DURRIDGE
Radon Capture & Analytics

Measuring Radon in Water with the DURRIDGE RAD7 Continuous Radon Monitor

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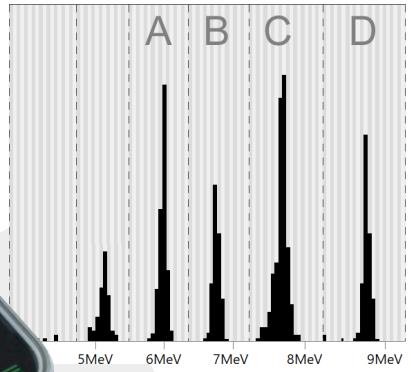
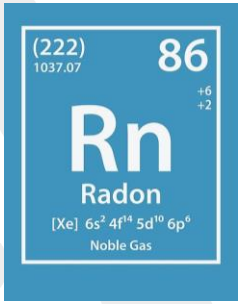
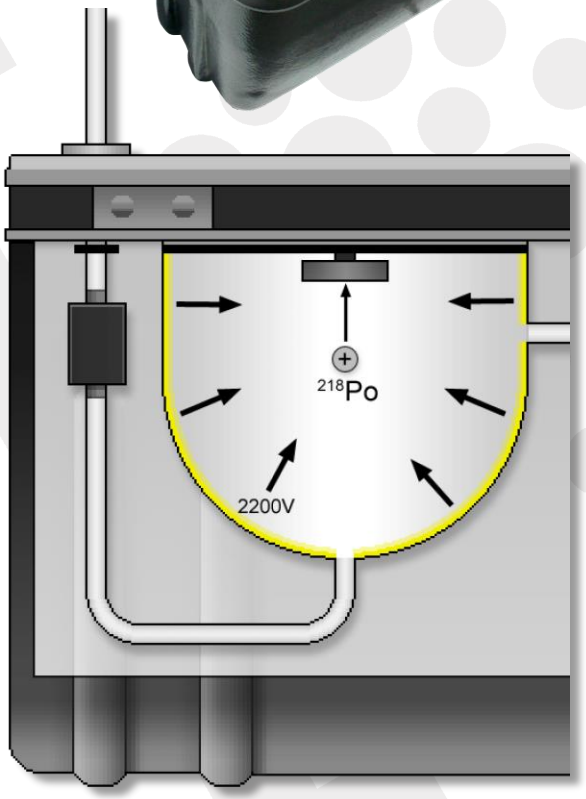
RAD7 Overview

- Continuous radon monitor.
- Electrostatic Precipitation of radon decay products followed by High-Resolution Alpha Spectrometry.
- Simultaneous, independent measurements of ^{222}Rn ('radon') and ^{220}Rn ('thoron').
- Nominal sensitivity (Normal Mode): 0.013 cpm/Bq/m^3 (0.5 cpm/pCi/L).
- Vanishingly small intrinsic background: 0.2 Bq/m^3 for the lifetime of the instrument (no ^{210}Po interference).
- Measurement range: 4 – 750,000 Bq/m^3.
- Over 3,800 scientific papers published using RAD7.



