The RAD8 Continuous Radon Monitor for Quantitative Groundwater Tracing Applications

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Abstract

- In 2001, Burnett, Kim & Lane-Smith [1] introduced the technique for measuring radon in water using a Durridge RAD7 continuous radon monitor [2] paired with a continuous water-air equilibrator, commercialised as the RAD Aqua. The RAD H2O, for discrete measurements, followed several years later [3] .
- In the two decades since, these techniques have gained popularity for their ease of use and fast results, and **radon measurements with the RAD Aqua and RAD H2O are now routinely used by aquatic scientists to quantitatively study groundwater movement in coastal, lacustrine and riverine systems.**
- To date, several thousand scientific works have been published using these devices and techniques pioneered by Durridge.
- Here, we present the RAD7's successor: the RAD8 continuous radon monitor. Redesigned from the ground up with aquatic science applications in mind, the RAD8 represents a technological leap forward in the researcher's toolkit.

70% Higher Sensitivity

- RAD8's patent-pending measurement chamber geometry has been optimised using several approaches, including full 3D electrostatic field analyses on a per-volume basis and Monte Carlo simulations, with models validated through real-world testing.
- Commissioning tests and calibration data show that **RAD8 achieves a sensitivity 70% greater than that of the RAD7**, despite having a smaller measurement chamber.

Fully Ruggedised and Waterproof (Even with the Lid Open!)

- RAD8 is **IP67 waterproof and dust proof**, and designed to float.
- Can be operated in wet or dusty environments, or even at sea, without fear of damage from incidental water contact.
- Dual controls: touchscreen and physical membrane buttons.

Benchmarking Test: MnO2 Fibre with radium-226 & thorium-232

- Henrietta Dulai – University of Hawai'i.
- Using the method first described in [4].

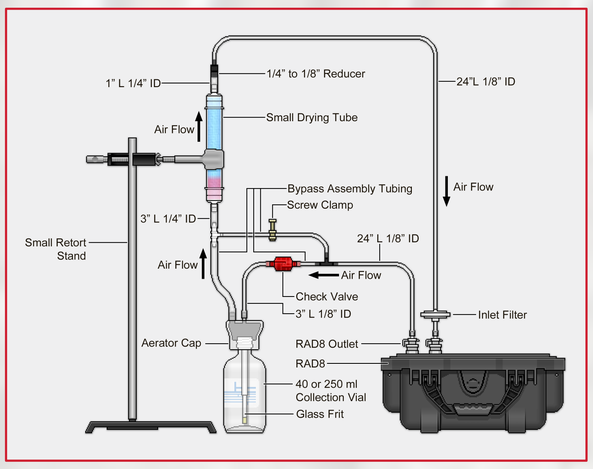
- RAD7: 104.7 +/- 8.6 Bq/m^3
- RAD8: 102.5 +/- 15.4 Bq/m^3

- RAD7: 37.5 +/- 1.8 Bq/m^3 (thoron)
- RAD8: 37.5 +/- 1.7 Bq/m3 (thoron)

Benchmarking Test: RAD H2O

- Measuring a radium-free radon-in-water source [5] in a 40 ml RAD H2O sample vial.
- Reference: RAD7 running in built-in WAT40 mode.
- RAD8 uses calculated air-water conversion factors, rather than the empirically determined ones that were used by the RAD7's WAT40 & WAT250 modes [6]. **This brings RAD H2O in-line with Capture's Big Bottle analysis tools.**

- RAD7: 83.46 +/- 8.14 Bq/L
- RAD8: 86.4 +/- 2.33 Bq/L



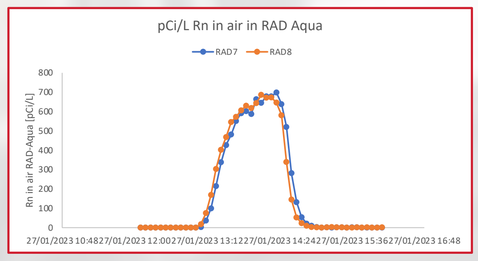
Wireless Connectivity & Enhanced Data Storage

