMP in a closed circuit, following the standard procedure [6] (Fig. 1b). The probe was inserted to a depth of 0.7–1.0 m, and radon concentrations were recorded after a 10-minute waiting period to allow for thoron decay. The mean values indicated on the monitor were taken as the final concentrations.

All observation sites were georeferenced, and results were analyzed to examine spatial patterns in relation to lithology and hydrogeology.

Data Calculation and Results

A total of 168 observation sites in the Shida Kartli region were georeferenced using GPS.

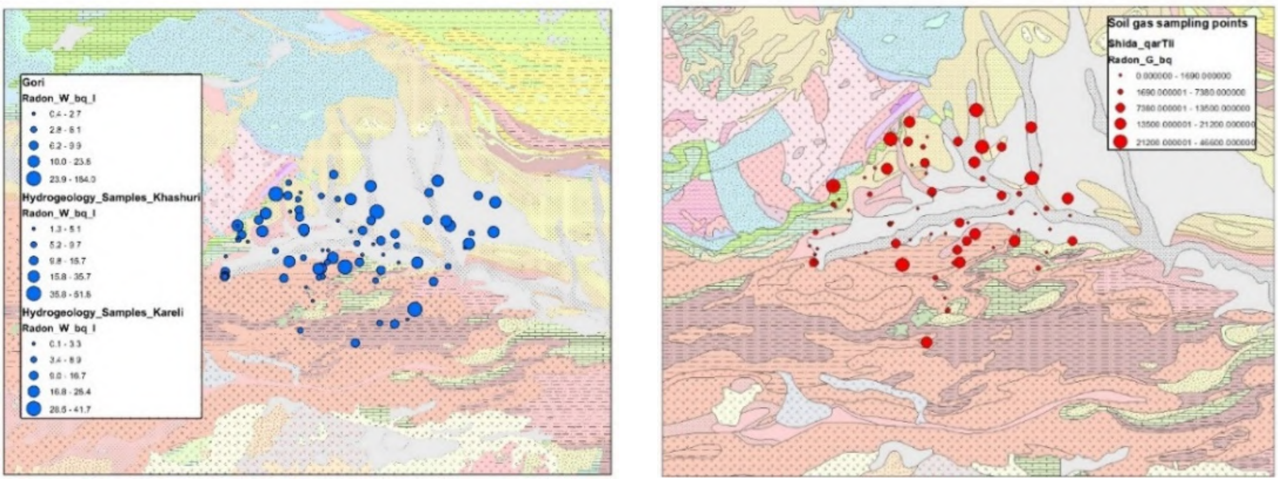


Fig. 2. Location of water and soil gas sampling points on the geological map [7]

Radon in Water

The ^{222}Rn activity concentration in the water samples was calculated using equation (1), accounting for radon transferred from water to air within the measurement setup and the fraction remaining in the aqueous phase [4]. Measurements were generally performed immediately after sampling; in cases of delayed measurement, decay correction was applied according to equation (2).

The ^{222}Rn activity in water was calculated using:

$$c_{Water} = \frac{c_{Air} \times \left(\frac{V_{System} - V_{Sample}}{V_{Sample}} + k\right) - c_0}{1000} \quad (1)$$

Where: c_Water – ^{222}Rn concentration in water sample [Bq/L], c_Air – ^{222}Rn concentration [Bq/m3] in the air of the circuit, c_0 – ^{222}Rn concentration before sampling (zero level) [Bq/m3], V_System – interior volume of the circuit [in our case 1.102 L], V_Sample – volume of the water sample [in our case 0.1 L], k – ^{222}Rn distribution coefficient [0.26, since the measurements were performed in the temperature range 10-30 °C].

If there was a delay between sampling and measurement, decay correction was applied:

$$C_0 = C \times e^{\frac{ln2}{t_{1/2}}} \Delta t \quad (2)$$

Where C_0 is the value at the moment of sampling, C is the measured value, $t_{1/2}$ is the half-life of ^{222}Rn, Δand t is the time delay between sampling and measurement.

Basic statistical analysis for the sampled water points is presented in Table 1. Arithmetic mean (AM) ^{222}Rn concentrations were higher in springs (12.79 Bq/L) than in boreholes (9.05 Bq/L). Concentrations ranged from 1.24 to 51.76 Bq/L in springs and from 0.08 to 25.62 Bq/L in wells. These values are consistent with ranges obtained in previous studies in Georgia [8-11].

