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EURAMET

traceRadon

Field testing a portable two-filter dual-flow-loop ^{222}Rn detector

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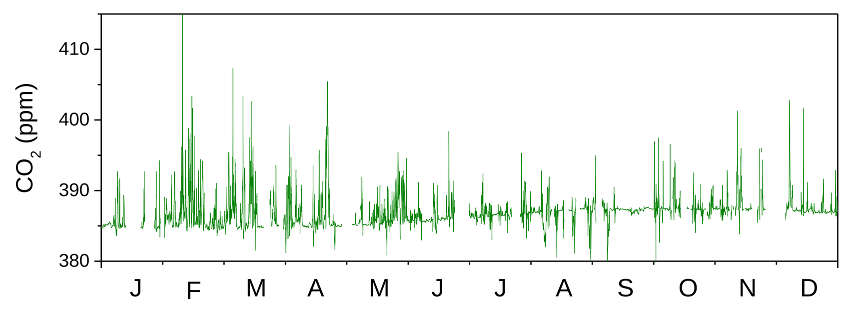
Radon exposure poses a public health risk, but ^{222}Rn is also a powerful tracer for atmospheric mixing and transport studies. For the benefit of the climate, air quality and radiological protection research communities, portable radon monitors are required for outdoor environmental applications ($0.1 < {}^{222}$Rn ≤ 100 Bq m^{-3}). Calibrations should be traceable to the International System of Units and temporal resolution should be ≤ hourly.

Current state of the art in outdoor atmospheric ^{222}Rn monitoring

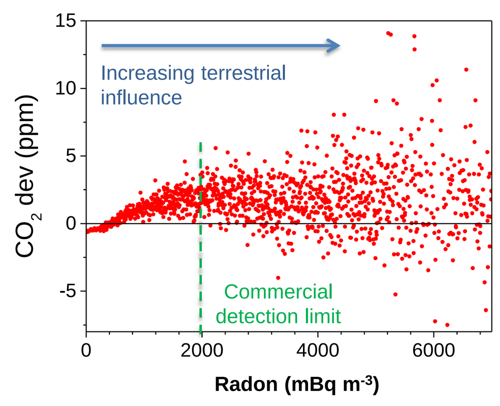
The capability to reliably monitor hourly atmospheric radon activity concentrations with detection limits of ≤0.03 Bq m^{-3} via research-grade dual-flow-loop two-filter detectors has existed for decades (Williams and Chambers 2016). Since radon is an unambiguous indicator of terrestrial influence on air masses, the benefits of this capability are clear and have been extensively reported (e.g. Chambers et al. 2016, 2018, 2019).



1-year of hourly CO_2 concentrations recorded at Cape Grim, Tasmania, 250 km south of the Australian Mainland.

Deviations of CO_2 from the monthly mean value resulting from land-based sources and sinks show decreasing variability with decreasing degree of recent land contact as determined using radon as a proxy for terrestrial influence

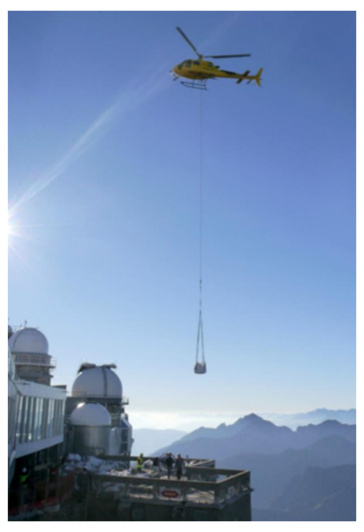
The detection limit of commercial instruments is not sufficient to resolve "clean" oceanic values.



