Thoron (^{220}Rn) and radon (^{222}Rn) in closed space
Will ventilation help in dose reduction?

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space Will ventilation help in dose reduction?

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Workplace and Environmental Radiation Safety

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Thoron (^{220}Rn) and radon (^{222}Rn) in closed space

Will ventilation help in dose reduction?

Thoron (thorium series)

^{220}Rn
55.6s

Radon (uranium series)

^{222}Rn
3.82d

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space

Will ventilation help in dose reduction?

Thoron (thorium series)

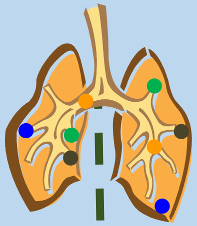
^{220}Rn 55.6s

Thoron progeny

^{216}Po 0.145s → ^{212}Pb 10.6h → ^{212}Bi 1.01 h

^{212}Bi → ^{212}Po 64% 0.003 s

^{212}Bi → ^{208}Tl 36% 3.06m



Radon (uranium series)

^{222}Rn 3.82d

Radon progeny

^{218}Po 3.1m → ^{214}Pb 26.8m → ^{214}Bi 19.9m → ^{214}Po 104μs

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space

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Thoron (thorium series)

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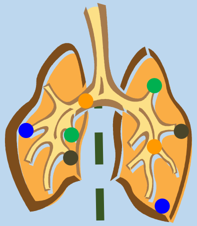

Radon (uranium series)

^{222}Rn
3.82d

D (μSv h^{-1}) = 3.1 x 10^{-3} C (Bq m^{-3})

Radon progeny

^{218}Po 3.1m → ^{214}Pb 26.8m → ^{214}Bi 19.9m → ^{214}Po 104μs

Safety Guide for Monitoring, Assessing, and Recording Occupational Radiation Doses in Mining and Mineral Processing; ARPANSA (2011) Radiation Protection Series 9.1 Annex A, page 32

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space

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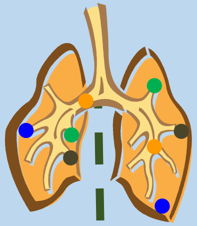

Radon (uranium series)

^{222}Rn
3.82d

Increase

D (μSv h^{-1}) = 3.1 x 10^{-3} C (Bq m^{-3})

Radon progeny

^{218}Po
3.1m

^{214}Pb
26.8m

^{214}Bi
19.9m

^{214}Po
104μs

Increase

Safety Guide for Monitoring, Assessing, and Recording Occupational Radiation Doses in Mining and Mineral Processing; ARPANSA (2011) Radiation Protection Series 9.1 Annex A, page 32

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space

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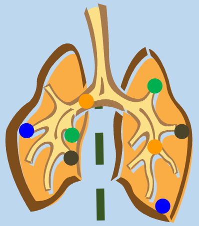


Radon (uranium series)

^{222}Rn
3.82d

D (μSv h^{-1}) = 3.1 x 10^{-3} C (Bq m^{-3})

Radon progeny

^{218}Po 3.1m → ^{214}Pb 26.8m → ^{214}Bi 19.9m → ^{214}Po 104μs

For the same activity concentration in air, thoron (^{220}Rn) radiation dose rate is about 10 times that of radon (^{222}Rn).

Safety Guide for Monitoring, Assessing, and Recording Occupational Radiation Doses in Mining and Mineral Processing; ARPANSA (2011) Radiation Protection Series 9.1 Annex A, page 32

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space

Will ventilation help in dose reduction?

Thoron (thorium series)

^{220}Rn
55.6s

No reference level guideline is available for thoron (^{220}Rn).

Considering the activity concentration to dose conversion factors it should be perhaps assumed as 1/10 of that of radon (^{222}Rn)

Radon (uranium series)

^{222}Rn
3.82d

Reference level for further action

Workplace 1000 Bq m^{-3}

Homes 200

ARPANSA recommended radon (^{222}Rn) reference level is traceable to ICRP recommendations. It corresponds to about 10 mSv y^{-1} radiation dose rate.

Radiation Protection Series 1: ARPANSA (Republished 2002)
Also retained in Guide for Radiation Protection in Existing Exposure Situations (ARPANSA 2017)

Thoron (^{220}Rn) and radon (^{222}Rn) in **closed space**
Will ventilation help in dose reduction?

Benchtop simulation

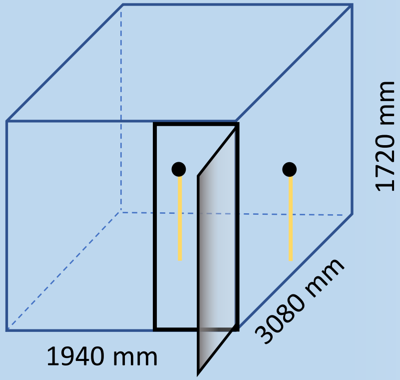
Mineral Sand

2.75×10^{-3} m^3

Empty Room

Concrete structure

10.3 m^3



ANU

Thank you

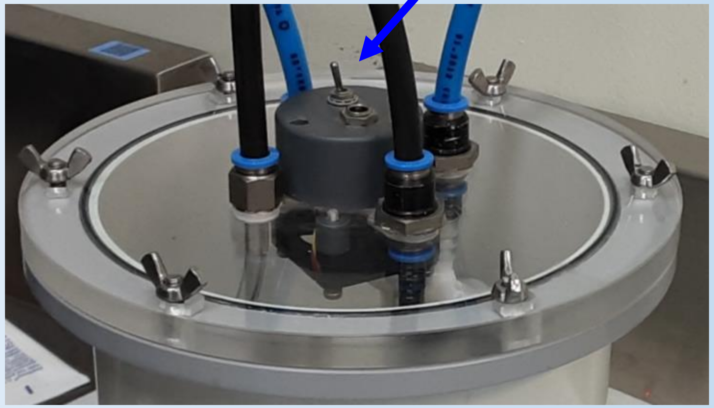
Thoron (^{220}Rn) and radon (^{222}Rn) in closed space
Will **ventilation** help in dose reduction?

