Effects of radon background variations on measurements of Ra-226 through its progeny

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NKS GammaUser, 07.10.2014

Statens strålevern
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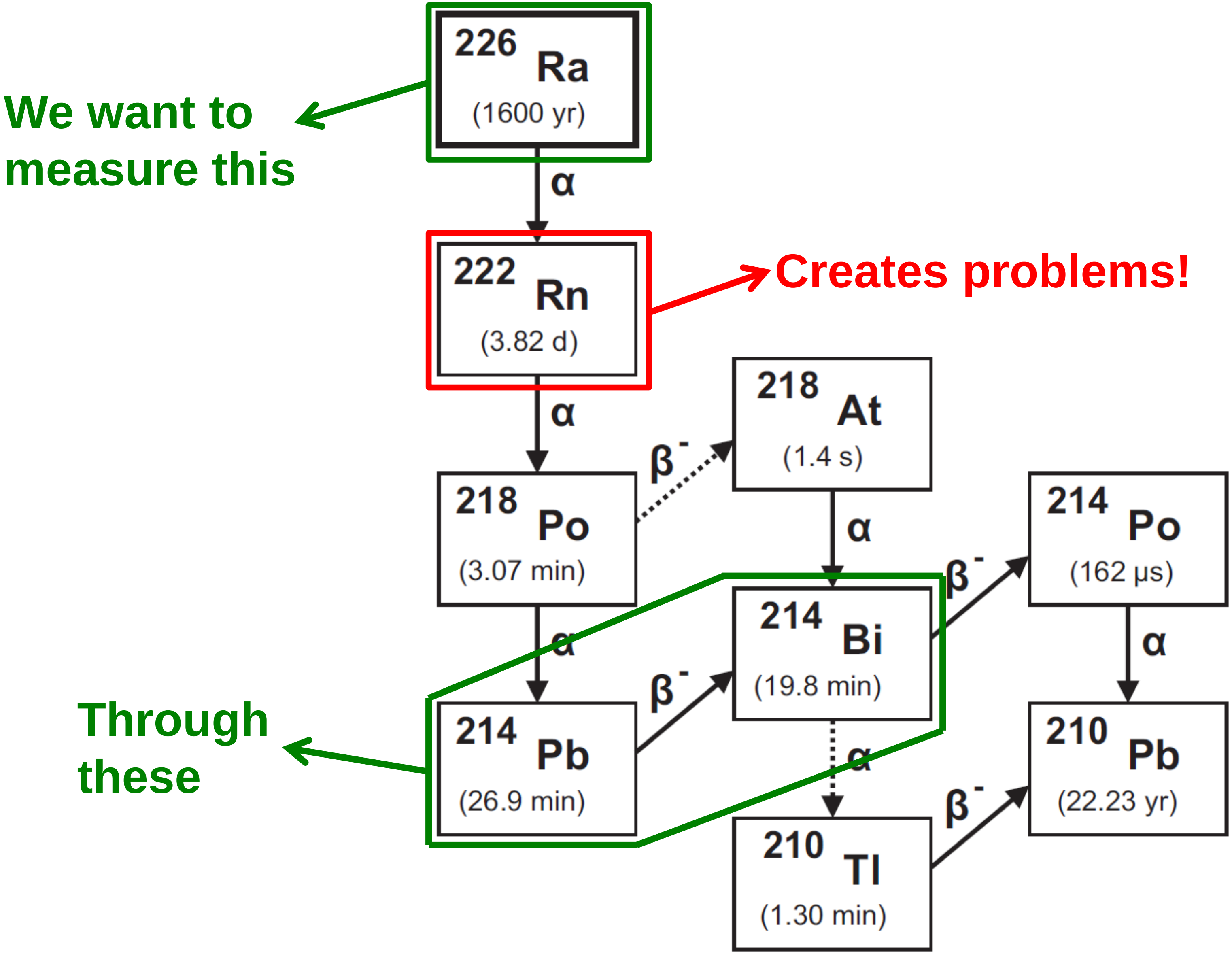
Measuring Ra-226 by gamma spec