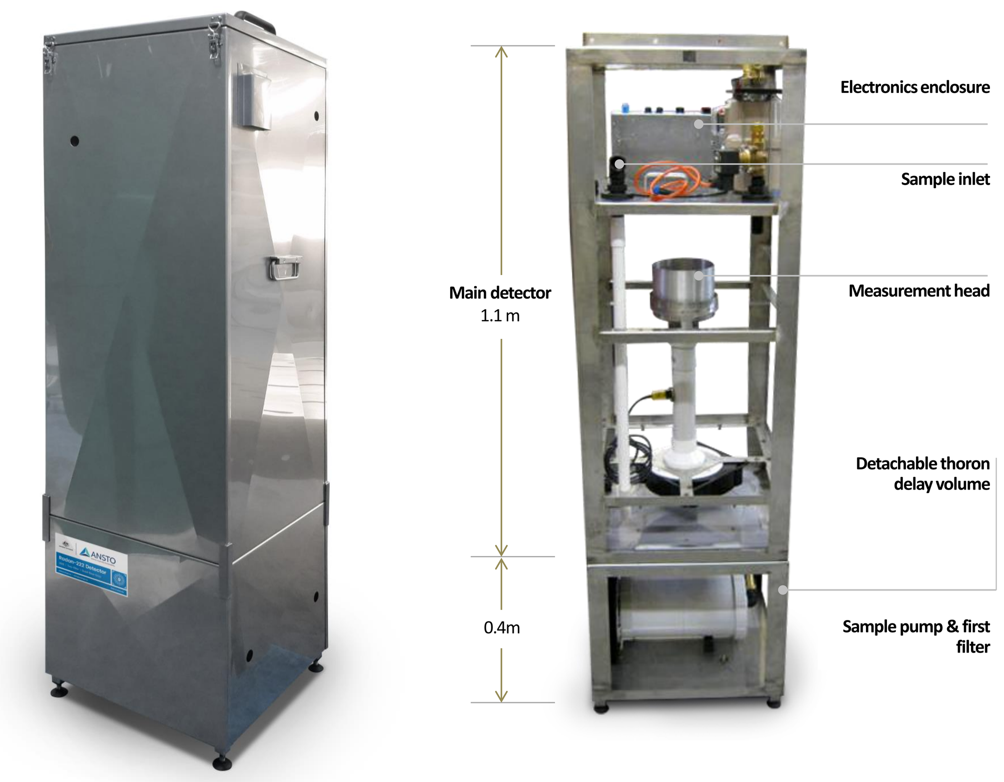
However, since detection limits for the two-filter method are directly linked to the volume of the measurement chamber, to date, detector size (portability) has posed considerable logistical problems. Typically, remote sites either have limited available space, or it is logistically challenging to deliver and install such large equipment.

The 5000 L and 1500 L radon detectors at Cape Grim, Tasmania, are 5 m and 3 m long, respectively, and require 4-6 people to relocate.

A helicopter was required to deliver a 1500 L ^{222}Rn detector to the Pic du Midi baseline station in the French Pyrenees because a 3 m detector could not fit in the available cable car.



Door frames had to be removed from the station laboratory to install a 1500L ^{222}Rn detector at the GAW Antarctic Baseline Station, King Sejong.