Air movement by using a fan

Benchtop simulation

Mineral Sand

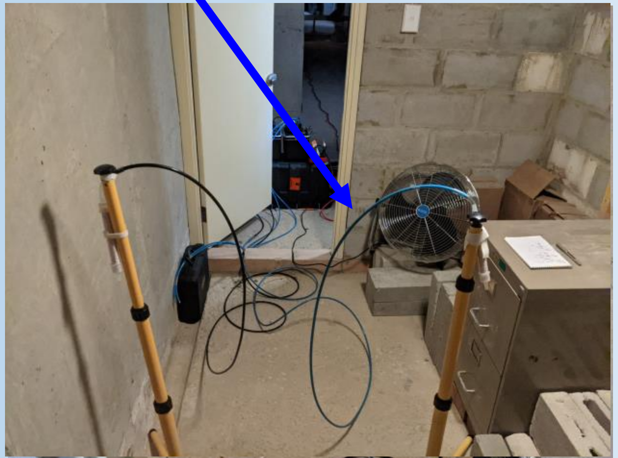
2.75×10^{-3} m^3



Empty Room

Concrete structure

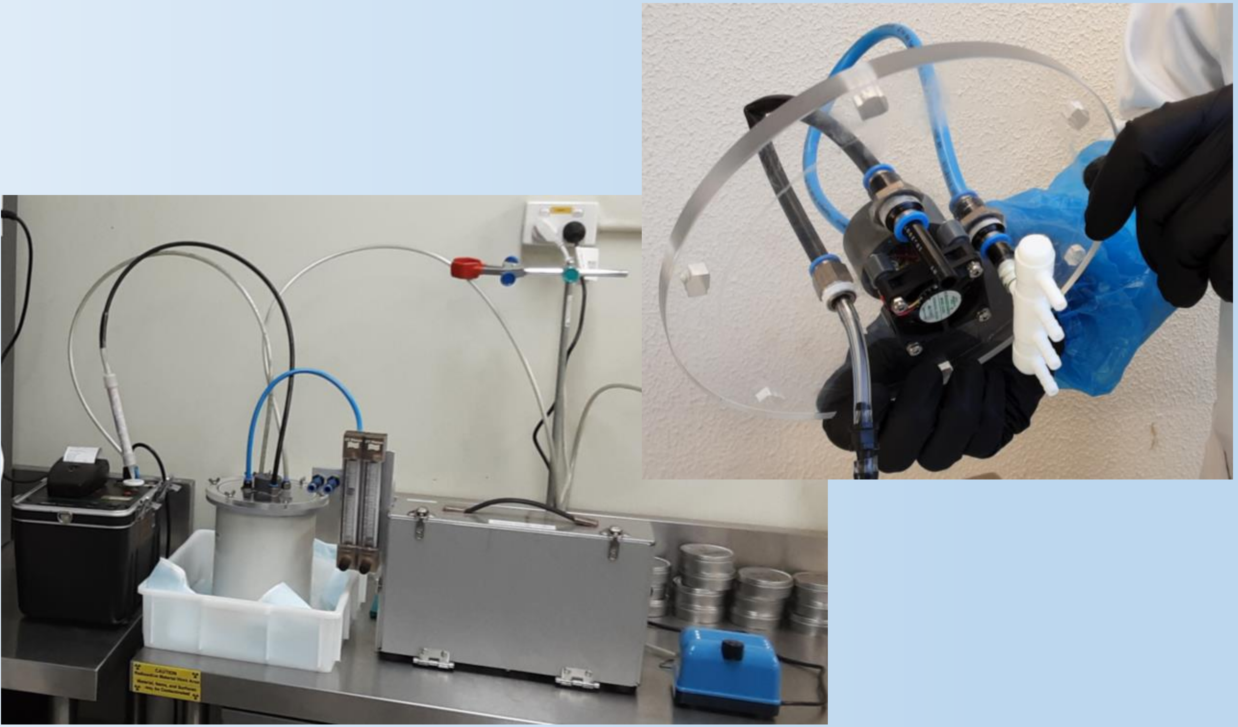
10.3 m^3

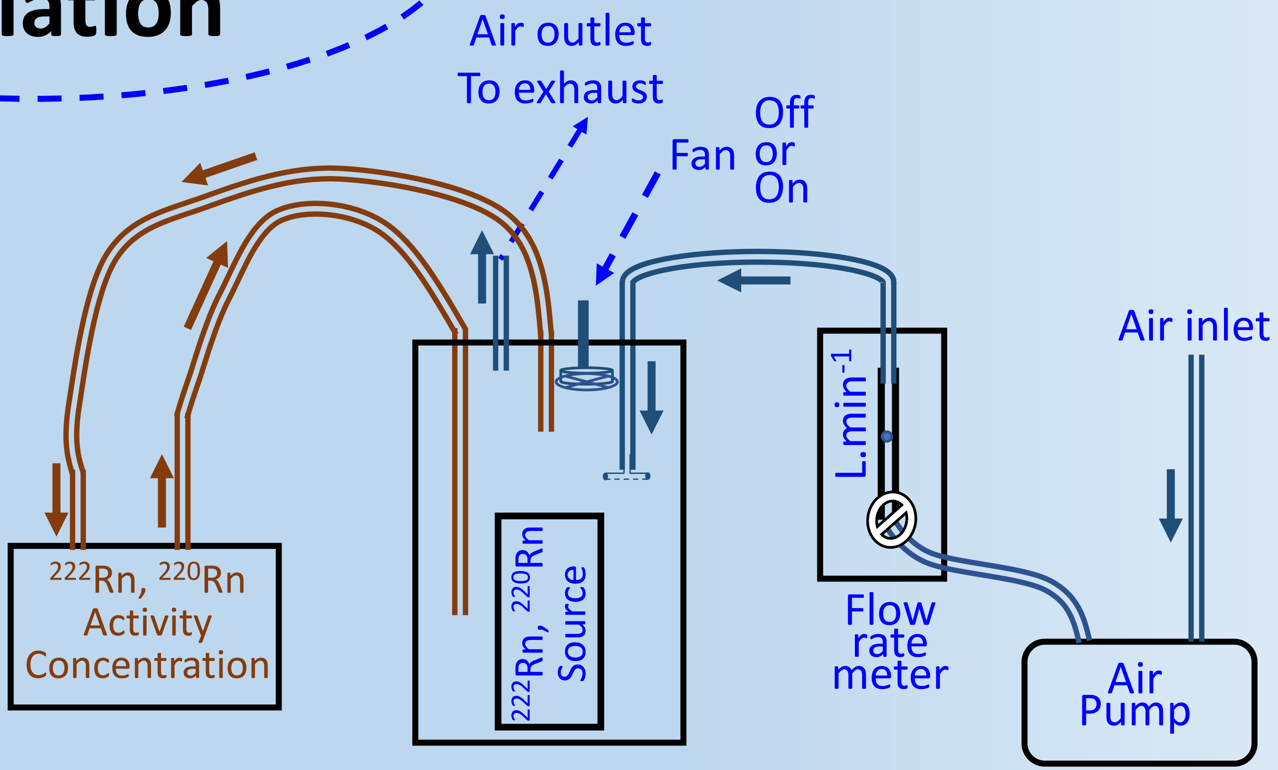


Thoron (^{220}Rn) and radon (^{222}Rn) in closed space
Will **ventilation** help in dose reduction?

Benchtop simulation

Forced ventilation





Thoron (^{220}Rn) and radon (^{222}Rn) in closed space Will ventilation help in dose reduction?