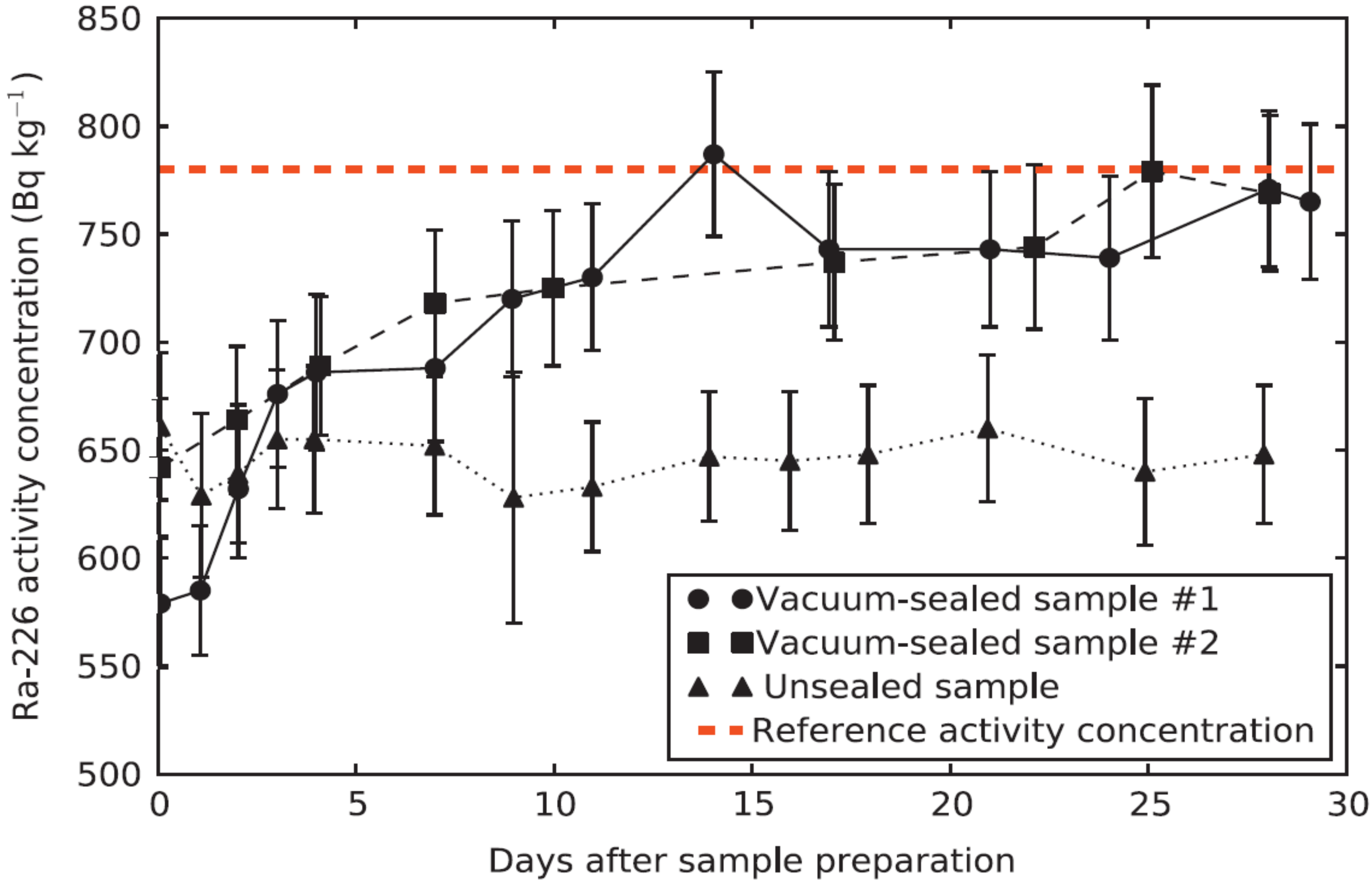


Sample preparation