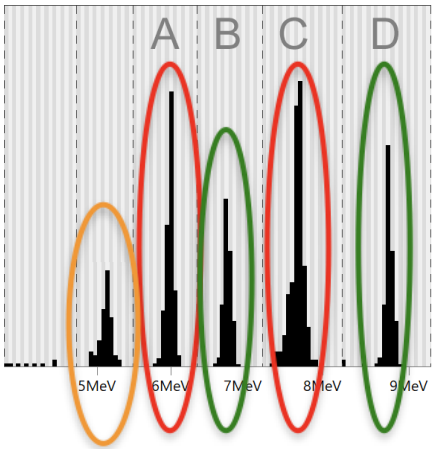




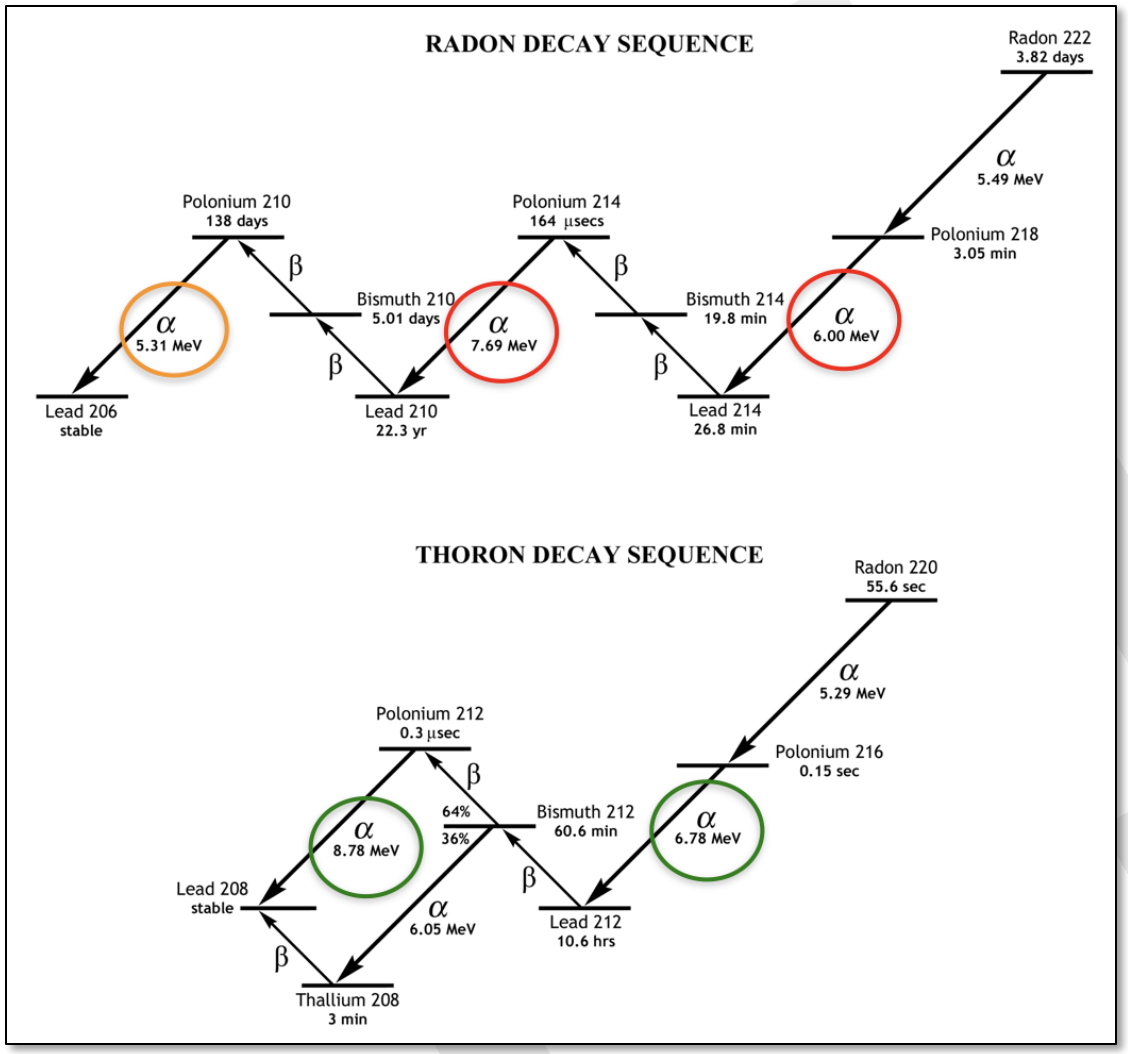
Radon Decay Chain & RAD7

Very good energy resolution ensures:

1) Near-perfect background rejection (inc. long-lived background from ^{210}Po – orange peak)



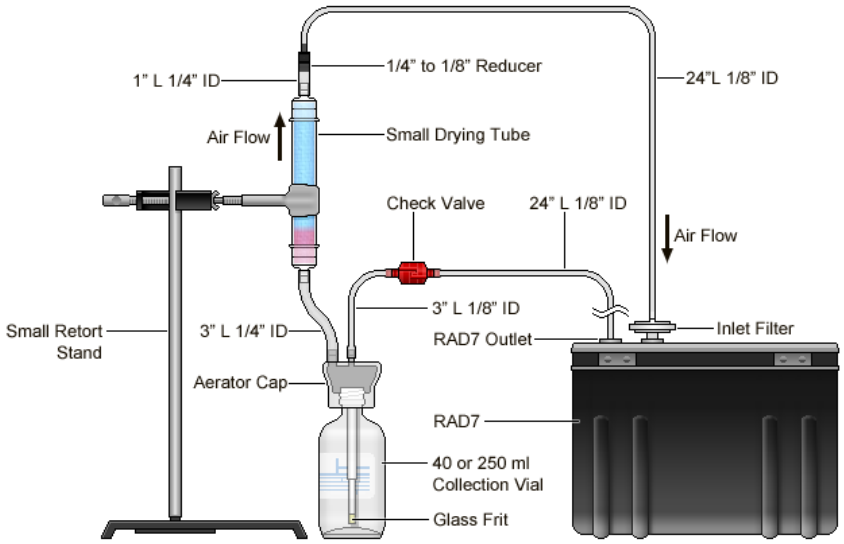
2) Simultaneous, independent measurements of radon (red peaks) and thoron (green peaks).



