MEASUREMENT OF RADON EXHALATION RATE USING LOCAL TECHNIQUE

Lamiaa Abdelrazik

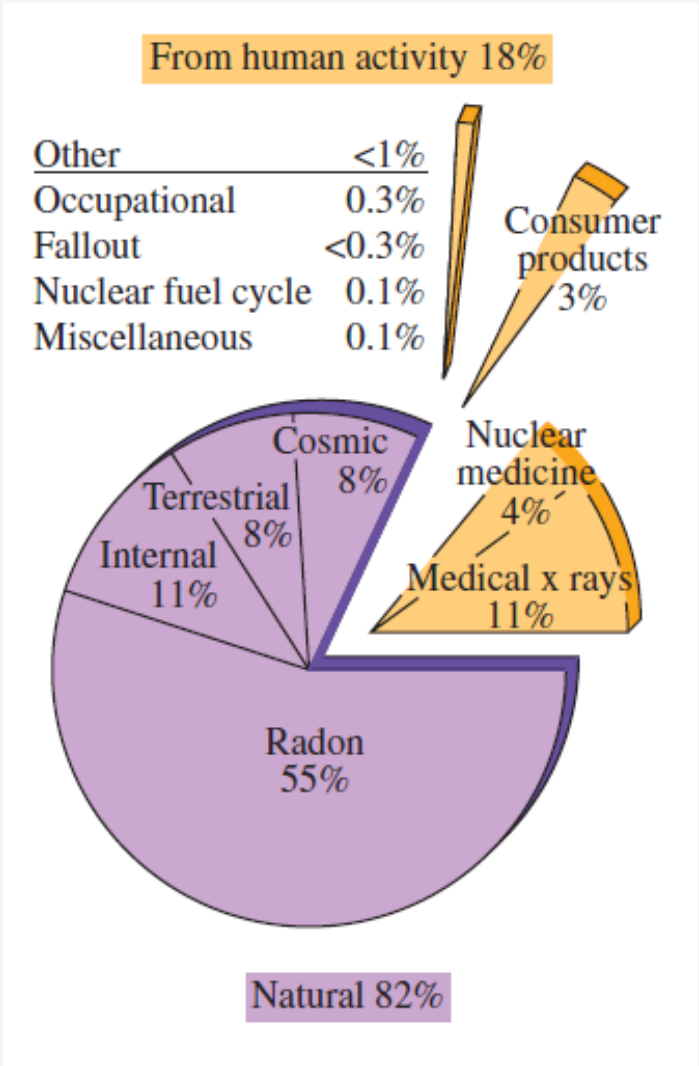
Egypt

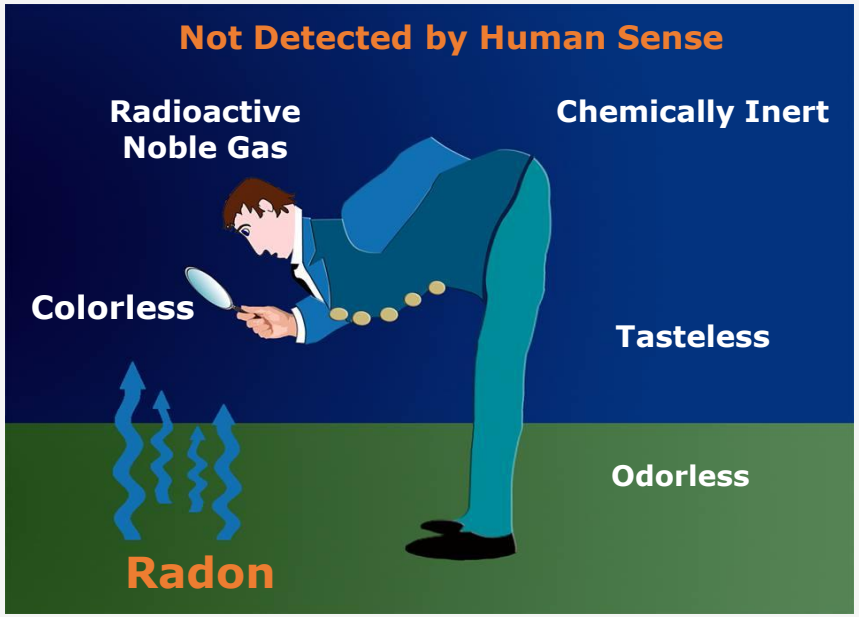
Prof. Dr. H. M. El-Samman

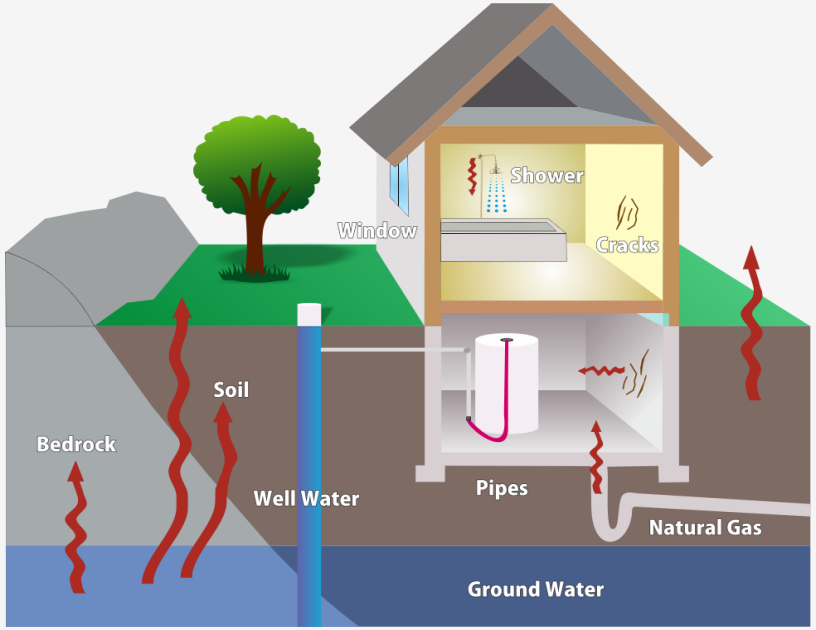
Prof. Dr. W. M. Arafa

Prof. Dr. A. H. Ashery

Why Radon!





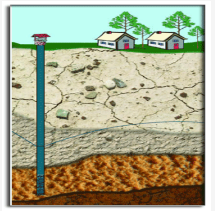


https://www.interiorhealth.ca/YourEnvironment/RadonGas

Soil & Rocks

Building Materials

Ground Water



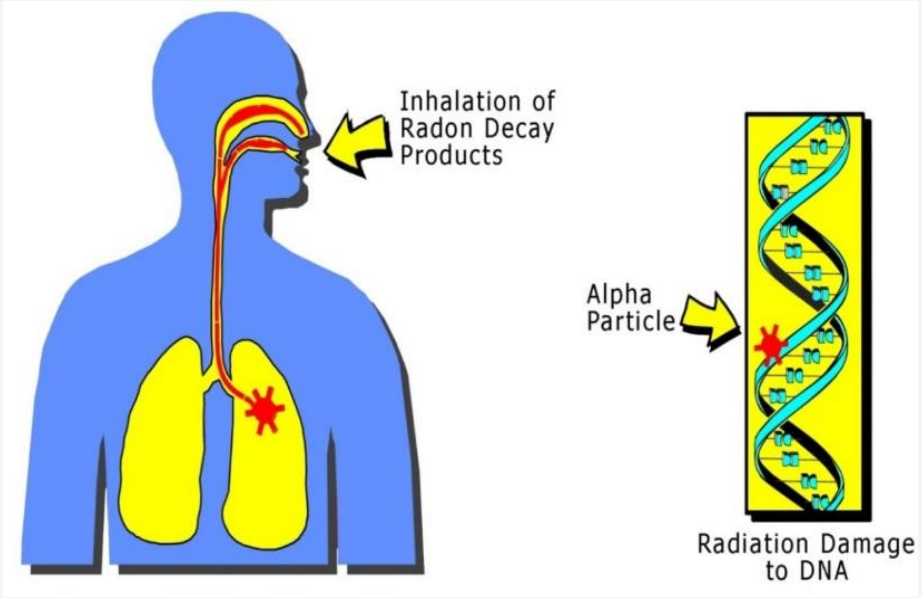
Natural Gas

Radon Daughters and Health Hazard

^{235}U → Rn-219 → $T_{1/2}$ = 4 sec

^{232}Th → Rn-220 → $T_{1/2}$ = 55.6 sec

^{238}U → Rn-222 → $T_{1/2}$ = 3.82 d



https://www.housetohomeinspect.com/radon-testing/

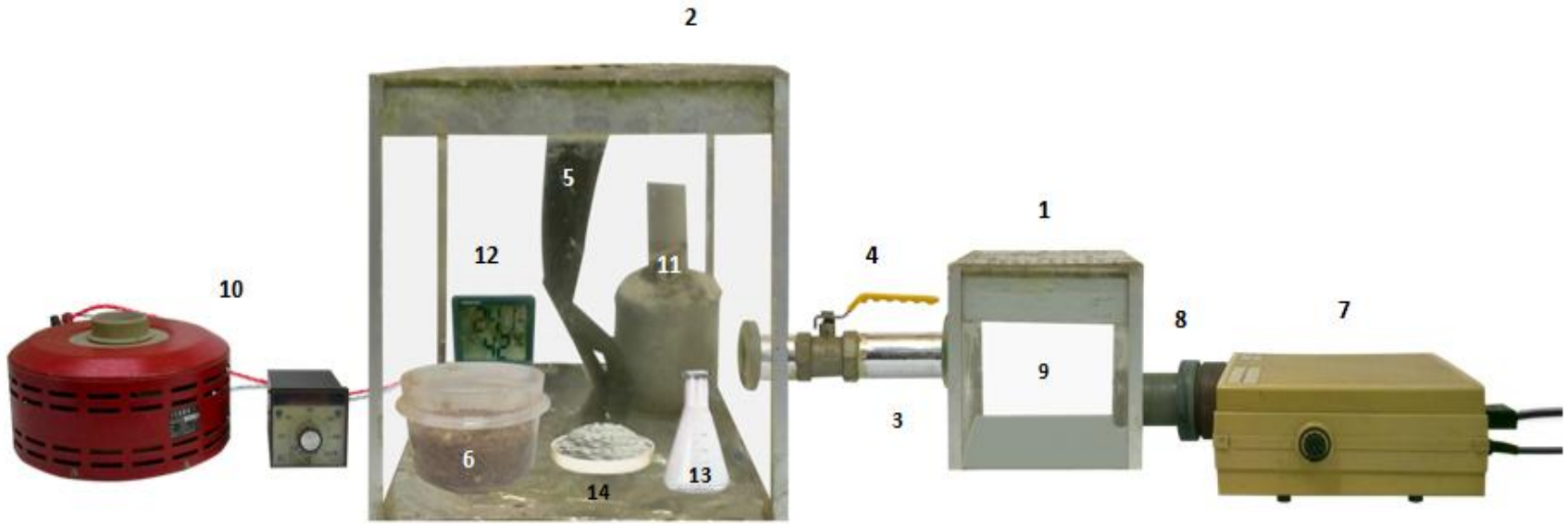
^{222}Rn → ^{218}Po → ^{214}Pb → ^{214}Bi → ^{214}Po → ^{210}Pb → ^{210}Bi → ^{210}Po → ^{206}Pb

