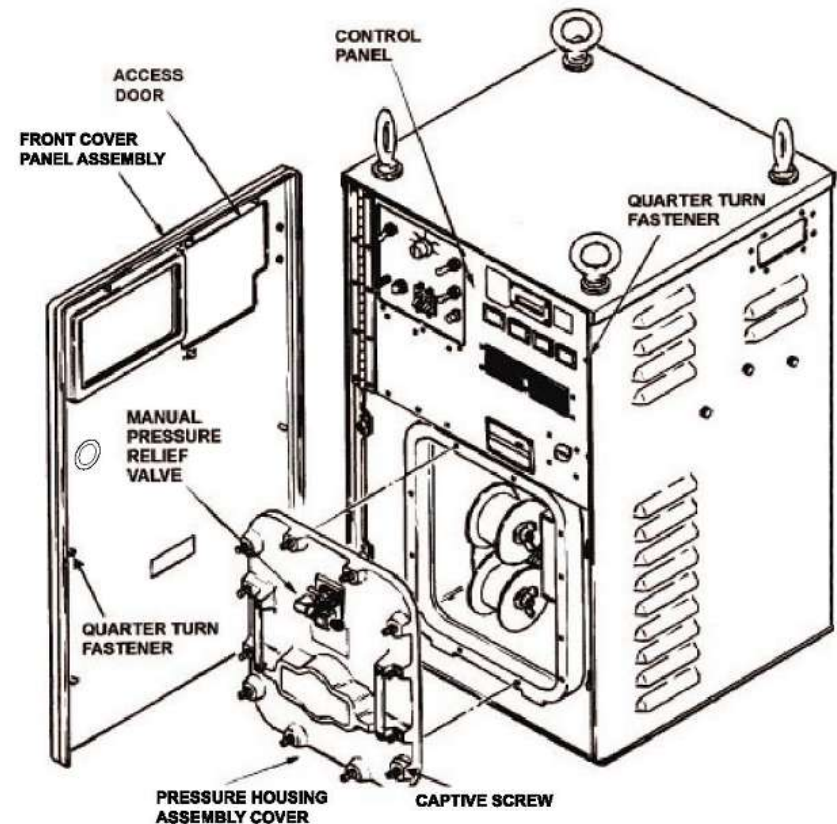


Continuous Air Monitor Algorithm Development

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ICRS-11 & RPSD-2008, April 13-18

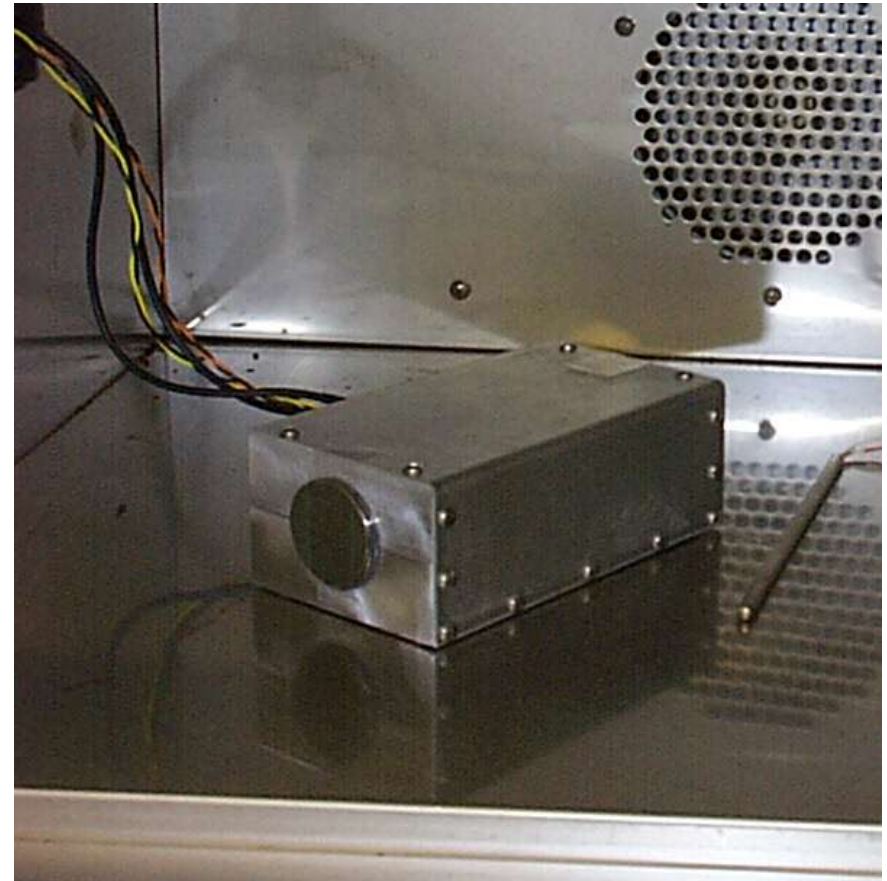
How does the present design work?