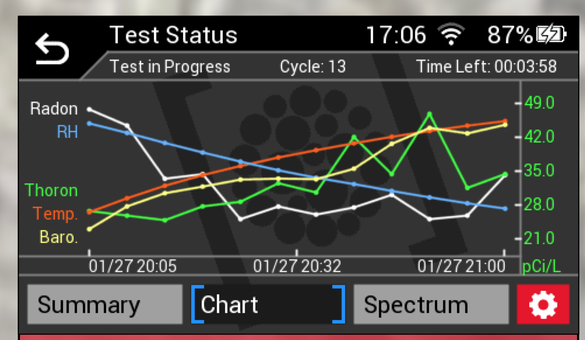
- Built-in WiFi connectivity, as well as one COM port (data download and remote control) and two USB ports for accessories.
- **Onboard storage for orders of magnitude more data than the RAD7**, including full-resolution spectral information in 5-minute 'time slices'.

Benchmarking Test: RAD Aqua

- Henrietta Dulai – University of Hawai'i
- RAD Aqua water-air exchange setup of [1], modified to incorporate RAD8 and RAD7 in series, sampling air in a closed loop with the RAD Aqua.
- Response to low-high-low step-changes in radon concentration are shown below.
- **Both response time and radon concentration in very good agreement with RAD7 reference.**

- RAD7: 24.9 +/- 3.3 Bq/L
- RAD8: 24.6 +/- 3.0 Bq/L



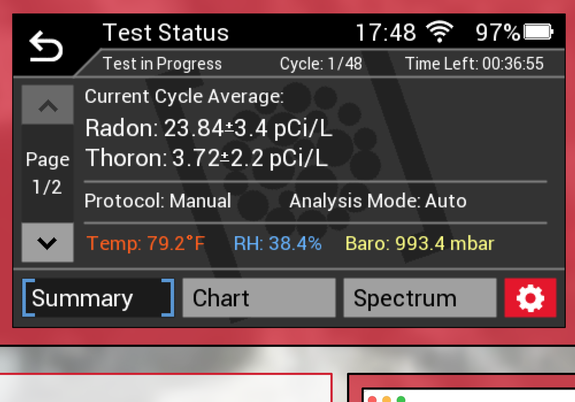


On-Device Data Visualisation

- View radon / thoron time series data on-screen as it comes in, to get a picture of the trend over time at a glance.
- Spectrum display empowers users to make their own data quality checks in real time, allowing them to identify problems and fix them in the field.
- **Avoid the need for repeat measurements!**
- RAD8 stores both reduced data and full-spectrum information in 5-minute 'time slices', which can be combined and split in Capture after the event – **never worry about setting the wrong Cycle length again!**

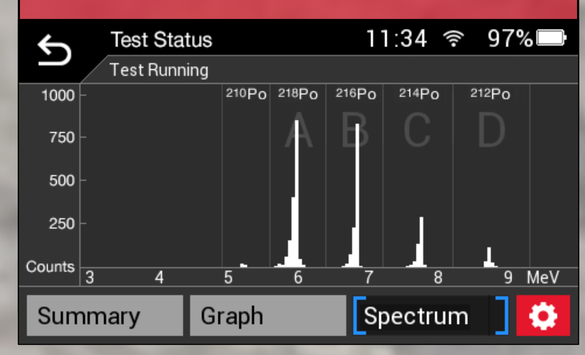
Measure up to 2,500,000 Bq/m3

- RAD7 shaping time: 100 µs. Digitiser frequency: 40 kHz.
- RAD8 shaping time: 4 µs. Digitiser frequency: 30 MHz.
- This speed increase enables the RAD8 to **measure extremely high radon / thoron concentrations** before pulse pileup and deadtime begin to impact linearity.



Real-time readout

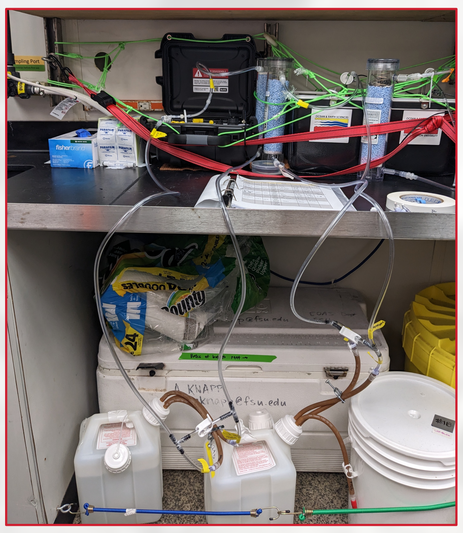
- RAD8 displays continuously updating radon and thoron activity concentrations, with their associated uncertainties.
- **Users thus have access to the most up-to-date information**, and an early warning of changing radon / thoron activity concentrations.