RAD H_2O – Overview

- Lee & Kim (2006).
- Radon in discrete water samples (40 or 250 ml).
- Built-in RAD7 Protocols: WAT-40 & WAT-250 (40 ml and 250 ml sample vials).
- LLD of ~ 370 Bq/m^3 radon-in-water with built-in 30-minute test protocol.

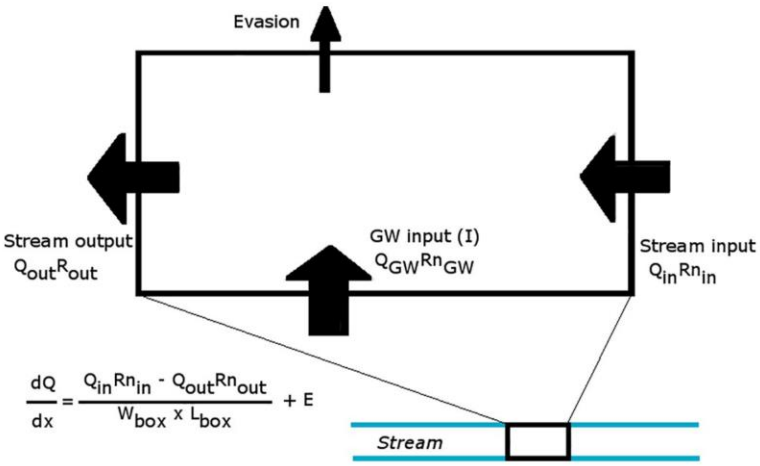
RAD H_2O Configuration



- Important to note sample collection time, for radon decay correction.
- Temperature dependence of the water-air radon partition coefficient can be safely ignored due to small size of samples.

RAD H2O – McKenzie, Dulai, Chang 2019

- Used here in Hawai'i to provide input to a radon mass-balance model, in order to calculate coastal SGD and riverine baseflow fluxes.
- See Henrietta Dulai's presentation on Thursday: "Temporal variability and trends of coastal radon mass balance components".