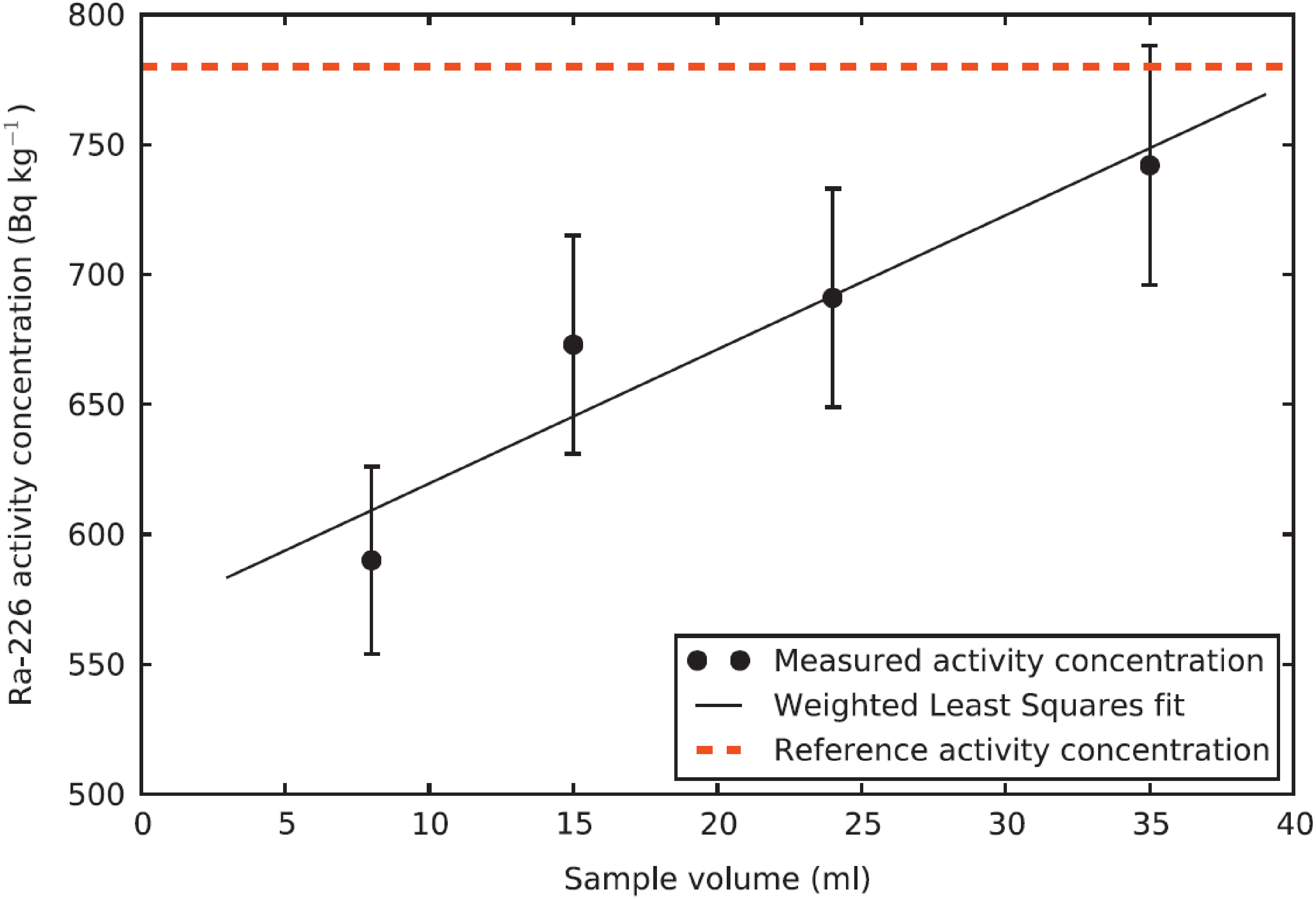
Minimum 21 day build-up period for secular equilibrium