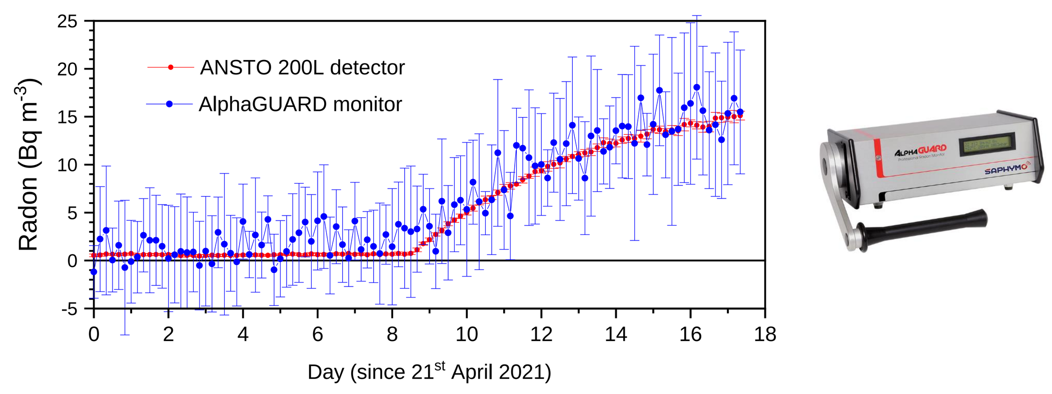


New portable two-filter dual-flow-loop ^{222}Rn detector

A compact two-filter detector was developed for the EMPIR 19ENV01 *traceRadon* Project. This 200 L detector is 1.5 m tall and 48 cm wide. It separates into 2 pieces for transport, is constructed of marine grade stainless steel, has low maintenance requirements and power consumption (~100W at 240V). Since the longest piece is 1.1m, it can be transported inside a standard vehicle. Vertically-oriented, with the detector stacked on top of the ^{220}Rn (thoron) delay volume, it can also fit in the space of a standard 19" instrument rack, making it suitable for even small, remote laboratories.

The detector has a sampling flow rate of 12-15 L min^{-1}, a <45-minute response time (correctable in post processing; Griffiths et al.. 2016), and has a 30-minute temporal resolution. It's sensitivity to radon is estimated to be 2.5 – 3 counts per minute / Bq m^{-3}, yielding a lower limit of detection around 0.15 – 0.2 Bq m^{-3}.

To investigate the comparative performance of the new 200 L radon detector and a leading contemporary commercial portable radon detector (AlphaGUARD PQ2000 PRO), both instruments were placed in a calibration chamber and radon concentrations increased over a range of representative environmental concentrations (0.5 – 15 Bq m^{-3}).



*Here we show **4 hourly μ±σ** calculated from 30-min observations. While linear regression indicated similar calibrations (AG=0.984*ANSTO+1.01; R^2=0.91), the measurement uncertainty associated with the new 200L portable detector was substantially lower than that of the AlphaGUARD, which has a reported detection limit of 2-3 Bq m^{-3}.*

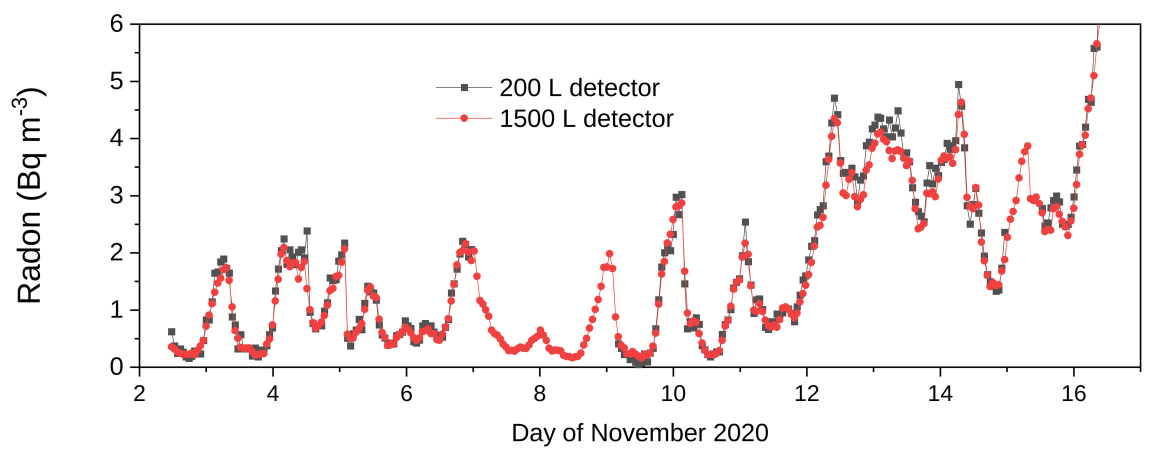
The portability vs accuracy trade-off (200 L vs 1500 L detectors)

What are the changes in functionality in choosing a portable 200 L detector over a 1500 L detector? To investigate, a 2-week comparison was performed between the two models of two-filter detector. Sampling was conducted 3 m above ground level, 15 km from the coast, near Sydney, Australia.

Both detectors were calibrated by injecting radon from a Pylon ^{226}Ra source for 5 hours into the sampling air stream. Changes in ambient radon resulted in a calibration uncertainty of ~6%. The σ of 30-miniute instrumental background estimates was 0.07 and 0.02 Bq m^{-3}, for the 200 and 1500 L detectors respectively.

