NRRPT® NEWS

National Registry of Radiation Protection Technologists

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Chairman's Message

Dave Biela

I cannot believe that four years have gone by since becoming Chairman of the Board. This is my last article as Chairman of the NRRPT. I want to start thanking the people that helped me through all this. First of all DeeDee our Executive Secretary who is a good friend and keeps the entire organization under control. I have worked with her now for almost 21 years and she does an excellent job keeping everything in order. Second, I want to thank the Board and Panel. I do not know how many of you know this, but the Board and Panel members are all volunteers who put in countless hours at meetings and home, to keep the organization operating and growing. Thank you for all the support you have provided to me over the years.

I hope the holidays were good for all of you and that the winter weather is not treating you to poorly. The last two years have been really good for the technician seeking employment. The stimulus package opened up many opportunities within the Department of Energy. Events within the commercial nuclear field should provide opportunities for many years to come once newly licensed reactors are built and begin to come on line. There is a period once the stimulus money ends this June and until the need at the reactors start that may be a little tough on technicians. As always I encourage all of you to do what you can to make yourself as marketable as possible. If you have not sat for the NRRPT exam yet, make that a goal. The next two exams in the U.S.

are February 26th and August 6th, with the Canadian exam January 31st. If you are registered, look towards furthering your education, do not stop. Help others around you prepare for the exam, or help them improve their abilities.

The NRRPT along with other organizations are reaching out to grammar schools, high schools and colleges to inform students of the potential needs in the nuclear industry. Over the next eight to ten years our industry will be losing approximately 60% of the work force to retirement. Because of all the cutbacks to the college nuclear programs after the US reactor program was stopped, there is currently only about a 30% rate of replacement entering the field. This shortfall does not even include staffing the new reactors. While colleges have begun to start up their nuclear programs, it still is up to all of us to communicate the future needs of the industry to the students, so pass the word.

I want to thank all of you for the honor of being the NRRPT Chairman and welcome Kelly Neal as the new Chairman. I know that Kelly will do a great job.

Sincerely,
Dave Biela
NRRPT, Chairman of the Board

Testing, testing...

Todd Davidson

Welcome again to the feature "Testing, testing." As stated previously, this feature will present test questions as well as general test-taking strategies and advice. Please share the questions and solutions with other workers in the field who have not passed the NRRPT test.

Problem

How many half-value layers of shielding are required to reduce a radiation field of 300 R/h at 30 cm from an object such that a member of the public may work for 40 hours next to the object?

Solution

To answer this, we must ensure that the value for the radiation field is reduced to the point that a member of the public can work next to the object for any amount of time. Members of the public must be monitored if they are likely to be exposed to one-half of their legal limit, which is 50 mrem/y, therefore they must be monitored if they are likely to receive more than 25 mrem.

$$\frac{25mrem}{40h} = 0.625\frac{mrem}{h} = 625\frac{\mu rem}{h}$$

Next, we must calculate how many times we must halve the original value to get to the final value. Assume 1 R = 1 rem.

$$I = I_0\left(\frac{1}{2}\right)^N$$

$$\left(\frac{I}{I_0}\right) = \left(\frac{1}{2}\right)^N$$

Continued on page 8

Correction for Radon/Thoron Progeny in Savannah River Site Air Samples

By Dennis Hadlock

Radon and Thoron are naturally-occurring radioactive gases that emanate from building materials and the earth and are also present in some facilities as a decay product from previous SRS missions. When Radon and Thoron decays, their progeny are particulate matter that can become attached to atmospheric dust particles. These daughter products are commonly referred to as Rn-Tn. It is these particles that are collected during air sampling. Because the Rn-Tn decays by alpha and beta emissions, all data from analysis of filter papers and planchets must be corrected for these decays so that the analyses are not positively biased.

The decay modes for Radon/Thoron and their progeny are shown in Figure 1 [DHEW 1970] [Brown 1986]. Because only an extremely small percentage of the Rn daughter products will continue to decay past the Pb-210 radionuclide (21-year half-life) in the time period involved in analyzing air samples, it is assumed, for calculation purposes, that Pb-210 is a stable daughter of Rn. This assumption allows the simplification of the Rn-Tn decay correction calculations without sacrificing accuracy.

