NAREL Standard Operating Procedure for Using the Ludlum Alpha/Beta System to Determine α and β Exposure from Radioisotopes carried on Airborne Dust.

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1.0 PURPOSE

This document's *raison d'être* is to detail the case for creating an ancillary protocol for the RadNet monitoring stations.

1.1 SCOPE

This document describes how an operator may determine the radioactivity due to the short lived isotopes carried on airborne dust particles.

1.2 General Comments

1.2.1 Motivation

The small time commitment required of the EPA's Standard Operating Procedure lowered the barrier for several students to volunteer in the shared responsibility for running the RadNet station at the University of Nebraska, Kearney. During the typical routine the:

Operator:

1. retrieves the filter from the air monitoring station, and records information from station's computer display.
2. places the filter in the sample tray and leaves it for five or more hours.
3. records the results of four measurements using the equipment provided.
4. completes some record keeping tasks.
5. packages and posts the filter with its data sheet to the EPA.

However as time went on the students wanted to know more about the "meaning" of the data being collected.

This motivated the development of this ancillary procedure for using the Ludlum Alpha/Beta System as a dosimeter to determine the airborne component of our exposure to short lived radioisotopes.

1.2.2 Limitations

1.2.2.1 Empirical versus Analytical

The intent of this protocol is to produce an identifiable quantity to be compared with a convenient established benchmark.

In response to the Indoor Radon Abatement Act of 1988, the EPA established an "action limit" of 4000 pCi/m^3 for radon mitigation.

The reporting of a measurement relative to a standard is characteristic of dosimetry rather than analysis. Therefore the resulting reports carry the title, "**Air Dosimetry Report**".

The fitting routine of section 2.7 is not intended to suggest an identification of isotopes in the sample. The information is only useful for determining the approximate rate radioactivity accumulates on the air filter during a collection cycle.

Appendix III on page 15 contains additional comments regarding the approximations used in this evaluation procedure.

1.2.2.2 Operator Commitment

The extant RadNet protocol requires little of the monitoring station operators with respect to understanding the science. As stated above (in section 1.2.1) the established protocol requires a small time commitment from the operators.

1. This ancillary protocol requires attention to data taking details spanning about five hours (or more) on each of two days per week.
2. The operator must be conversant with details of curve fitting.
3. The operator must be aware of the idiosyncrasies of data generated by stochastic processes.

Only appropriately motivated and qualified operators should consider implementing this protocol.

1.2.2.3 Equipment

Special attention to detail (See section 2.5 page 4) is needed to insure reliable data while using the Ludlum Alpha/Beta System for assessing the activity of short lived radioisotopes captured on filters by the RadNet air sample systems.

2.0 Data Acquisition

2.1 Purpose

This section provides instructions intended to insure consistency in determining the activity of short lived isotopes among RadNet air samples collected during each sample collection interval.

2.2 Scope and Application

This section describes the procedures for using the Ludlum Alpha/Beta System for performing gross alpha and beta counts of RadNet air filters. It is to be used by RadNet air sample collectors to count air filters during the five hours following each sample collection interval. This procedure is only applicable to Ludlum instruments that have been calibrated in accordance with the NAREL Standard Operating Procedure for Calibration of the Ludlum Alpha/Beta System (FMM/SOP-11); it cannot be used with instruments calibrated at the factory by Ludlum Measurements, Inc.

2.3 Equipment and Supplies

2.3.1 Ludlum Model 2241-2 Survey Meter (aka the Scaler).

2.3.2 Ludlum Model 43-1-1 Scintillator (aka the Detector).

2.3.3 Air Dosimetry Data Sheet.

2.3.4 Two sample dishes, one holding a clean filter.

2.3.5 Digital clock synchronized to a UTC signal.

2.4 Retrieving Filter from Air Sampler

Retrieve the **filter to be counted** from the air sampler following the procedure detailed in RadNet/SOP-13 with **the following addendum**:

Use the UTC time to:
Record to the **nearest minute** the time (t_{stop}) the air sampler **air flow stops**.

2.5 Scaler Counting Time

The Scaler is programmed to provide two (2) second updates while performing a one (1) minute count. This is the normal operating mode for counting scintillation events in the Detector due to alpha/beta and alpha particles emanating from the RadNet air filters. The alpha/beta to alpha settings are switch selectable involving an automatic self-checking routine which further constrains how rapidly data can be collected.