→ β

↓ α

Experimental Work

The Constructed Chamber



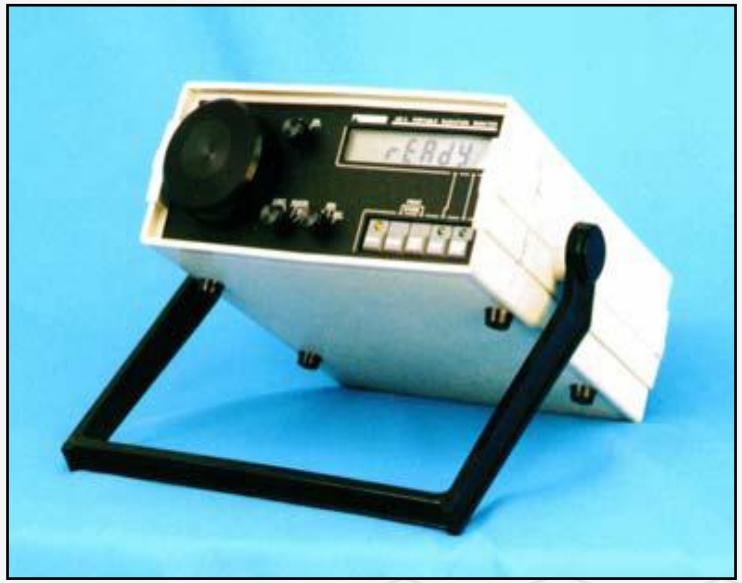
1. Sample Chamber
3. Connection Tube between the two Chambers
5. Hole with rubber Gloves
7. AB-5 Monitor
9. CR-39 Detector
11. Heater
13. Flask with water

2. Measuring Chamber
4. Valve
6. Building Material Sample
8. CPRD Detector
10. Temperature Controller
12. Thermo-Hygrometer
14. $CaCl_2$ Crystal

1. Active Method

AB-5 Monitor

Continuous Passive Radon Detector "CPRD"



$$C_{Rn} = \frac{NCPM}{S}$$

C_{Rn} : is the radon gas concentration (PiC/l).

NCPM : is the net count per minute.

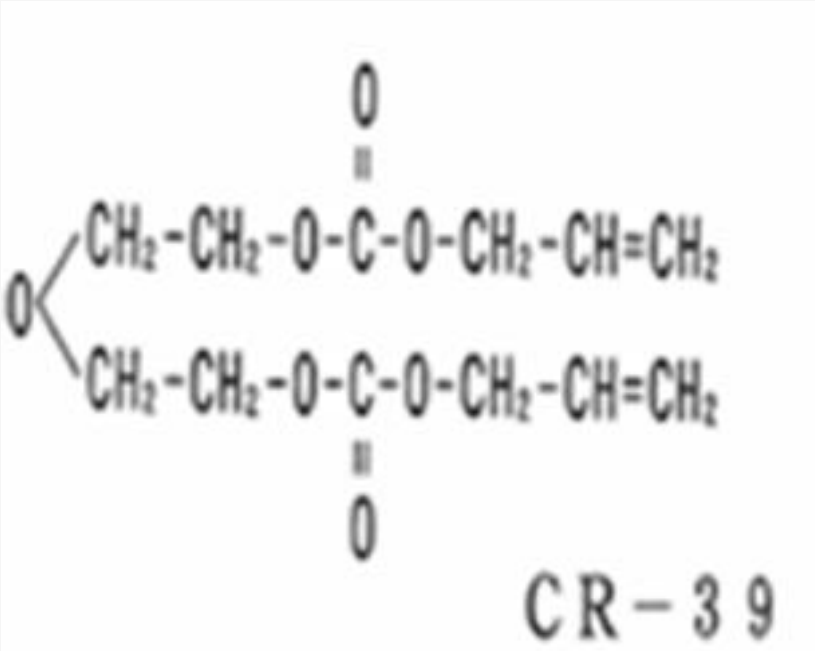
S : is the counting sensitivity value (CPM/PCi/l).

2. Passive Method
Solid State Nuclear Track Detector "SSNTD"

CR-39 Film

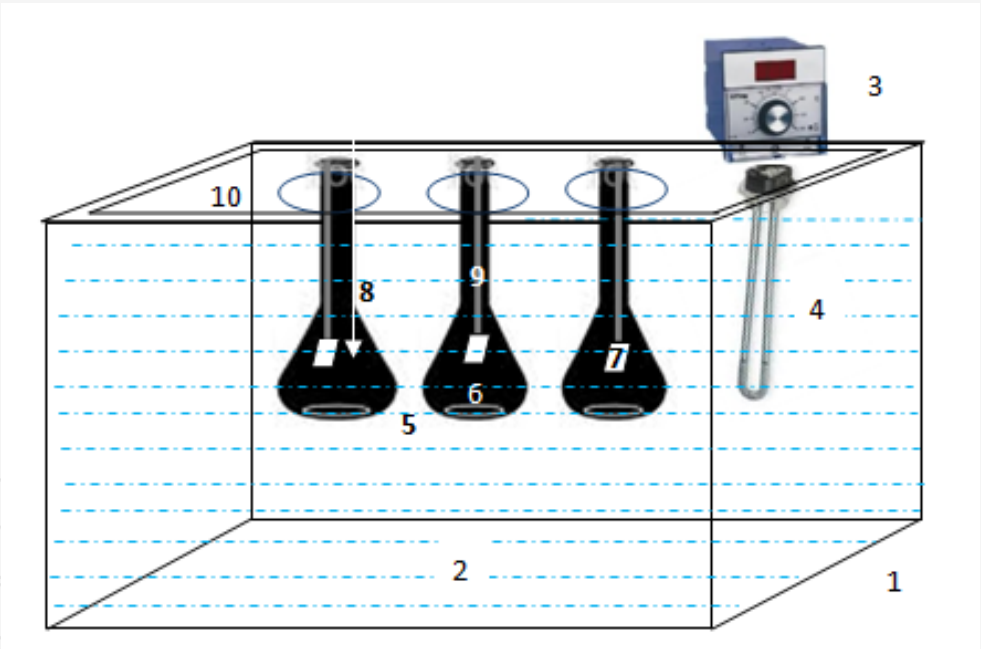
- CR-39 films are Polyallyl diglycoal Carbonate (ADC)

- CR-39 has a chemical formula $C_{12}H_{18}O_7$



The chemical structure of the CR-39 detector

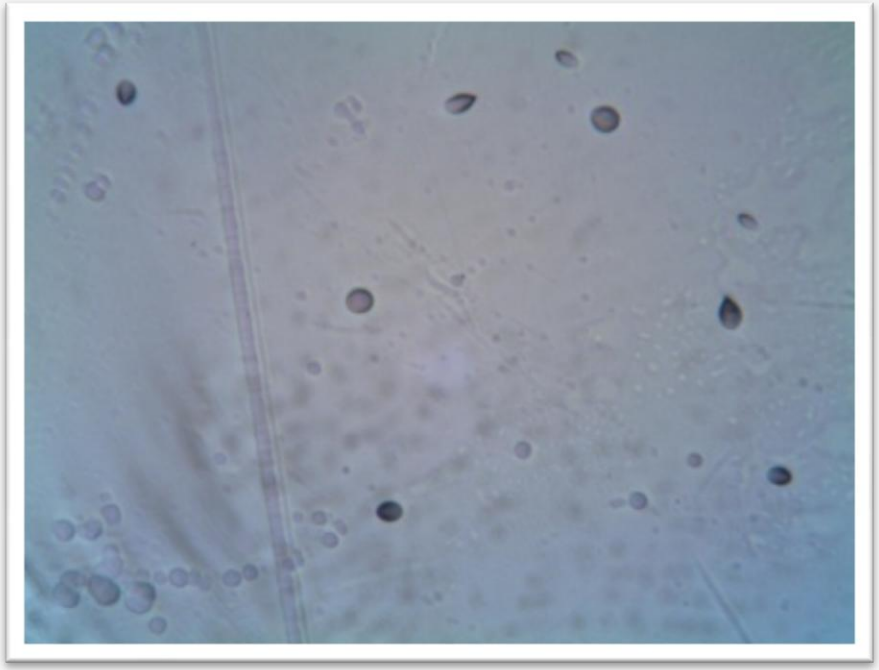
Chemical Etching Process



NaOH solution

6.25N - 70°C - 6h

Tracks Counting System



The cross section of the CR-39 detector

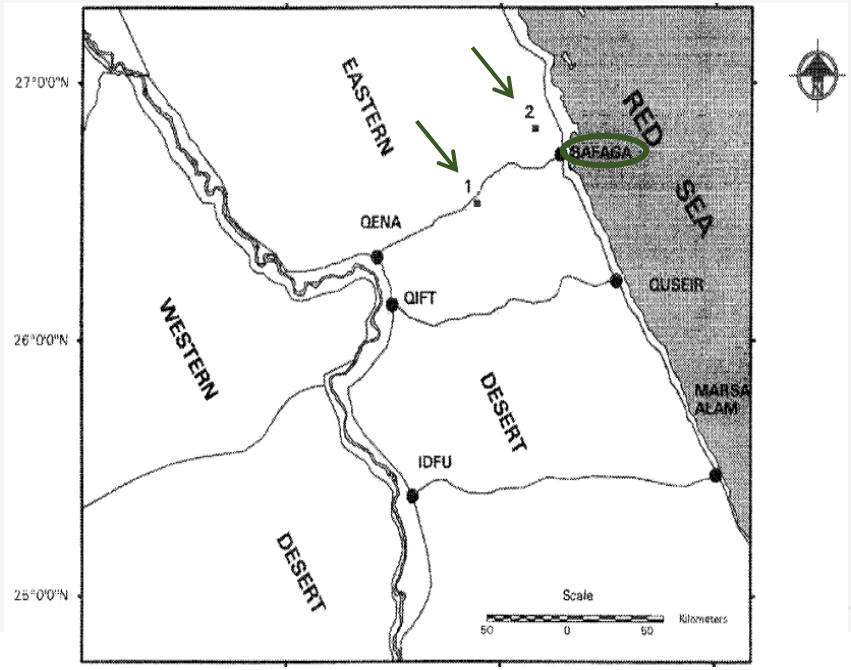
$$Rn\ Conc. = \frac{T}{k.t}$$

T : is the average number of tracks (tracks/cm^2).
K : is the calibration factor (tracks.cm^{-2} .d^{-1}/ Bq.m^{-3}).
t : is the exposure time (day).