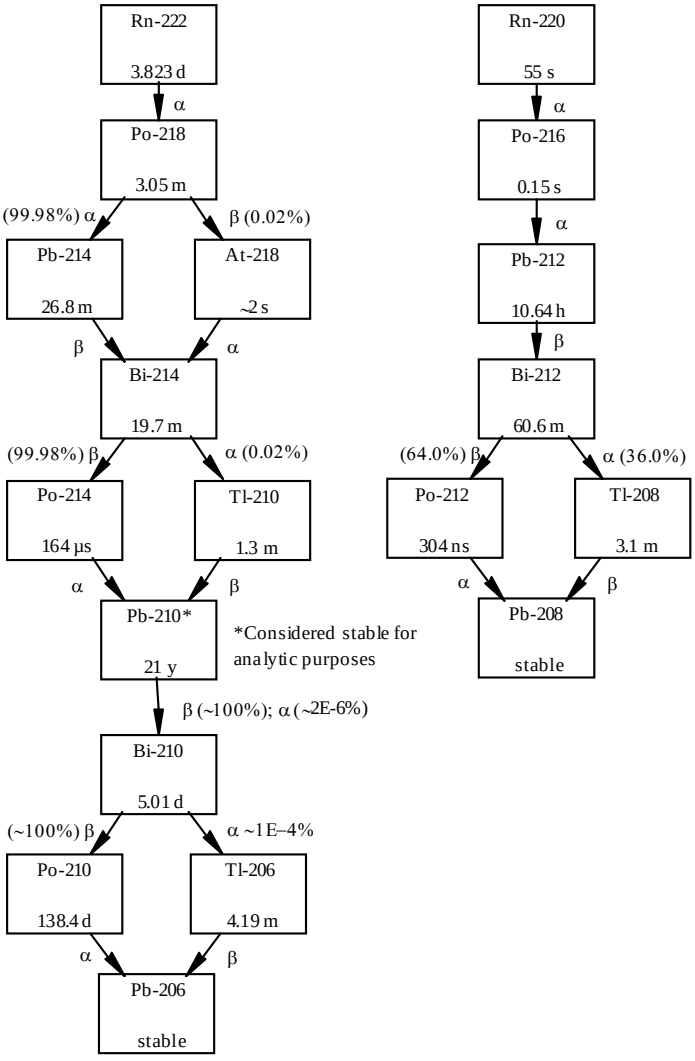

Figure 1. Radon and Thoron Decay Chains

Radon Decay Correction

In the analysis of the collection medium for alpha emitters, the relationship in equation 1 is true.

$$C_T(t) = C_A(t) + C_{Rn}(t) + C_{Tn}(t) \qquad \{Eq.\ 1\}$$

Where: $C_T(t)$ = Total Count Rate at time t

$C_A(t)$ = Count Rate due to unknown alpha at time t

$C_{Rn}(t)$ = Count Rate due to Rn daughters at time t

$C_{Tn}(t)$ = Count Rate due to Tn daughters at time t

The number of unknowns that Eq. 1 contains is dependent on the number of separate analyses performed on the sample. That is:

$$\begin{aligned} C_T(t_1) &= C_A(t_1) + C_{Rn}(t_1) + C_{Tn}(t_1) \\ C_T(t_2) &= C_A(t_2) + C_{Rn}(t_2) + C_{Tn}(t_2) \\ &\Downarrow \\ C_T(t_n) &= C_A(t_n) + C_{Rn}(t_n) + C_{Tn}(t_n) \end{aligned}$$