- Air is brought through a paper filter via a pump mechanism.
- The filter is continuously moving from a roll paper feed source.
- The detector is a scintillator/PMT combination placed approximately 1 inch offset from the active sampling location.
- The paper takes approximately 30 minutes to move from the sampling location to the counting position.
- Alarms are based on gross counting thresholds.
- Only local alarm capability.



Preliminary Prototype Design and Testing Completed

- All RSL testing indicates final prototype will meet Navy specifications.
- Initial prototype passed all critical tests.
- Initial prototype did not fail any tests performed.
 - Tests not conducted include drip-proof test.

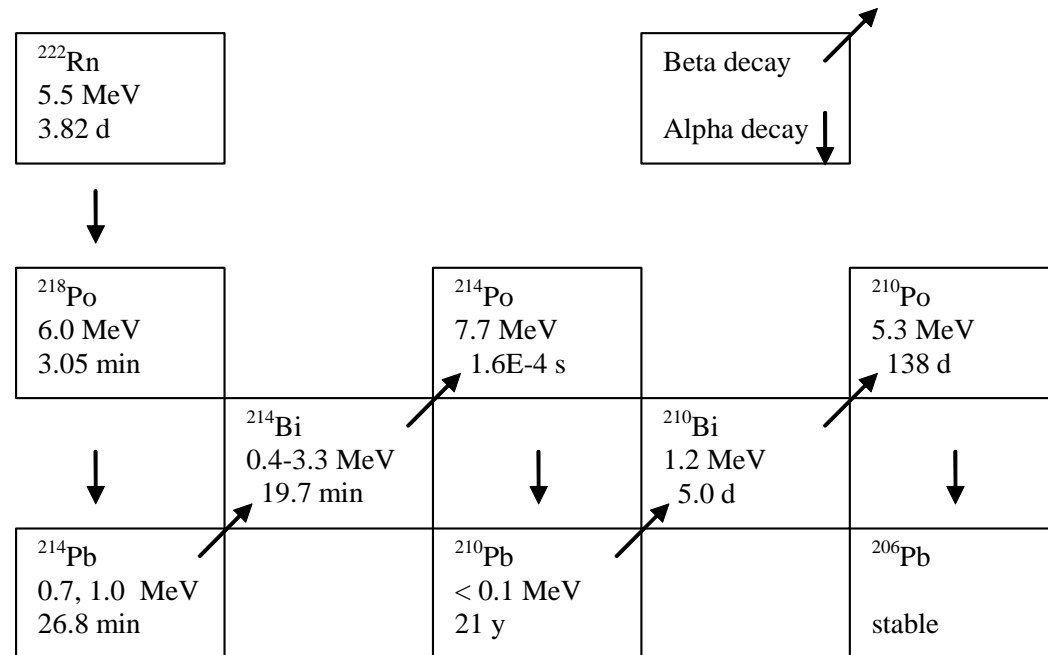


Why Spectrometry?

- Alarms are attributed to radon progeny causing high beta activity during a temperature inversion on shore.
- By measuring the alpha simultaneously with the beta, the beta, due to radon, can be accurately predicted allowing it to be subtracted from the total beta being monitored.
 - The NGAPD is primarily a beta air monitor.
- By compensating for the radon progeny under all credible source term distributions (including interaction on the air filter), a robust algorithm can be developed to prevent false alarms.
 - Too many false alarms will cause sailors to not respond, they will assume any alarm is a false alarm.
 - If the alarm threshold is raised, the sensitivity of the instrument is compromised.