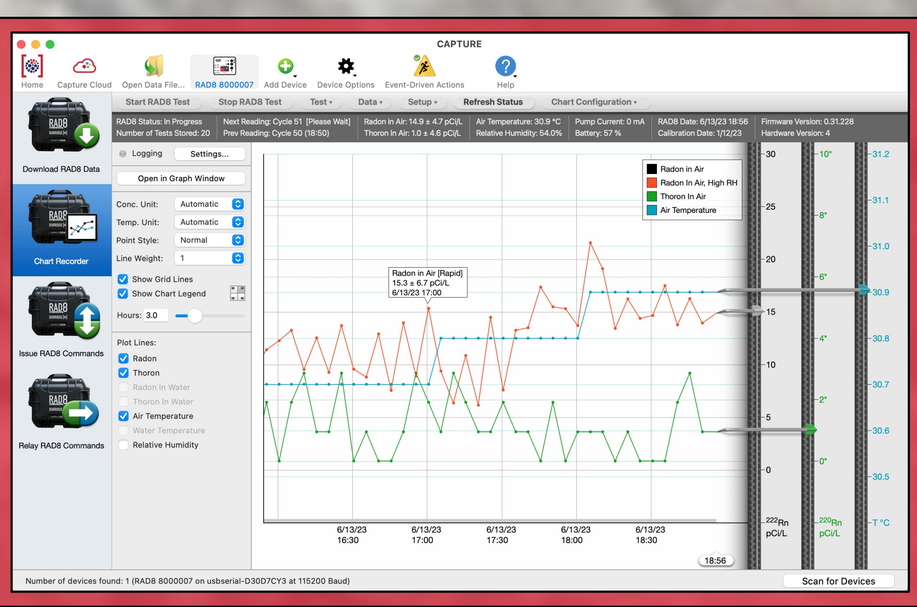


Benchmarking Test: Custom Big Bottle Setup

- Joseph Tamborski – Old Dominion University.
- Water samples collected from the Elizabeth River in 8L jerricans.
- Custom setup akin to RAD H2O & Big Bottle System.
- Water sample never comes into contact with air, which eliminates a major potential source of sampling error.

- RAD7: 10.67 +/- 1.15 dpm/L
- RAD8: 10.95 +/- 1.21 dpm/L





Capture Pro 8 with Capture Cloud

- Capture Pro 8 software for Windows and macOS offers **an expanding suite of data graphing and analysis tools.**
- Capture Cloud provides automated uploading and retrieval of RAD8 data, and the sharing of data with colleagues around the world.
- Capture Cloud Data Browser offers **powerful tagging and search functionality**, making it easy to organize and locate RAD8 data from any project, device, date range, or location.

References

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[2] Durridge Company Inc. RAD7 Radon Detector https://durridge.com/products/rad7-radon-detector/.

[3] Lee, J. M., & Kim, G. (2006). A simple and rapid method for analyzing radon in coastal and ground waters using a radon-in-air monitor. Journal of Environmental Radioactivity, 89(3), 219–228. https://doi.org/10.1016/j.jenvrad.2006.05.006

[4] Kim, G., Burnett, W. C., Dulaiova, H., Swarzenski, P. W., & Moore, W. S. (2001). Measurement of 224 Ra and 226 Ra Activities in Natural Waters Using a Radon-in-Air Monitor. Environmental Science & Technology, 35(23), 4680–4683.

[5] Kitto, M. E., Menia, T. A., Bari, A., Fielman, E. M., & Haines, D. K. (2010). Development and intercomparison of a reusable radon-in-water standard. Radiation Measurements, 45(2), 231–233. https://doi.org/10.1016/j.radmeas.2010.02.002
https://doi.org/10.1021/es010804u

[6] Lee, K. & Burnett, W., Determination of air-loop volume and radon partition coefficient for measuring radon in water sample, J. Radioanal. Nucl. Chem. 298 2 (2013) 1359–1365.

Acknowledgements

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