QUESTION 13

GIVEN: use of CAM beginning at 0800 hours to monitor airborne beta emitting radionuclides at a power reactor facility and data relating to an airborne release:

- \( F = \) monitor flow rate = 1 ft\(^3\) min\(^{-1}\) = \(2.83 \times 10^4\) cm\(^3\) min\(^{-1}\);
- \( R = \) filter retention = 0.9;
- \( E = \) counting efficiency = 0.3 c d\(^{-1}\);
- \( R_b = \) background rate excluding collected radon progeny on filter = 70 c min\(^{-1}\);
- \( T_{1/2} = \) effective half-life of radon progeny = 30 minutes; so
- \( \lambda = \) effective decay constant for radon progeny = \((\ln 2)/T_{1/2} = 0.0231\) min\(^{-1}\); and

Table of ALIs in \(\mu\)Ci and DACs in \(\mu\)Ci cm\(^{-3}\) for Co-60, I-131, and Cs-137.

SOLUTIONS AND ANSWERS(*) TO PARTS A THROUGH E:

A. A radon progeny “beta concentration” \(U_1\) of \(3 \times 10^{-10}\) \(\mu\)Ci cm\(^{-3}\) is present with an “effective half-life of 27 minutes”. At 0900 hours or for a sampling interval \(t_1\) of 60 minutes, the gross counting rate \(R_g\) that should be observed on the monitor is calculated:

Comment and assumptions: It is not clear what is meant by the given phrase, “...beta concentration of \(3 \times 10^{-10}\) \(\mu\)Ci cm\(^{-3}\) with an effective half-life of approximately 27 minutes.” How does the “concentration” have an effective half-life? I assume that the stated effective half-life refers to the activity of radon progeny on the filter sample and not that associated with the airborne concentration of progeny. The beta activities of the radon progeny, 27 minute half-life Pb-214 and its daughter 20 minute half-life Bi-214, would not exist on the filter under transient equilibrium conditions at any significant activity level; so a 27 minute effective half-life is not likely. The apparent or “effective half-life” would vary with the sampling time, the relative airborne concentrations of radon progeny, and the time after the end of sampling. The effective half-life after the end of sampling would vary from a value of about 45 minutes at 20 minutes after the end of sampling to a value corresponding to the transient equilibrium value of 27 minutes at about 600 minutes after the end of sampling. An approximate “effective half-life” of about 35 minutes might be observed at 60 minutes after the end of sampling. The radon progeny effective half-life stated in this part of the question differs from that given above; so the radon progeny effective decay constant is calculated now: \(\lambda = (\ln 2)/(27 \text{ min}) = 0.0257\) min\(^{-1}\), which with other given data gives \(R_g\) if it assumed incorrectly that the given radon progeny concentration \(U_1\) can be considered as representing a single radionuclide having the values specified for \(\lambda, R, F,\) and \(E\) above:

\[
R_g = R_b + (2.22 \times 10^6 \text{ dmin}^{-1} \mu\text{Ci}^{-1}) \frac{U_1 R F E}{\lambda} (1 - e^{-\lambda t_1}) = (70 + 156) c \text{ min}^{-1} = 226 c \text{ min}^{-1}.
\]

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B. From the observation of a net counting rate increase $R_s$ of 40,000 c min$^{-1}$ over a sampling interval $t$ of 10 minutes, the airborne concentration $U$ of beta emitters with half-lives much greater than 10 minutes is calculated on the assumption that no significant decay is associated with radionuclides causing $R_s$:

$$U = \frac{R_s}{ERFt} \left( \frac{1 \muCi}{2.22 \times 10^6 d \text{ min}^{-1}} \right) = 2.36 \times 10^{-7} \muCi \text{ cm}^{-3}.$$  

C. Four advantages of a whole body count over urine bioassay for detecting suspect inhalation intakes of $^{137}$Cs and $^{60}$Co include: 1. Both radionuclides are easily detected by high intensity gamma rays associated with their decay. 2 Whole body counting provides a rapid evaluation of whether significant intakes took place, while urine bioassay generally requires a longer time for the collection of 24 hour samples and the separate chemical processing and counting of the samples. 3 Whole body counting provides a direct measurement of the body burden, which can be directly related to the internal dose rate while urine bioassay requires the use of an assumed biokinetic model for first the estimation of an intake from the urine data and then an estimate of the committed dose from an intake to committed dose conversion factor based upon the assumed biokinetic model. 4. Repetitive whole body counts provide a measure of the clearance rate and the cumulated activity, which can be directly related to the internal dose over the time of measurements while urine bioassay only indicates what has been excreted with the urine and not the activity remaining in the body nor the activity that also may have been excreted by other excretion pathways, e.g. by the fecal pathway.

D. For an air concentration $U$ of $2 \times 10^{-6} \muCi \text{ cm}^{-3}$ comprised of 25% $^{60}$Co and 75% $^{137}$Cs, the CEDE for an exposure time $t$ of 1 h is calculated since both DACs are based upon the stochastic-effect-based limit of 5 rem for an exposure of 2000 DAC-h:

$$CEDE = \left( \frac{0.25 U}{DAC_{Co}} + \frac{0.75 U}{DAC_{Cs}} \right) t \left( \frac{5 \text{ rem}}{2000 \text{ DAC} \cdot h} \right) = 0.188 \text{ rem}.$$  

E. The CDE to the thyroid and the CEDE for an intake of 2 ALI of $^{131}$I and an intake of 0.5 ALI of $^{137}$Cs are calculated for a thyroid stochastic risk weighting factor $w_T$ of 0.03:

$$CDE = 2 \text{ ALI} \left( \frac{50 \text{ rem}}{\text{ ALI}} \right) = 100 \text{ rem},$$

and

$$CEDE = 0.5 \text{ ALI} \left( \frac{5 \text{ rem}}{\text{ ALI}} \right) + w_T CDE = 2.5 \text{ rem} + 3 \text{ rem} = 5.5 \text{ rem}.$$