Of the alpha-emitting radionuclides that are of concern at SRS, Pu-238 has the shortest half-life (86 years). As a result, it can be assumed that the count rate due to unknown alpha (C_A) remains constant during the sample analysis. That is:

$$C_A(t_1) = C_A(t_2) = \rightarrow = C_A(t_n) = C_A$$

In addition, because $C_{Rn}(t_1)$ and $C_{Tn}(t_1)$ can be related to $C_{Rn}(t_2)$ and $C_{Tn}(t_2)$ by the radioactive decay equation, the number of unknowns is reduced to three. Therefore, the preceding set of equations can be rewritten as:

$$\begin{aligned} C_T(t_1) &= C_A + C_{Rn}(t_1) + C_{Tn}(t_1) \\ C_T(t_2) &= C_A + C_{Rn}(t_2) + C_{Tn}(t_2) \\ C_T(t_3) &= C_A + C_{Rn}(t_3) + C_{Tn}(t_3) \end{aligned}$$

This set of equations can be simplified further by placing constraints on t_1, t_2, and t_3. Because these analyses are used to support the radiological control program in a facility, results must be completed within a reasonable time period. As previously stated, it is assumed that Pb-210 is stable; therefore, the longest-lived radionuclide in the Rn decay chain is Pb-214 with a 26.8 minute half-life (t½). Since after 7 half-lives (t½'s) less than 1% of the original radioactivity remains, it can be assumed that few, if any, Rn daughters are present after 188 minutes (7 t½'s). At SRS, the first analysis is normally completed about 6 hours (»13.5 t½'s) after the collection media is removed from service. At this time, less than »0.008% of the Pb-214 would be remaining. As a result, the concentration of Rn daughters is assumed to be zero ($C_{Rn}(t) = 0$) and the analysis need only be corrected for the Tn daughters.

Thoron Decay Correction

The preceding set of equations from section can now be reduced to equations 2a and 2b.

$$C_T(t_1) = C_A + C_{Tn}(t_1) \quad \{Eq.\ 2a\}$$

$$C_T(t_2) = C_A + C_{Tn}(t_2) \quad \{Eq.\ 2b\}$$

Solving Eq. 2b for $C_{Tn}(t_2)$ yields equation 3.

$$C_{Tn}(t_2) = C_T(t_2) - C_A \quad \{Eq.\ 3\}$$

$C_{Tn}(t_2)$ can be related to $C_{Tn}(t_1)$ by the expression $C_{Tn}(t_2) = C_{Tn}(t_1)e^{-\lambda(\Delta t)}$

Here, the value of the decay constant, l, is 0.0651 hr^{-1}, which corresponds to Pb-212, the longest-lived Tn daughter. Making this substitution into Eq. 3 and solving for $C_{Tn}(t_1)$ results in equation 4.

$$C_{Tn}(t_1)e^{-\lambda(\Delta t)} = C_T(t_2) - C_A$$

$$C_{Tn}(t_1) = \frac{C_T(t_2) - C_A}{e^{-\lambda(\Delta t)}} \quad \{Eq.\ 4\}$$

Substituting the expression in Eq. 4 into Eq. 2a and solving for C_A results in the final equation, Eq. 5.

$$C_T(t_1) = C_A + \frac{C_T(t_2) - C_A}{e^{-\lambda(\Delta t)}}$$

$$C_T(t_1)e^{-\lambda(\Delta t)} = C_A e^{-\lambda(\Delta t)} + C_T(t_2) - C_A$$

$$C_A - C_A e^{-\lambda(\Delta t)} = C_T(t_2) - C_T(t_1)e^{-\lambda(\Delta t)}$$

$$C_A\left(1 - e^{-\lambda(\Delta t)}\right) = C_T(t_2) - C_T(t_1)e^{-\lambda(\Delta t)}$$

$$C_A = \frac{C_T(t_2) - C_T(t_1)e^{-\lambda(\Delta t)}}{1 - e^{-\lambda(\Delta t)}} \quad \{Eq.\ 5\}$$

When this derivation was originally performed at SRS, it was to determine the corrected plutonium count rate. As a result, C_A was originally termed C_P, and Eq. 5 is commonly referred to as the C_P Equation. In addition, $C_T(t_1)$ and $C_T(t_2)$ are known as C_1 and C_2. The value for l is defined as 0.0651 hr^{-1}, and t_1 and t_2 typically are about 6 and 24-hours after the sample is taken. Therefore, after making these substitutions, the C_P Equation, in operational terms, is contained in Eq. 6.

$$C_p = \frac{C_2 - C_1\left(e^{-0.0651(\Delta t)}\right)}{1 - e^{-0.0651(\Delta t)}} \quad \{Eq.\ 6\}$$

Example 1:

Given: C_1 = 450 dpm; C_2 = 100 dpm; and Dt = 19 hours, Calculate C_P.