Results

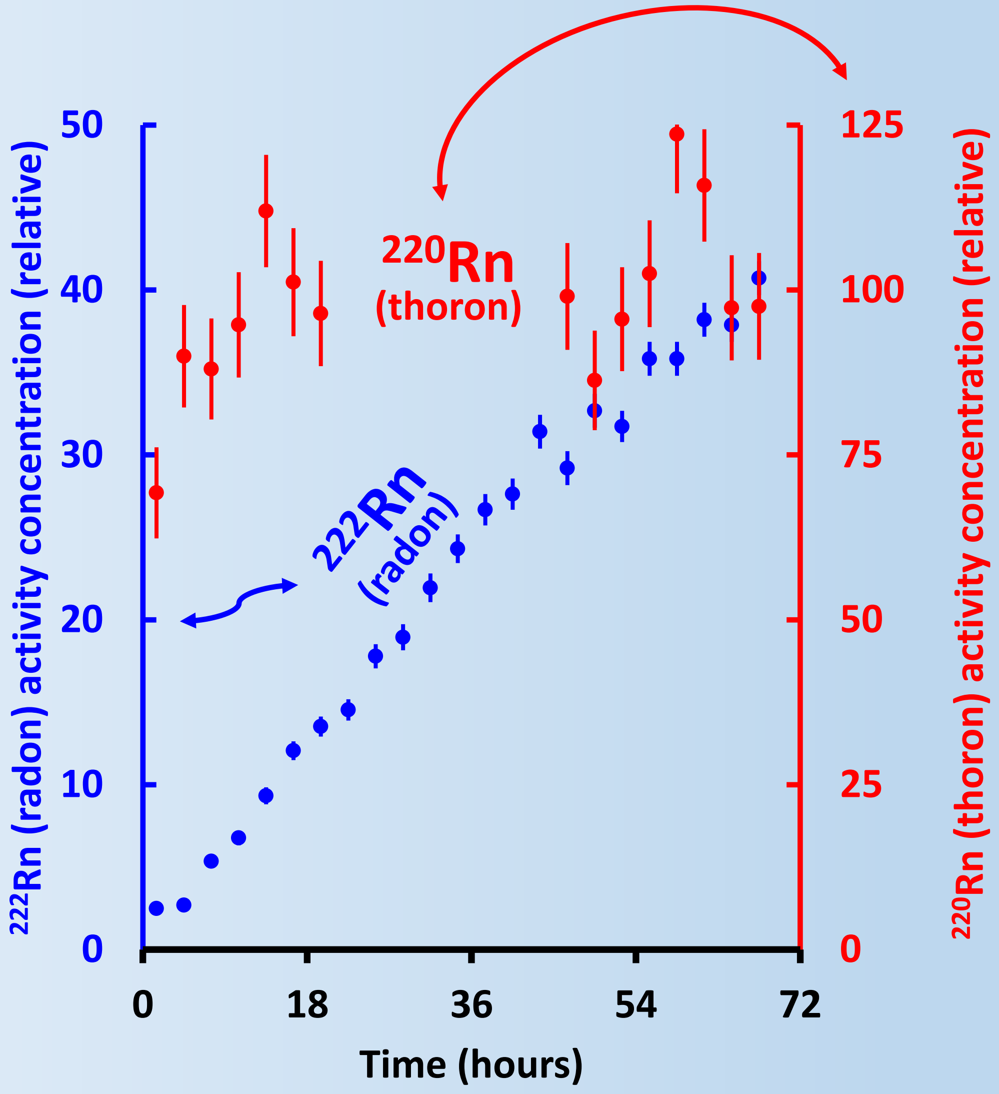
Radon and thoron activity concentration

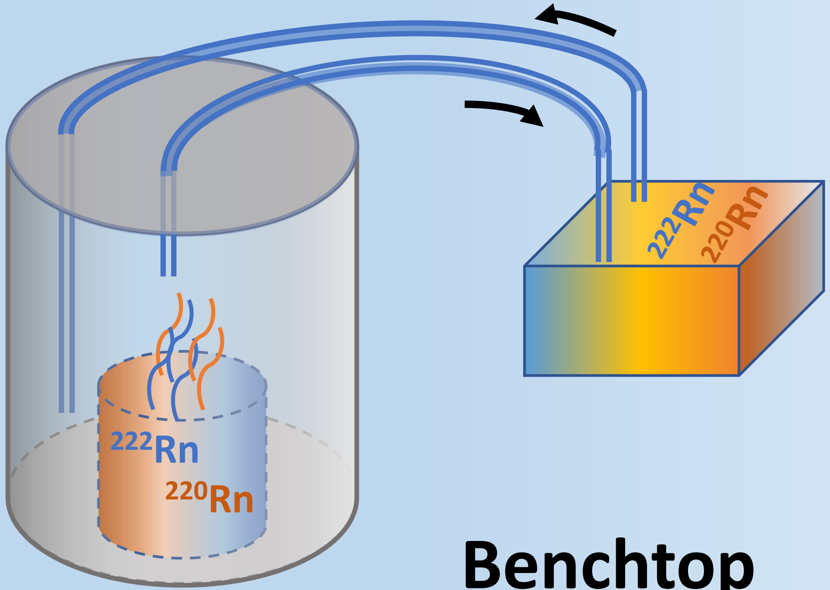
1: Build up in a sealed space

2: Effect of air movement

3: Effect of forced ventilation

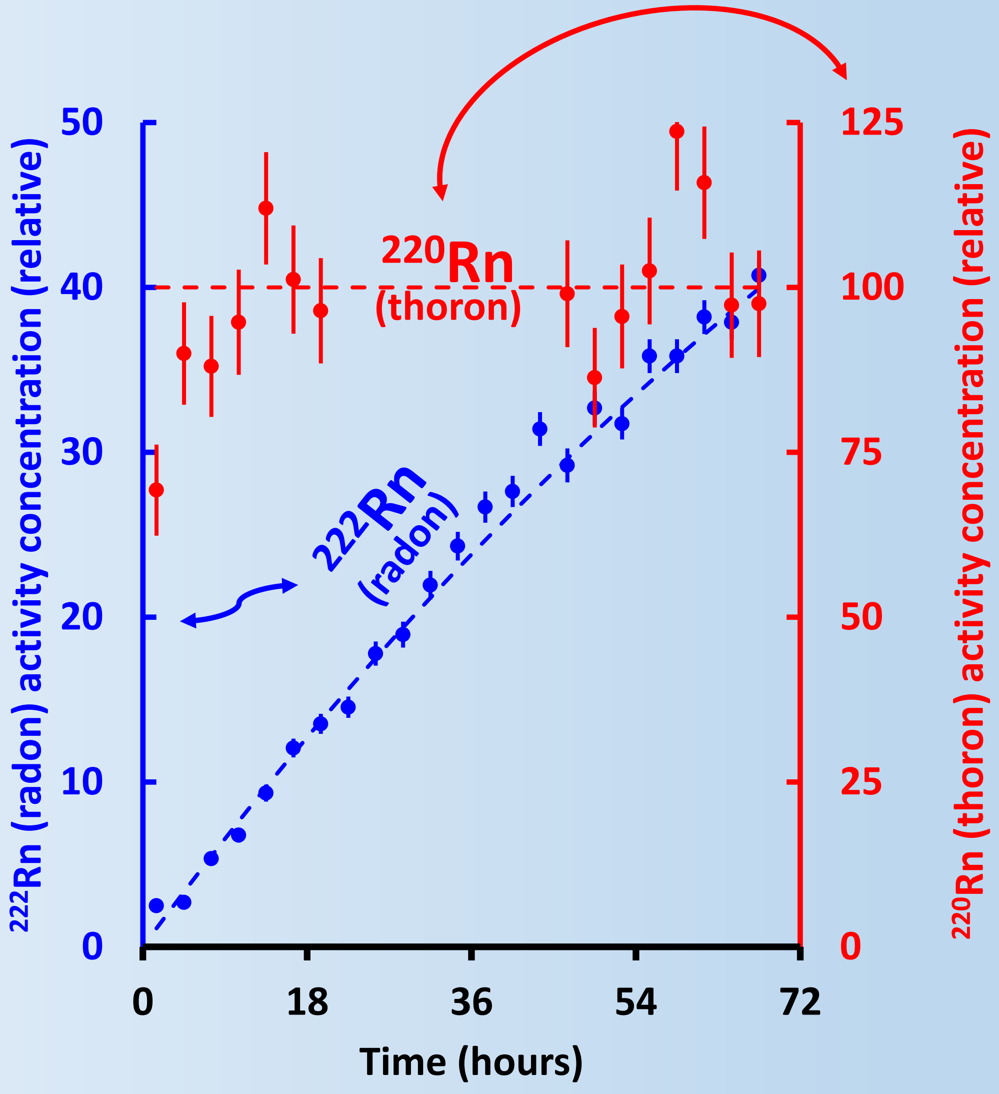
1: Radon and thoron activity concentration build up in a sealed space





Benchtop simulation

1: Radon and thoron activity concentration build up in a sealed space



$$C_t = C_{s,s} \left[1 - e^{-\{\ln(2)\, t / T_{1/2}\}}\right]$$

C_t : Activity concentration in air at time t

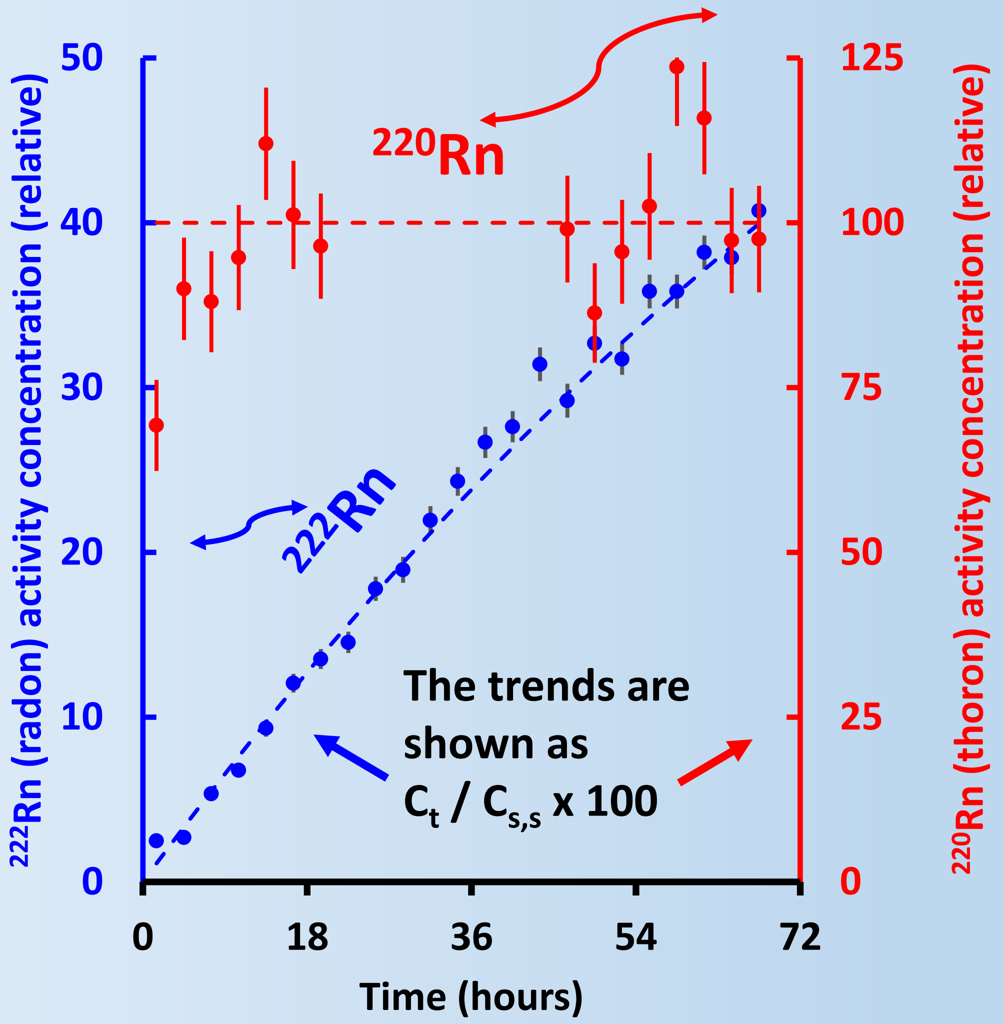
$C_{s,s}$: Sealed space, steady state activity concentration

$T_{1/2}$: Half life of the isotope

^{222}Rn (radon) – 91.8 hours (3.824 days)

^{220}Rn (thoron) – 0.0154 hours (55.6 s)

1: Radon and thoron activity concentration build up in a sealed space



$$C_t = C_{s,s}\,[1 - e^{-\{\ln(2)\,t\,/T_{1/2}\}}]$$

C_t : Activity concentration in air at time t

$C_{s,s}$: Sealed space, steady state activity concentration

$T_{1/2}$: Half life of the isotope

In benchtop simulation results:

$C_{s,s}$ ^{222}Rn (radon) – 8180 ± 440 $Bq.m^{-3}$

$C_{s,s}$ ^{220}Rn (thoron) – 395 ± 14 $Bq.m^{-3}$

1: Radon and thoron activity concentration build up in a sealed space

Enclosed spaces are generally not completely sealed.

- Natural ventilation occurs through doors and windows.
- Rooms and tunnels may also have fans installed for air velocity and air circulations.
- Ventilation shafts may exist in underground tunnels. They are often equipped with fan-forced air exhaust systems.