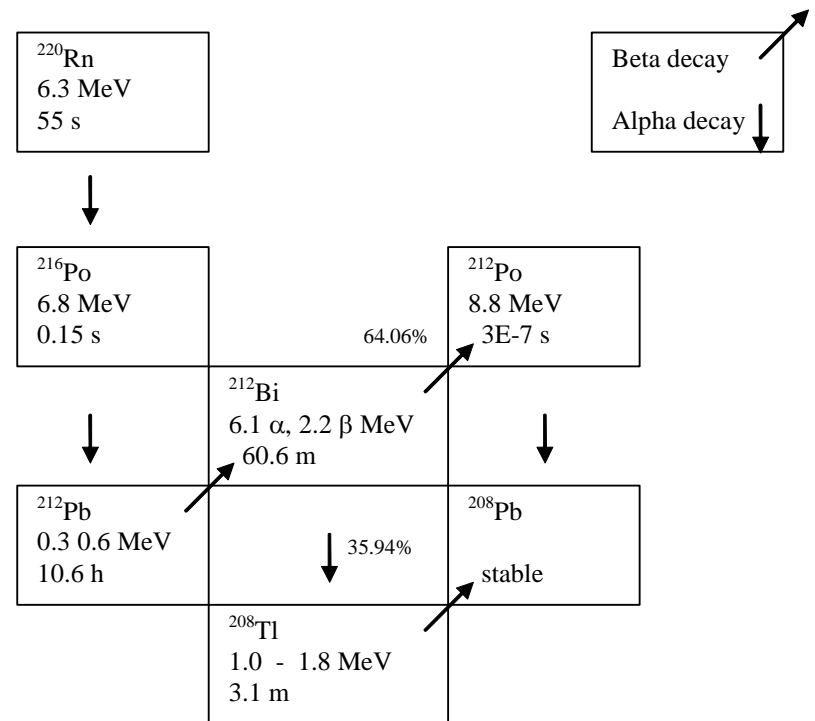
Radon (^{222}Rn) Progeny

- Characteristic half hour decay constant
- Typical environmental activity ratios for first 4 progeny isotopes 1/0.9/0.6/0.4
- Continual equilibrium of ^{214}Po with ^{214}Bi
- Negligible ^{210}Pb in ambient aerosols



Thoron (^{220}Rn) progeny

- Negligible ^{216}Po
- Continual equilibrium of ^{212}Bi and ^{212}Po
 - ^{212}Po will have 64.06% the activity of ^{212}Bi
- Branching ratio for ^{212}Bi is approximately 2/3 beta and 1/3 alpha



Basic Relationships

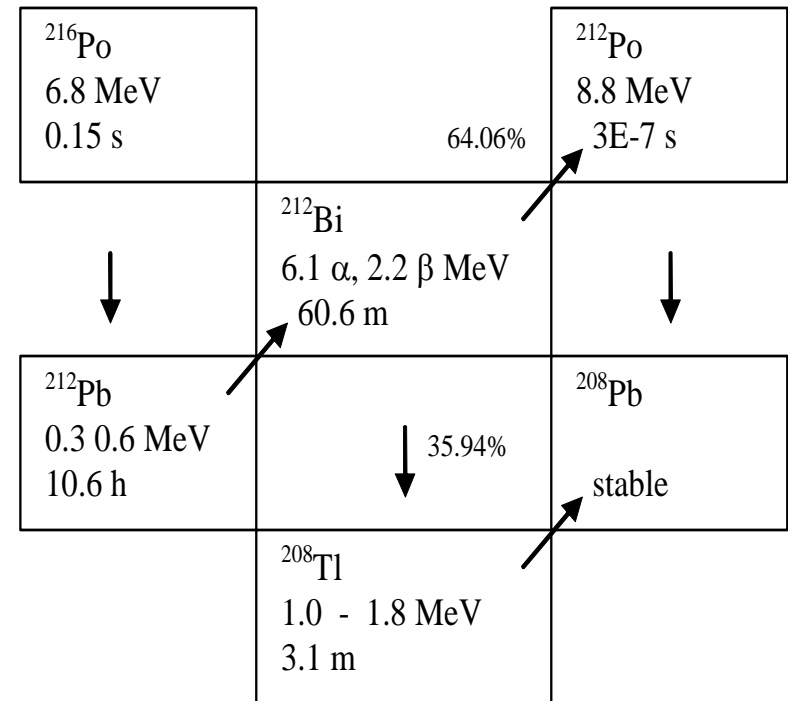
- Radon will have approximately equal alpha and beta contributions:

$$Ac_{Rn}(\beta) = Ac_{Rn}(\alpha)$$

- Thoron can utilize the 8.8 MeV decay of ^{212}Po as a metric.
 - Some attention to detail is required here

