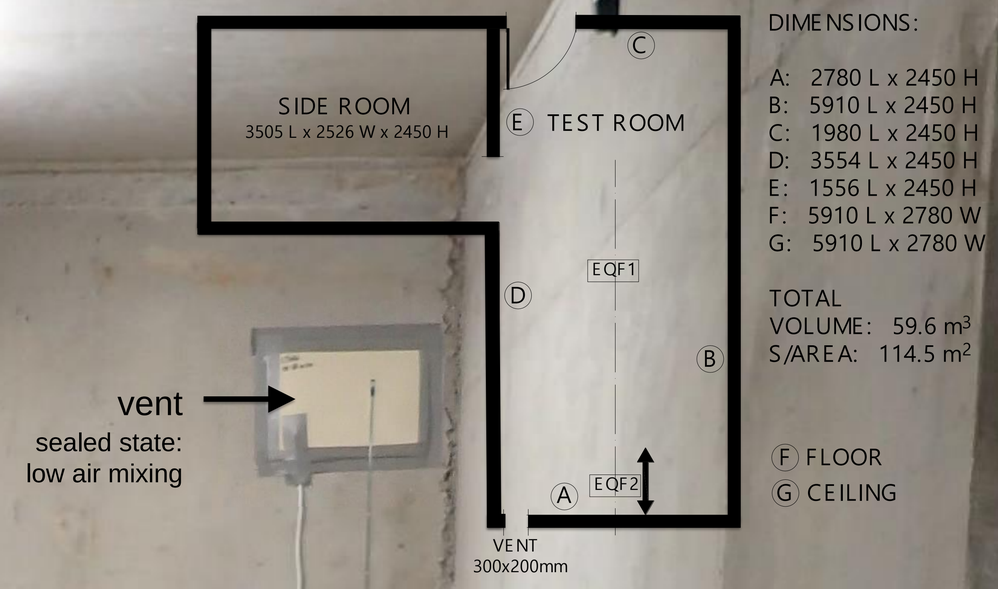
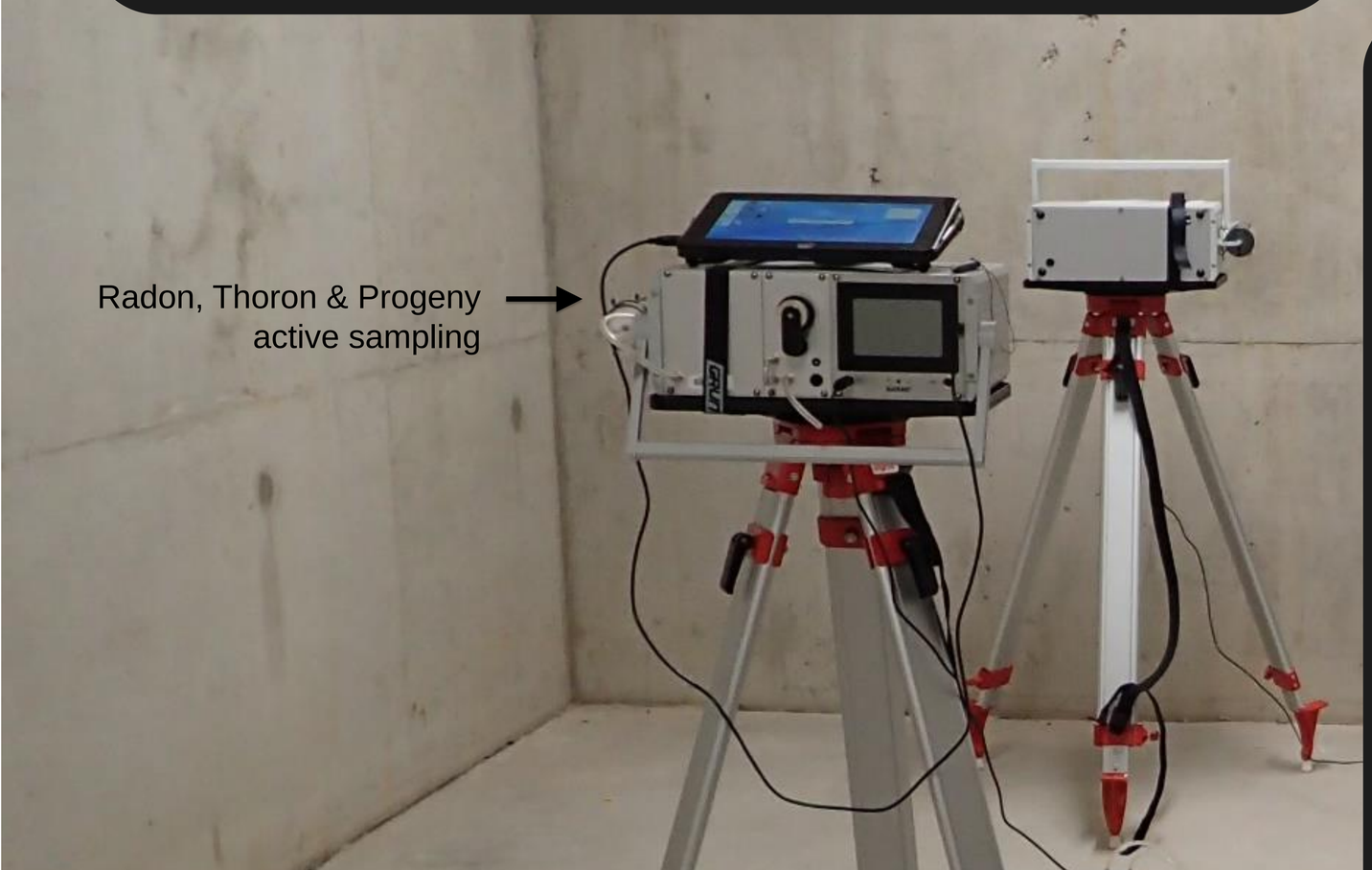
Radon, Thoron and Progeny Distribution in a Low Air Mixing Environment

