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Improvement of The Metrological Support of The Radon Gas Measuring Instrument

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Abstract: The article provides information about the invention of the RR-4M type radonometer, designed to measure the volumetric activity of radon in air, water, and soil. A user manual, calibration methodology, and measurement procedure for the RR-4M radonometer have also been developed in the form of a national standard.

Keywords: Air, water, soil, radon gas, radonometer, methodology, measurement, calibration, user manual, radon impact, soil air, radon in water, radioactive, volumetric activity, radon monitoring, international standards.

Introduction:

In the Republic of Uzbekistan, efforts are underway to determine the amount of radon, control it, and establish an environmental monitoring system. At the same time, it is among the urgent tasks to improve the regulatory and legal document base in this field, prepare user manuals for radon detection equipment, align procedures with international standards, and develop modern measurement methodologies and calibration procedures.

The relevance of measuring the volumetric activity of radon gas is extremely high in modern life, as radon is a naturally occurring radioactive gas that is present invisibly in many regions, posing a potential health risk to many people.

The danger of radon gas to human health lies in its potential to cause changes in the lungs through long-term inhalation at high concentrations, which can even lead to lung cancer. The World Health Organization (WHO) and other health organizations have confirmed that radon is the second leading cause of lung cancer. Therefore, it is essential to measure radon levels in order to identify its risk and take preventive measures.

According to the Decree of the President of the Republic of Uzbekistan dated July 14, 2018, "On Additional Measures to Improve the Efficiency of Commercialization of Scientific and Scientific-Technical Activity Results," the task was given to develop and manufacture a radonometer based on a semiconductor detector of charged particles to measure the volumetric activity of radon in soil, water, and air [1].

Based on this task, for the first time in our Republic, scientists of the Institute of Nuclear Physics under the Academy of Sciences of Uzbekistan developed the RR-4M type radonometer. This measurement complex allows for the determination of the volumetric activity of naturally radioactive aerosols formed during the decay of radon and thoron, as well as monitoring the volumetric activity of radon gas in air, water, and soil in real-time. The complex includes an autonomous air pump equipped with various sample collection devices, enabling the collection and measurement of radon samples in various environments (such as water, air, and soil air).

The measurement range of this radonometer is from 1 to 20,000 Bq/m^3, and its relative measurement error is ±15% [2].

The user manual for the RR-4M type radonometer was developed in the state language to ensure clarity and accessibility for all. During its development, the passport of the device, requirements and rules for electrical safety, relevant national, international (regional), and foreign standards in the fields of standardization, metrology, and conformity assessment, as well as relevant legislative and regulatory document requirements, safety and environmental standard requirements, and the manufacturer's recommendations were taken into account. The norms were defined based on practical test results.

Based on research conducted in our Republic, it was concluded that several main types of measurement instruments have been used to measure the volumetric activity of radon gas. These include devices such as AlphaRad Plus, AlphaGUARD, and other similar measuring instruments. Now, the RR-4M type radonometer can also be added to this list.

It was identified that, although these measurement instruments are available, there were no established measurement methodologies for determining the volumetric activity of radon in air, water, and soil compositions. While there are international standards written in English that are close to this need, analytical studies showed that these standards are not adopted in our Republic, and the instruments and methods described in them differ significantly.

In 2024, the methodology for measuring the volumetric activity of radon gas in air, water, and soil compositions was developed in our Republic. The developed measurement methodology was designed as a national standard and was registered under the number O‘zMSt 402:2024 by the national standardization body, the Uzbek Institute for Standards.

The principle of the measurement method is based on detecting the presence of radon gas in the analyzed air. During the nuclear decay of radon, alpha particles with energies ranging from 5.3 to 8.8 MeV are produced. These particles, upon striking the surface of the registration detector, generate a charge that is converted into a voltage pulse by a preamplifier sensitive to charge. Subsequently, the electronic circuit amplifies it, filters it from low-energy noise, and transmits it to a control device for data accumulation according to a specific technological regulation. Later, the accumulated data is transferred to a computer, where it is processed and documented [2].

The scope of application of this Uzbekistan national standard includes residential buildings, sanitary-epidemiological services, medical institutions with radon baths, construction organizations, meteorological and seismic service organizations involved in earthquake prediction, as well as public and industrial buildings. It is intended for measuring the volumetric activity of Radon-222. Additionally, it may be used by individual entrepreneurs and legal entities involved in the design, construction (major repair or reconstruction), and utilization of residential buildings, public and industrial structures.

According to this measurement methodology, when measuring the volumetric activity of radon in water samples, radon gas is extracted from the water using a bubbling method via an air pump and transferred into the measurement chamber of the RR-4M radonometer, where its volumetric activity is measured and determined.

There are two methods for measuring the radon gas flux density on the soil surface by collecting the amount of radon emitted from the soil surface in a special chamber and determining its activity:

Method 1: Radon samples are collected and then analyzed using a separate measuring instrument.

Method 2: Radon is directly sent to the measuring chamber and analyzed on-site. Method 1 is used for preliminary rapid assessment, while Method 2 is applied for precise control and in cases of high radon flux density.

To measure the volumetric activity of radon in the air samples collected in the sampling container, an air sample is taken, and the volumetric activity of radon is determined using a special measuring device — the RR-4M radon meter. The sample is mixed with the measurement chamber, and the measurement is carried out over a period of 20 minutes [3].

The RR-4M, RR-5M, RR-6M, and RR-7M types of radon meter measurement complexes. The comparison methodology was developed and presented based on the standard “State system for ensuring the uniformity of measurements of the Republic of Uzbekistan. Documents on methods and means of verification of measuring instruments. General requirements” and taking into account the requirements for acceptance (approval) and registration. It was approved under the number QU16.276:2024 [4].