<u>Overall:</u> $\mathbf{[Rn]_{1500} = 0.932[Rn]_{200} + 0.038 \quad R^2 = 0.986}$

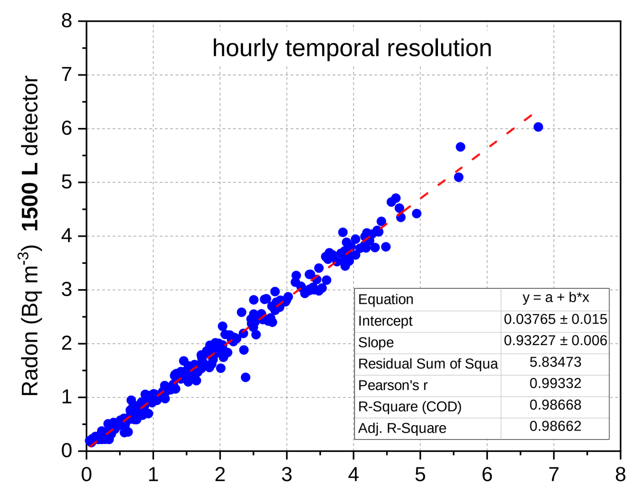
The deviation from 1 of the regression slope is primarily attributable to the calibration uncertainty. Objectives of the *traceRadon* project include reducing the calibration uncertainty of the 200 L detector and making calibrations traceable to the SI. Slight differences in instrument response times yielded R^2 = 0.986. Uncertainty in instrumental background estimates is likely responsible for the non-zero regression offset.

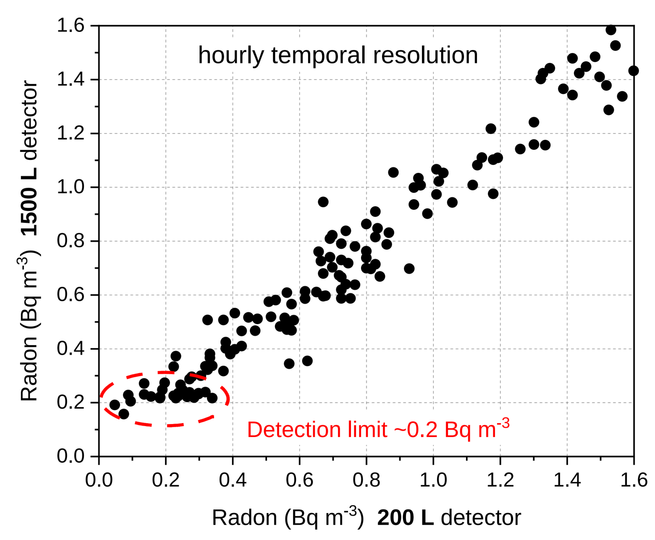


The comparative performance of the 200 and 1500 L radon detectors at this non-baseline site (where ambient radon concentrations varied from 0.2 – 6 Bq m^{-3}) was quite good (see above). The faster response time of the 200 L detector compared with the 1500 L detector is evident in the increased structure at higher radon concentrations.

However, as evident from the expanded scale plot of the linear regression (bottom right), the lower limit of detection of the 200 L detector in the setup used for this intercomparison was around 0.2 Bq m^{-3}. By comparison, the detection limit of the 1500 L detectors is typically 0.025 – 0.03 Bq m^{-3}.