Measurement on HPGe detector for appropriate time period

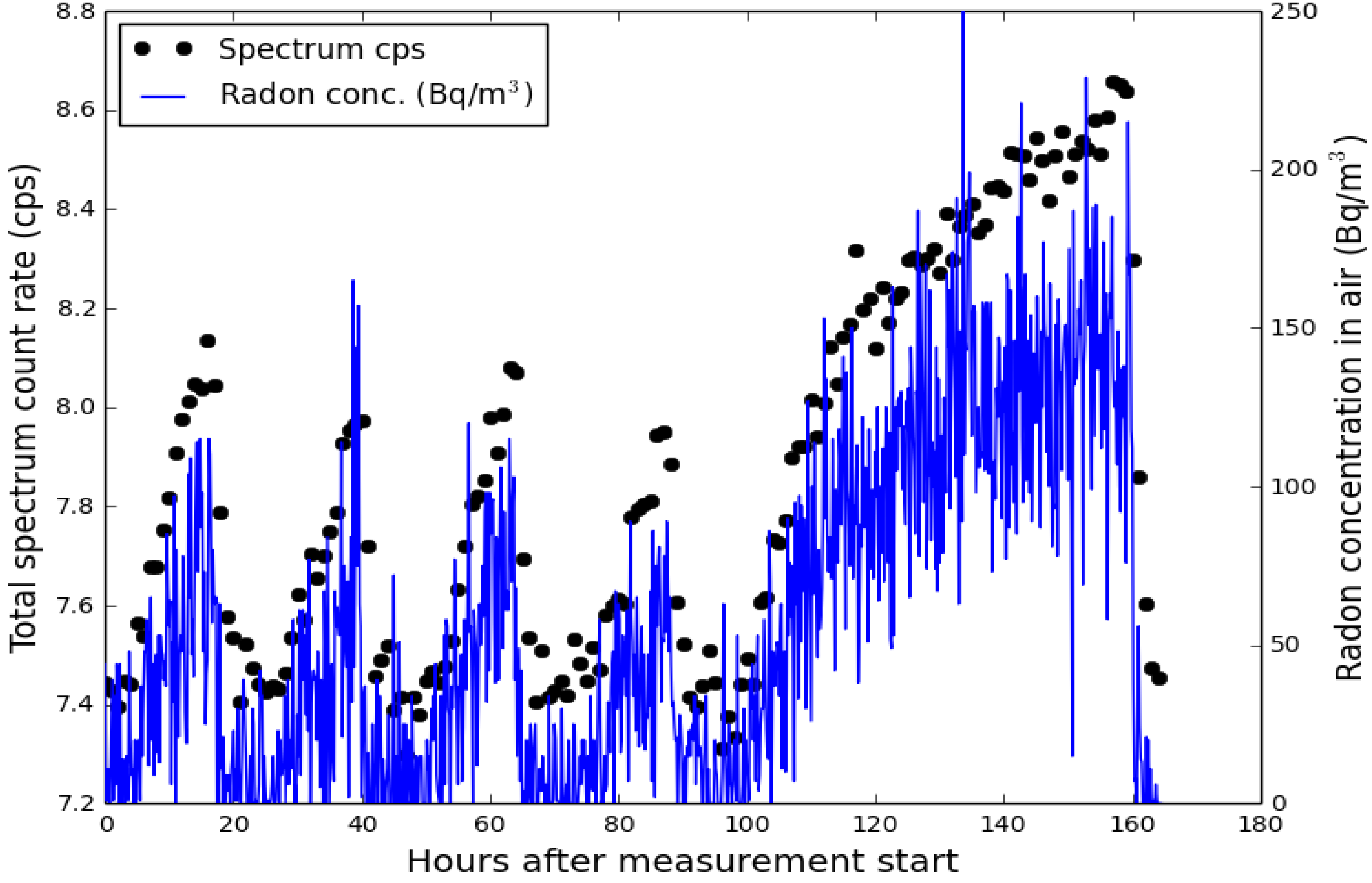
Secular equilibrium



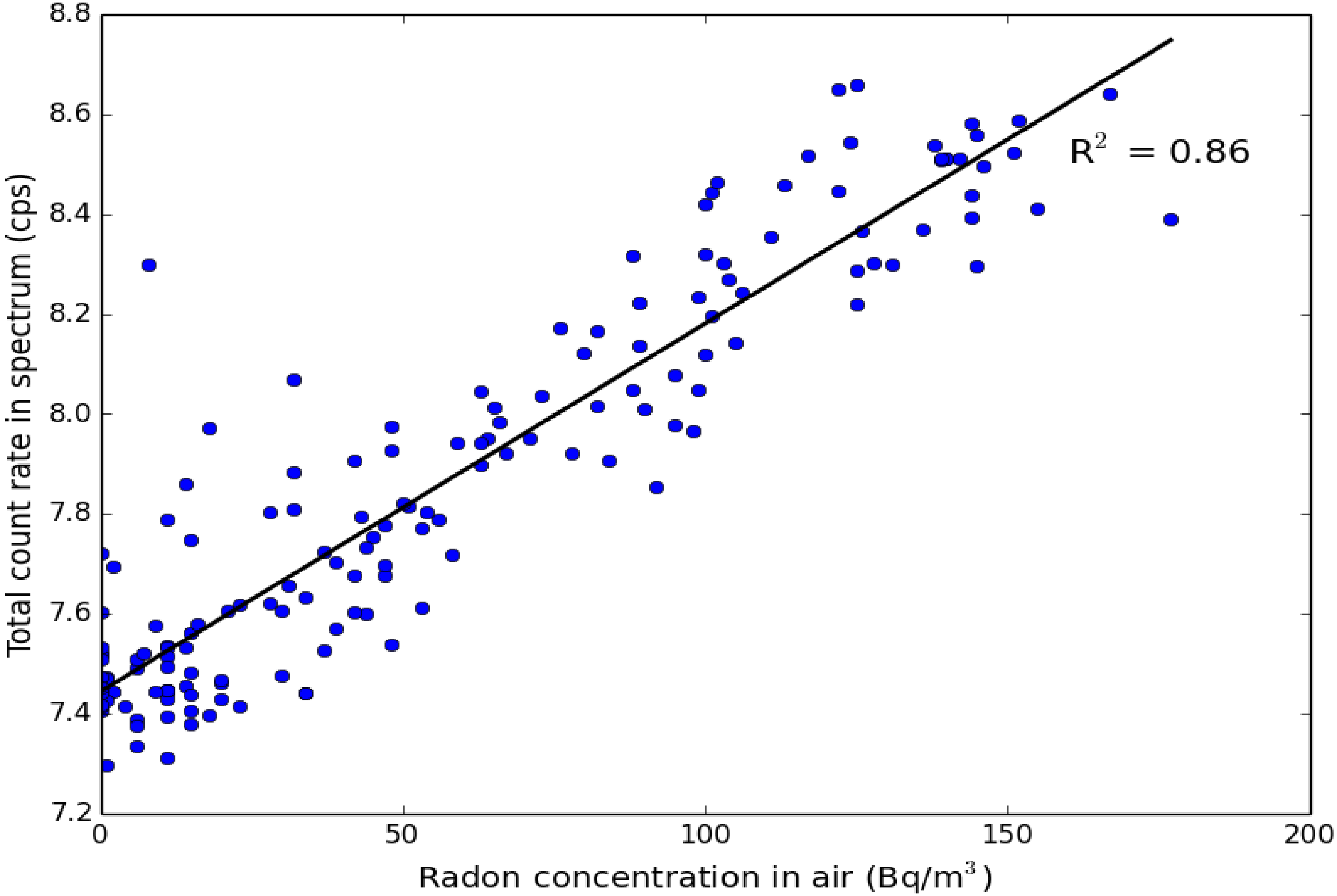
Full beakers only!