$$C_t = C_{s,s}\left[1 - e^{-\{\ln(2)\, t / T_{1/2}\}}\right]$$

Results

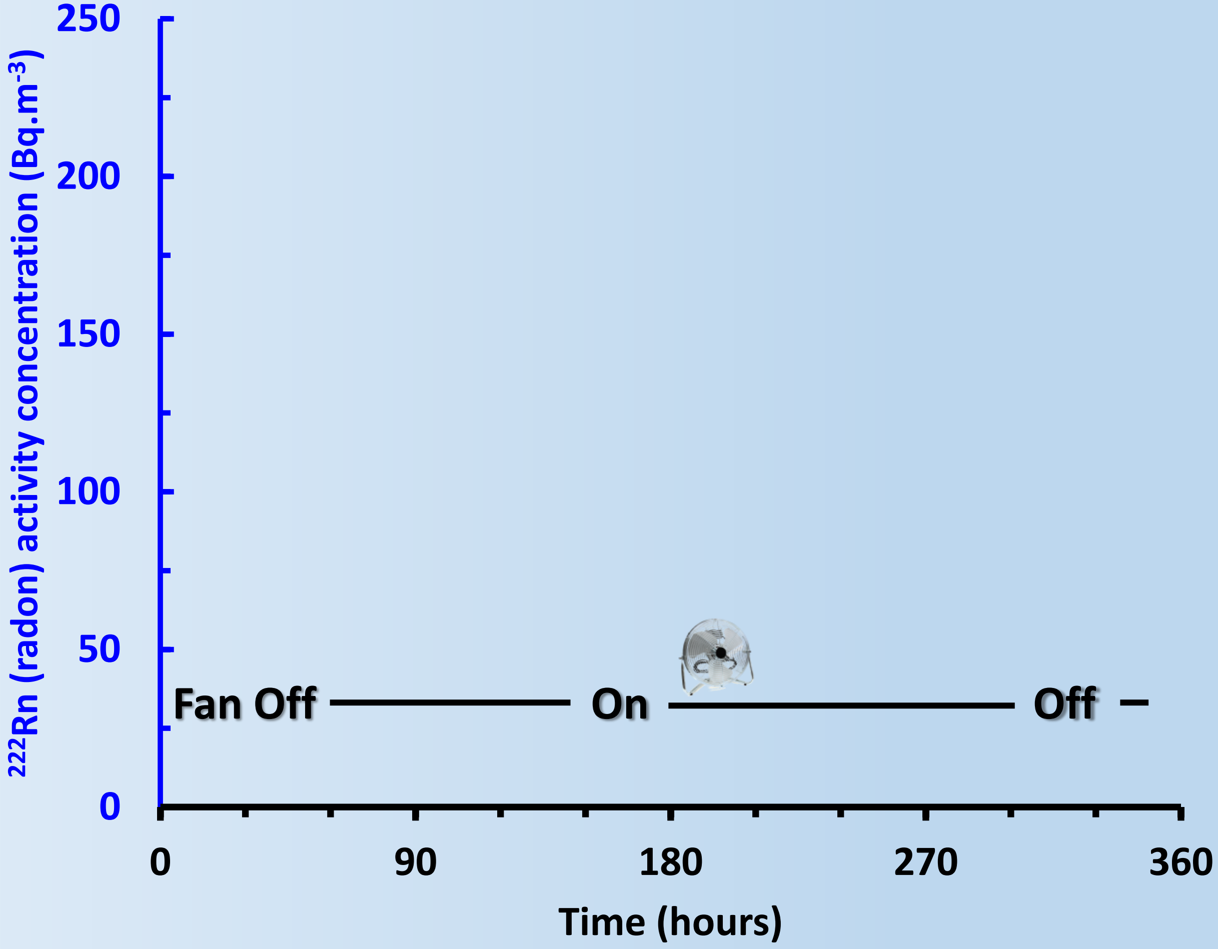
Radon and thoron activity concentration

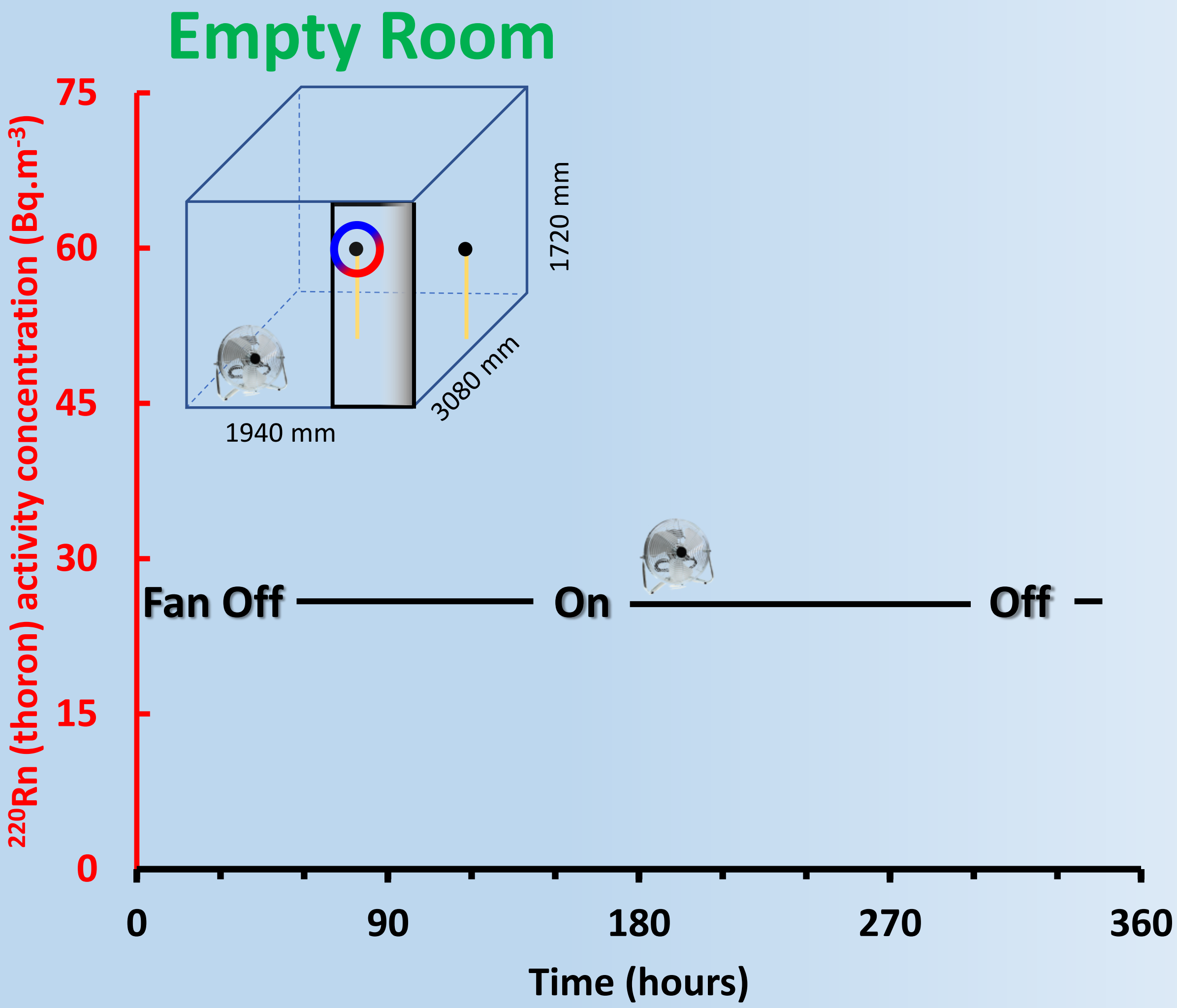
1: Build up in a sealed space

2: Effect of air movement