Safety requirements and comparison conditions are implemented according to the procedure defined in the “Radiation Safety Standards and Basic Sanitary Rules for Ensuring Radiation Safety” [5].

The radon meter comparison methodology includes visual inspection, testing, determination of metrological characteristics, and identification of the measurement error of radon’s volumetric activity [6].

In the implementation of these comparison procedures, the following technical devices, which have the highest accuracy and are most convenient to use, are utilized:

AlphaGUARD PQ2000PRO volumetric radon activity radon meter: measuring range of radon volumetric activity in air is from 100 Bq/m³ to 2•10⁶ Bq/m³, with relative measurement error limits of ±6 % at a 0.95 confidence level [7];

Radon chamber with a volume of at least 15 m³ containing a radiation source, capable of generating radon-222 in the range from 1•10² Bq/m³ to 4•10⁵ Bq/m³;

Control barometer M67 or another type of aneroid, with a pressure measurement range from 81.3 kPa to 105.3 kPa;

Thermo-hygrometer of NT-3 type: temperature measurement range from -20 °C to 50 °C, absolute error ±0.5 °C, and relative humidity range from 5 % to 95 %, with absolute error ±4 %.

When the required button of the radon meter is pressed, the radon meter's pump (air blower) should operate. In this case, the radon meter is considered ready for operation.

The measurement error of the radon meter being compared is determined using a comparison method.

To determine the relative error of the radon meter, the AlphaGUARD PQ2000 radon meter or another radon meter with similar metrological characteristics is placed in a radon chamber containing a radon radiation source, and the results are compared. During the inspection, the temperature and relative humidity inside the radon chamber are monitored using a digital thermo-hygrometer, and the pressure is monitored using an aneroid barometer.

According to the operating instructions, the reference radon meter is started. The volumetric activity of radon-222 in the radon chamber is monitored using the reference radon meter according to its operating instructions. The radon meter being compared is then started for measurements according to its operating instructions.

RESULTS

Using the AlphaGUARD radon meter and the radon meter being compared, measurements are carried out 5 times at 1-minute intervals. The average value of the measured quantity, **Qs**, is determined.

$$Q_s = \frac{\sum_{i=1}^{n} Q_{is}}{n} \qquad (2.1)$$

here: **Qs** – the average value of radon-222 measured by AlphaGUARD, Bq/m³; **n** – number of measurements; **Qis** – the i-th measured value of radon-222 by AlphaGUARD, Bq/m³.

Q_{is1}	176	Bq/m³
Q_{is2}	177	Bq/m³
Q_{is3}	176	Bq/m³
Q_{is4}	177	Bq/m³
Q_{is5}	178	Bq/m³
Q_s	**176,8**	Bq/m³

The measurement result of the compared radon meter is calculated using a similar formula.

$$Q = \frac{\sum_{i=1}^{n} Q_i}{m} \qquad (2.2)$$

here: Q is the average value of radon-222 measured by the compared radon meter, Bq/m³; m is the number of measurements; Q_i is the i-th measured value of radon-222 by the compared radon meter, Bq/m³.

Q_{i1}	175	Bq/m³
Q_{i2}	175	Bq/m³

Q_{i3}	175	Bq/m^3
Q_{i4}	175	Bq/m^3
Q_{i5}	175	Bq/m^3
Q_s	**175**	Bq/m^3

The relative error, δ, %, of the compared radon meter is calculated according to the following formula:

$$\delta = \delta_o + \left| \frac{Q_s - Q}{Q_s} \right| \cdot 100 \quad (2.3)$$

here: the main relative error of the reference radon meter, as indicated in the calibration certificate; Qs - readings of the reference radon meter, Bq/m³; Q - readings of the compared radon meter, Bq/m³.

δ	1,168099548	≤	15

The relative error of the compared radon meter is specified in the manufacturer's technical documentation.

DISCUSSION

As a result of the conducted analysis, it was found that the RR-4M radon meter is not only adapted to local conditions but also competes with foreign analogues in a number of technical specifications.

CONCLUSION

For accurate measurement and effective monitoring of radon gas, the introduction of modern, precise, and reliable measuring instruments, as well as the improvement of their metrological support, is of great importance. The development of national radon meter types such as the RR-4M, the creation of standardized measurement methodologies, user manuals, and calibration methods for them provide reliable data in this field and play a crucial role in protecting public health. These achievements in metrology serve to scientifically and practically strengthen the radon monitoring system.

The developed national standard O‘zMSt 402:2024 "Methodology for measuring the volumetric activity of radon in air, water, and soil" has been introduced to the Uzbekistan Standards Institute, Navoi Mining & Metallurgy Combinat JSC, and the S.A. Azimov Physics-Technical Institute of the Academy of Sciences of the Republic of Uzbekistan. The calibration methodology QU16.276:2024 for radon meter measurement complexes "RR-4M", "RR-5M", "RR-6M" and "RR-7M" has been introduced to Navoi Mining & Metallurgy Combinat JSC and the S.A. Azimov Physics-Technical Institute of the Academy of Sciences of the Republic of Uzbekistan. The user manual for the measuring instrument for radon quantity in air, water, and soil, and the software DGU 29059 "Algorithm for measuring radon quantity in air, water, and soil and software for post-processing measurement results considering measurement uncertainty" have also been introduced to the S.A. Azimov Physics-Technical Institute of the Academy of Sciences of the Republic of Uzbekistan, and it has been noted that these works are scientifically and prospectively significant.

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