Solution 1:

$$C_p = \frac{100 - 450\left[e^{-0.0651(19)}\right]}{1 - e^{-0.0651(19)}} = \frac{100 - 131}{0.71} = \frac{-29}{0.71} = -41\,\text{dpm}$$

When Cp calculates to a negative value it can be assigned the value 0 cpm to simplify the resulting concentration calculation. In this example, the entire radioactivity detected is assumed to be Tn daughter products.

Example 2:

Given: C_1 = 450 dpm; C_2 = 400 dpm, and Dt = 20 hours; Calculate C_P.

Solution 2:

$$C_p = \frac{400 - 450\left[e^{-0.0651(20)}\right]}{1 - e^{-0.0651(20)}} = \frac{400 - 122}{0.728} = \frac{278}{0.728} = 382 \text{ dpm}$$

In this example, 382 of the 400 dpm from C_2 are assumed to be long lived radioactivity and 18 dpm is attributed to Tn daughters.

The units associated with C_P are dependent on the units of C_1 and C_2. Normally, this would be in dpm, but will work equally well with cpm, µCi, or even µCi/cc.

Normally, only the alpha analysis employs the C_P equation to correct for the Tn contribution. The concentration calculation for beta-gamma utilizes the analysis results directly.

Significance of the C_p 6 and 24-hr Decay Periods

The decay times of 6 and 24-hr for C_P calculations were, at one time, so ingrained in the radiological culture at SRS that the formula was taught assuming that the delta time for the counts was always 18-hrs. Many radiological controls personnel were under the impression that the use of any times other than the 6 and 24-hr time period would provide invalid results. The purpose of this section is to show what happens to the radioactivity on a filter paper over the analysis period. This illustration will show that the 6-hr decay time is critical for accurate results but that the delta time between the 6-hr count and the next count is not nearly as important.

Figure 2 illustrates the decay of radioactivity on a filter paper where the radioactivity contains Rn daughters, Tn daughters, and some long lived radioactivity (in this case Pu) of interest. This example is not exact to the physical sciences but will serve the purpose of illustrating what happens to the Rn-Tn daughters and the long-lived radionuclide(s) of interest during the selected time periods.

In this example, we start out with 5000 counts of Rn daughters, 2000 counts of Th daughters, and 200 counts of Pu. Over the first six hours the Rn daughters, who have an effective t½ of about 35 minutes go through a little over 10 t½'s. This reduces the Rn daughter counts by a factor of 1,024. This decay time of 6-hrs allows the Rn daughters to decay to insignificant levels so that only two decay schemes of concern are left; that of the long-lived Th daughter (Pb-212, 10.64-hr t½) and the Pu. With only two decay schemes to work with, and Pu being essentially constant over the time periods we are looking at, the Cp calculation will easily work. As such, the 6-hr post sample decay period is critical but not absolute. In other words, you want a minimum of 6-hrs to ensure the short lived daughters have decayed away. If you allow the air sample to decay longer than 6-hrs, it will not adversely affect the calculation.

Figure 3 is the same example over a 120-hr decay period. Figure 4 is again the same example except that the Y axis has been truncated at 2000 counts to include all of the Tn decay while expanding the graph for clarity.