Samples Collection

Soil Samples

Soil sample Code no.	Origin
1	Gabel El Misikat
2	
3	
4	Gabel El Majal
5	



Building Materials Samples

White Cement

Gray Cement

Sand

Ceramic

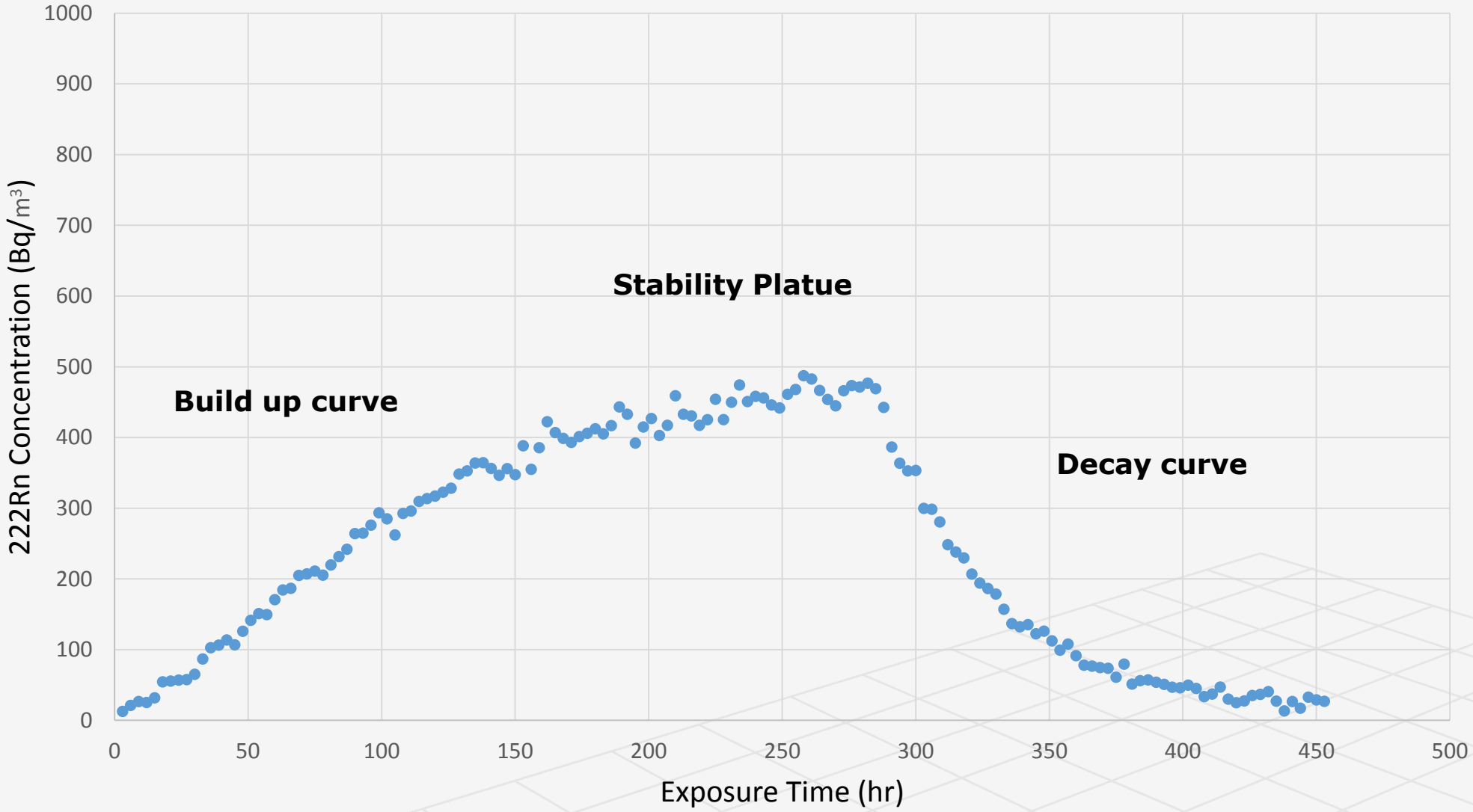
Marble

Granite

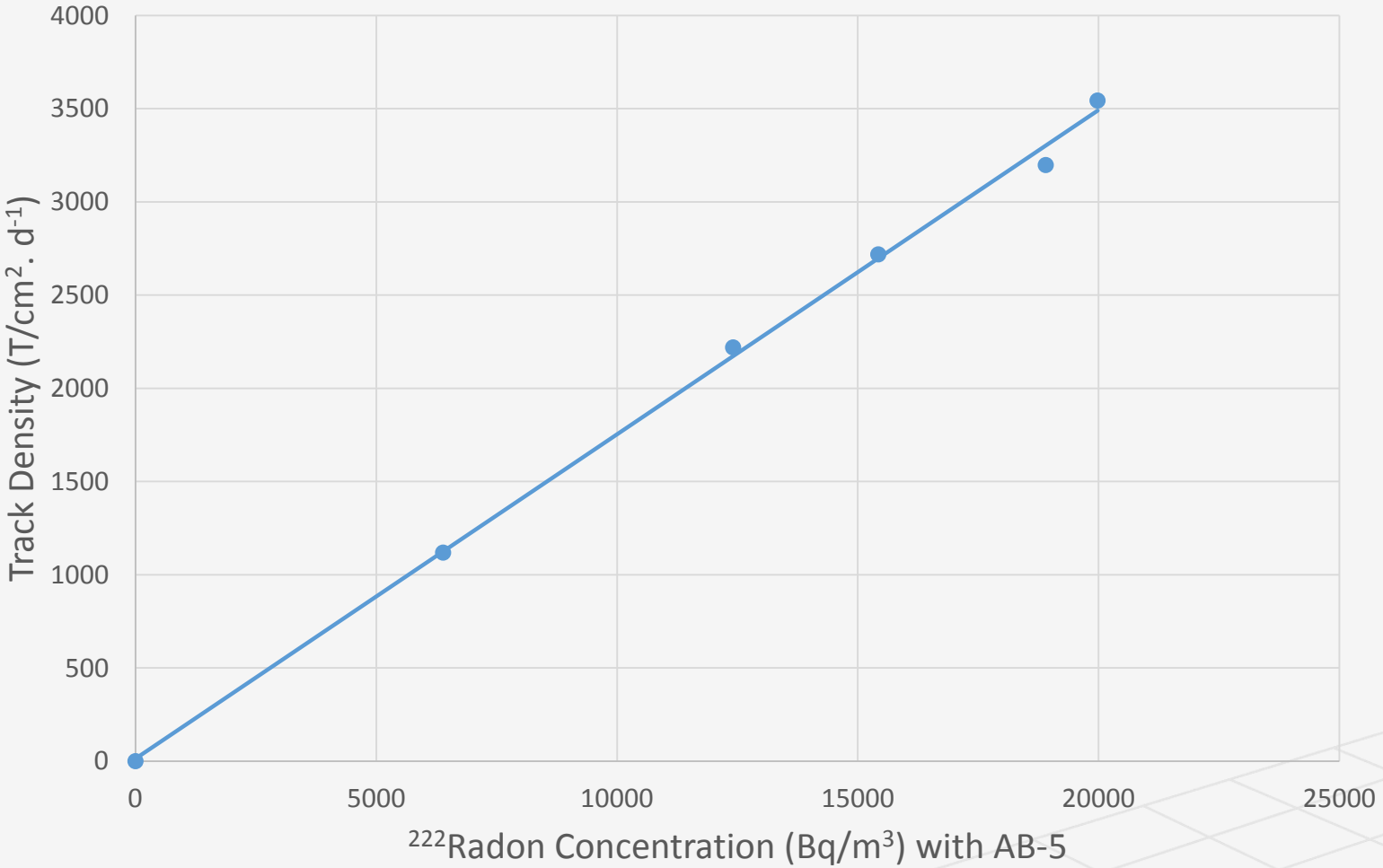
Fertilizers Samples

Type of fertilizers	Origin
Fertilizer (1)	Alexandria Company for Fertilizers and Chemical Industries
Fertilizer (2)	Financial and Industrial Company for Fertilizers and Chemical Industries