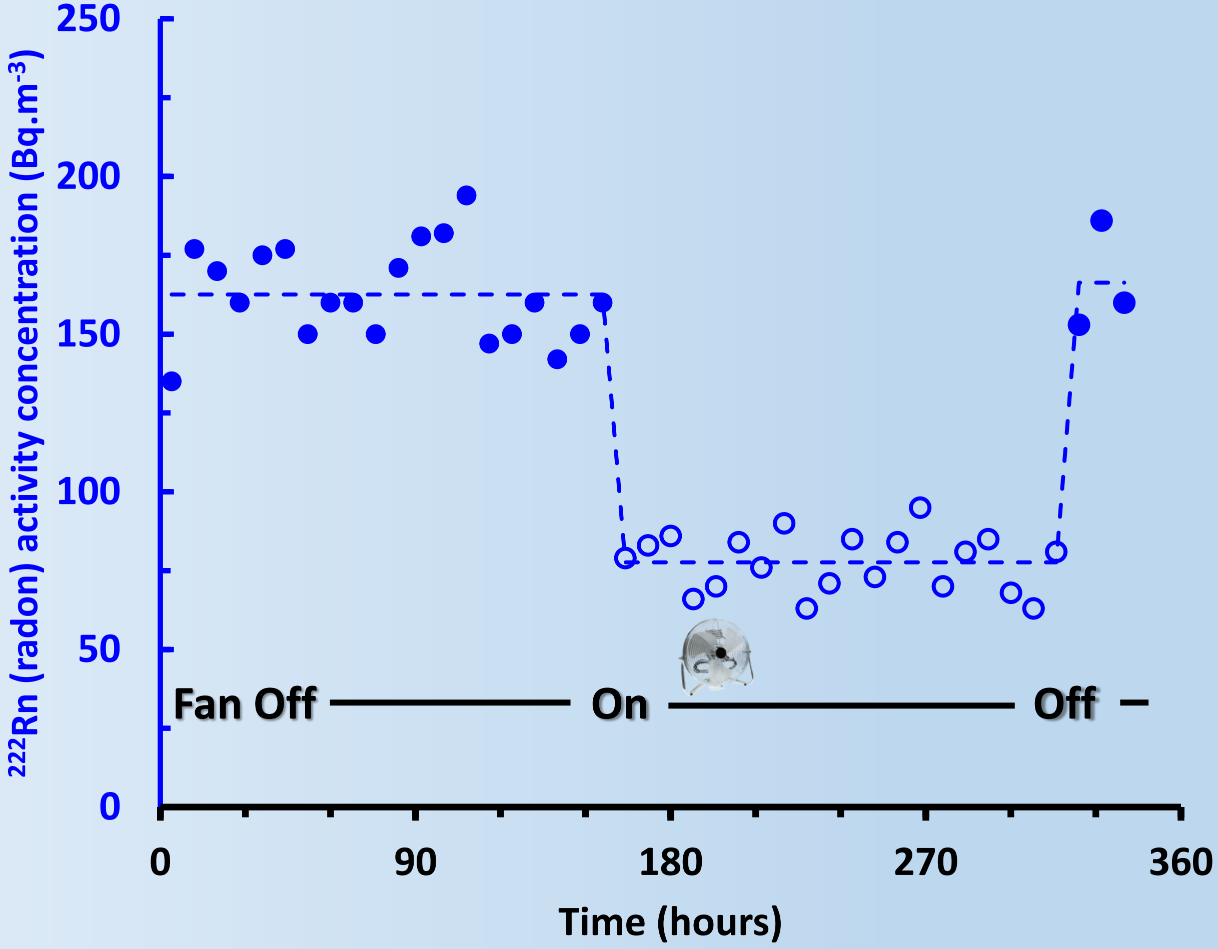
3: Effect of forced ventilation

2: Radon and thoron activity concentration
Effect of air movement

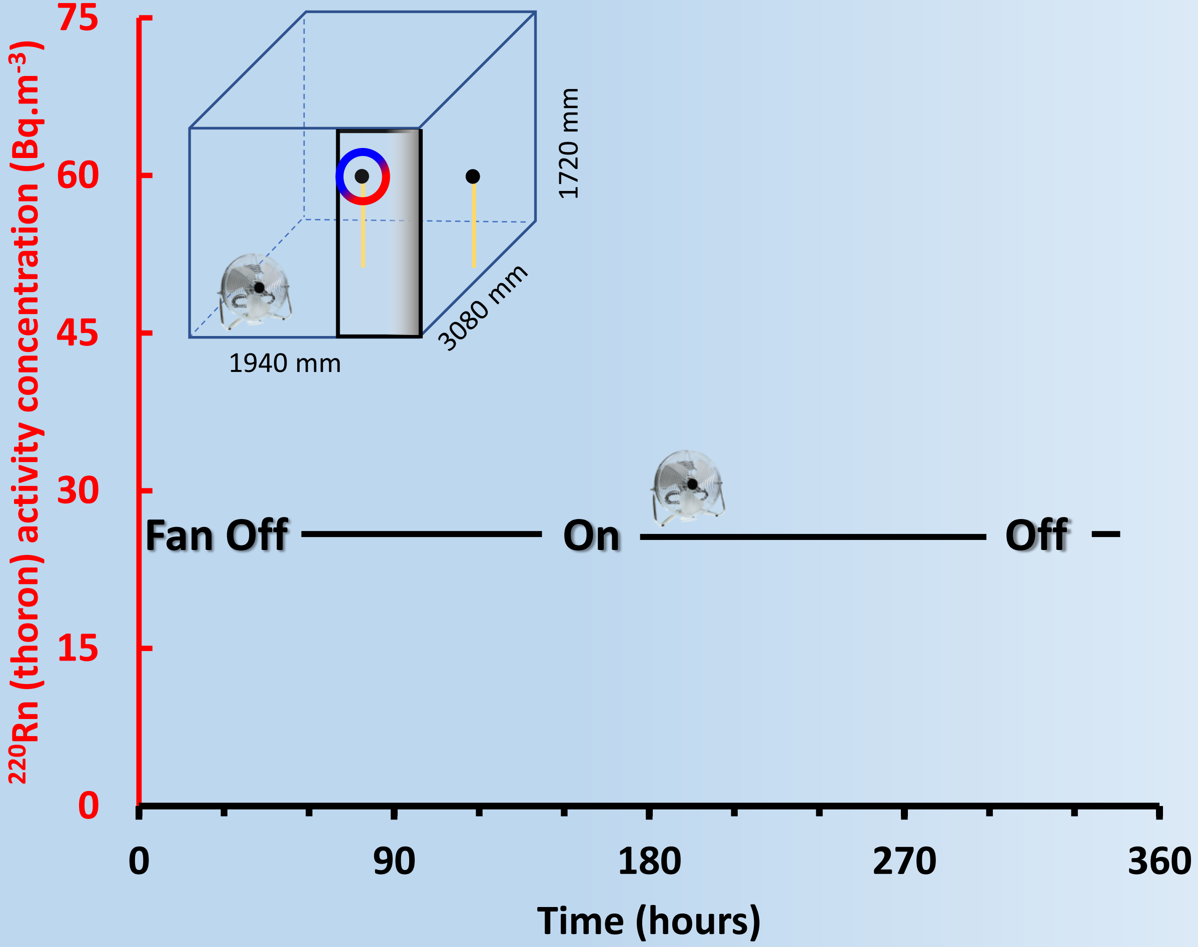




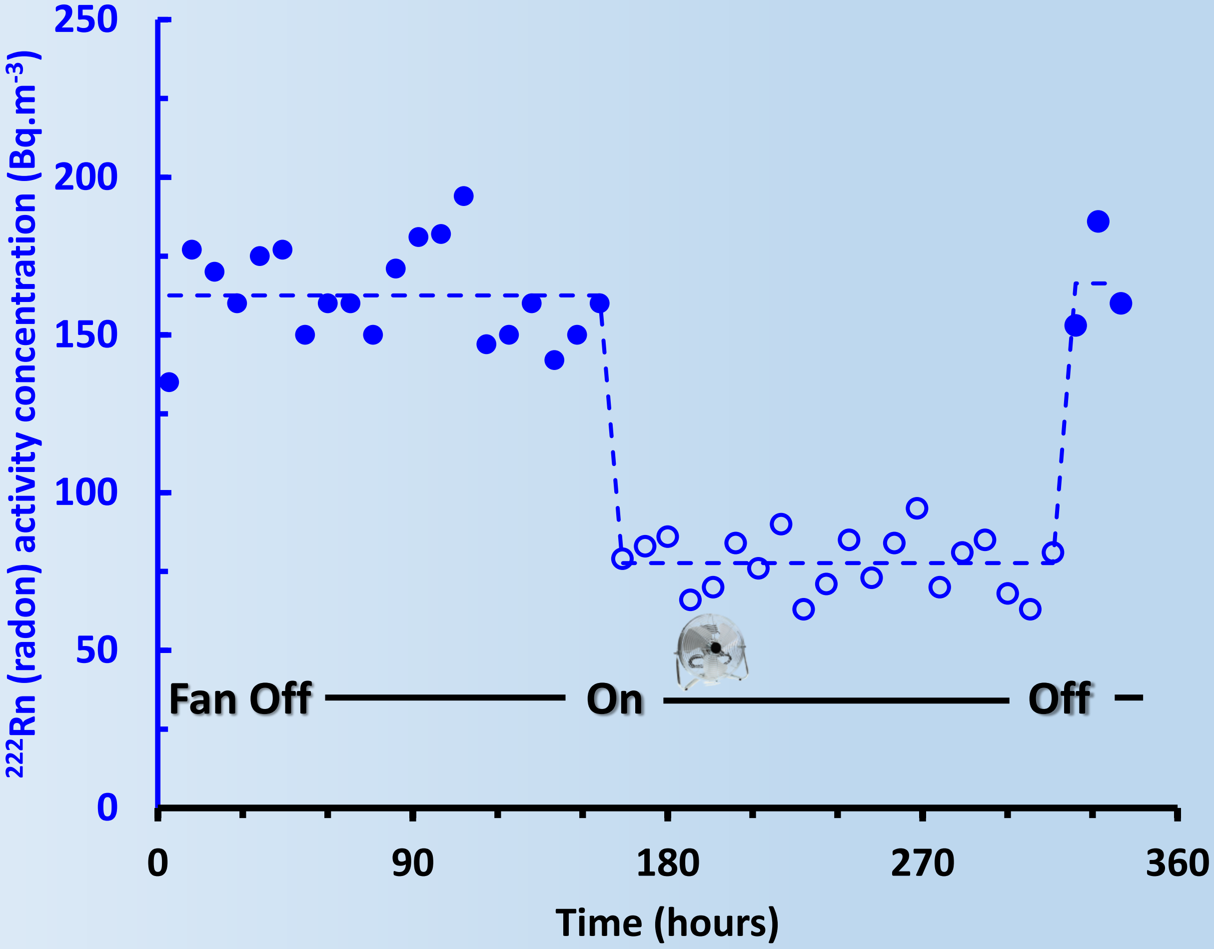
2: Radon and thoron activity concentration
Effect of air movement