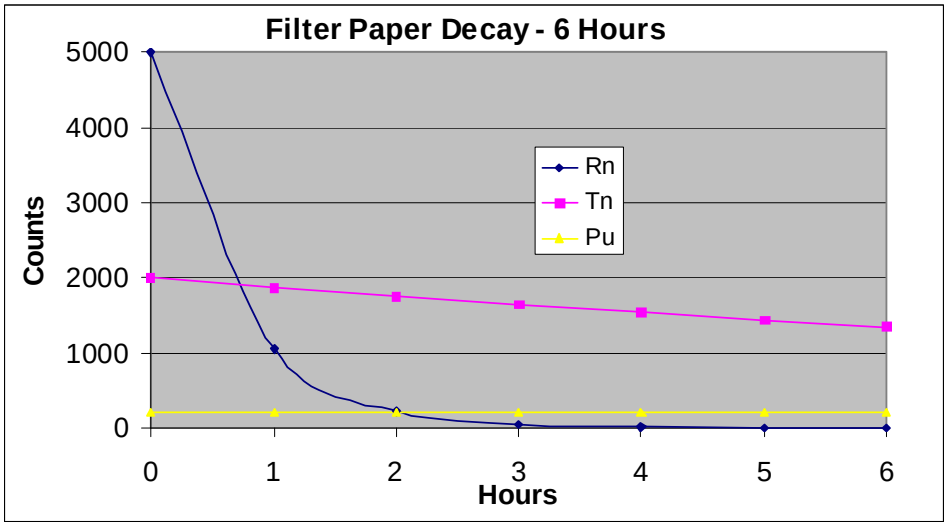

Figure 2. Filter Paper Decay Over 6 Hours

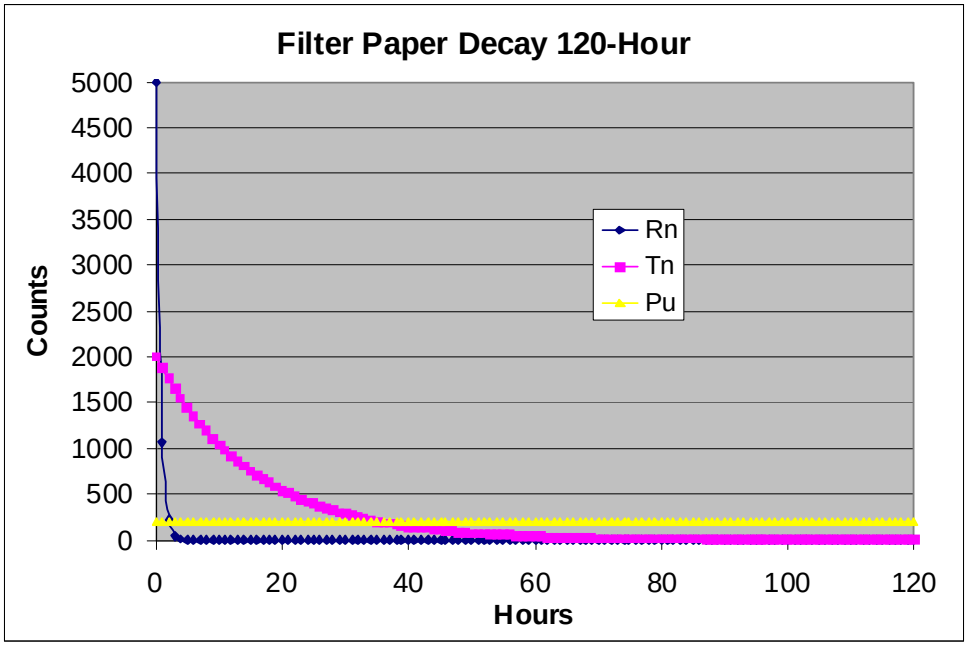

Figure 3. Filter Paper Decay Over 120 Hours

Looking at Figure 4 past the 6-hr point you can see that any analysis of the sample will include the counts of the Pu plus the counts from the Tn. The purpose of the C_P calculation is to determine the percentage of counts from the Rn and then subtract it from the total counts to determine the counts from Pu. The historical 24-hr post decay period served two purposes. The delta time of 18 hours between the 6 and 24-hr analysis results in almost two t½'s for the Pb-212, and thus a factor of almost 4 lower counts due to Tn between the two analyses, and the 24-hr decay period was convenient; with the second analysis 24 hours after the sample time, determining when to perform the second analysis was very easy; same time, next day.

Convenience aside, the decay of the Pb-212 to about ¼ of its original radioactivity ensured that the variance in counting statistics would not mask the decay of the Pb-212. This can be accomplished by as little as one t½ between the first and second count. It should be noted that as the time delta between the first and second count is reduced, the chance of a false result increases.