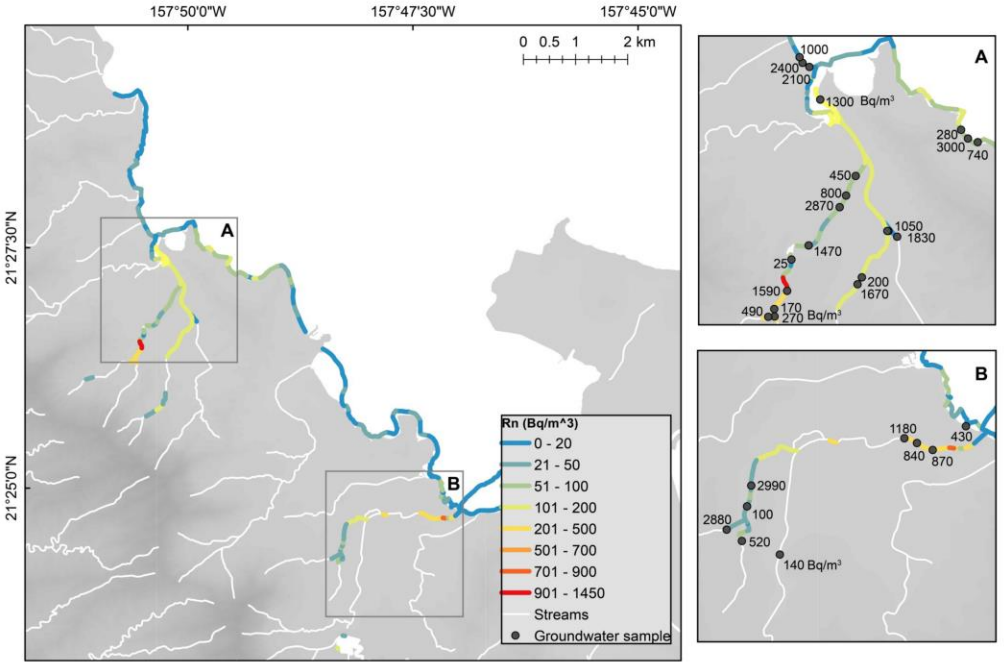


Fig 4. Non-modeled coastal and stream surface radon (Bq/m^3) concentrations for Kāneʻohe Bay and studied streams (July sampling period). Stream surface radon concentrations (lines) and discrete (dots) groundwater radon concentrations are shown for (A) Kahaluʻu and ʻĀhuimanu and (B) Kāneʻohe areas.

- Q_in, Q_out: water flux (m^3 / day) at box in / out boundary.
- Rn_out, Rn_in: radon-in-water concentration (Bq/m^3) at in / out box boundary.
- Rn_GW: radon concentration in the groundwater.
- E: evasion (Bq m^2 / day)
- dQ/dx: change in stream discharge per box.
- W_box, L_Box: width and length of box (m)

Big Bottle System – Overview

- LLD ~ 37 Bq/m^3 (x 10 lower than RAD H_2O).
- Glass and Soda Bottle versions.
- Temperature dependence of water-air partition coefficient necessitates measuring temperature with the supplied probe.
- Weigel (1978) - empirical formula for the partitioning of radon between water and air as a function of T (basis of air-water conversion in CAPTURE software). Later extended to a 2D correction (T and salinity) by Schubert et al. (2012) - added to CAPTURE after a feature request at the last RaRn conference in Delmenhorst.

- Larger water-to-air volume ratio => larger signal => lower LLD.
- Higher T at measurement time => lower k in Weigel equation => larger signal. K is roughly 0.25 at room temperature.

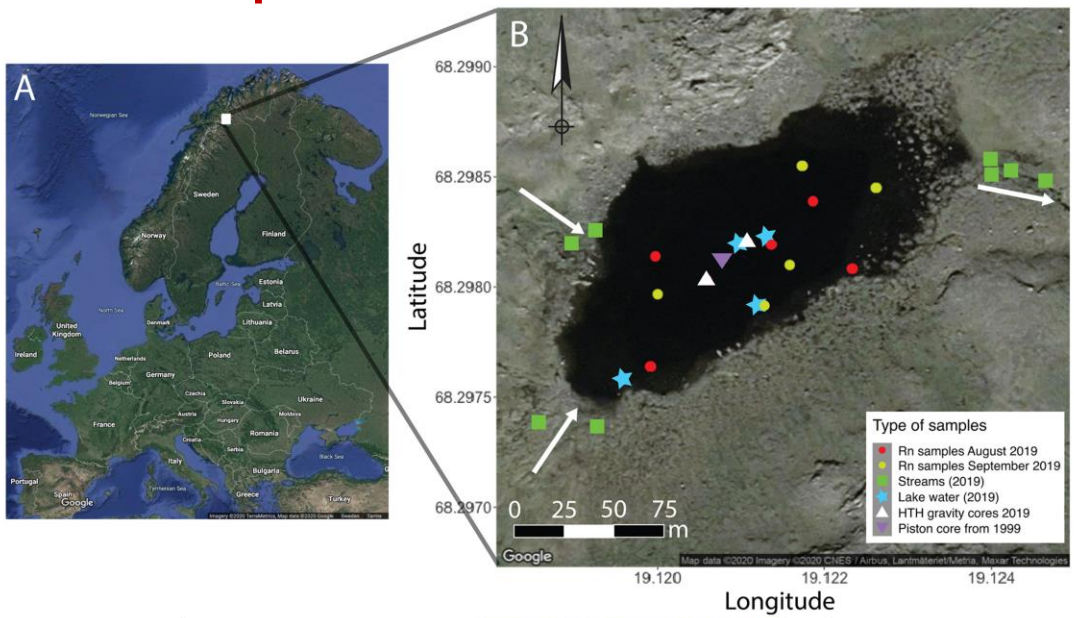
$$C_{air} = \frac{C_{wat}}{\frac{V_{air}}{V_{wat}} + k}$$