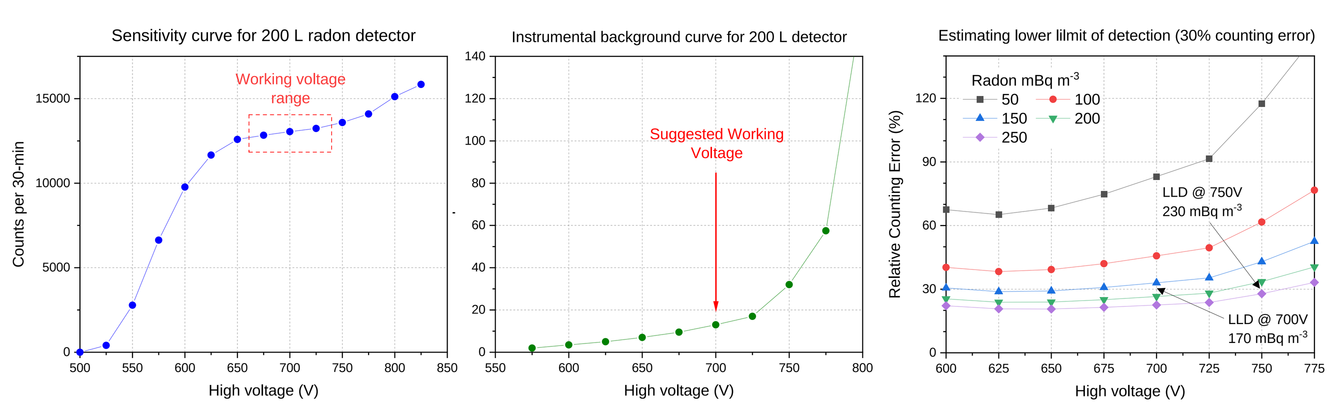
The difference in performance of these two instruments would therefore only be significant at high altitude, or baseline stations, where radon concentrations below 0.2 Bq m^{-3} are frequently observed (e.g., Chambers et al. 2016).





Optimizing detector performance

The detectors working voltage was set at 750 V for the initial field tests. Subsequent checks of the sensitivity and background characteristics have indicated that a working voltage of between 675 - 700 V would be more appropriate. Reducing the working voltage to within this range is expected to reduce the lower limit of detection (LLD) to between 0.15 - 0.17 mBq m^{-3}. Future optimization of the internal flow rate (second flow loop) is also planned, to see whether the theoretically-predicted LLD of 0.13 can be achieved. Tests of a new style of detector measurement head are also underway, with a view to improve the ^{222}Rn measurement sensitivity by up to a factor of 4.



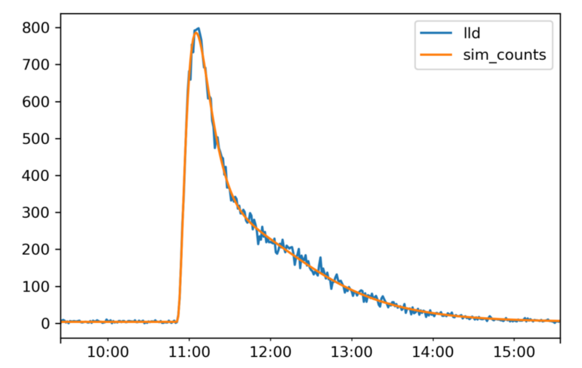
Response Time

The deconvolution model of Griffiths et al. (2016) for response time correction of two-filter radon detectors was able to reproduce results of a 1-min spike test on the 200 L detector using a 21 kBq Ra-226 source.

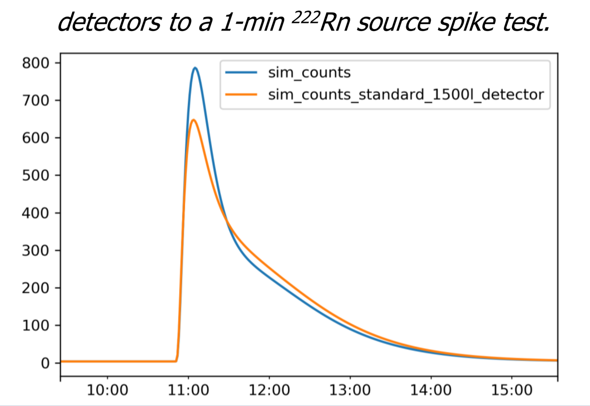
Comparison of response characteristics between the 200 L and 1500 L detectors indicates a faster response by the 200 L detector.

Overall, results from preliminary tests of the prototype 200 L two-filter dual-flow-loop ^{222}Rn detector indicate that it will be a valuable tool for air quality and radiological protection studies in a range of urban and remote environments, and potentially a convenient calibration transfer standard device for the *traceRadon* Project.

Observed vs simulated counts per minute for a 1-min ^{222}Rn source spike test on the 200 L detector.



Comparison of simulated response of 200 & 1500 L detectors to a 1-min ^{222}Rn source spike test.



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