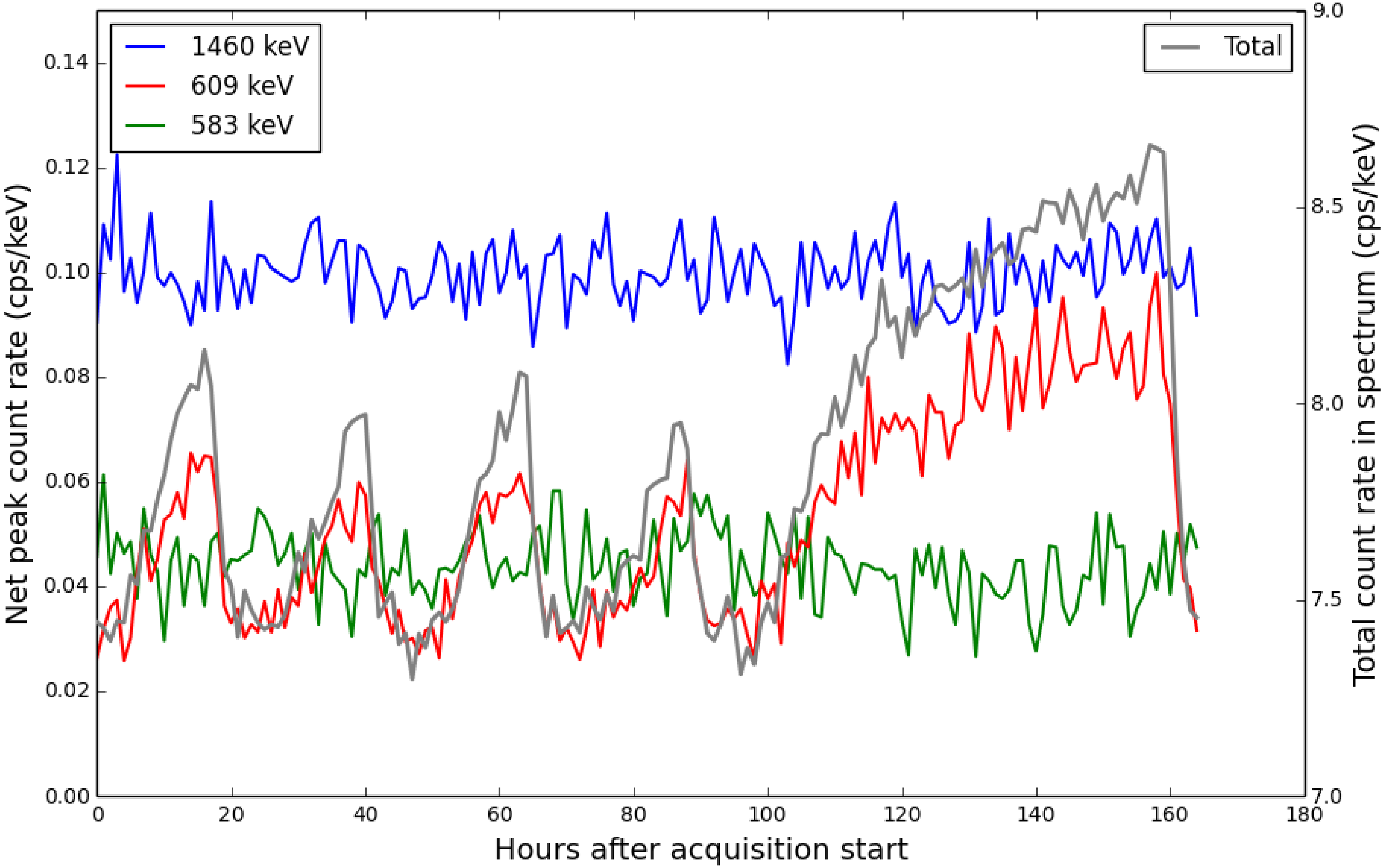
Variations in spectrum background



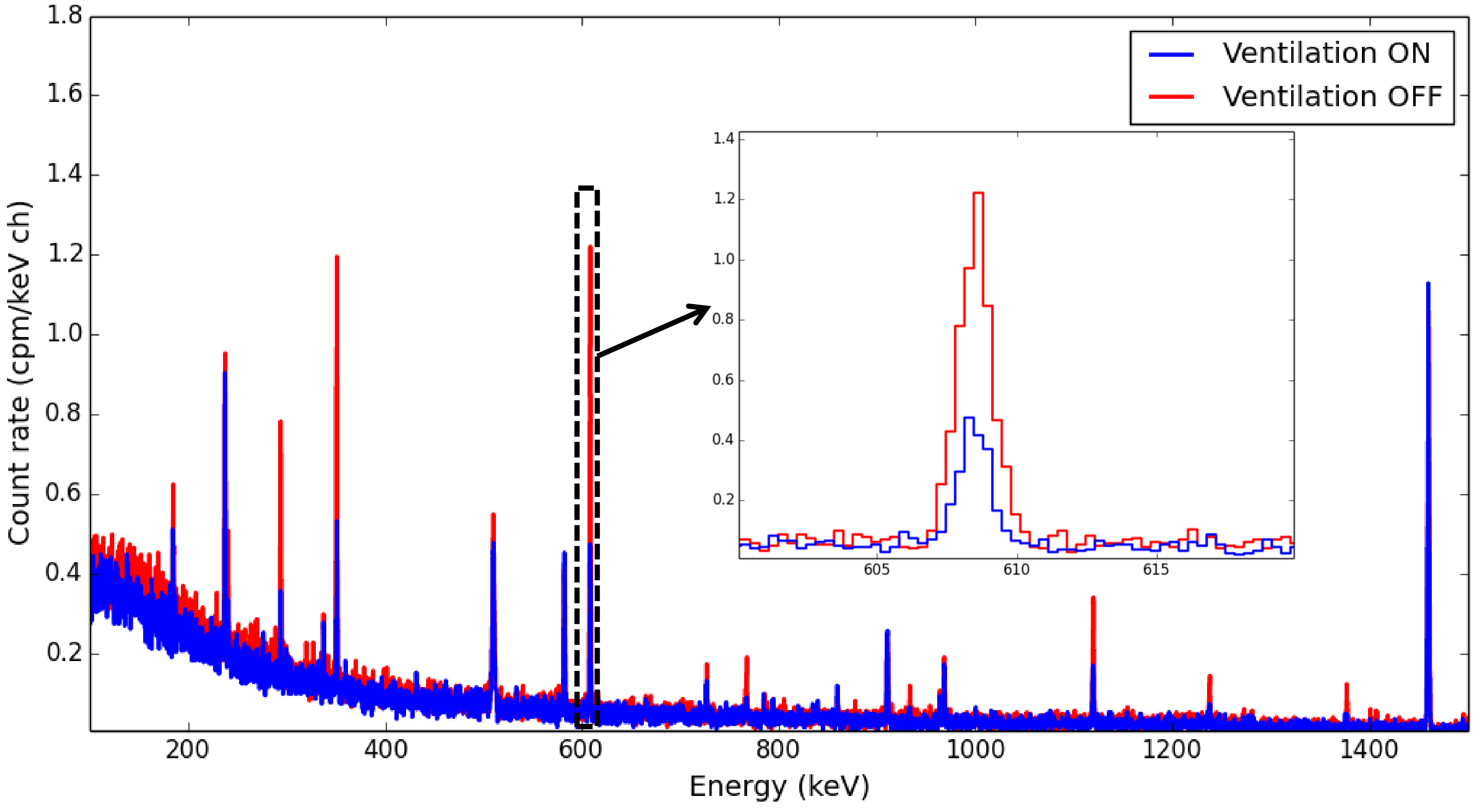
Correlation to radon levels



Variation of specific peaks



Background spectrum



«Case study»

- 300 sediment samples:
  - Sample mass 10-25 g
  - Ra-226 activity 15-30 Bq/kg

- 609 keV peak sample count rate: **~0.3-0.7 cpm**
- 609 keV peak background count rate: **~0.2-0.6 cpm**

- Large errors (30-200%) introduced when using inappropriate background corrections not considering temporal variation

Impact on MDA

- IAEA 385 Irish sea sediment
  - Ra-226 activity: 21.6-22.4 Bq/kg

Spectrum #	Nuclide	MDA (Bq/kg), Background ventilation off	MDA (Bq/kg), Background ventilation on	Ratio
1	^{214}Pb	2.8	2.2	1.3
	^{214}Bi	3.2	2.5	1.3
2	^{214}Pb	2.2	1.5	1.5
	^{214}Bi	2.3	1.6	1.4
3	^{214}Pb	4.2	2.6	1.6
	^{214}Bi	4.6	3.0	1.5

Solutions?