Chamber Test



Calibration of CR-39 Detector



$$\rho_o = k\, C_o$$

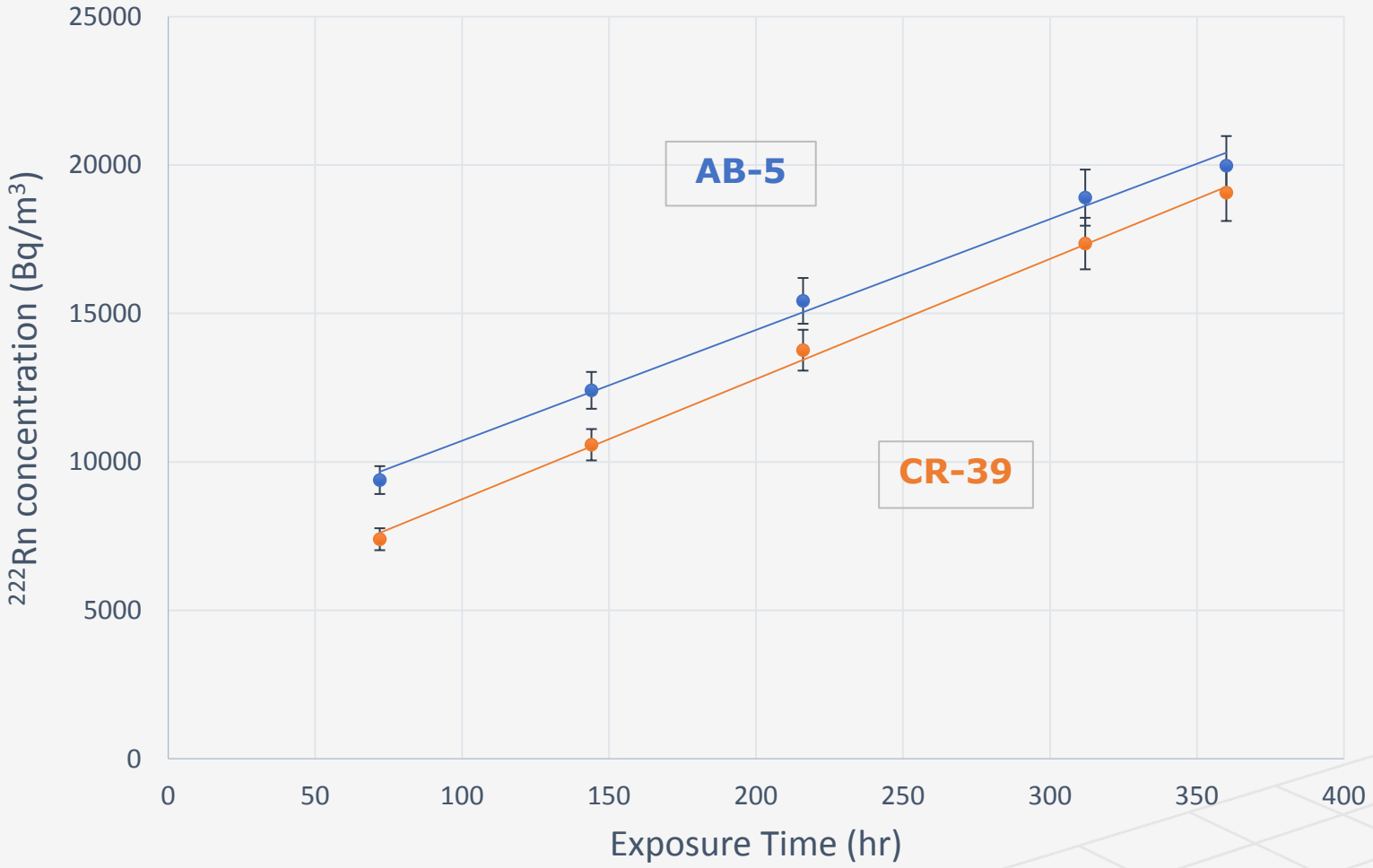
Abo-Elmagd M.*

Calibration Factor

0.177 track.cm^{-2}.d^{-1} per Bq.m^{-3}

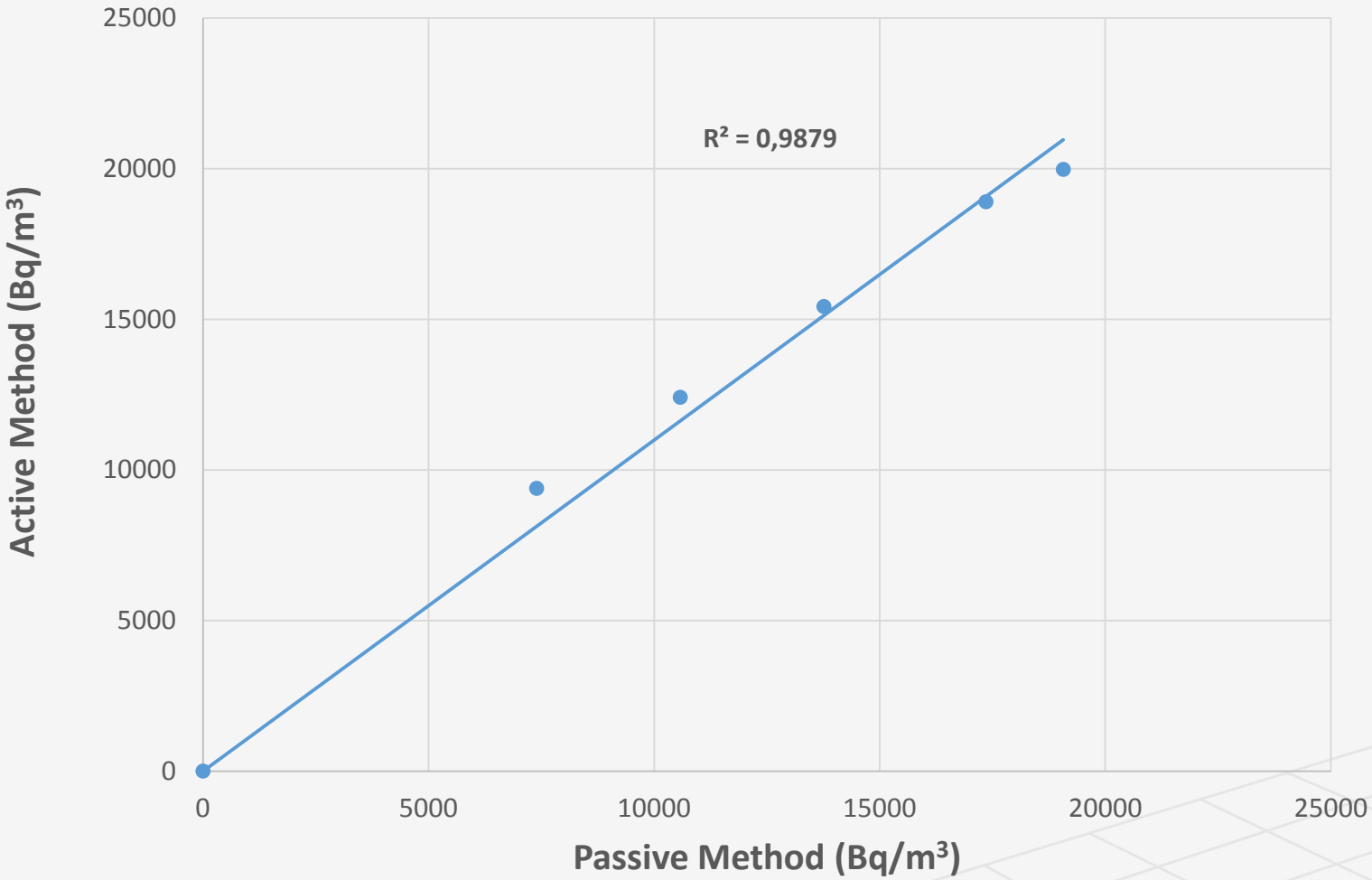
* Abo-Elmagd M., Metwally S.M., El-Fikib S.A., Eissa H.M., Salama E., 2007, Passive and active measurements of radon-related parameters inside ancient Egyptian tombs in Luxor, Radi. Meas. 42, 116 – 120.

Comparison between Active and Passive Detectors



Linear correlation between radon concentration measured by active and passive detectors and the exposure time.

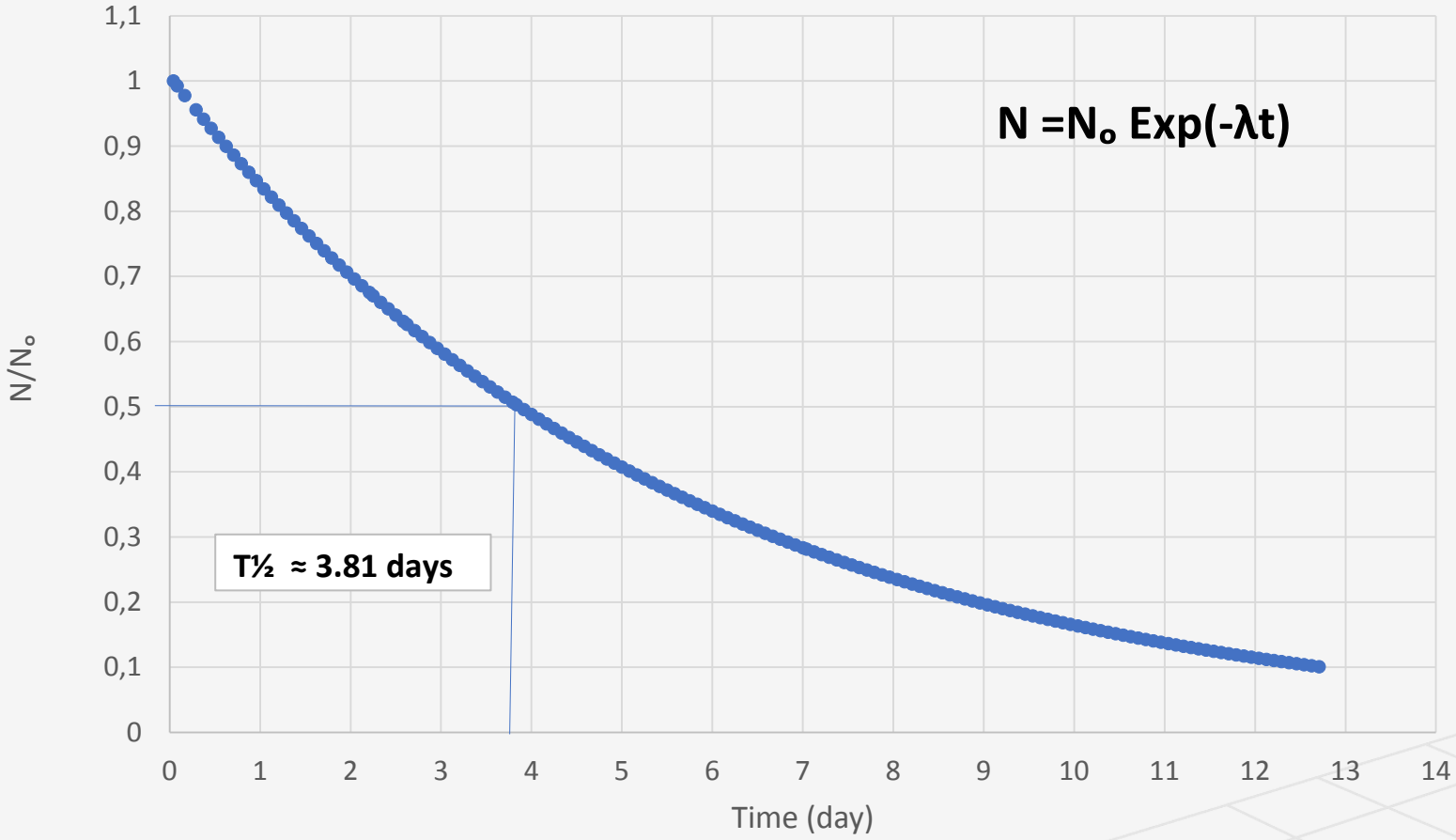
Comparison between Active and Passive Detectors



A good correlation between the performance of the two detectors with correlated coefficient 0.98

The passive method (the cheapest method) give reliable data.

Determination of Radon Half-life Time Inside the Chamber



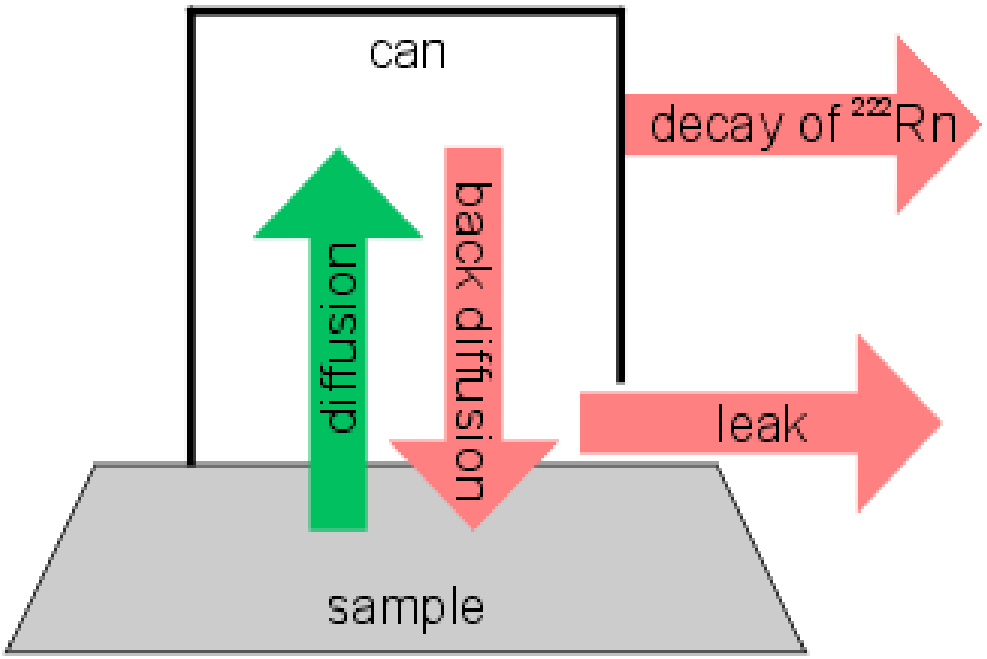
The experimental half-life time of radon was found to be 3.81 days, which is in perfect agreement of the known half-life time of radon 3.82 days.