The exponential curves have a large initial slope that becomes much smaller over the five hour measurement cycle. Therefore, ideally, the filter's activity should be sampled frequently during the first part of the measurement cycle.

As the "counts" become smaller the relative precision ($n \pm \sqrt{n} = n\,[1 \pm 1/\sqrt{n}\,]$) diminishes, and a less frequent sampling schedule becomes desirable.

The first column of the **Air Dosimetry Data Sheet** suggests a schedule for the sequence of measurements detailed in section 2.6. The result is shown graphically on pages 3, and 4 of **20140718Report.pdf**.

2.6 Counting Air Filter to determine the α, and β activity from Short Lived Isotopes

These measurements should begin as soon as possible after the filter is removed from the air sampler. Place the filter to be counted in the empty sample dish.

2.6.1 Ensure that the **Det 1/Det 2** toggle switch is in the **Det 2** position for counting alpha plus beta particles emanating from the filter.

2.6.2 Place the scintillator face over the dish containing the **filter to be counted**. Initiate a one (1) minute count for counting **combined alpha/beta** with **Off/Ratemeter/Scaler** rotary switch in the **Scaler** position and depressing the **Count** switch located in the carrying handle.

2.6.3 When the instrument has completed counting, record the displayed **COUNTS** in the (α, β) column of the **Air Dosimetry Data Sheet**.

2.6.4 Ensure that the **Det 1/Det 2** toggle switch is in the **Det 1** position for counting only the alpha particles emanating from the filter.

2.6.5 Initiate a one (1) minute count for counting **alpha** with **Off/Ratemeter/Scaler** rotary switch in the **Scaler** position and depressing the **Count** switch located in the carrying handle.

2.6.6 Record to the **nearest minute** the time in the (t) column of the **Air Dosimetry Data Sheet**.

2.6.7 When the instrument has completed counting, record the displayed **COUNTS** in the (α) column of the **Air Dosimetry Data Sheet**.

2.6.8 Carefully place the scintillator face over the dish containing the **clean filter**.

2.6.9 Ensure that the **Det 1/Det 2** toggle switch is in the **Det 2** position for counting alpha plus beta particles emanating from the filter. Initiate a one (1) minute count for counting **combined alpha/beta** with **Off/Ratemeter/Scaler** rotary switch in the **Scaler** position and depressing the **Count** switch located in the carrying handle.

2.6.10 When the instrument has completed counting, record the displayed **COUNTS** in the **(CFC)** column of the **Air Dosimetry Data Sheet**.

2.6.11 Turn the **Off/Ratemeter/Scaler** rotary switch in the center of the instrument to the **OFF** position.

Repeat the sequence from 2.6.1 to 2.6.11 to complete at least ten (10) rows of date on the **Air Dosimetry Data Sheet**.

If the klaxon sounds:
The Ludlum Model 2241-2 Survey Meter is preset by the EPA to sound an alarm if the count is too large. From the Technical Manual, "In an alarm condition (ratemeter or scaler), depressing RESET will silence the audible alarm."

If this happens, complete only the steps needed to record the displayed **COUNTS** in the (α, β) , and (α) columns of the **Air Dosimetry Data Sheet**. Repeat the readings on a ten minute schedule until the alarm no longer sounds. Then complete the schedule using the timing pattern starting at the ($\approx$ +00:10) row.

Back fill the (CFC) column with the average of the (CFC) values already recorded.
Do not use these data points in the analysis described in **section 2.7**.
If the klaxon sounds:

Complete the calculations as indicated on **Air Dosimetry Data Sheet** to fill <u>all columns</u> of the data sheet.

Refer to section 6.5.4 of FMM/SOP-10 and use more than one **Air Dosimetry Data Sheet** if needed.