D.M. Watson, R. Kleinschimdt, P. Chauhan, K. Coles
Radiation & Nuclear Science, Forensic & Scientific Services, Health Support Queensland, Queensland Department of Health
P.O. Box 594, Archerfield, 4108, Queensland, Australia
drew.watson@health.qld.gov.au

ABSTRACT

Radiation dose from exposure to radon-222 (radon, Rn), radon-220 (thoron, Tn) and progeny radionuclides is of interest to people entering places of low ventilation, namely tourist caves, historical mines, and building basements. This study utilises active sampling instrumentation to measure spatial variation of Rn, Tn, and respective progeny in a controlled environment akin to a building basement under two air flow conditions, being enclosed (low air mixing) and minimal forced air flow (enhanced air mixing). Experimental results confirm that in low air mixing environments, Tn concentration decreases exponentially with distance from an exhalation surface. With enhanced air mixing, the Tn concentration was more uniform. Thoron progeny (TnP), Rn and radon progeny (RnP) concentrations remained relatively uniform regardless of distance from an exhalation surface and consistent under low and enhanced air mixing conditions. These results exemplify the effect of even very low levels of air mixing upon the distribution of Tn which is short-lived compared with Rn, RnP and TnP. This work has implications for enclosed spaces with limited ventilation by demonstrating the significance of the location of Tn measurement apparatus relevant to exhalation surfaces, and the limitation of using equivalent equilibrium concentrations to infer TnP concentrations.





METHOD

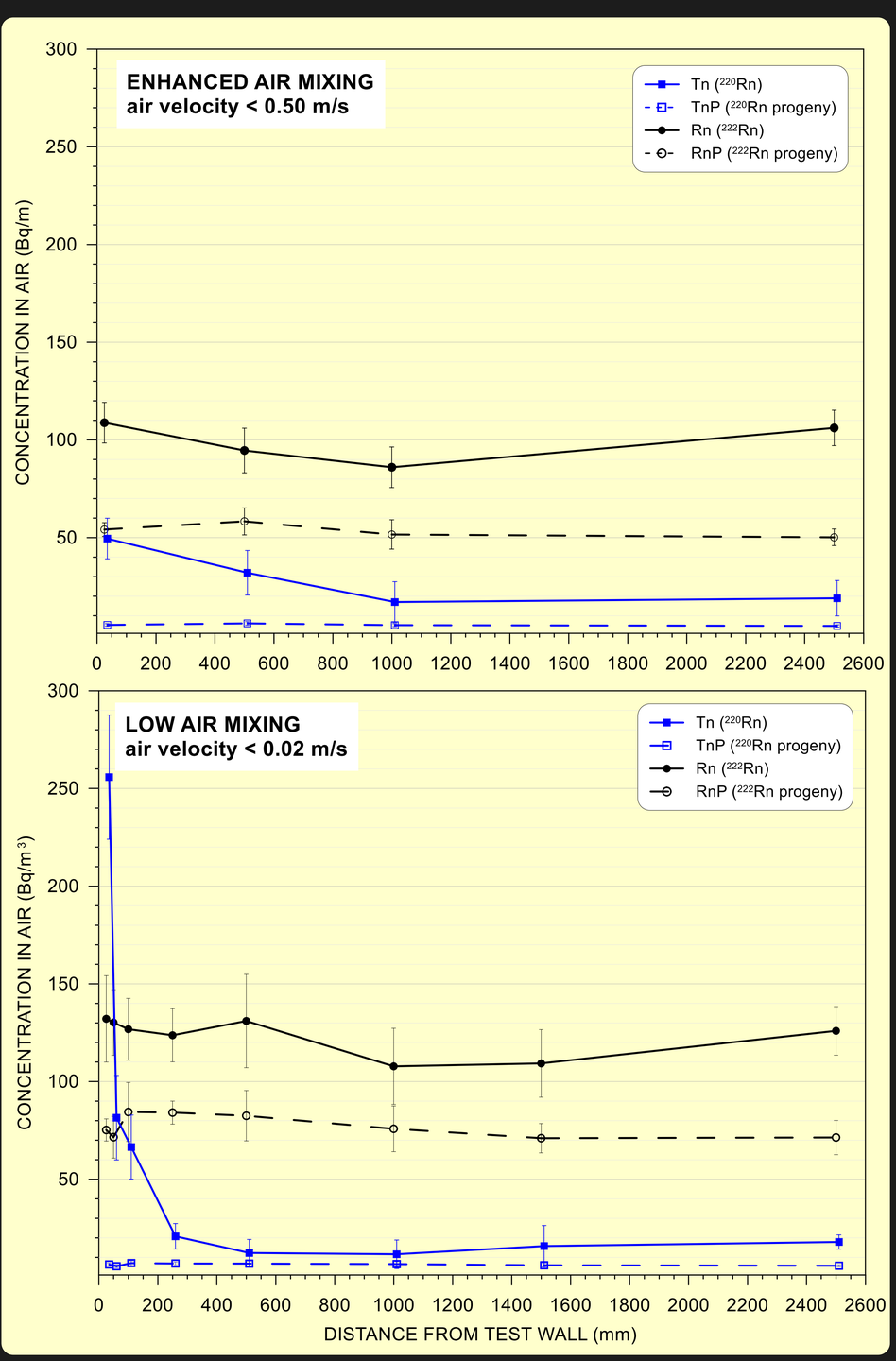
A 'test room' of simple design was used for control over environmental conditions. All internal surfaces were bare concrete (no paint or sealant) for uninhibited exhalation of Rn and Tn gas. The test room included a service cut-out 'vent' in Wall A, the 'test wall' (refer to schematic above). This vent allows air exchange with air external to the test room.