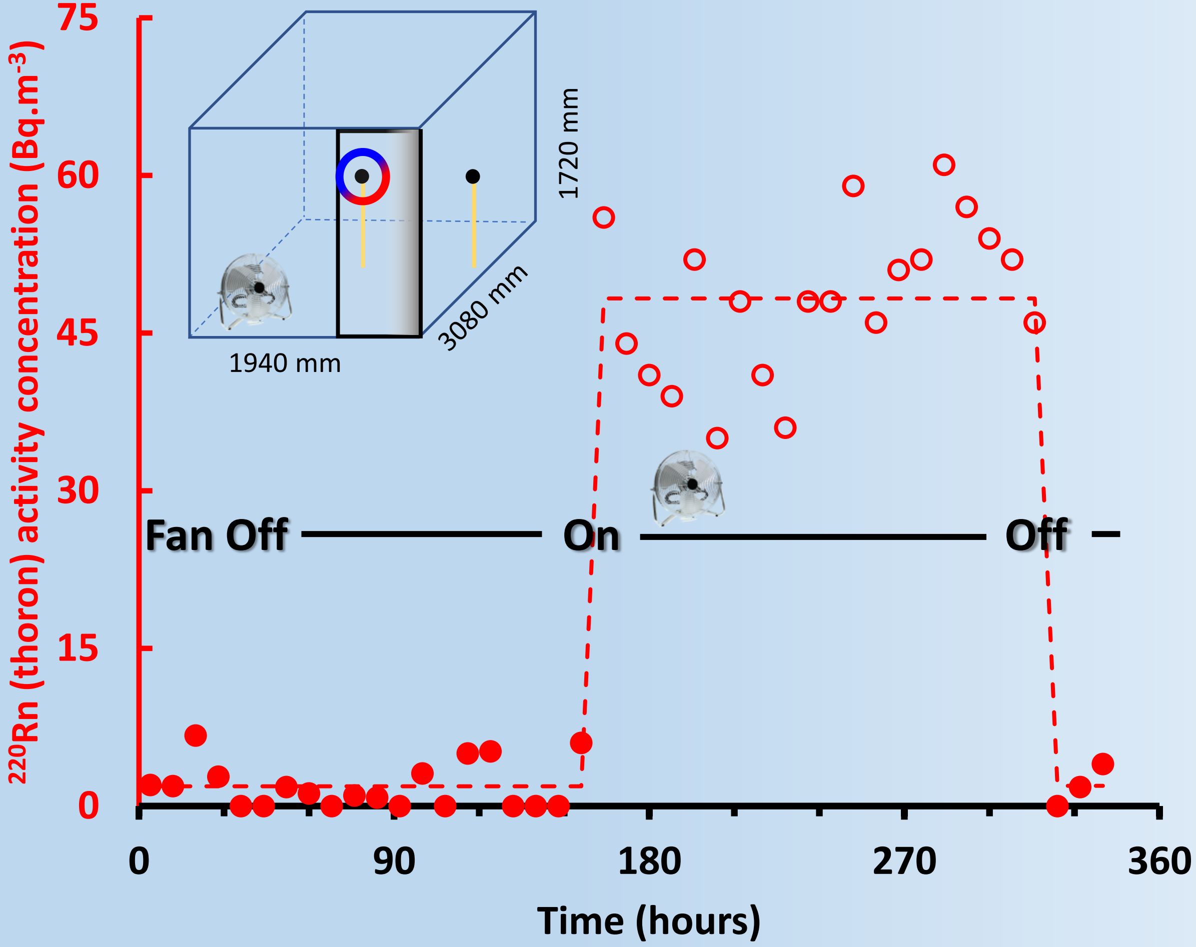
Empty Room



2: Radon and thoron activity concentration
Effect of air movement



Empty Room



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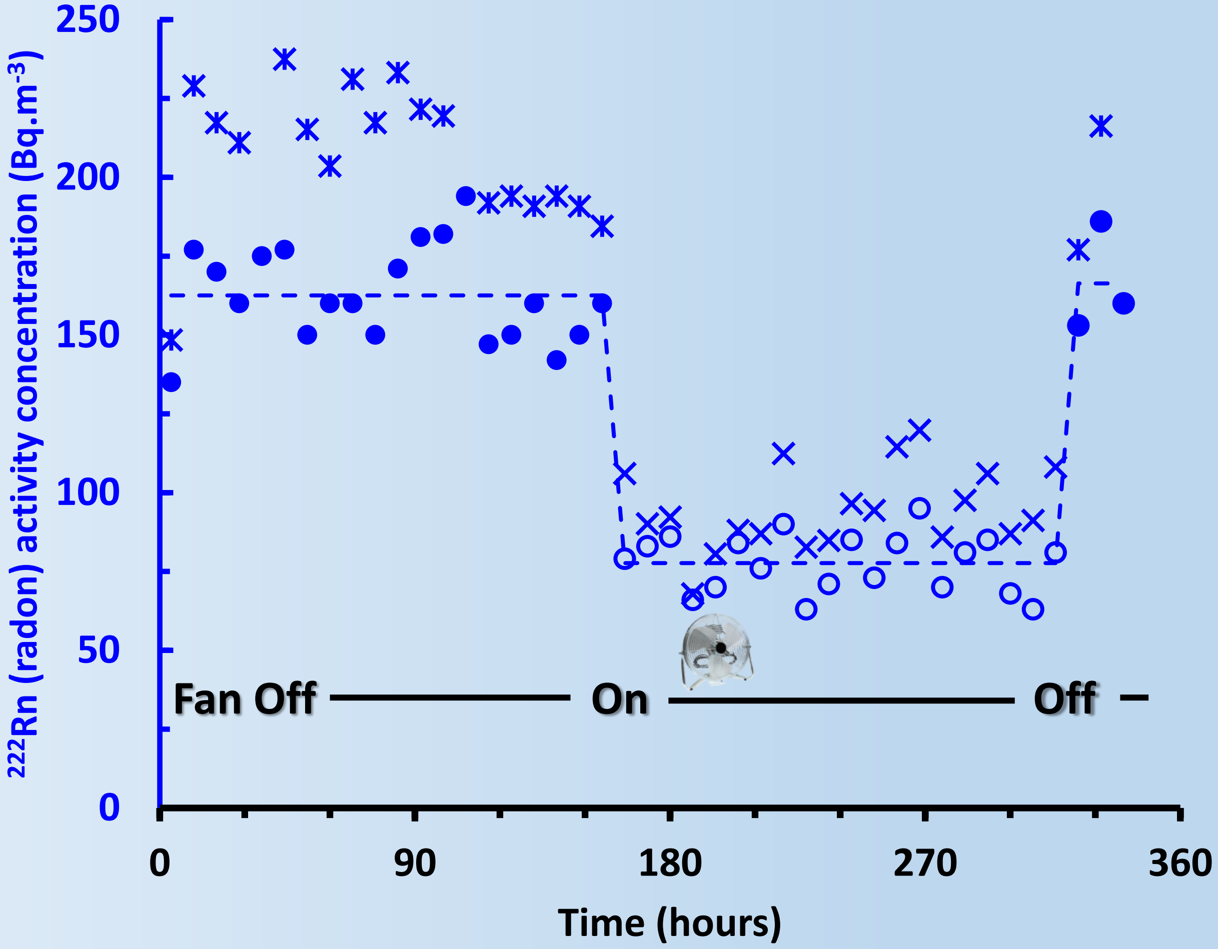
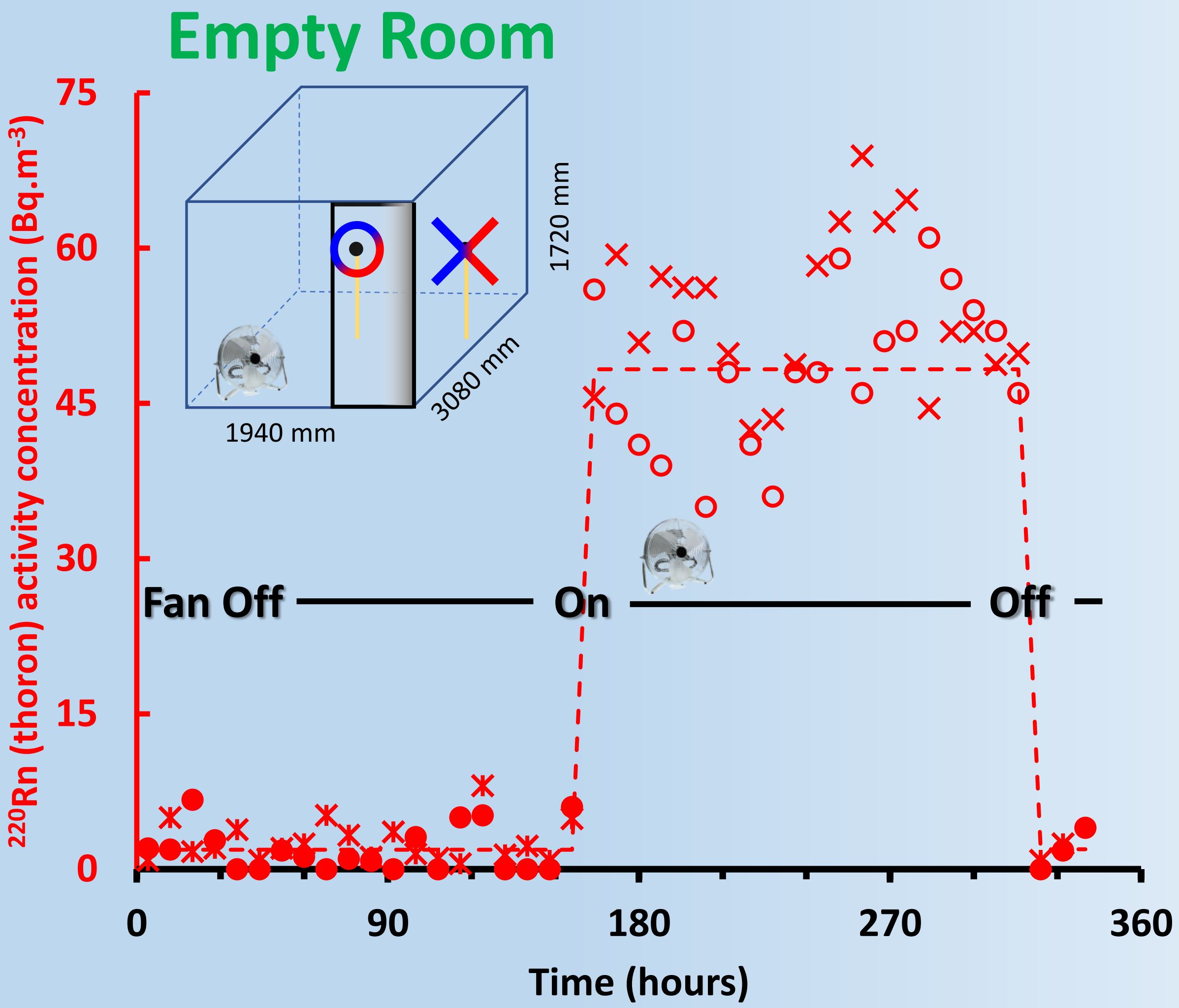
Effect of air movement





