RAP Conference Proceedings, vol. 10, pp. 1–5, 2025
ISSN 2737-9973 (online) | doi: 10.37392/RapProc.2025.01
RAP-PROCEEDINGS.ORG

THE RADON EYE MONITOR: A REVIEW OF BENEFITS AND PROBLEMS

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Abstract. *The RadonEye is an active radon gas monitor that has become increasingly popular for some years. Among consumer grade active radon monitors it is the most sensitive one. It is sold for a fair price and it is easy to operate via a Smartphone app through Bluetooth connection. This makes it useful for individual radon monitoring and for research in the framework of Citizen Science, for example in the context identifying radon priority areas, recording radon time series or measuring radon exhalation. If limitations are considered, it can be used in scientific research. In this paper its benefits and problems are reviewed and examples of its usage given.*

Keywords: *Radon Eye, active radon measurement, calibration, time series*

1. Introduction: Why Using Active Radon Monitors?

Radon gas (Rn; here we deal mainly with the isotope ^{222}Rn from the ^{238}U series, if not stated otherwise) concentration is measured in different environmental compartment and media for different purposes. Among compartments are the indoor and outdoor atmospheres, the air in caves, soil gas and ground and surface water bodies. The range of purposes covers different aspects of radiation protection and scientific applications, mainly in tracer research or background control in ultralow-level radiation experiments in particle research. In environmental protection, an interesting application is monitoring of NAPL (non-aqueous phase liquids) in the ground.

In some cases, one is interested in long-term mean Rn concentration, which is traditionally measured with passive monitors, mainly SSNTD (track-etch detectors). The method is well established, robust and cheap. The main application is indoor Rn monitoring and in particular assessing compliance with regulation, that is, testing whether a reference level is exceeded or not, because this is the criterion for mitigation action. For this objective the method is sufficiently accurate and precise.

However, for other purposes one needs temporally resolved Rn data. To this end one uses continuously, active Rn monitors which generate quasi-continuous concentration time series; "quasi" denotes that in fact mean concentrations over contiguous short periods such as an hour are recorded. The choice of instrument depends not least on the length of the periods, which define the temporal resolution, and of the required precision of the data.

Another evident factor is cost. In the last years, low-cost devices have appeared on the market, which are based on semiconductor detectors or ionisation chambers. These devices have quickly become popular. Among the purposes are:

Rn protection:

- Time-discriminative indoor Rn measurement, if one is for example interested in Rn in work places during working hours only;
- Sort-term screening of indoor Rn if no long-term concentration is needed, but only a decision on whether a reference level is likely exceeded; this can also be achieved for example with cheap charcoal detectors, but if frequently used for this purpose, active monitors are competitive.
- Verification of the effectiveness of mitigation measures, such as ventilation systems.[2]

Citizen Science:

- Active monitors which display the Rn concentration in almost real-time are attractive as they do not require waiting for a result for a long time. This can motivate concern with Rn exposure, stimulate scientific curiosity and contribute to democratisation of science.
- Large amounts of results can be shared in a community or with radioprotection authorities and used in mapping of Rn levels or of Rn priority areas (RPA; areas in which action, e.g., by preventive measures or allocating resources for remediation should be taken with priority.)

Scientific research:

- While expensive professional-grade active Rn monitors have high standards of QA and are owned by institutions with access to QA infrastructure, this is often not the case for cheap consumer-grade instruments. However, if limitations are considered, such monitors may also be used in a scientific context. Typical

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[2] I thank one reviewer for pointing to this important application.

applications are recording Rn time series in tracer research, in studies about the dynamic of agents and pollutants in complex ambient systems that are controlled by meteorological factors.

The review of literature, own experiments and analyses reported here are taken from publications [1, 2], the contribution to the RAP conference 2025 [3] and another recent conference contribution [4] and current unpublished research.

2. The Radon Eye Monitor

The RadonEye (Fig. 1) is produced by the South Korean company FTLab [5]. Measurement is based on a pulse ionisation chamber which is also used in the EcoCube monitor by Ecosense (possibly the same company with different name).

The instrument has become increasingly popular for some years. Among consumer grade active radon monitors it is the most sensitive one. The basic version is sold for a fair price, currently (July 2025) about 200 Euro. It is easy to operate via a Smartphone app through Bluetooth connection. It has been subjected to performance tests by different laboratories, in general showing acceptable to good results [6 – 15].