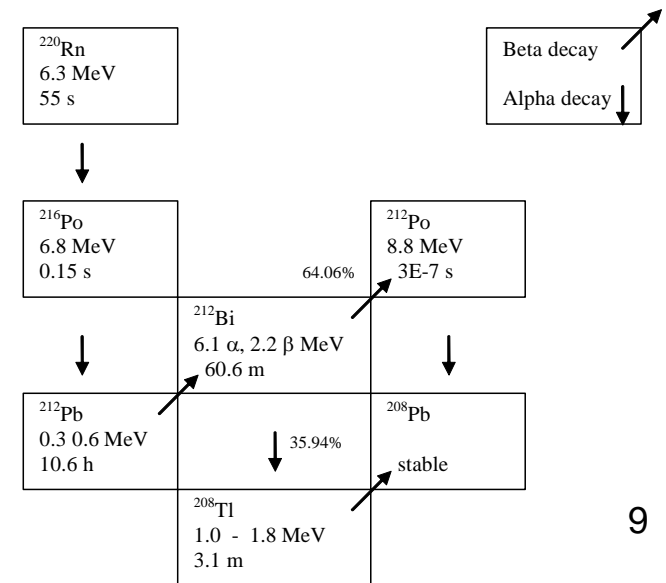
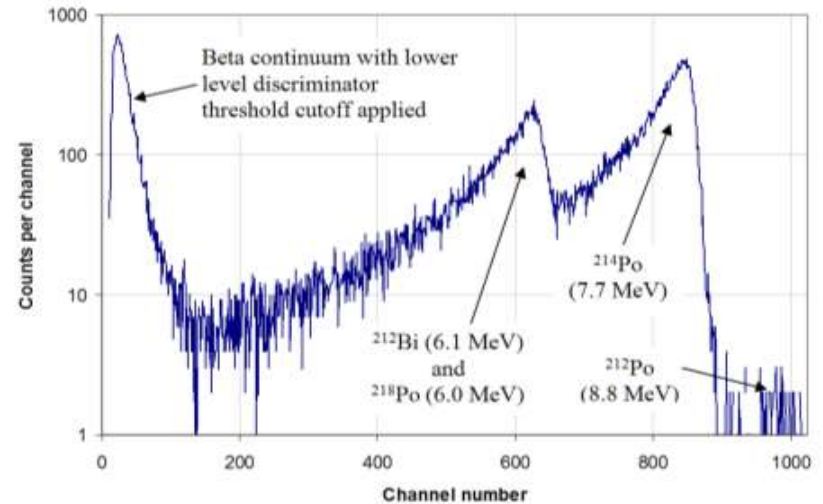
Thoron beta activity

- For each ^{216}Po α , there is a ^{212}Bi β .
- For each ^{212}Bi β , there are 0.6406^{-1} or 1.56 ^{212}Pb β 's.
- For each ^{212}Pb β , there are 0.3094 ^{212}Bi α 's.
- $A_{\text{Tn}}(\beta) = A_{\text{Po}} [1 + 1.56(1 + 0.3594)]$.



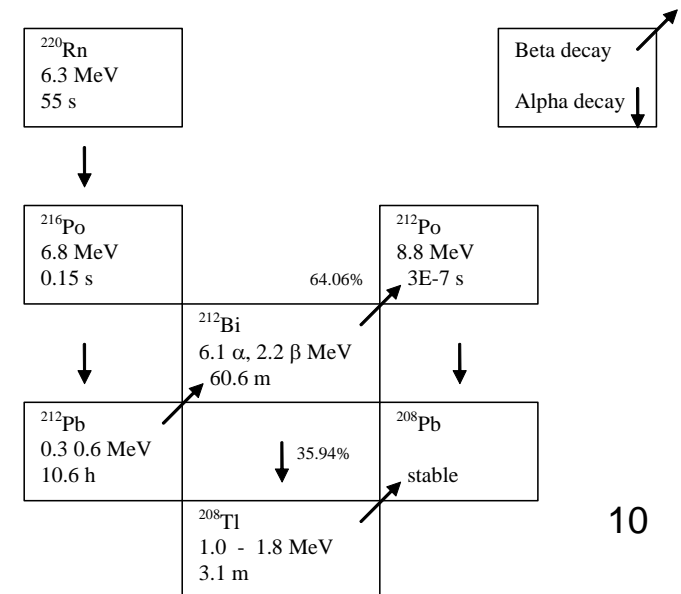
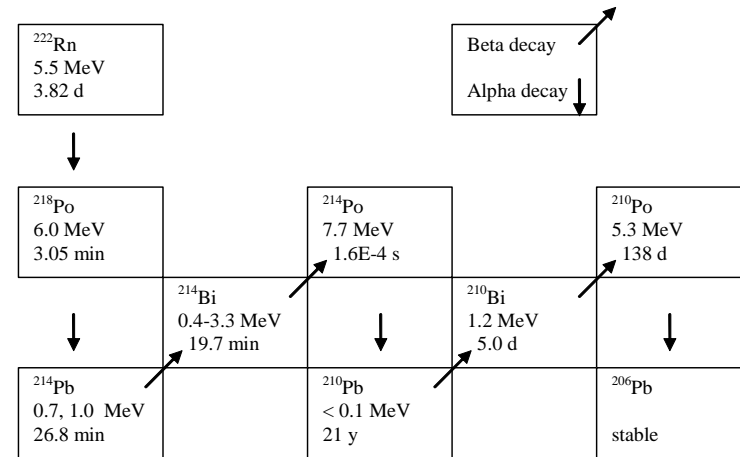
Prior to Combining Rn and Tn