2.7 Calculate the α, and β activity of Short Lived Isotopes

For a given air sample the number of α (and/or β) emitting isotopes decreases over time:

$$\mathcal{N} = (\mathcal{N}_{t=0})\, e^{-\lambda t} \tag{2.7.1}$$

Defining activity as $\mathcal{A} \equiv -d\mathcal{N}/dt$, it is easy to show that the activity decreases over time:

$$\mathcal{A} = (\mathcal{A}_{t=0})\, e^{-\lambda t} \text{ , where , } \mathcal{A} = \lambda\mathcal{N} \tag{2.7.2}$$

A single exponential function does not provide a good fit to the data collected as per section 2.6. A four parameter fit (linear combination of two exponents) seems to suffice.

Use a curve fitting routine:

1. online example: http://zunzun.com/
2. local example: KaleidaGraph

to fit the α, and β data each to a linear combination of two exponentials.

$$\mathcal{A} = \mathcal{A}_1 e^{-\lambda_1 t} + \mathcal{A}_2 e^{-\lambda_2 t} \tag{2.7.3}$$

α **fit**

Plot (α Act. in pCi) versus ($t - t_{\text{stop}}$) of the **Air Dosimetry Data Sheet**

β **fit**

Plot (β Act. in pCi) versus ($t - t_{\text{stop}}$) of the **Air Dosimetry Data Sheet**

All lambda values must be positive. If needed weight the data to emphasize the earlier data. The sketch provides a visual confirmation that the fit is reasonable.

The various $\mathcal{A}_i$ represent the activities at the moment the sampler's **air flow stops**. For each component, approximate the dust accumulation rate as a constant, therefore the the activity of each component of radiation on the filter is given by the differential equation:

$$\frac{d\mathcal{A}}{dt} = \mathcal{R} - \lambda\mathcal{A}e^{-\lambda t} \tag{2.7.4}$$

Solving this differential equation allows us to determine, $\mathcal{R}$, the rate of deposition for each of the components of radiation while the filter was in the RadNet air sample system. The equation:

$$\mathcal{R} = \left\{ \frac{\lambda\mathcal{A}}{(1 - e^{-\lambda t})} \right\} \Bigg|_{t=t_{\text{stop}}} \tag{2.7.5}$$

produces $\mathcal{R}$ in (pCi/hr). Multiplying by (sample time/sample volume) gives the radiation concentration (pCi/m^3) for the sample cycle.

3.0 Concluding Remarks

This procedure has produced radiation concentration values consistent with the oft-quoted 400 pCi/m^3. As expected the radiation concentration, as determined by this procedure, is exceptionally variable.

The addition of Air Flow monitoring equipment to produce a “wind rose” during each sample cycle might provide valuable insight into the origins of the radiation carried on airborne dust.

We in the USA are not doing as well as we should with respect to our STEM curricula at all levels of education. RadNet site specific projects could provide an opportunity to develop Citizen Science Projects. These projects would be particularly valuable if they were designed to be multidisciplinary. Kearney, NE is rich with opportunities in this regard.

Kearney is surrounded by a large agricultural region. Variation in dust levels should correlate with agricultural activity. Radiation levels in the dust should depend upon the types of agricultural practices.

The Union Pacific Railroad operates a major transportation corridor less than 700 meters south of the EPA’s stationary Air Monitoring Station. A very large number of Wyoming Coal cars pass along these tracks daily. Everybody should know coal contains uranium

(see *e.g.*, http://www.epa.gov/radiation/tenorm/coalandcoalash.html)

and its concomitant radon daughter isotopes. Radiation levels determined by this process should depend upon the ebb and flow of Wyoming being transferred eastward along this heavily used transportation corridor. Certainly other EPA Air Monitoring Stations are operating in equally interesting environments. Even more intriguing: The RadNet protocol itself practically demands I develop this ancillary protocol.

Quoting the RadNet Document: FMM/SOP-10

> **Section 6.4 Counting Filters**
> NOTE: Filters should not be counted until at least five hours after removal from the air sampler, to allow time for decay of interfering radon daughter isotopes.
>
> **Section 6.5 Preliminary Results Evaluation**
> If the β CONCENTRATION exceeds 1 pCi/m^3 or the α CONCENTRATION exceeds 0.7 pCi/m^3, wait 30 minutes and count the filter again. If the activity on the second count is about half of the activity on the first count, then it is probably due primarily to unusually high ambient radon concentrations and no further action is required. If there is no significant decrease in the activity after one hour, contact the RadNet program Manager for instructions.