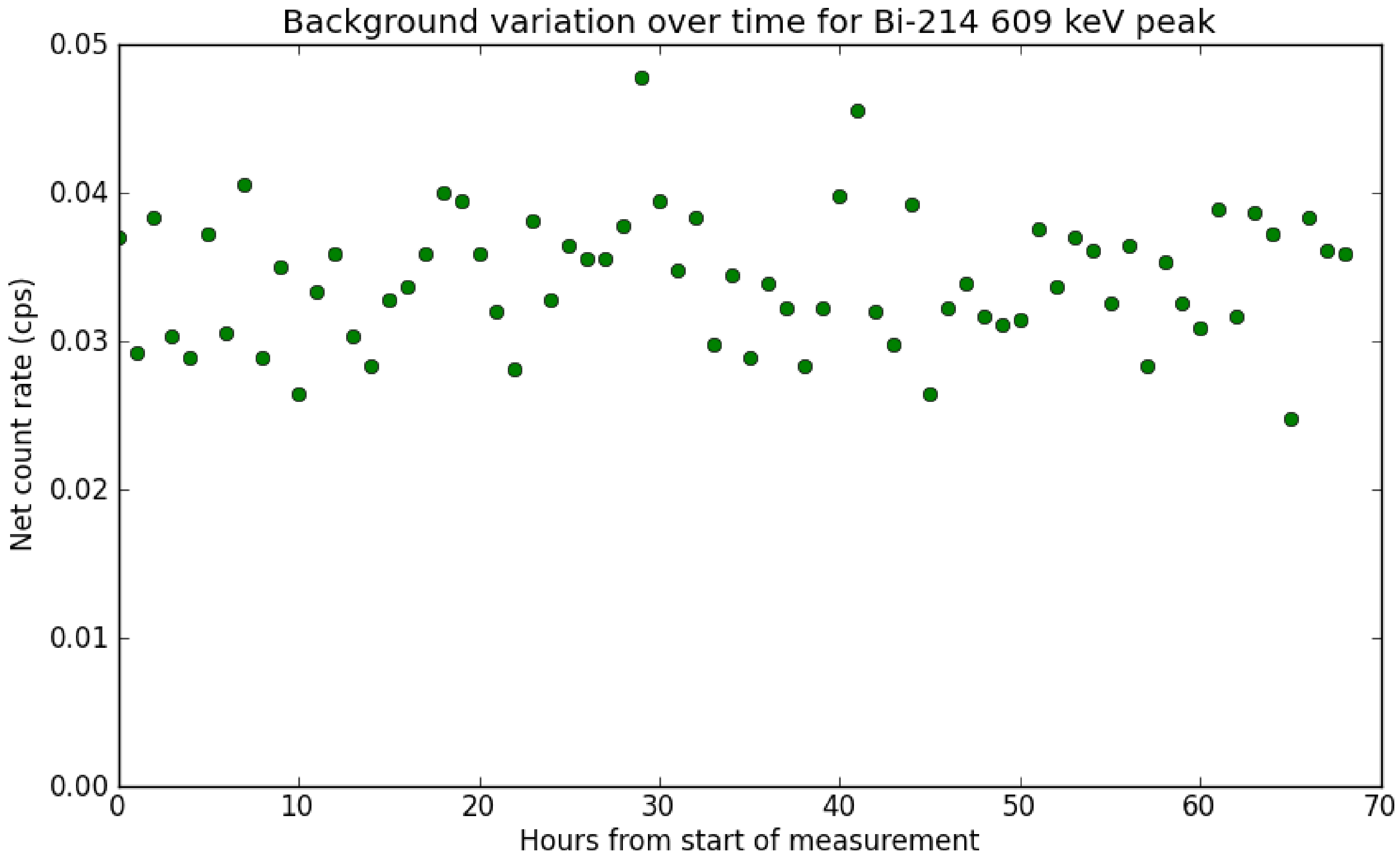
- ~~Solution 1: Background spectrum taken over excactly the same time period as measurement.~~

- ~~Solution 2: N_2 flushing of lead castle.~~

- ~~Solution 3: Using a HPGe detector or Atmos for continuous monitoring of background radon level in lab and making a post-measurement correction.~~

- Solution 4: Convince building supervisor/janitor to leave ventilation on 24/7.