- The 6 MeV peak has contributions from radon and thoron.
- The 8.8 MeV peak assay can be used to determine the thoron contribution to the largely radon 6 MeV peak.



?? Combing the Equations

- Correcting for the 6 MeV peak requires subtracting $0.6404/0.3594=1.78$ as many alphas as assayed for the 8.8 MeV peak.
- Utilize calibrated regions of interest (ROI).



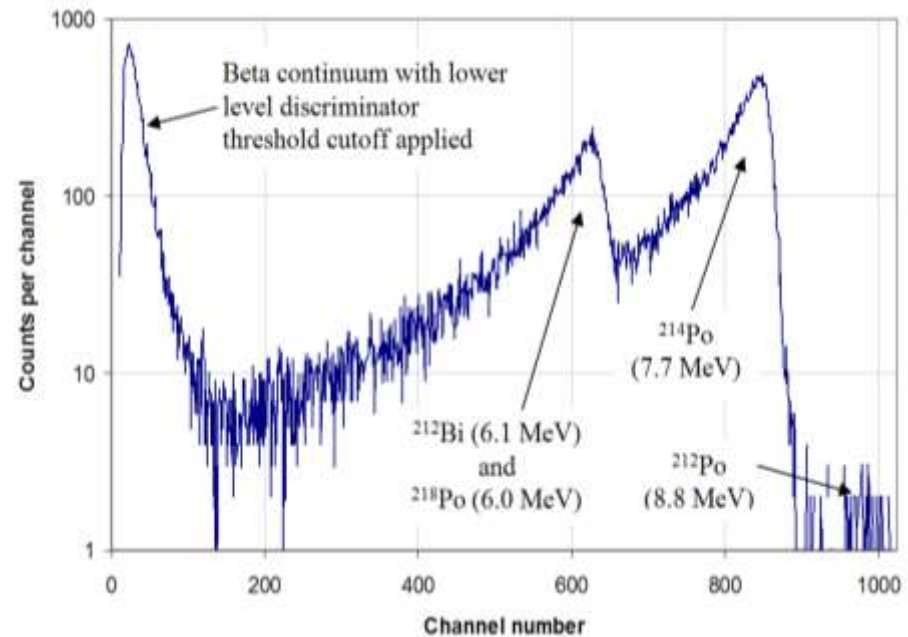
Utilize Equilibrium Distributions

- Aerosol plate out is effectively a decay term modeled here using equilibrium estimates.
- Thoron values used 1/0.8/0.8 and radon 1/0.9/0.6/0.4 (NCRP 94)

$$\begin{aligned} \text{Ac}(\beta) = & \text{Ac}_{212\text{Po}}(8.8 \text{ MeV } \alpha) \cdot [1 + 1.561 \cdot (1 + 0.3594) / 0.8] + \\ & \text{Ac}_{214\text{Po}}(7.7 \text{ MeV } \alpha) + \text{Ac}_{218\text{Po}}(6.0 \text{ MeV } \alpha) \cdot 0.6 / 0.4 - \\ & 1.78 \cdot \text{Ac}_{212\text{Po}}(8.8 \text{ MeV } \alpha) \cdot 0.4 / 0.6 \end{aligned}$$