Correction of Radon Concentration

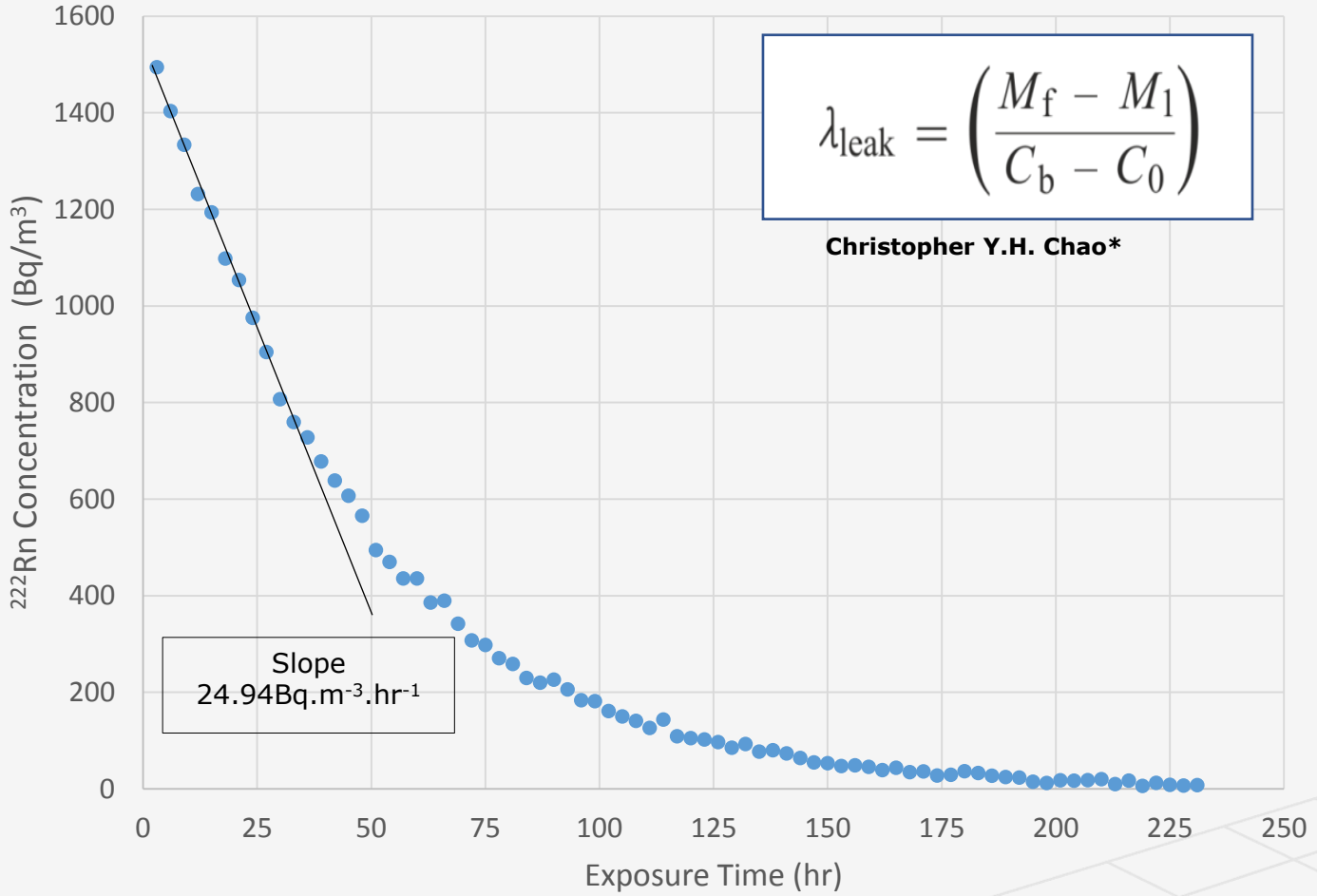
It is very important to take into consideration:

1. The air exchange due to chamber leakage

2. When the radon concentration in the chamber starts to approach that of the radon concentration in the sample, radon has significant probability of diffusing back into the sample.



Leakage Rate Calculation



$$\lambda_{leak} = \left(\frac{M_f - M_1}{C_b - C_0} \right)$$

Christopher Y.H. Chao*

Reference	$\lambda_{leakage}$ (hr^{-1})	Average value
Present work reference sample (High activity sand)	$1.35 * 10^{-2}$	$1.198 * 10^{-2}$
Present work Using Sample No.1	$1.03 * 10^{-2}$	
Tomasella, et al.,	$2.95 - 3.32 * 10^{-2}$ $1.15 - 1.77 * 10^{-3}$	------

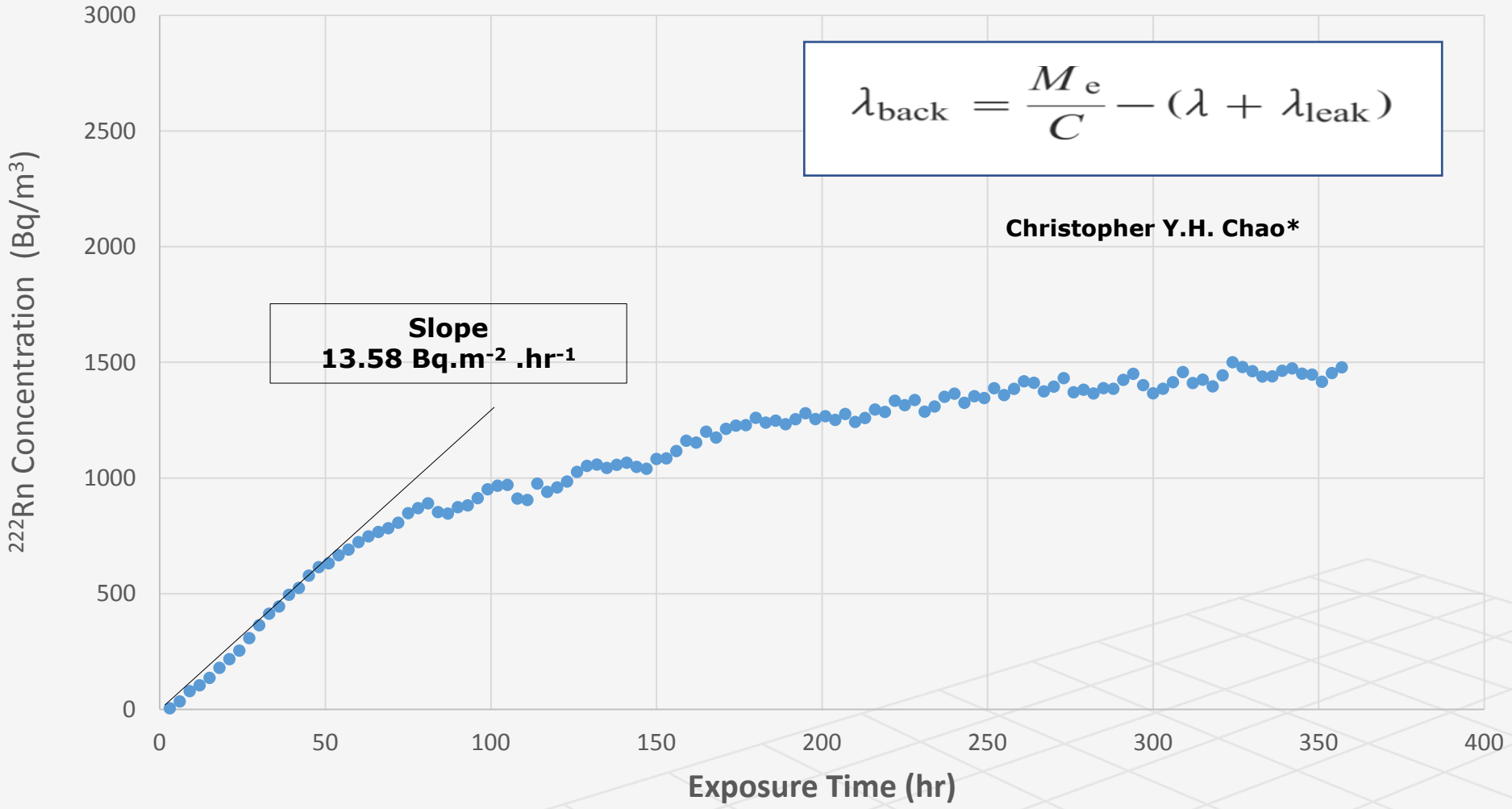
The leakage value depends on the chamber design and the sealing way across the whole system.

* Christopher Y.H. Chao, Thomas C.w. Tung, Daniel W.T. Chan, Gohn Burnett, 1996. Determination of radon emanation and back diffusion characteristic of building materials in small chamber tests. Building and environment 32(4), 355-362.

Back Diffusion Calculation

$$\lambda_{back} = \frac{M_e}{C} - (\lambda + \lambda_{leak})$$

Christopher Y.H. Chao*



Back Diffusion Coefficient Values

Soli Sample code	$\lambda_{diffusion}$ (hr^{-1})
1	$9.49*10^{-3}$
2	$5.40*10^{-3}$
3	$7.75*10^{-3}$
4	$1.44*10^{-2}$
5	$3.59*10^{-3}$

Sample Type	$\lambda_{diffusion}$ (hr^{-1})
White cement	$2.8*10^{-2}$ - $8*10^{-2}$
Gray Cement	$1.2*10^{-2}$ - $8.7*10^{-2}$
Sand	$3.5*10^{-3}$ - $7.6*10^{-2}$
Ceramic	$1.0*10^{-2}$ - $1.3*10^{-2}$
Marble	$7.5*10^{-3}$ – $10.4*10^{-2}$
Granite	$4.7*10^{-3}$ - $6.0*10^{-3}$
Fertilizer	$3.1*10^{-3}$ – $8.4*10^{-3}$

The value of back diffusion depends on the **sample types** and **origin area**

Each area has a characterize specification (**grain size**, **porosity**, **radium contents**) which affects on the radon concentration and consequently the back-diffusion process.