$$k = 0.105 + 0.405\ e^{-0.0502T}$$

Big Bottle System – Examples

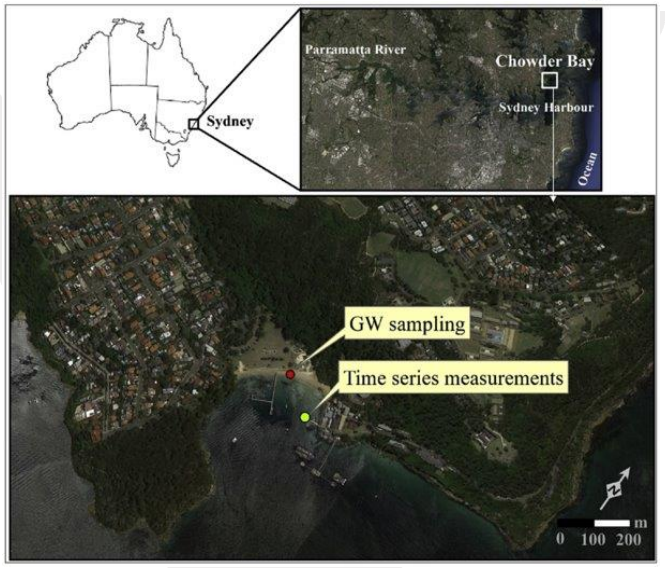
Zahajska et al. 2021

- Used here with 1.5 L soda bottles to measure very low levels (~ 100 Bq/m^3) of radon in an Arctic Lake near Abisko, Sweden.
- Investigation of silicon dynamics - dissolved silica (DSi) from GW discharge.
- Samples taken from ~ 0.5 - 1.5 m depth. Water pumped into bottle, and allowed to overflow, before capping with no headspace.



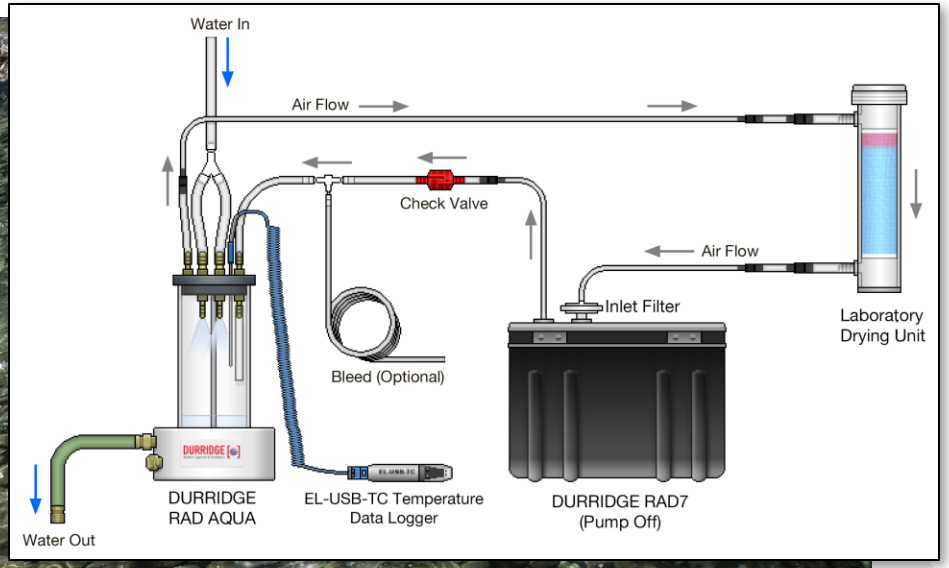
Sadat-Noori et al. 2018

- Used here with 6 L HDPE bottles to measure very low levels (~ 100 Bq/m^3) of radon in Sydney Harbour.
- Investigation of SGD as a driver of dissolved greenhouse gas concentrations (CO_2, CH_4, N_2O).
- > 2hr counting time.