Table 1. Basic statistical analysis for the sampled water points

		^{222}Rn concentration / Bq/L						
Type	No. points	Min	Max	Median	AM	ASD	GM	GSD
Spring	63	1.24	51.76	9.97	12.79	10.47	9.62	2.19
Borehole	27	0.08	25.62	5.38	9.05	8.50	4.39	4.75

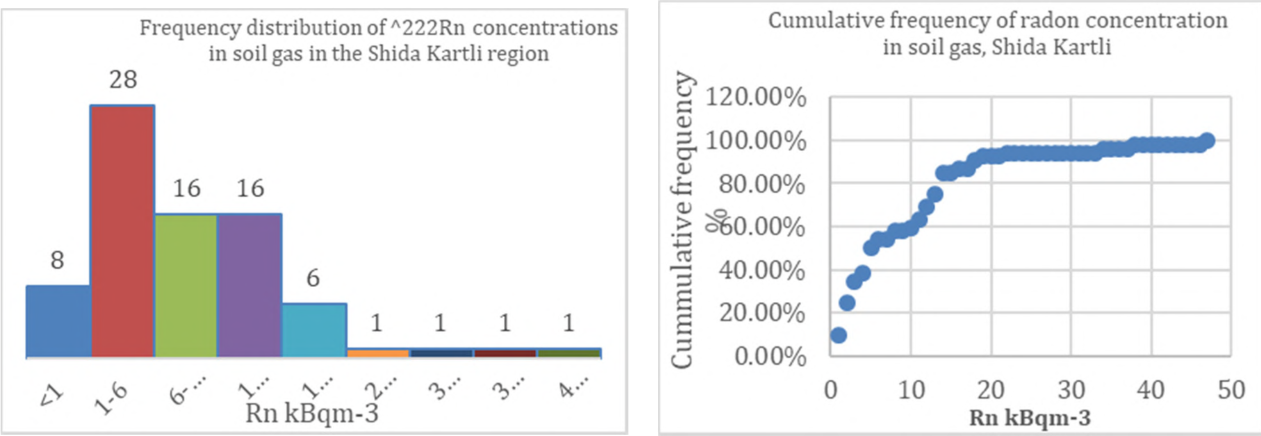
Most measured ^{222}Rn concentrations in water are in the low to moderate range, with the majority of springs and wells exhibiting values below 15 Bq/L. Approximately half of the springs show concentrations between 1 and 6 Bq/L, while about 30% fall in the 6–15 Bq/L range. A few points exhibit elevated values, with one spring reaching 51.76 Bq/L and one well at 25.62 Bq/L. The cumulative frequency distribution approximates a log-normal pattern, with a long tail caused by these high values. One of the main factors contributing to this variation is the presence of locally elevated radon, likely controlled by specific lithological features and uranium/thorium-bearing formations along groundwater flow paths. Although the dataset is limited for detailed statistical analysis, it provides valuable insights into the spatial distribution of ^{222}Rn and the underlying hydrogeological processes in the Shida Kartli region, highlighting areas where localized geological or hydrogeological conditions can lead to elevated radon concentrations in certain springs and wells.

Radon in Soil Gas

Measured soil gas ^{222}Rn concentrations ranged from 0 to 47 $kBq \cdot m^{-3}$, with an arithmetic mean (AM) of 9 $kBq \cdot m^{-3}$ and a geometric mean (GM) of 5 $kBq \cdot m^{-3}$. The standard deviation (ASD) is 8 $kBq \cdot m^{-3}$, with a geometric standard deviation (GSD) of 3.5 and a log-standard deviation of 0.5. The median value is 7 $kBq \cdot m^{-3}$. These values show substantial spatial variability, reflecting heterogeneity in lithology, soil properties, and shallow hydrogeological conditions. Although localized anomalies were observed, the dataset provides a reliable overview of ^{222}Rn distribution in the shallow subsurface. This information is critical for identifying radon-prone areas and supports integration with GIS-based spatial analysis of radon risk in Shida Kartli.

Table 2. Basic statistics of ^{222}Rn concentration in soil gas in volcanic rocks, Shida Kartli

	^{222}Rn concentration / kBq m^{-3}						
No	Min	Max	Median	AM	ASD	GM	GSD
78	0.09	46.60	7.40	8.79	8.43	5.12	3.49



a. **b.**

Fig. 3. a) Frequency distribution of ^{222}Rn concentrations in soil gas in the Shida Kartli region; b) cumulative frequency in percent.

Most measured soil gas ^{222}Rn concentrations (28 values) fall within the 1–6 kBq·m^{-3} range, while a single measurement is observed in the 21–51 kBq·m^{-3} range, representing a localized anomaly. The cumulative frequency distribution closely follows a log-normal pattern, with a minor deviation observed in the 9–13 kBq·m^{-3} range. This distribution indicates that, although most sites exhibit low to moderate radon levels, occasional high values reflect local heterogeneities in subsurface radon sources and migration pathways.

Conclusion

This study provides the first integrated assessment of ^{222}Rn concentrations in water and soil gas in Shida Kartli, Georgia. Water measurements revealed generally low to moderate radon levels, with isolated high values in some springs (up to 51.76 Bq/L) and wells (up to 25.62 Bq/L). Soil gas measurements showed a wider range (0–47 kBq·m^{-3}), reflecting local variations in lithology, soil properties, and shallow hydrogeological pathways.

Although most concentrations are below guideline limits, localized anomalies highlight areas where radon migration is enhanced by geological or hydrogeological features. These findings provide valuable insight into radon distribution, supporting targeted monitoring and risk management strategies in the region.

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