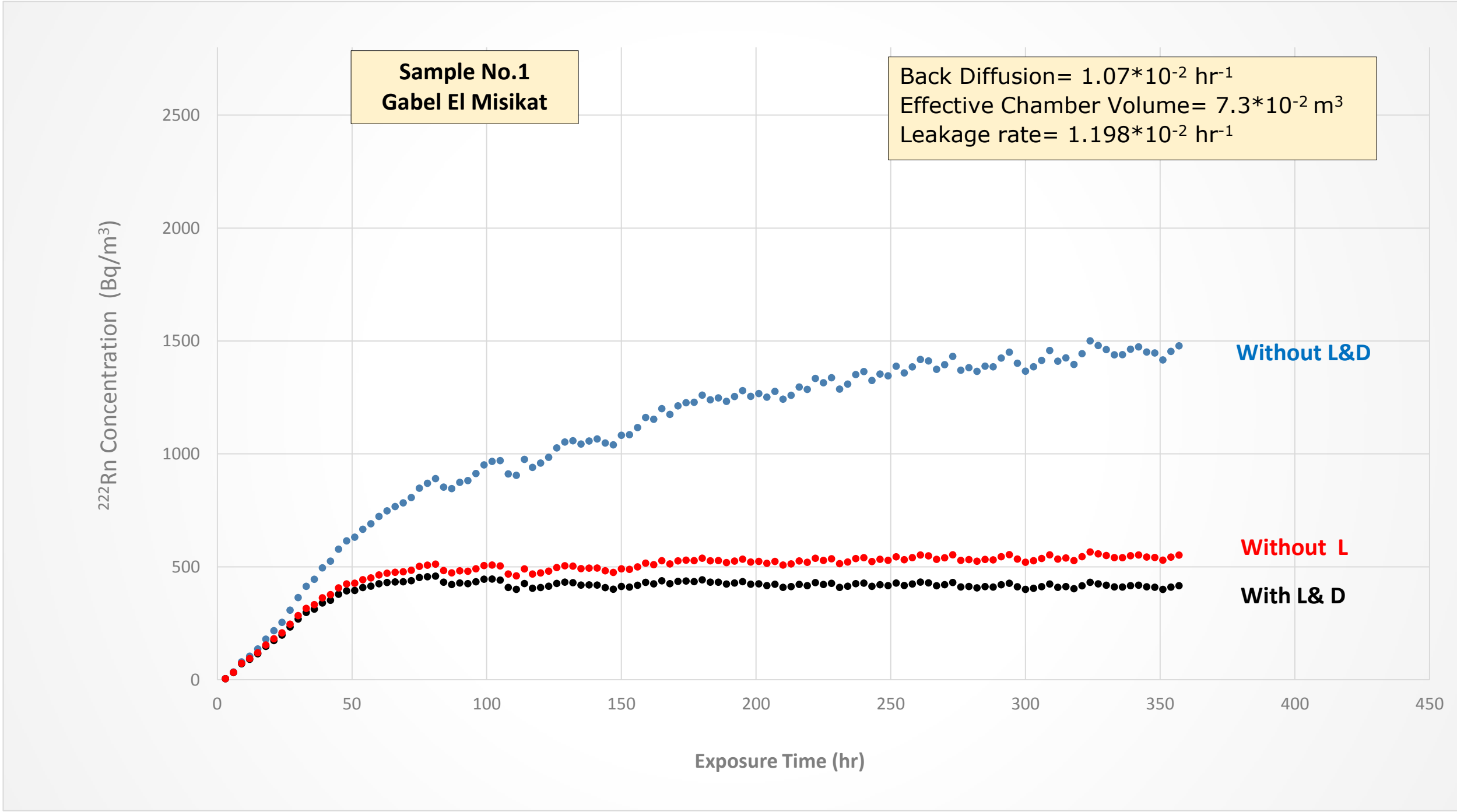
Effective Time Constant Calculation

$$\lambda_{eff} = \lambda + \lambda_{leak} + \lambda_{back}$$

Radon Decay constant
0.00755 hr^{-1}

Radon Decay constant
Due to back diffusion

Radon Decay constant
Due to leakage
0.00119 hr^{-1}


Sample No.1
Gabel El Misikat
Back Diffusion= 1.07*10-2 hr-1
Effective Chamber Volume= 7.3*10-2 m3
Leakage rate= 1.198*10-2 hr-1
222Rn Concentration (Bq/m3)
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
Exposure Time (hr)
Without L&D
Without L
With L& D

Measurement Radon Concentration

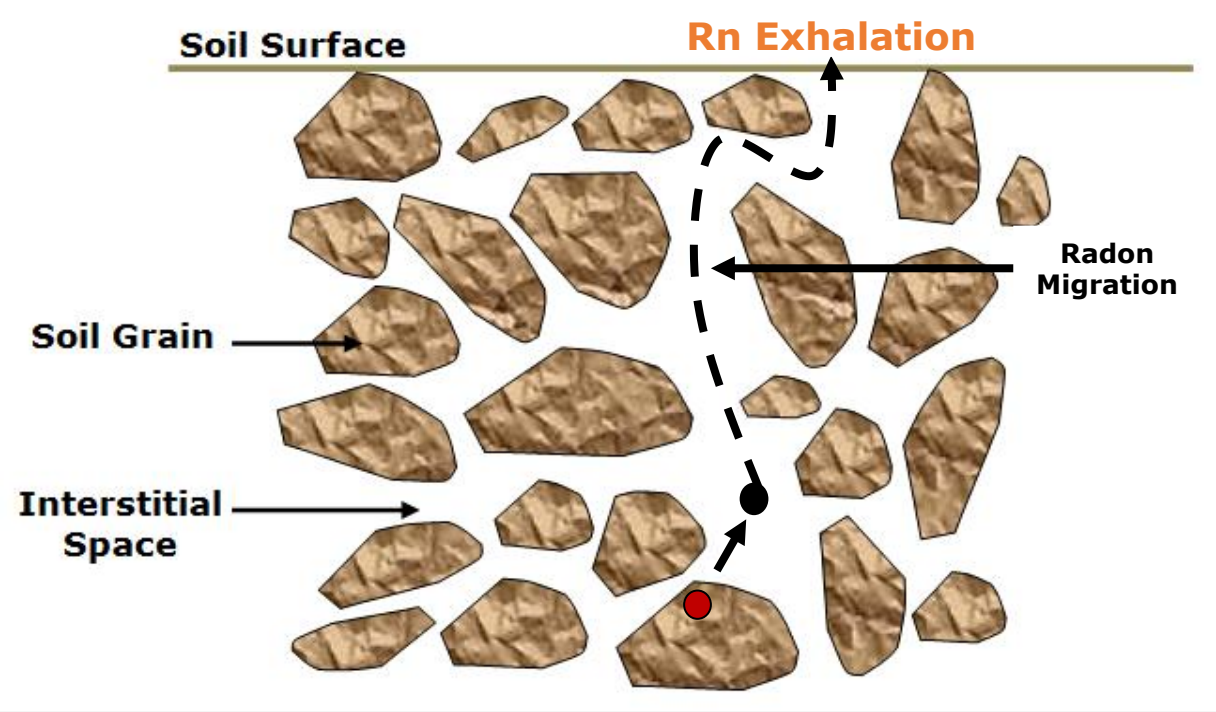
Samples	Radon concentration (Bq/m^3)
Soil	36.91 – 1754.77
Building Materials	9.2 – 72.68
Fertilizers	69.94 -192.45

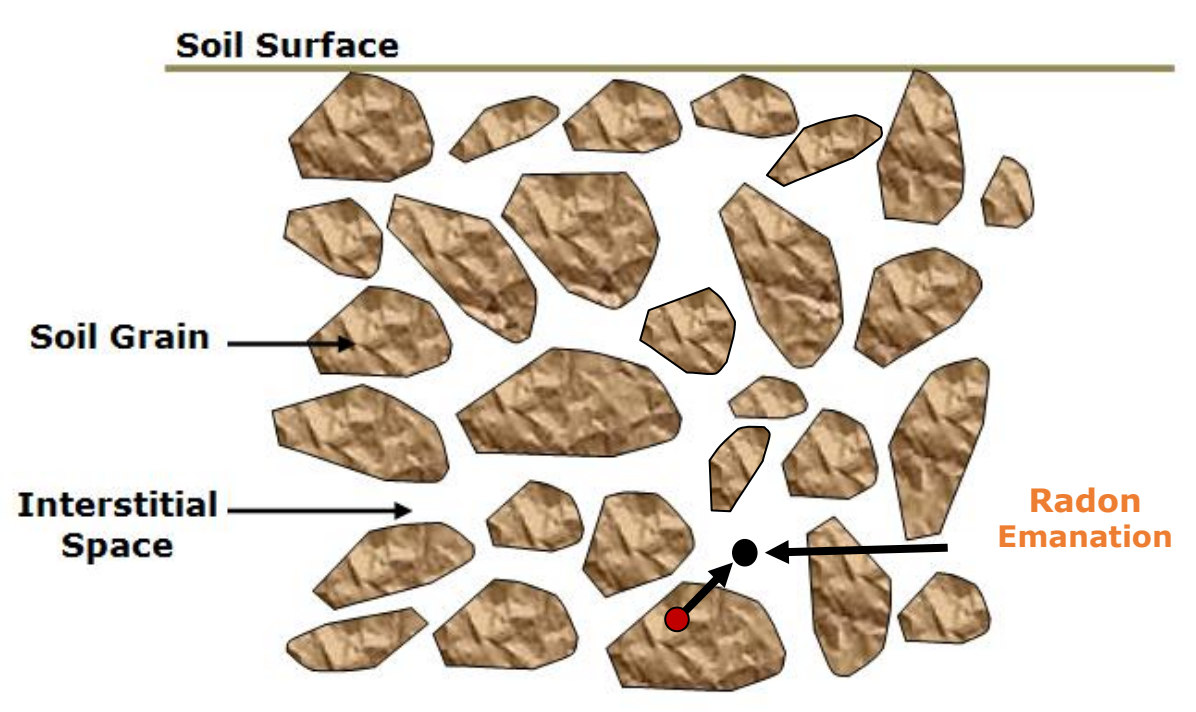
The radon concentrations in the Gabal El-Misikat higher than Gabal El-Majal

The radon concentrations in all building materials and fertilizers samples is below the world average value (200 Bq/m^3)* and hence do not pose any health hazard.

*(International Commission of Radiation Protection) (ICRP)

Measurement of Radon Free Exhalation Rate & Emanation Rate





Radon Exhalation is the number of atoms leaving the soil per unit surface per unit time. ($Bq/m^2.hr$)

A good indicator of radon risk

The process that controls the movement of radon atoms from solid grains into free spaces of materials (pores, micropores and cracks) is called Emanation process.