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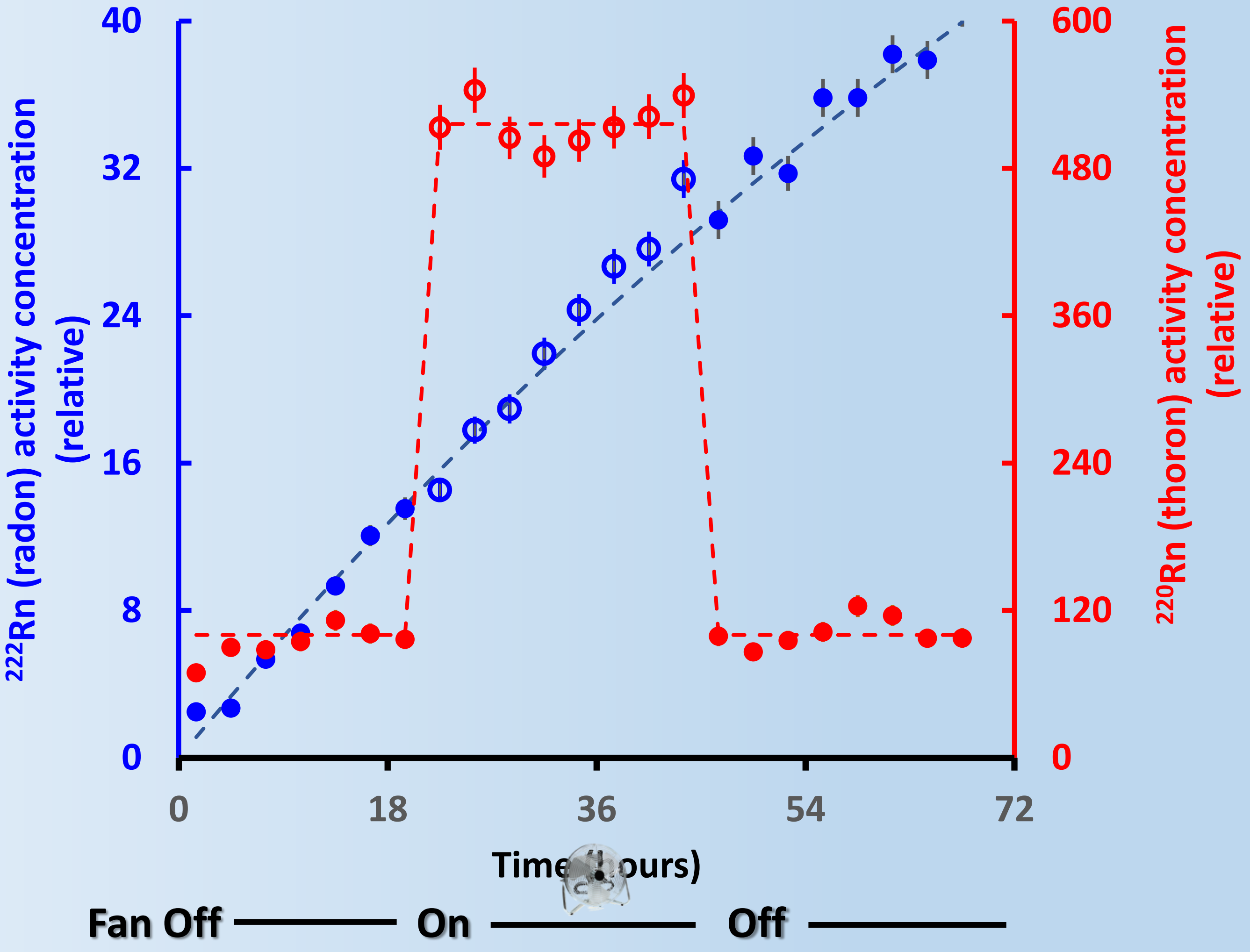
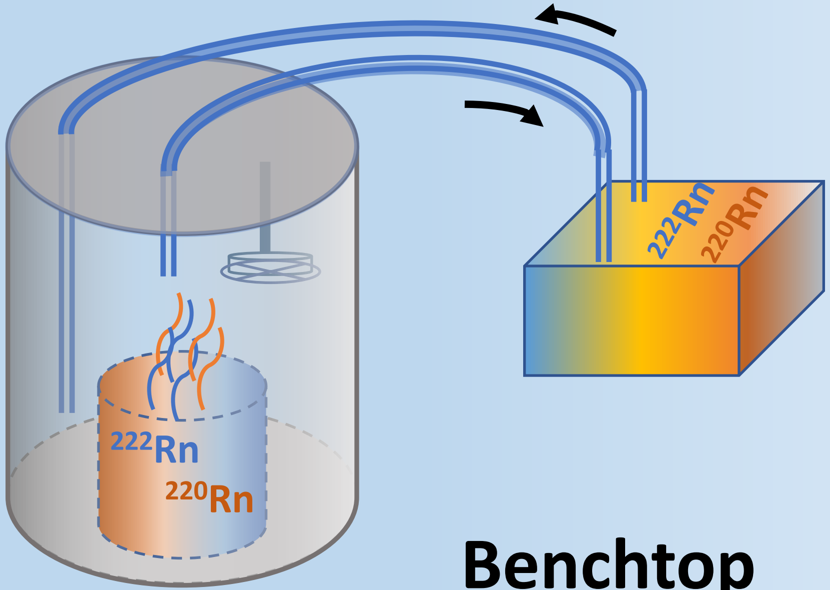
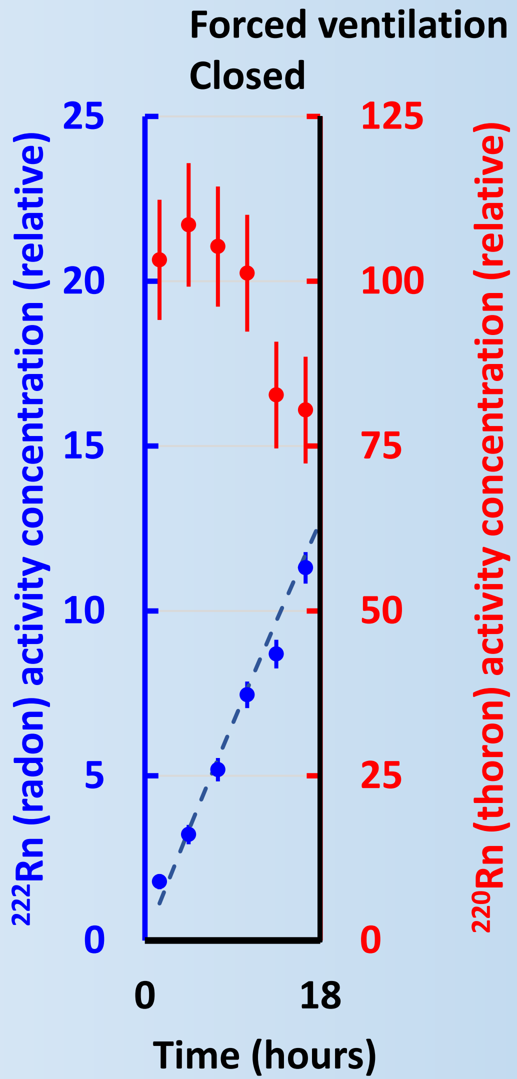
Effect of air movement