The nominal sensitivity of the RadonEye is 1.35 cpm / (100 Bq/m^3), which is similar to the professional-grade Rad 7 (Durridge). For comparison, the consumer-grade monitors View Plus (Airthings): 0.042, Correntium Pro (Airthings): 0.17, Spirit (Radonova): 0.12; for further comparison the professional Rad-8 (Durridge): 2.2, and the Alphaguard (Bertin): 5 cpm/(100 Bq/m^3). The latter are reference instruments and are certainly of higher QA standards, but they are almost two orders of magnitude more expensive. Higher sensitivity is only achieved by special purpose devices, such as the ANSTO Rn monitors [16], used in atmospheric tracer and climate research.

RadonEye monitors are delivered with – apparently, as it is not explained by the manufacturer – the nominal sensitivity as calibration factor. Experiments with parallel measurement with several devices showed deviations up to about 20%. This may be acceptable for screening measurements but it is problematic if accurate values are required, for example if decision about mitigating or remedial action should be taken. If the decision depends on whether a reference level RL is exceeded, correctly assessing concentration $c>RL$ or $c<RL$ is crucial. An erroneous decision can have serious legal and economic consequences.

The information about calibration given by the manufacturer is inconsistent, see the overview in [2]. However, it is clear that for the low-price individual calibration of each instrument is not feasible. Therefore, one may wish re-calibration; but this is expensive because it is labour intensive and done by dedicated and certified laboratories. A cheap alternative is secondary calibration, see sec. 3.1.

Experiments with several RadonEyes have revealed further issues:

(1) Periods of some days were observed when spurious Rn peaks occurred. These are isolated, meaning not correlated to previous or following measurements. Since ambient conditions do not change dramatically within 1 hour (the reporting period of the RadonEye) due to the natural inertia of environmental processes, the physical reason must be in the instrument itself or perhaps response to external signals other than Rn. So far, it has not been explained.

(2) The internal evaluation algorithm which cannot be accessed by the user rounds the Rn concentration to integers. Given the statistical uncertainty of the values, this is acceptable; but when exposing the monitor to low Rn concentrations, as typical for the outdoor atmosphere, for rooms in higher floors or in regions with low geogenic Rn potential, one finds that certain nominal concentrations are systematically missing. The sets of missing values are different between RadonEye exemplars. This must be an issue of the algorithm; however, the manufacturer declined commenting on this, quoting business secret [1, 2].

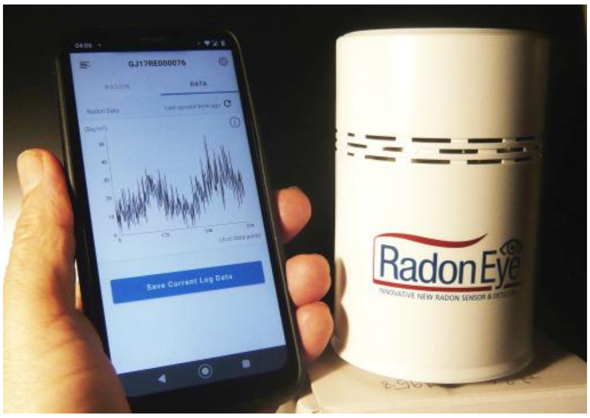

Figure 1. The RadonEye monitor and recorded time series as shown in a Smartphone app through a Bluetooth connection.

3. Experiments and Examples of Time Series

In this section experiments are reported that serve QA of the RadonEye, and others which shall explore its potential in scientific research, mainly related to Rn as a tracer and time series analysis techniques.

3.1. Secondary calibration

A simple way to perform secondary calibration is exposing the RadonEye parallel and synchronous, that is at the same location, during the same period and with coinciding sampling intervals, together with a certified instrument, for example an Alphaguard (Fig. 2). During the period the ambient Rn dynamic should be high, like in the example shown in the Figure. A paper about the procedure is in preparation [17].

Such experiment is cheap – one only has to let them measure together for some days or a week or so. Then one performs a regression analysis which yields the internal background and the calibration factor. This is certainly less precise than a “proper” calibration in a Rn chamber but the additional uncertainty (additional to the uncertainty stemming from measurement statistics) is probably acceptable for most applications.

Usually Alphaguards, Rad7 and similar are owned by research or radioprotection institutes. In my opinion, it would make sense that they offer a service for users of consumer-grade monitors for secondary calibrating their devices. As said, the effort is minimal and it would certainly improve the quality and reliability of Rn measurements performed individually or in a Citizen Science context.