The EPA's disinterest in the short lived isotopes is emphasized in (2.) of the **Guide for Counting Air Filters (to accompany FMM/SOP-10)**

> 2. Wait at least 5 hours after removing an air filter from the RadNet air monitor before counting the filter (counting the day after removing the filter is OK).

Short lived isotopes have a higher specific activity than long lived isotopes. See equation (2.7.2) and notice that large λ corresponds to short lived.

The "interfering radon daughter isotopes." comment convinced me to more fully explore the transient radiation in the dust sampled by the EPA's air sampler. Short lived isotopes never survive to get to the EPA laboratory, therefore "interfering" might be an appropriate adjective for "radon daughter isotopes" from the point of view of the EPA scientists. This, however, is most certainly not the case for the EPA RadNet field operators.

As one of those EPA RadNet field operators, I am very interested in the interfering radon daughter isotopes. In fact, I would go so far as to say, I think the transient radiation is a least as important to monitor as the information extracted at EPA's laboratory.

3.1 Recommendation

> As this suggested procedure does not interfere with the EPA's SOP for Using the Ludlum Alpha/Beta System for Counting RadNet Air Filters in any substantial way, I propose it be made available to other RadNet Monitoring Station operators to be used at their discretion.

4.0 Appendices:

I Air Dosimetry Data Sheet (20140718Report.pdf)

Air Dosimetry Data

Ionizing Activity of Radon Daughter Isotopes

Filter #: 370 Station #: 724 Kearney, NE Sampled Days : 20140714 ⟶ 20140718

t_{stop} : 13:46 HH:MM (¡ Use Local Clock !) Sample time : $94.8\overline{6}$ hr Sample volume : 5691.7 m^3

	t HH:MM	(α,β) DET 2	(CFC) DET 2	Net(α,β) (α,β) − CFC	(α) DET 1	Net(β) Net(α,β) − (α)	α Act. in pCi $(\alpha)\times 1.70$	β Act. in pCi Net$(\beta)\times 1.18$	$(t - t_{stop})$ (hr)	
≈ + 00:10	13:54	24217	401	23816	2482	21334	4219.4	25174.12	$0.13\overline{3}$	
≈ + 00:20	14:05	20648	440	20208	2167	18041	3683.9	21288.38	$0.31\overline{6}$	
≈ + 00:30	14:15	17829	480	17349	1925	15424	3272.5	18200.32	$0.48\overline{3}$	
≈ + 00:45	14:30	14379	455	13924	1536	12388	2611.2	14617.84	$0.73\overline{3}$	
≈ + 01:00	14:45	11794	445	11349	1282	10067	2179.4	11879.06	$0.98\overline{3}$	
≈ + 01:20	15:05	9482	429	9053	967	8086	1643.9	9541.48	$1.31\overline{6}$	
≈ + 01:50	15:35	7535	420	7115	731	6384	1242.7	7533.12	$1.81\overline{6}$	
≈ + 02:40	16:25	5773	467	5306	568	4738	965.6	5590.84	2.65	
≈ + 03:55	17:41	4775	413	4362	427	3935	725.9	4643.30	$3.91\overline{6}$	
≈ + 05:25	19:35	4346	427	3919	418	3501	710.6	4131.18	$5.81\overline{6}$	

II 20140718Report.pdf

The next four pages include the air dosimetry report file **20140718Report.pdf**. The sample cycle for this report was from 14 July 2014 to 18 July 2014.

Unlabeled

The first page contains a summary of results. The reported value in pCi/m^3 sans context is less than helpful. The statement, "The average inhaled dose is about 400 pCi/m^3." is a bit more informative. But, as the cognoscenti know, no level of ionizing radiation can reasonably be considered safe. Comparing to the norm might generate undo alarm or complacency in readers of these reports. Noting the value relative to EPA's action level for remediation places the reported values in a proper context.

Page 2

The second page is the same for all reports.

The first section highlights the "how" of the monitoring program.

The second section sketches the mathematical foundation of the analysis.

Page 3 & Page 4

The final pages provides some detail to the data analysis.

Air Dosimetry Report

Ionizing Activity of Radon Daughter Isotopes

This report is intended to inform you of the "background radiation" in the vicinity of Kearney Nebraska.