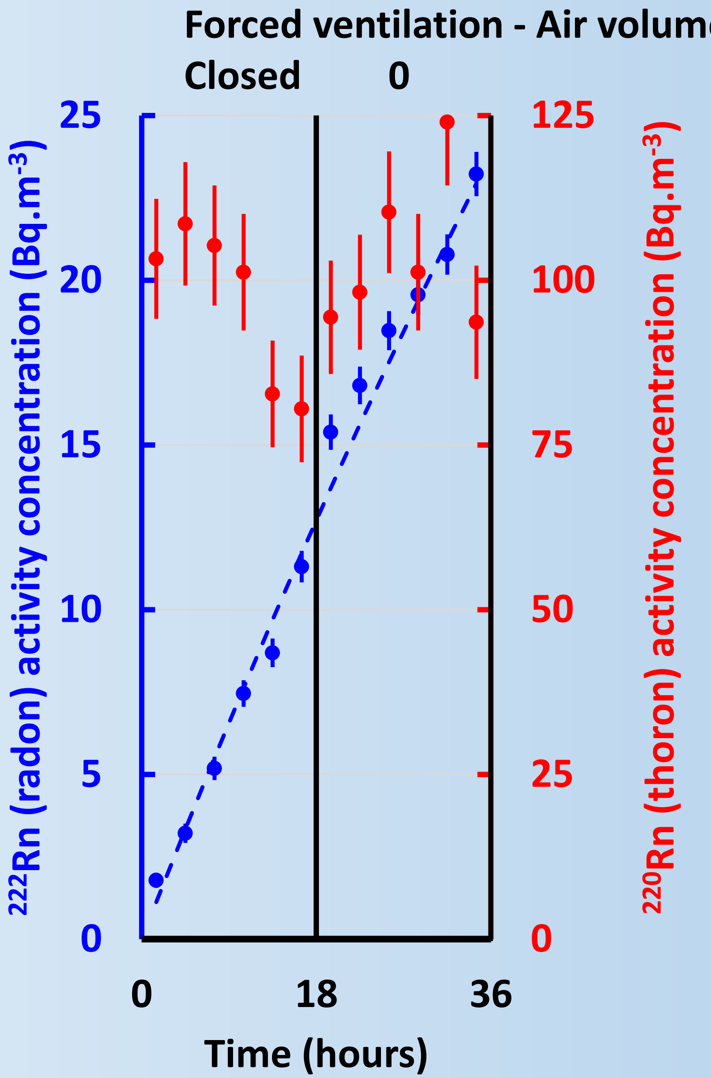
Benchtop simulation

3: Radon and thoron activity concentration
Effect of forced ventilation



Benchtop simulation

3: Radon and thoron activity concentration
Effect of forced ventilation



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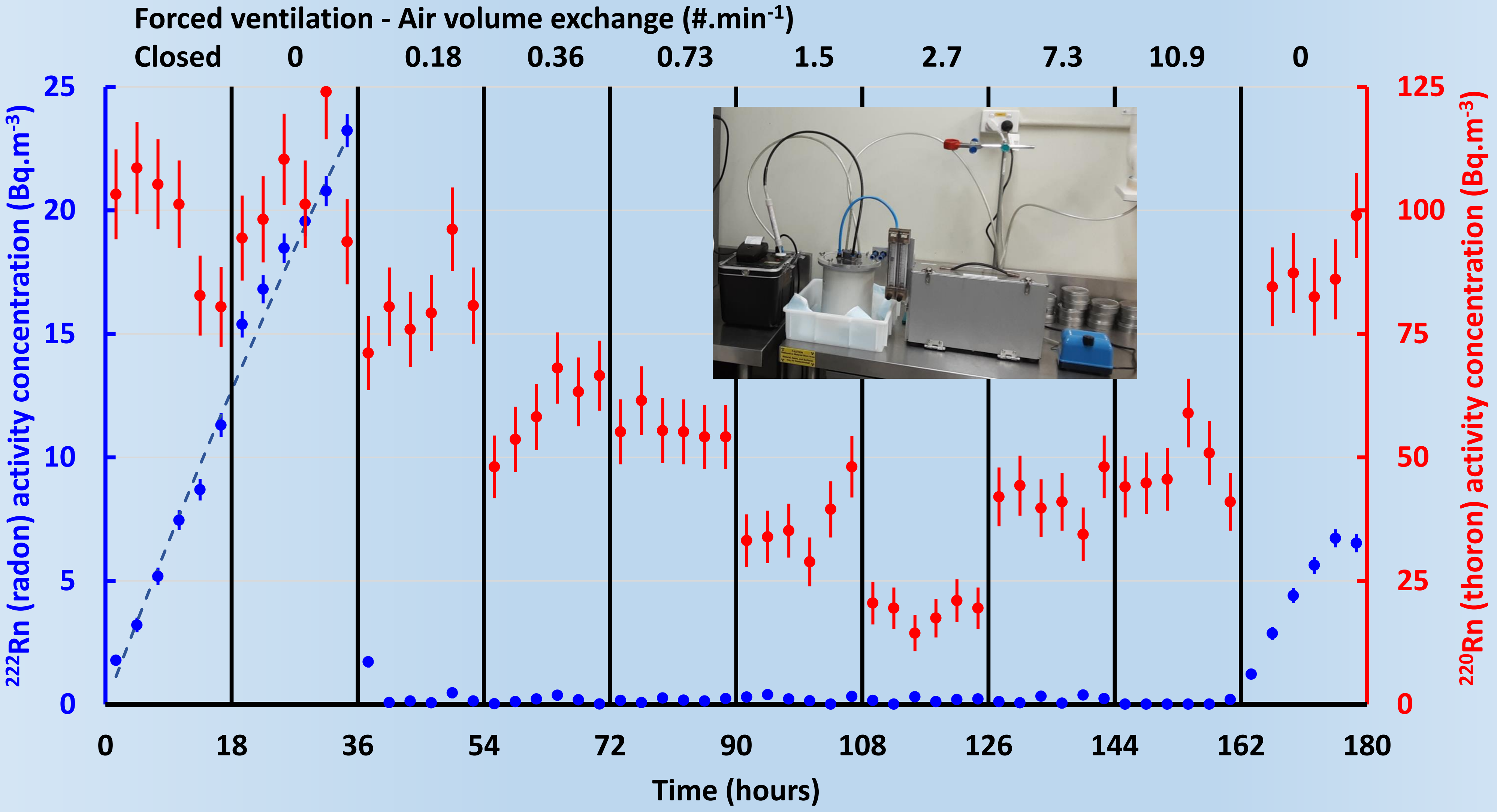
Effect of forced ventilation



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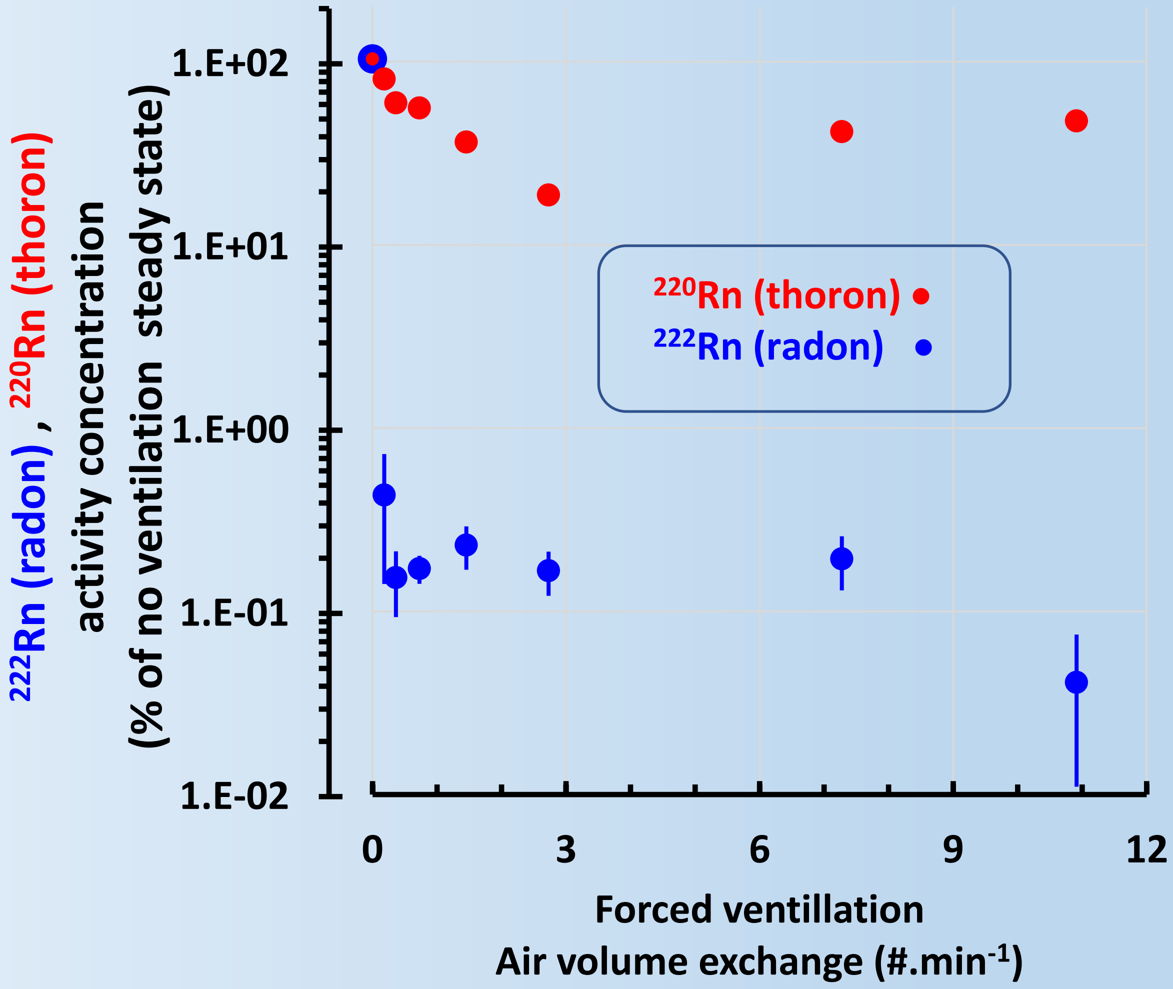
Effect of forced ventilation



Thoron (^{220}Rn) and radon (^{222}Rn) in closed space Will ventilation help in dose reduction?

Conclusions

Lessons from this study

	Behaviour	
Enclosed space	**Radon (^{222}Rn)**	**Thoron (^{220}Rn)**
Build up	Slowly to steady state (days – weeks)	Steady state within minutes
Air circulation and agitation	Air mixing may change and average out activity concentration	Dramatic increase in activity concentration is possible
Fan forced ventilation	Effective	May be only partly effective

Thoron (^{220}Rn) and radon (^{222}Rn) in closed space Will ventilation help in dose reduction?

Conclusions

Lessons from this study

- Dose calculation based only on radon (radon progeny) in enclosed spaces may be inconclusive. Presence of thoron (thoron progeny) should not be ignored.

- Air movement and ventilation set ups in underground tunnels, caves, mines, and other enclosed spaces should be checked for the effect on thoron related radiation dose as well.