For 'low air mixing' tests, the vent was sealed (air velocity at the vent <0.02m/s, measured by *Testo 435* anemometer). For 'enhanced air mixing' tests, a small fan was placed in the open vent forcing air into the test room (air velocity ≤ 0.50m/s). The test room door remained closed and the room unoccupied during programmed measurement cycles. No aerosol generating activities occurred in the test room or encompassing rooms.

Primordial uranium and thorium concentrations, as respective parent radionuclides for Rn and Tn, was estimated for the test room building material using a scintillation detector (*GF Instruments Gamma Surveyor*, 2x2" BGO). Rn and Tn exhalation rates were measured on the test wall and two other surfaces of the test room using a 415cm^2 cup and active Rn/Tn monitor (*SARAD RTM1688*).

Concentrations of Rn, RnP, Tn and TnP were measured using two *SARAD EQF3200* instruments, in 2h intervals for ≥ 24h. Air intakes were at 1m height and distances of 0.05, 0.10, 0.15, 0.25, 0.50, 1.00, 1.50 and 2.50m from the test wall during low air mixing conditions. Measurements were repeated at distances of 0.05, 0.50, 1.00 and 2.50m from the test wall under enhanced air mixing conditions.

RESULTS - Radon, Thoron & Progeny Concentrations



RESULTS - test room conditions

Location	eU Bq/kg	eTh Bq/kg	^{40}K Bq/kg	Rn exhalation Bq/m^2/h	Tn exhalation Bq/m^2/h
Wall A	23.5	31.7	398	3.5	42.7
Wall B	22.2	33.7	404	3.3	43.5
Wall C	23.5	32.9	413	-	-
Wall D	23.5	30.0	404	-	-
Floor F	33.3	43.8	579	-	-
Floor F (dup.)	30.9	46.3	551	4.2	54.3
Ceiling G	22.2	27.6	373	-	-
Average	***25.6***	***35.1***	***446***	***3.7***	***46.8***

DISCUSSION & CONCLUSION

Rn, RnP and TnP were relatively constant regardless of distance from the test wall for both low air mixing and enhanced air mixing conditions.

Under low air mixing conditions, Tn concentrations decrease exponentially with increasing distance from the exhalation surface, from 256Bq/m^3 at 0.05m, to ~20Bq/m^3 for ≥ 0.25m from the test wall. Under enhanced air mixing conditions, Tn is more uniform decreasing from 50Bq/m^3 at 0.05m, to ~20Bq/m^3 for ≥ 1.00m from the test wall.

This spatial distribution of Rn, RnP, Tn and TnP concentrations is attributed to the respective half-lives. In the absence of air mixing, Tn having a relatively short half-life ($T_{1/2}$ 56s) is concentrated in proximity to exhalation surfaces.

These results are consistent with other research investigating Tn and TnP concentrations in enclosed spaces [1,2] and demonstrates the importance of air mixing in considering measurement locations and using equivalent equilibrium concentrations to relate TnP with Tn.

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REFERENCES

1. Janik, M., et al., Comparative analysis of radon, thoron and thoron progeny concentration measurements. Journal of Radiation Research, 2013. 54(4): p. 597-610.
2. Kleinschmidt, R., et al., The presence and dosimetry of radon and thoron in a historical, underground metalliferous mine. Journal of Sustainable Mining, 2018. 17(3): p. 120-130.