Success!


Background variation over time for Bi-214 609 keV peak
Net count rate (cps)
0.00
0.01
0.02
0.03
0.04
0.05
0
10
20
30
40
50
60
70
Hours from start of measurement

Reference material measurements

- IAEA 385 – Irish sea sediment, 50 % coaxial p-type detector

Nuclide	Measured activity (Bq/kg)	Reference activity (Bq/kg)	Deviation	Z-score
K-40	559 ± 56	607 (604-612)	-7.9 %	1.75
Ra-226	22.8 ± 2.2	21.9 (21.6-22.4)	+4.1 %	0.72
Ra-228	32.8 ± 3.4	32.0 (31.3-32.5)	+2.5 %	0.52

- IAEA 385 – Irish sea sediment, 40 % coaxial p-type detector

Nuclide	Measured activity (Bq/kg)	Reference activity (Bq/kg)	Deviation	Z-score
K-40	586 ± 58	607 (604-612)	-3.0 %	0.76
Ra-226	21.3 ± 2.2	21.9 (21.6-22.4)	-2.7 %	0.63
Ra-228	32.3 ± 3.2	32.0 (31.3-32.5)	+0.9 %	0.25

Conclusion:

Accurate analysis of Ra-226 through its progeny is possible!

- Full sample beaker, isolated for Rn escape
- 3 week build-up period for secular equilibrium
- Well-determined laboratory background levels
- Corrections for sample geometry, coincidence summing etc.
- Consider spectral interferences

Thank you for your attention!

References:

Alexander Mauring, Torbjörn Gäfvert, Thomas Bandur Aleksandersen, 2014. **Implications for analysis of ^{226}Ra in a low-level gamma spectrometry laboratory due to variations in radon background levels**, Applied Radiation and Isotopes 94, 54-59.

Alexander Mauring, Torbjörn Gäfvert, 2013. **Radon tightness of different sample sealing methods for gamma spectrometric measurements of ^{226}Ra**, Applied Radiation and Isotopes 81, 92-95.

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Implications for analysis of ^{226}Ra in a low-level gamma spectrometry laboratory due to variations in radon background levels

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H I G H L I G H T S

- Effects of temporal radon variations in a gamma spectrometry laboratory have been studied.
- Measurements of ^{226}Ra from its progeny may be significantly disturbed.
- For a case of low-level sediments, errors of more than 100% are observed.
- Minimum detectable activities may be over- or underestimated by 30–60%.
- Accurate background determination is crucial to avoid measurement errors.

A R T I C L E I N F O

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Systematic effects

A B S T R A C T

The background spectrum of HPGe detectors is found to vary significantly as function of the radon concentration in the air surrounding it, especially with regard to the count rates of ^{222}Rn daughter peaks. This effect is shown to potentially have a large impact on measured values of radon daughter activity concentration, as well as detection limits for low-level measurements. As these radionuclides are commonly used for estimating the activity of ^{226}Ra, care needs to be taken to ensure that background levels are accurately determined.

1. Introduction

Radium is an important radionuclide to consider in environmental radiation protection due to its prevalence in nature and high radiotoxicity. Accurately determining its activity levels in environmental samples is therefore of significant interest. High resolution gamma spectrometry is frequently used for assessing the concentration of radium isotopes in environmental matrices due to its quick and non-destructive nature. However, for the case of ^{226}Ra challenges arise when attempting to measure it directly due to the interference from ^{235}U to its only measurable photopeak at 186 keV; an issue that is often not easily resolved without having good knowledge of uranium levels in the sample (Dowdall et al., 2004). Instead, ^{226}Ra is therefore often determined through its progeny (typically non-interfering peaks of ^{214}Bi and ^{214}Pb) after assuming radioactive equilibrium in the decay chain. The process is further complicated by the presence of the noble gas ^{222}Rn as part of this radioactive decay chain (see Fig. 1) as it may emanate out of the sample material and container, changing the effective measurement geometry, prompting gas tight measurement beakers to be used for this purpose.

One of the primary components to the background spectrum of a HPGe detector arises from radon and its daughters, in addition to cosmic radiation and the intrinsic radioactivity of the detector and building materials surrounding it (Núñez-Lagos and Virto, 1996). As radon is a noble gas, it may permeate any detector shielding that is not completely gas tight and subsequently decay through the rest of the decay chain, emitting photons that may be registered in the spectrum, thus affecting peak count rates. While peaked background corrections are included in all commonly available gamma spectrometry analysis software packages, these corrections do not consider the fact that the radon background level of the laboratory may vary both in the short term as well as in the long term. In particular, the presence or absence of

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