RAD AQUA – Continuous Radon-in-Water

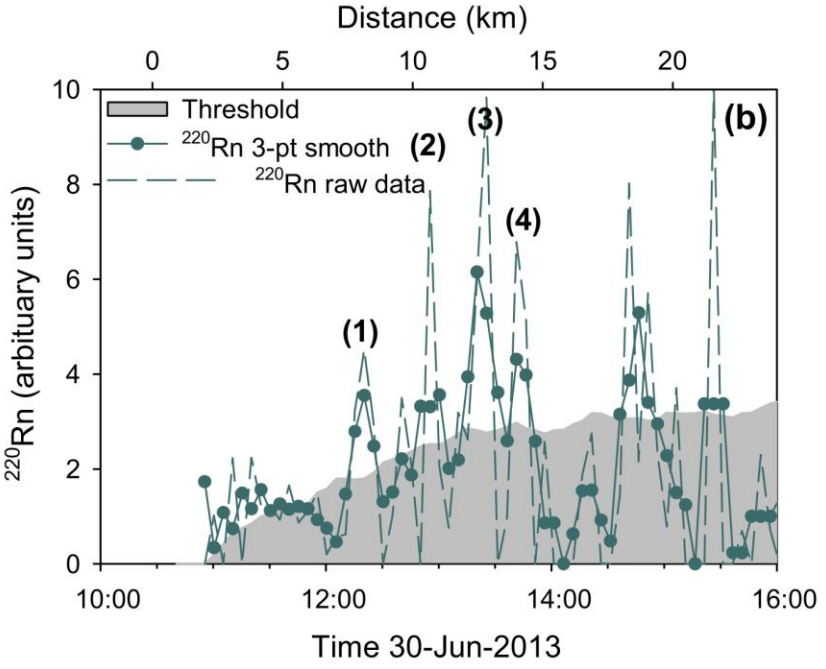
- Radon and Thoron Measurement: Continuous monitoring in water.
- Foundational papers: Burnett, Kim & Lane-Smith (2001) & Dulaiova et al. (2001).
- 95% response to radon in 30 minutes (thoron much faster – strongly dependent on air flow rate).
- Same low radon LLD as BB system (~ 37 Bq/m3).
- Clean and Safe: Involves no hazardous materials or chemicals.
- Deploy on a boat and combine with GPS for spatial mapping. Or, deploy at a fixed location to track temporal changes.
- Larger total water sample volume => smooth out heterogeneities.



Maro, Spain 2016. Image credit: Juan Miguel Perez, Daniel Montiel

RAD Aqua – Chanyotha et al. (2014)

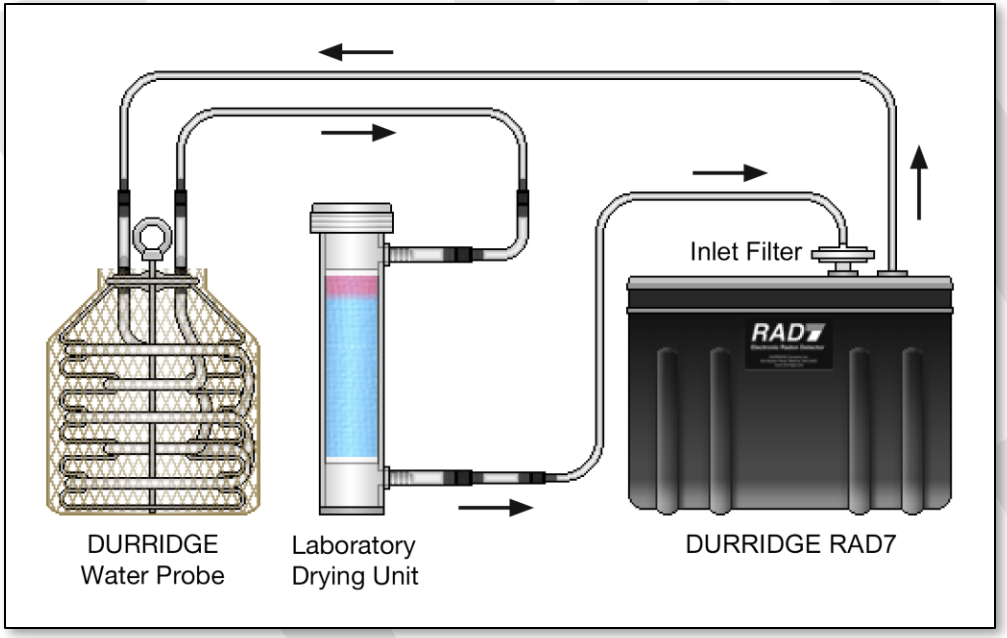
- Boat-based RAD7 + RAD Aqua setup used to prospect for groundwater flows into Klongs near Bangkok, Thailand.
- Use thoron: short half life = superior temporal (and hence spatial) resolution.
- Maximise water and air flow rates to minimise thoron decay en route to RAD7.
- Water flow rate in this work was 6 LPM.
- Max airflow rate for RAD7 ~ 2.5 LPM [Chanyotha et al. 2018].
- Defined Meaningful Thoron Threshold (MTT) - now implemented in CAPTURE (grey shaded area on graph).