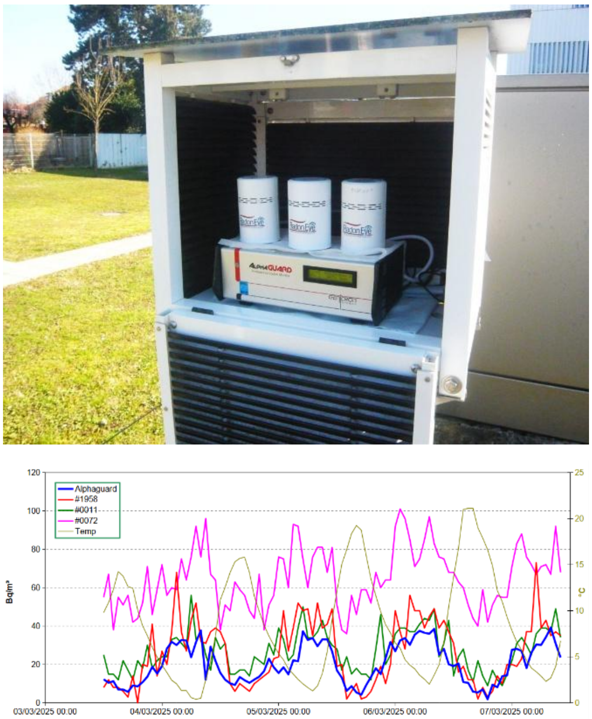

Figure 2. Parallel exposure of an Alphaguard and three RadonEyes.

3.2. Thoron

The RadonEye is sensitive to thoron (Tn, ^{220}Rn, half life 56 s, from the ^{232}Th series), as demonstrated in [9, 2], Fig. 3. If one is interested only in ^{222}Rn, the monitor should be placed such as to minimise the Tn influence. Indoors, main Tn sources are building materials which always contain Th; therefore, one would place the monitor some distance away from walls and floors. Due to the low half life, the molecular diffusion length is only 2.9 cm, but by advective or turbulent transport it can migrate further. The influence of geogenic Tn is expected to be negligible except if pathways for advective transport exist. The experiment shows that the RadonEye could be used for assessing Tn exhalation, but calibration for Tn and preparation of a standard procedure and protocol would be necessary.

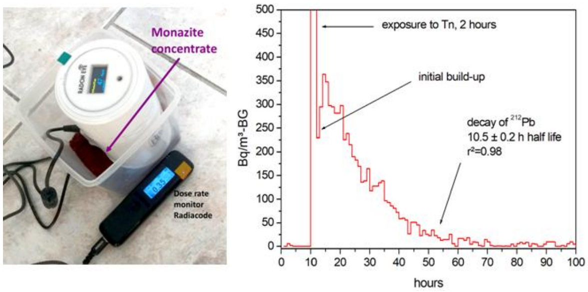

Figure 3. Exposure to Tn by placing a monitor above Th-rich monazite concentrate and resulting time series after removing the monitor from the Tn source.

3.3. Parallel measurements

Parallel synchronous measurements with several RadonEyes were performed to check the repeatability of results in the sense that different devices of the same model give the same result, up to measurement statistics. (To compare, parallel measurements with monitors of different model (sec. 3.1) allow assessing the reproducibility.) The results were encouraging as also measurements at very low Rn concentrations (outdoor) proved repeatable; however, one caveat is that RadonEyes which have been in use for longer time or in high-Rn atmosphere have higher internal background due to deposition of long-lived Rn progeny in the detector chamber. Nevertheless, the variability patterns coincide essentially [1, 2, 17].

3.4. Time series analysis

The RadonEye has sufficient sensitivity and temporal resolution to allow recording Rn time series with uncertainty tolerable for many applications, also in low-Rn environments, such as the outdoor atmosphere. Outdoor Rn concentration usually varies between nearly 0 and 50 Bq/m³. Expected patterns of diurnal (Fig. 4) and seasonal (Fig. 5), as well as aperiodic "synoptic" variability can be clearly demonstrated. The latter refer to variability mainly induced by weather episodes.

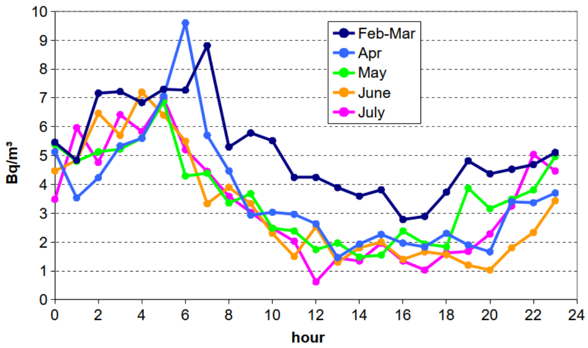

Figure 4. Mean outdoor Rn concentration per hour of the day, recorded in Berlin.