Measurements of Radon Exhalation Rate and Emanation Rate

$$E_x = \frac{C\,\lambda_{eff}\,V}{1 - e^{-\lambda_{eff} t}}$$

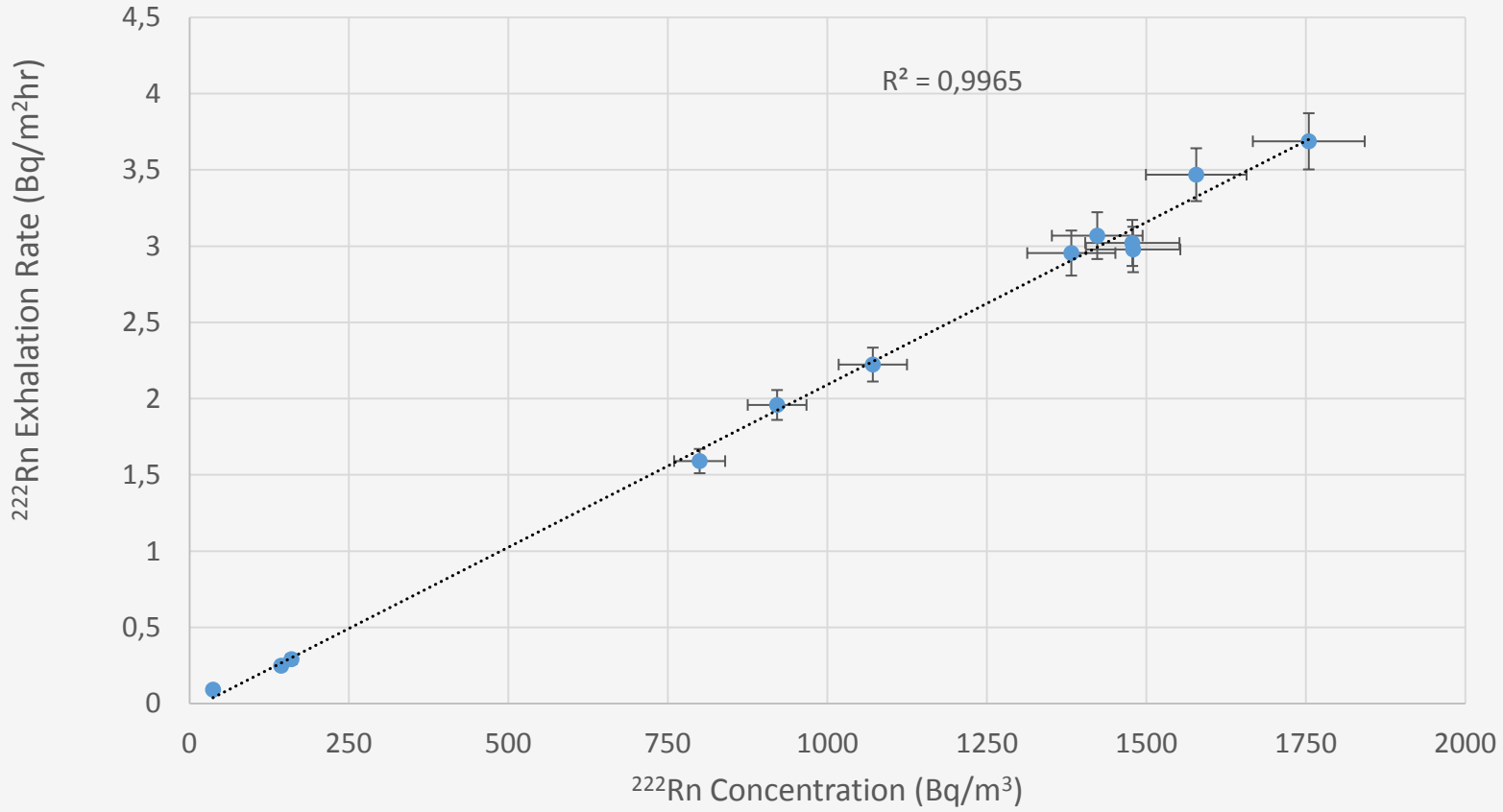
$$E_o = \left(M_e - \frac{q}{V} C_o\right)\frac{V}{A}$$

Samples	Radon exhalation rate (Bq/m².hr)	Radon emanation rate Bq/m².hr
Soil	0.09 -3.68	BDL* - 58.05
Building Materials	0.02 -0.29	BDL* - 10.06
Fertilizers	0.1377 -0.4	BDL*

*Below Detected Level

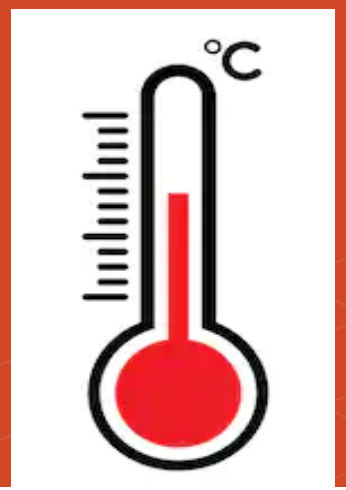
The great variation of exhalation and emanation rates is expected due to the difference of radium contents between the measured samples and its grain size

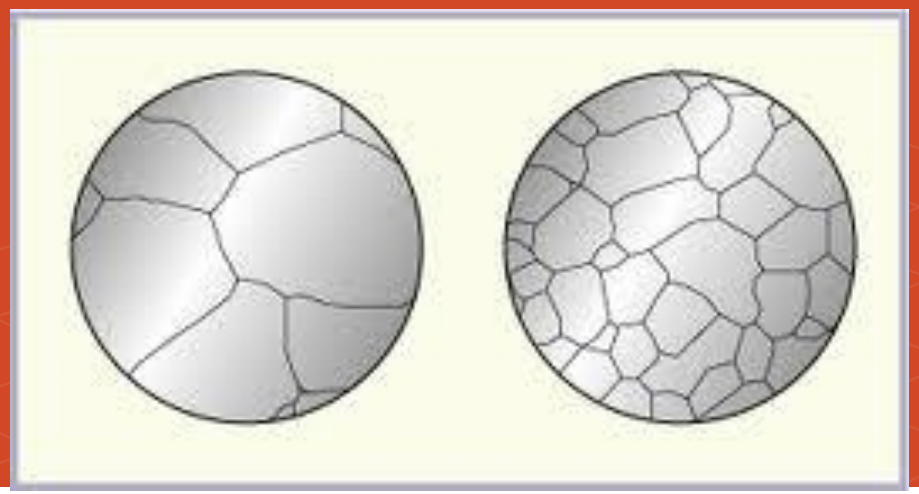
The Variation of Radon Exhalation Rate with Radon Concentration



There is a good correlation between radon concentration and radon exhalation rate

Factors Affecting Radon Concentration, Exhalation and Emanation Rates

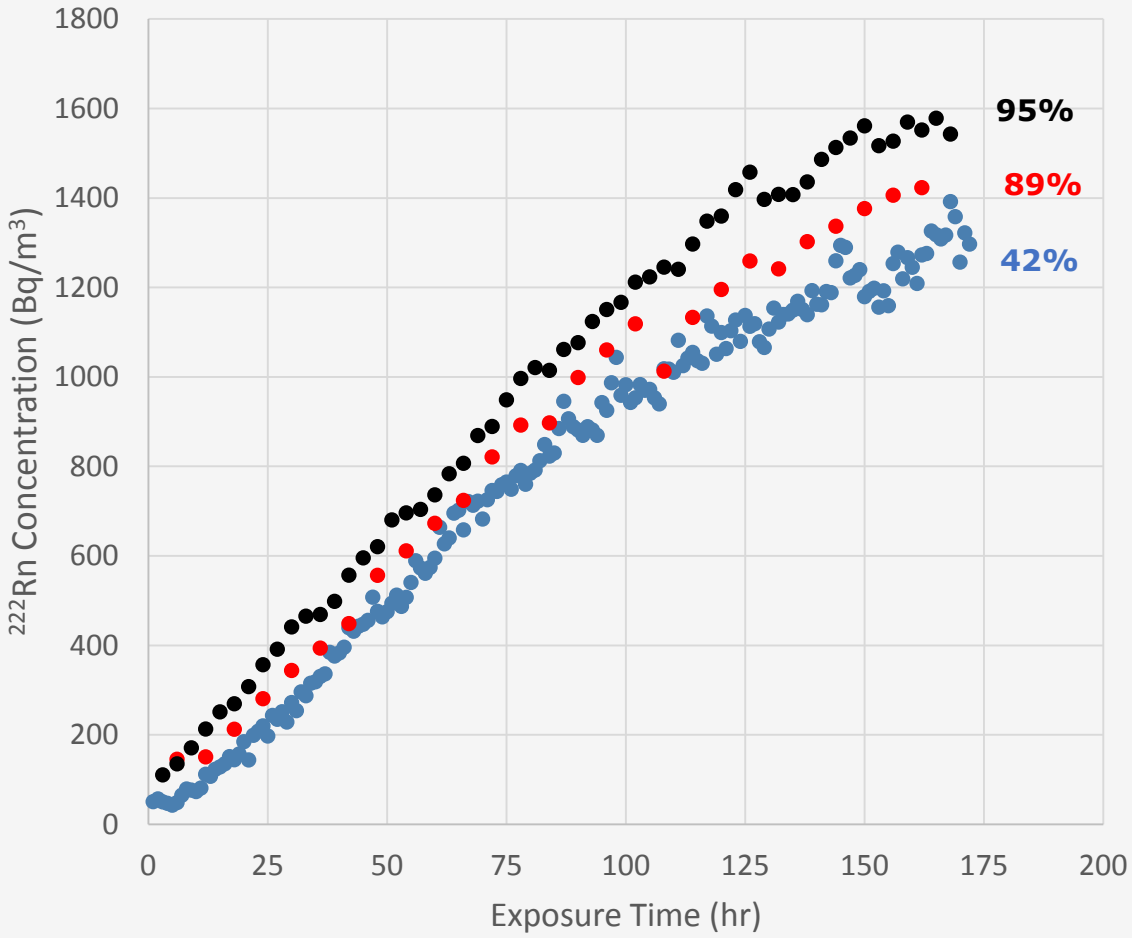




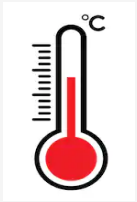
Effect of Relative Humidity

Humidity %	Rn conc. Bq/m³	Ex. Bq/m²hr	Em. Bq/m²hr
42	1382.48	2.95	41.40
89	1423.11	3.06	42.11
95	1578.31	3.46	42.96