- See Bill Burnett's keynote presentation for details.

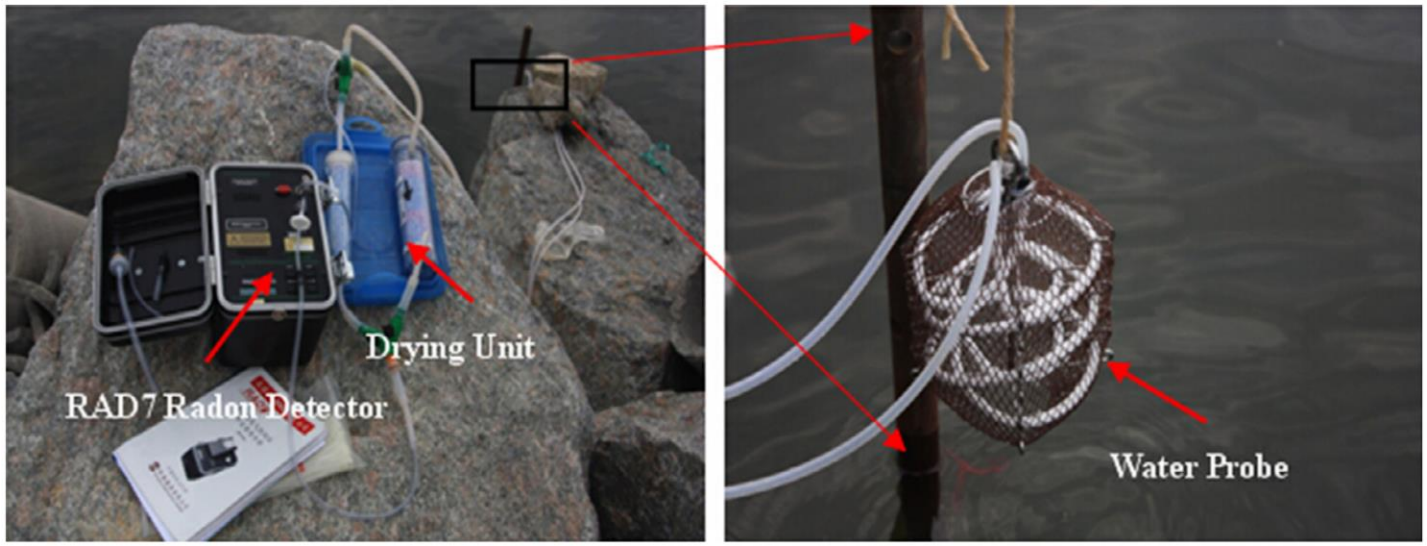
Water Probe - Passive Radon-in-Water

- Slow response (2+ hours) passive radon-in-water monitoring.
- Same high sensitivity as the RAD AQUA.
- Like other water accessories, Water Probe exchanges radon from water to air phase.



- Temperature-dependent partition coefficient means water temperature must be measured.
- Can also be used with the Active DRYSTIK for long-term, maintenance-free operation

Water Probe – Zhang et al. 2016



- Water Probe used to assess SGD into Laizhou Bay, China.
- Measured radon-in-water concentration used as input to mass balance model. Output: SGD flux.

A Few Other RAD7 Methods

1. Measure radon flux from sediments using a RAD7 and variation of RAD H_2O with e.g. 500 ml sample flask in an open-loop setup [Chanyotha 2014, 2016].

2. Measure dissolved radium-226 & radium-224 (albeit with ~ high LLD) with RAD H_2O, fitting the radioactive ingrowth [Kappke et al. 2013].

3. Measure low levels of dissolved radium-226 & radium-224 by flowing large samples of water through a cartridge containing MnO_2-impregnated acrylic fibre ('preconcentration'), then measuring radon and thoron ingrowth in a closed air loop using RAD7 [Kim et al. 2001].

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Thanks for listening!

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