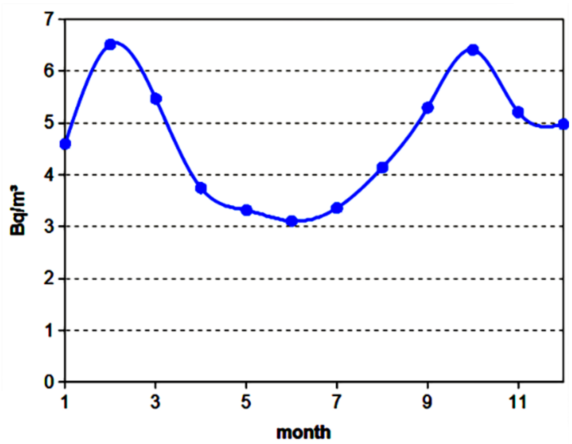

Figure 5. Seasonal variability of outdoor Rn concentration, Berlin.

Temporally variable controls of outdoor Rn are exhalation from the ground and the atmospheric mixing regime, dependent on turbulent and advective mixing and the mixing layer height which denotes the "lid" on the lower troposphere below which Rn and other pollutants can mix. Another possible source of aperiodic type of variability are seismic events. Periodicity can be assessed by Fourier analysis and periodograms (Fig. 6), while synoptic variability requires appropriate time series filtering [1, 4].

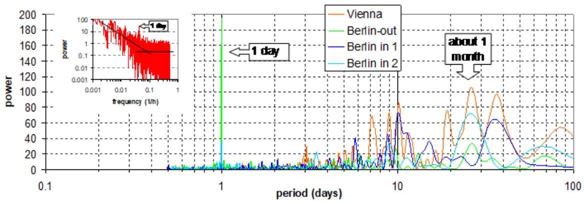

Figure 6. Periodograms of four Rn time series.

3.5. Statistical association between Rn and controls and proxies; tracer research

One distinguishes control or predictor-type dependence and proxy-type dependence. In the first case, a variable Y physically influences another variable X, called response variable; for example, Rn exhalation from the ground physically influences – together with other variables – the Rn concentration in the free atmosphere. In the second case, a variable Y physically influences – together with other variables – two different physically independent response variables X_1 and X_2, which are therefore statistically associated, although not directly physically connected. For example, the atmospheric mixing regime influences X_1 = outdoor Rn concentration and X_2 = particulate matter (e.g., PM2.5) or other pollutants (NOx, Fig. 7 for parallel time series, or O_3 concentration). X_1 and X_2 are not physically related but statistically associated.

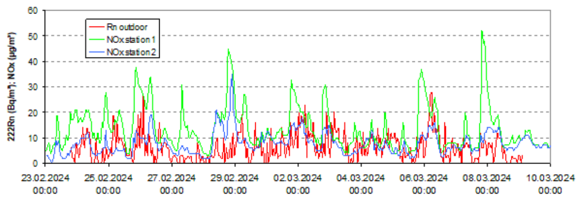

Figure 7. Parallel time series of outdoor Rn and NOx concentrations at two stations, Berlin.

The statistical association is "blurred" because of the influence of other controlling variables, sometimes called confounders in relation to the investigated association. In reality, dependence between variables is very complex and subject of much research. Rn which is easy to measure, can act as an indicator or tracer of atmospheric pollution as well as of the underlying generation (the Y) and transport processes (the links between the Y and the X). Using RadonEyes, initial investigation has been started for association between outdoor Rn and ambient dose rate and atmospheric pollution; first results in [4].

(It should be noted that the terminology proposed here is not authoritative. Sometimes the terms proxy and control are used interchangeably. However, I think that different types of physical and statistical relations should be denoted differently.)

The potential of Rn as tracer has been discussed comprehensively by [18]. For association between Rn and dose rate, see e.g. [19].

4. Conclusion

Altogether, the RadonEye is a useful radon monitor. It features the most sensitive detector among consumer grade active monitors, it is easy to use and its price is fair. However, calibration as delivered from the factory does not seem to be very reliable; if accurate results are needed, recalibration is therefore advised. It would be beneficial if institutes that own a calibrated professional-grade monitor could provide a service for secondary calibration which costs practically nothing. Certain statistical properties of the internal evaluation of the RadonEye should be further explored. One reviewer suggested to further exploring response to realistic mixed Rn/Tn exposure. The monitor can be used in Rn protection and mitigation and in scientific contexts, especially for tracer research. It may have a great potential in Citizen Science. In any case, one has to be aware of its technical limitations.

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