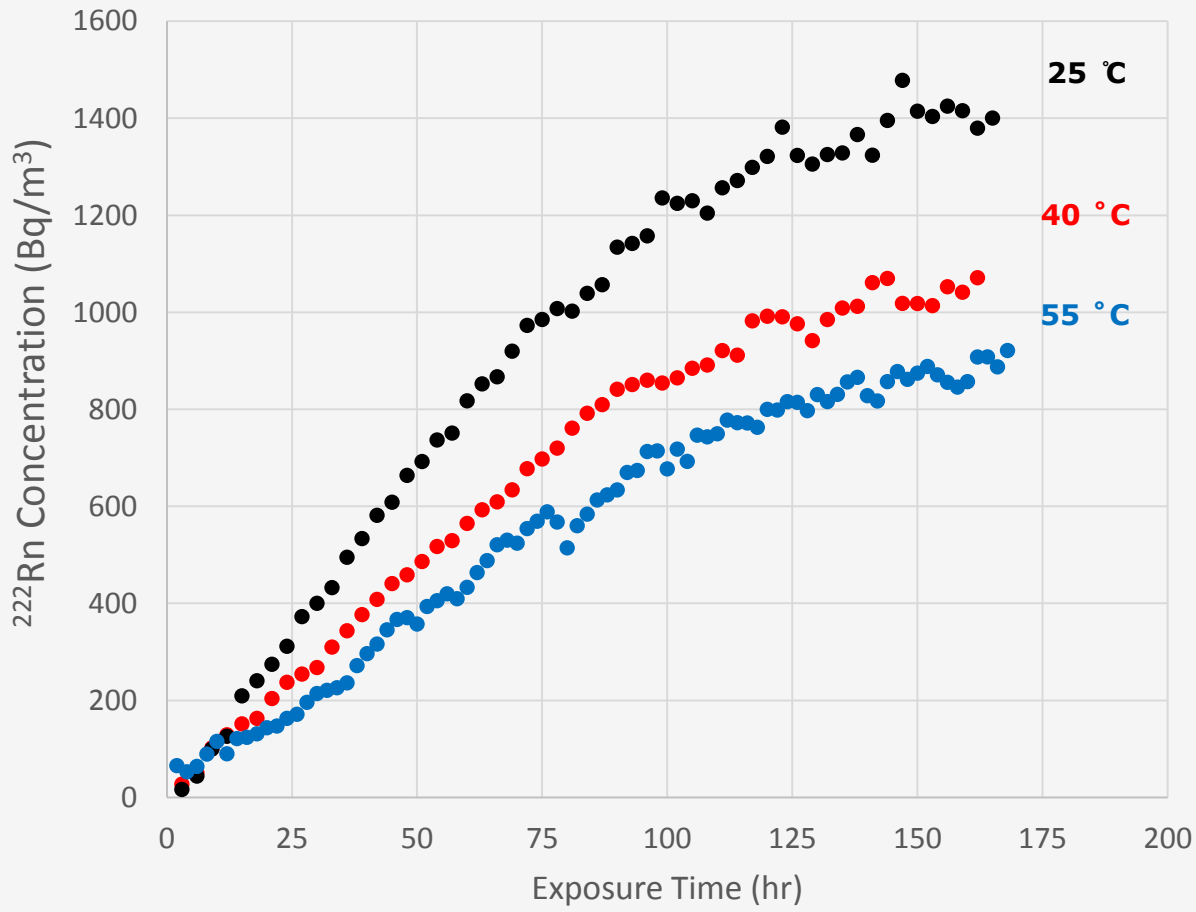
- An increase in the amount of water in the pore spaces increases the probability of capturing radon atoms in pore spaces and <u>not be reabsorbed by other grains</u>



Effect of Temperature



Temp. In ˚C	Temp. out ˚C	Rn conc. Bq/m³	Ex. Bq/m²hr	Em. Bq/m²hr
25	**22 – 24**	1478.13	3.63	9.02
40	**25 – 27**	1071.27	2.63	5.80
55	**26 - 29**	921.21	2.26	4.25



This phenomenon may be due to:

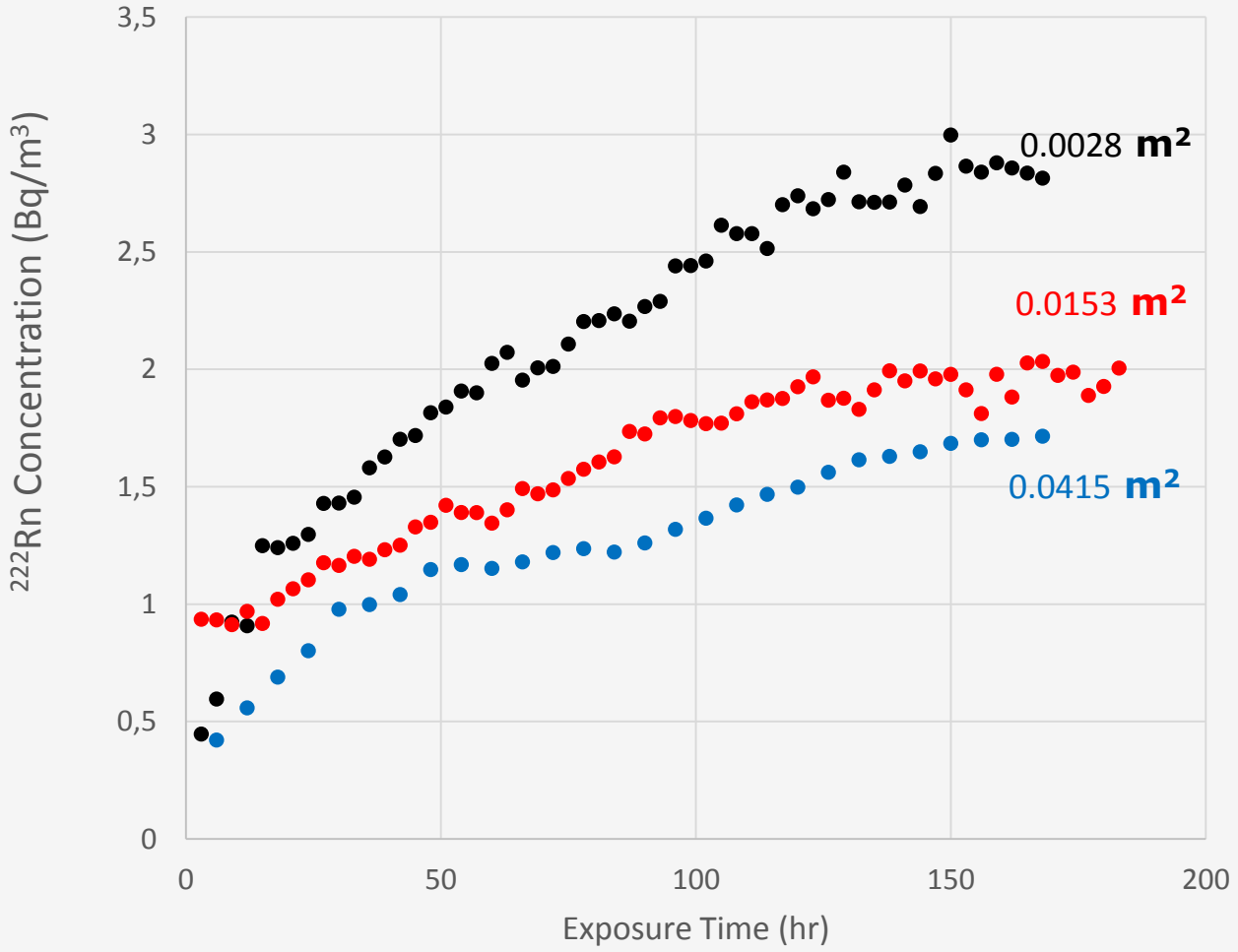
- The humidity decrease with increasing temperature.
- when temperature inside the chamber is higher than the outdoor; the warm air with low radon concentration may flows outside.

Effect of Sample Surface Area

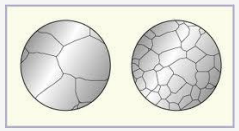
Exposure surface area (m^2)	Rn conc. Bq/m^3	Ex. Bq/m^2hr	Em. Bq/m^2hr
0.0028	1367.70	2.78	201.44
0.0153	977.26	1.96	18.04
0.0415	820.29	1.64	4.59

$$E_x = \frac{C(t)\ V\lambda}{A(1 - e^{-\lambda t})}$$

$$E_o = \left(M_e - \frac{q}{V}C_o\right)\frac{V}{A}$$

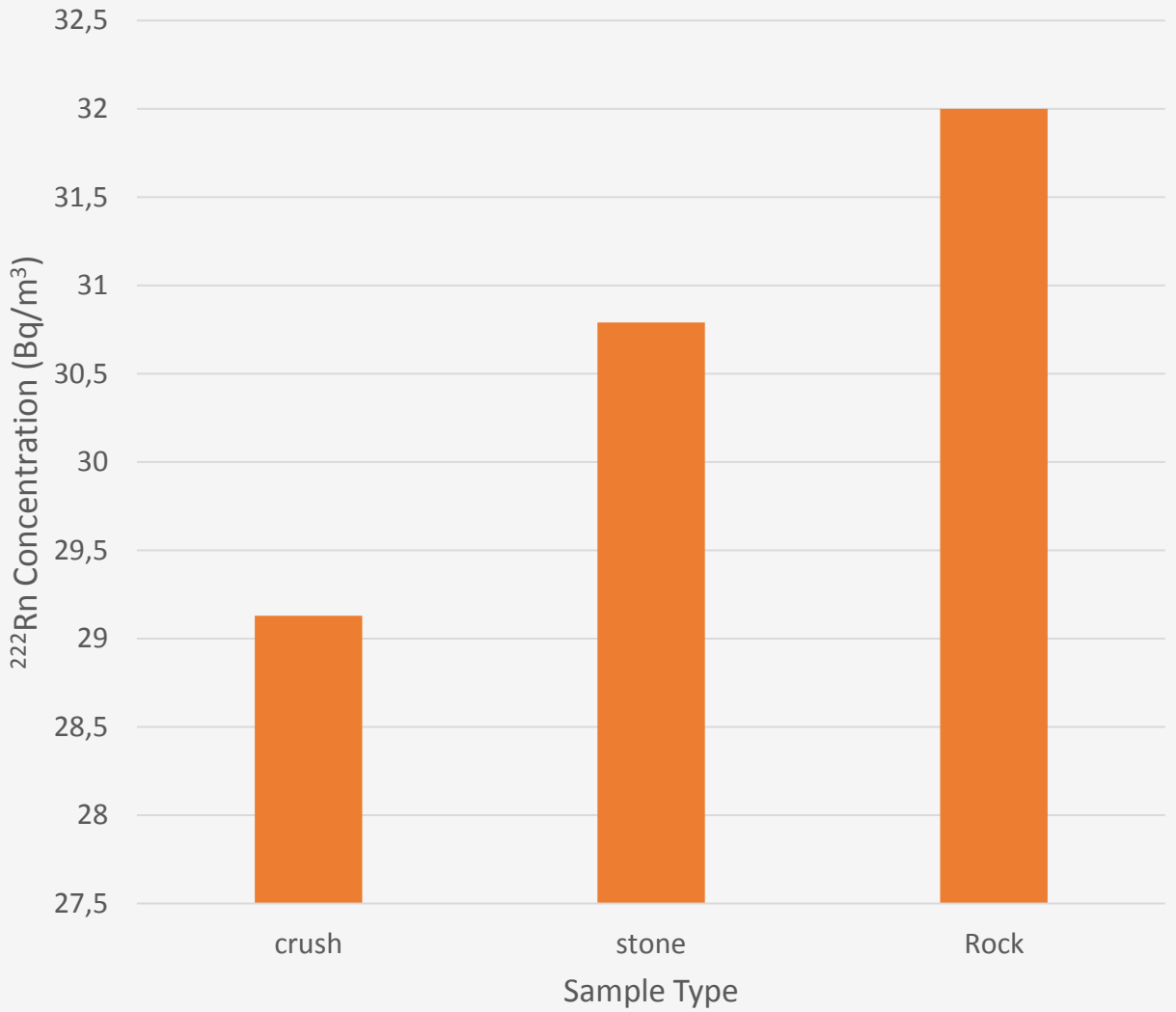


Effect of Grain Size



Grains form	Rn conc. Bq/m³	Ex. Bq/m²hr	Em. Bq/m²hr
Rock (> 2cm)	**32.00**	**0.29**	**8.14**
Stone (2cm - 5mm)	**30.79**	**0.22**	**9.09**
Crushed (< 2mm)	**29.13**	**0.20**	**10.06**

- The increase in pore space between grains allow radon to diffuse.



Thank you!

Friedrich Ernst Dorn
(1848 -1916)