Just as drinking water may reasonably contain radiological contaminants, dust carried in the air also contains natural radiological materials. The *Annual Water Quality Report* provided by the City of Kearney reports these values in picoCuries per liter. This report lists airborne radiological contaminants in picoCuries per cubic meter and compares the measured activity to the EPA's benchmark for Radon in your home.

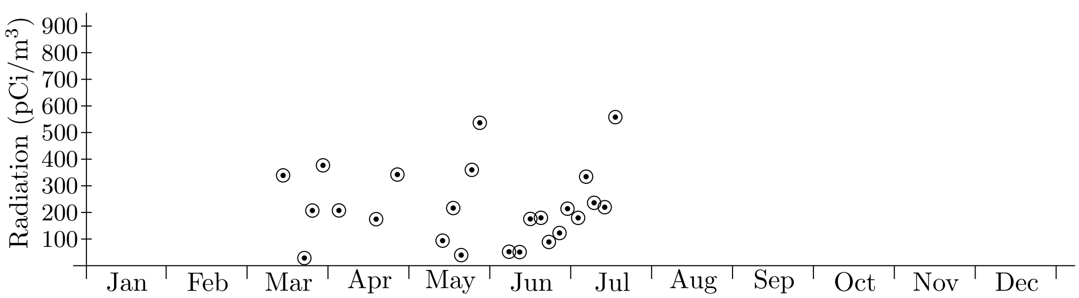
We captured dust from 14 Jul 2014 to 18 Jul 2014 ($t_{\text{stop}} \sim 94.9$ hr) in the EPA RadNet monitoring station located atop UNK's Bruner Hall of Science. Analysis shows that during that time dust particles carrying two types of radiation emitters produced exposure in the following amounts:

$$\alpha \text{ - exposure} \approx 64.18 \text{ pCi/m}^3$$
$$\beta \text{ - exposure} \approx 493.83 \text{ pCi/m}^3$$

The overall exposure rate for this time span was 558.0067 pCi/m^3.
Comparing this sample to the EPA standards, the measured exposure was about 14.0% of the EPA's benchmark for Radon in your home. The EPA recommends remediation if tests show your home contains 4000 pCi/m^3 or more.

If you approximate your respiration rate to be $12 \to 20$ breaths per minute, and your tidal volume (the amount of air you inhale each breath) to be about 0.0005 m^3/breath, then the results quoted in this report suggest an exposure in the range of $(1.7577 \to 2.9295)\mu$Ci/yr.

The chart below places this most recent value in context with previous results:



For more information regarding this and earlier reports, contact:

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Report Location: Folder # 20140718
Filter #: 370
Station #: 724 Kearney, NE
Sampled Days : 2014 07 14 → 2014 07 18

RadNet Air Monitoring

RadNet has more than 100 stationary (fixed) radiation air monitors in 48 states. ... RadNet runs 24 hours a day, 7 days a week, and sends near-real-time measurements of beta and gamma radiation to EPA's National Air and Radiation Environmental Laboratory (NAREL). ... Filters on the air monitors capture particles from the air (airborne particulates). Monitor operators collect the filters and send them to NAREL for testing that double-checks the monitor readings. Staff use these test results to calculate the concentration of radionuclides on the particles and find trends in airborne radiation.

The filters from each monitor are sent to EPA's NAREL, where they are analyzed for gross beta radiation. If beta activity in the sample exceeds one picocurie per cubic meter (1 pCi/m^3), the lab conducts a follow-up scan for gamma activity.

Background Radiation:

The ubiquitous ionizing radiation we are exposed to from natural as well as artificial sources in our environment is called background radiation.

Quotation from: http://www.epa.gov/enviro/facts/radnet/

> RadNet data provides a means to estimate levels of radioactivity in the environment, including background radiation as well as radioactive fallout from atomic weapons testing, nuclear accidents, and other intrusions of radioactive materials. RadNet also provides the historical data needed to estimate long-term trends in environmental radiation levels.

Local (volunteer) monitor operators operate these EPA RadNet monitoring stations with a standardized protocol as per *NAREL Standard Operating Procedure for Using the Ludlum Alpha/Beta System for Counting RadNet Air Filters* section 6.4 Counting Air Filters: NOTE: Filters should not be counted until at least five hours after removal from the air sampler, to allow time for decay of interfering radon daughter isotopes.