Using ROI's

- The beta ROI = channel 30 to 199 = ROI1
- ROI2 = channel 200 to 670
- ROI3 = channel 671 to 890
- ROI4 = channel 891 to 1024



Simplified ROI Equation

$$A(b) = ROI1 = 3.65 \cdot ROI4 + ROI3 + 1.5 \cdot ROI2 - 1.19 \cdot ROI4$$

Note we have not corrected for the lower level threshold cutoff

Lower Level Threshold

- Beta spectra are continuous to zero energy
- At zero energy, PIPS are very noisy
- Typical lower levels range up to many 10's of keV
- Current design not calibrated to know exact cutoff limit
- Calibration expected in next few months

Ongoing Activities

- Considerations of some circuit redesign for reducing low energy threshold
 - It can be done, but is **it** just a “nice to have” or can **it** provide a meaningful improvement to sensitivity **?....maybe, or else this thought needs to be finished**
- Manufacturer specifications for sensitivity
 - ^{90}Sr 24% ($E_{\beta\text{max}}$ for ^{90}Y 2.28 MeV)
 - ^{60}Co 15% ($E_{\beta\text{max}}$ for dominant mode 318 keV)
 - We know we can do better but should we?

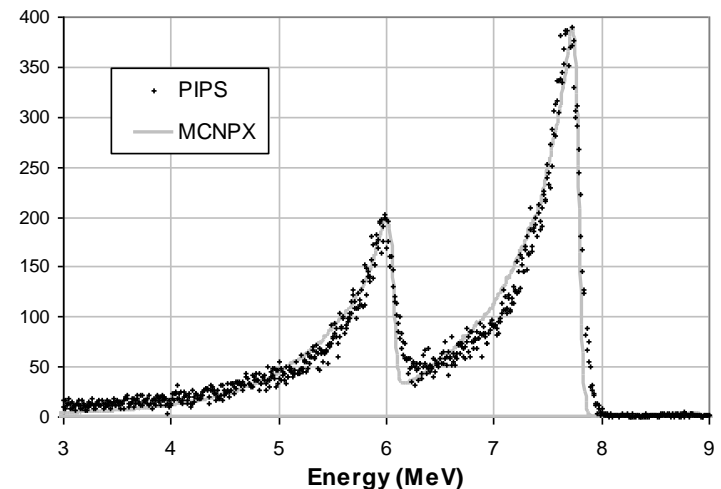
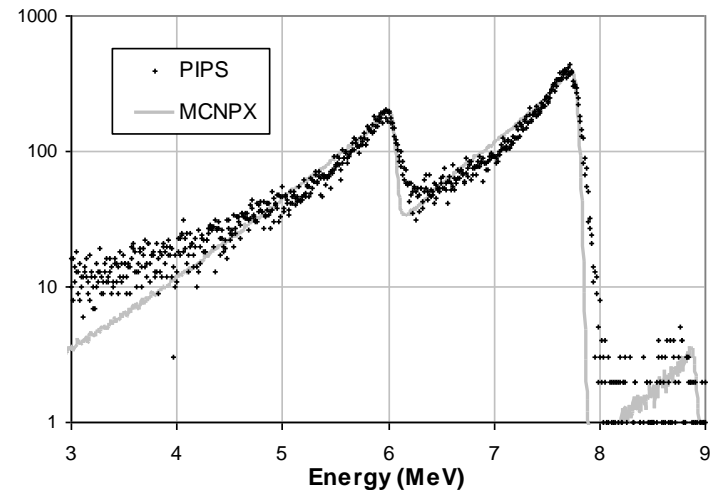
Algorithm Test Proof of Concept

Excellent agreement was obtained using literature values for air deposition on filter substrate (R. Pollanen, T Siiskonen. *Health Phys.* **90**, 167-175, 2006).

Attenuated deposition into the filter was modeled.

Credible radon, thoron and actinon distributions were modeled (100:10:1 source term ratios).

Hayes R. B., Marianno C. M. Use of MCNPX for alpha spectrometry simulations of a continuous air monitor. *Trans. Amer. Nucl. Soc.* **96**, 631-633, 2007.



Conclusions

- The algorithm is designed to accurately correct for NORM contributions to beta activity.
- The algorithm is based on basic principles of radionuclide decay, aerosol physics, and spectrometry analysis.
- The algorithm will be tested with MCNPX for expected operating environments.

Acknowledgements

- The United States Navy
- NAVSEA
- RSL
- NSTec
- DOE