For More Information: www.epa.gov/radnet/index.html

UNK's Auxiliary Protocol

This report is the result of a protocol developed at UNK to measure the activity of the interfering radon daughter isotopes highlighted in section 6.4 of the NAREL defined protocol. With this we develop a near real-time exposure history to short lived isotopes carried by airborne dust in our local area. As the air sampler is switched off the radiation load on the filter begins to diminish exponentially.

$$\mathcal{A} = \mathcal{A}_1 e^{-\lambda_1 t} + \mathcal{A}_2 e^{-\lambda_2 t}$$

Measuring the "decay" curves for the Alpha and Beta emitters we determine the accumulated activity for each at the moment the sampler was turned off ($t = t_{\text{stop}}$). We then estimate the accumulation rate ($\mathcal{R}$) for each type of ionizing radiation (α and β) trapped in the filter as the sampler ran for 3 or 4 days ($\approx$ 72 hr or $\approx$ 94 hr).

$$\mathcal{R} = \left\{ \frac{\lambda_1 \mathcal{A}_1}{(1 - e^{-\lambda_1 t})} + \frac{\lambda_2 \mathcal{A}_2}{(1 - e^{-\lambda_2 t})} \right\} \Bigg|_{t=t_{\text{stop}}}$$

While the rate of deposition is most likely not constant, we can estimate the average rate of deposition over the last several hours of sampling time, and use it to determine the reported radiation concentration.

Data on the next two pages illustrate how the reported result is calculated.

α Data

Table 1: Alpha Activity

Time (hr)	Count Rate (pCi)
0.13333	4219.4
0.31667	3683.9
0.48333	3272.5
0.73333	2611.2
0.98333	2179.4
1.31667	1643.9
1.81667	1242.7
2.65	965.6
3.91667	725.9
5.81667	710.6

The best fit to the data suggests two time constants for the Alpha particle emitters with their associated activities at the moment the sampler was shutdown.

$\mathcal{A}_1 = 4221.1$ pCi $\quad \lambda_1 = 0.91087\ \text{hr}^{-1} \quad \mathcal{A}_2 = 513.96$ pCi $\quad \lambda_2 = 0.00086217\ \text{hr}^{-1}$

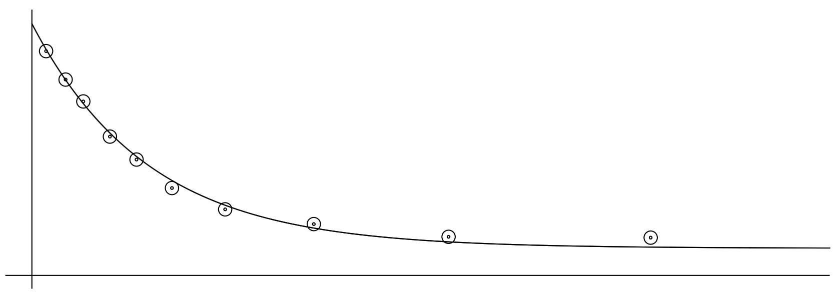

Figure 1: α Activity versus Time

This sketch[1] exists only to provide a visual representation of the phenomenological fit to the data.

α emitting radon daughter isotopes arrived at the filter with an average rate given by:

$$\mathcal{R} = \frac{\lambda \mathcal{A}_{\text{stop}}}{(1 - e^{-\lambda t_{\text{stop}}})} \Rightarrow \mathcal{R}_1 = 3844.8734\ \frac{\text{pCi}}{\text{hr}} @\ \tau_1 = 1.10\ \text{hr}\ ,\ \text{and}\ ,\ \mathcal{R}_2 = 5.6423\ \frac{\text{pCi}}{\text{hr}} @\ \tau_2 = 1159.86\ \text{hr}$$

$\mathcal{R} \times 94.86666\ \text{hr}/5691.7\ \text{m}^3 \approx 64.0846\ \text{pCi/m}^3$, and , $0.0940\ \text{pCi/m}^3$.

[1] The axes have neither scales nor units.

β Data

Table 2: Beta Activity

Time (hr)	Count Rate (pCi)
0.13333	25174.12
0.31667	21288.38
0.48333	18200.32
0.73333	14617.84
0.98333	11879.06
1.31667	9541.48
1.81667	7533.12
2.65	5590.84
3.91667	4643.3
5.81667	4131.18

The best fit to the data suggests two time constants for the Beta particle emitters with their associated activities at the moment the sampler was shutdown.

$\mathcal{A}_1 = 23555$ pCi $\qquad \lambda_1 = 1.2473 \text{ hr}^{-1}$ $\qquad \mathcal{A}_2 = 5360.5$ pCi $\qquad \lambda_2 = 0.045651 \text{ hr}^{-1}$

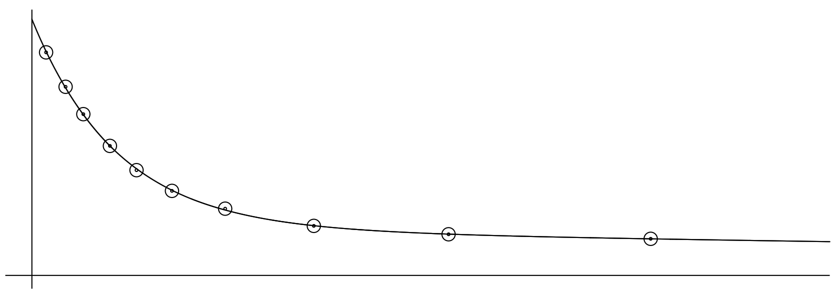

Figure 2: β Activity versus Time

This sketch[2] exists only to provide a visual representation of the phenomenological fit to the data.

β emitting radon daughter isotopes arrived at the filter with an average rate given by:

$$\mathcal{R} = \frac{\lambda \mathcal{A}_{\text{stop}}}{(1 - e^{-\lambda t_{\text{stop}}})} \Rightarrow \mathcal{R}_1 = 29380.1515 \, \frac{\text{pCi}}{\text{hr}} @ \, \tau_1 = 0.80 \text{ hr} \text{ , and , } \mathcal{R}_2 = 247.9749 \, \frac{\text{pCi}}{\text{hr}} @ \, \tau_2 = 21.91 \text{ hr}$$

$\mathcal{R} \times 94.86666 \text{ hr}/5691.7 \text{ m}^3 \approx 489.6950 \text{ pCi/m}^3$, and , 4.1331 pCi/m^3.

[2]The axes have neither scales nor units.

III Dust Accumulation (20140718Report.pdf)

The calculations of section 2.7 incorporate the approximation that the radiation accumulates on the filter at a constant rate.

It is unlikely that the radiation captured arrived at a constant rate during the sample cycle. Therefore the analysis contains a fundamental assumption that is probably false.

If the radioactivity in fact arrived mostly at the beginning of the collection cycle, then the activity would have "decayed" over several lifetimes until the end of the collection cycle. The report should therefore, report a much larger (but indeterminable) concentration in the air than it does.

If the radioactivity in fact arrived mostly at the end of the collection cycle, the concentration values may be determined in a straightforward manner using the equations of section 2.7.

Table 1 displays the values of the four assessed activities if the radiation was deposited on the filter for times much less than the full collection interval.

Table 1: Sample Interval (hr) Influences Reportable Concentration (pCi/m^3)

Sample Interval	Alpha 1	Alpha 2	Beta 1	Beta 2
0.25	314.6788	34.2695	1827.9678	359.4287
0.5	175.1769	17.1366	1055.3419	180.7399
0.75	129.4697	11.4256	805.9488	121.1795
1	107.1961	8.5701	687.0785	91.4013
2	76.4499	4.2869	533.7446	46.7436
5	64.7660	1.7170	490.6550	19.9862
10	64.0917	0.8603	489.6968	11.1286
20	64.0846	0.4320	489.6950	6.8128
30	64.0846	0.2893	489.6950	5.4692
40	64.0846	0.2179	489.6950	4.8617
50	64.0846	0.1750	489.6950	4.5422
60	64.0846	0.1465	489.6950	4.3606
94.86666	64.0846	0.0940	489.6950	4.1331

The effect of the approximation used in the calculations is to report the smallest values of activity consistent with the "decays" tracked in appendix I.

Without good reason, reporting these larger values would be irresponsible.