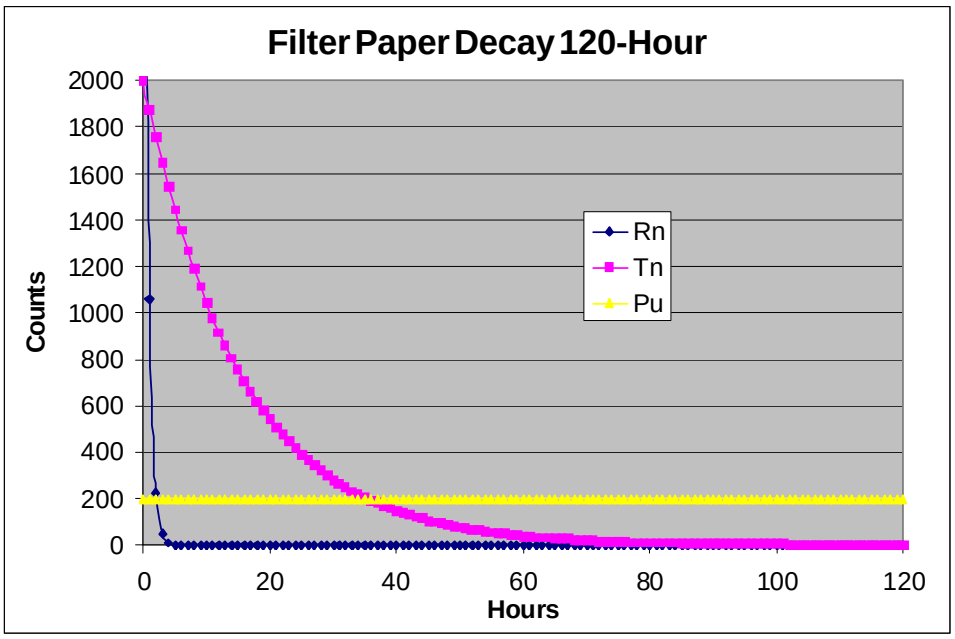

Figure 4. 120 Hour Decay with Truncated Y Axis

It should be apparent from the derivation of the C_P calculation and the graphical representation of what is physically occurring during the 120-hr decay period that a C_P calculation can be performed anytime, using any realistic delta time, during the 120-hr decay period. For example, due to working only day shift, samples pulled at the end of the day cannot be analyzed until the next day, about 15 hours later. This analysis can be used as the first count for the C_P calculation. The second analysis can be performed at the end of the day (about 10 hours later which is one t½) or the next morning (about 24 hours later) and be used as the second count. As long as the correct delta time (10 or 24 hours) is used in the C_P formula, the results should be accurate.

References

Brown, E. and R. B. Firestone, "Table of Radioactive Isotopes", John Wiley and Sons, 1986.
U. S. Department of Health, Education, and Welfare, Radiological Health Handbook, January 1970.

Continued from page 2

Take the natural logarithm of both sides of the equation.

$$\ln\left(\frac{I}{I_0}\right) = N \ln\left(\frac{1}{2}\right)$$

$$N = \frac{\ln\left(\frac{I}{I_0}\right)}{\ln\left(\frac{1}{2}\right)} = \frac{\ln\left(\frac{0.625}{300000}\right)}{\ln(0.5)} = \frac{-13.08}{-0.693} = 18.87$$

NRRPT has a New Logo!

For quite a few years now the membership of the NRRPT has informally crossed international boundaries. We have known registrants that work in the commercial nuclear industry in both Canada and Mexico, and quite possibly other countries with technologists that maintain a US address but spread the value of the Registry beyond the US borders.

Until 2006 these registrants studied the same professional texts and regulations that govern our operations within the United States. What this meant was that even though these candidates did not work under the US regulations, in order to be successful in the examination, they were required to become familiar with the US regulations.

In 2005, the Board of Directors and the Panel of Examiners formally addressed this issue in the development of a Canadian examination for Technologists. While the science of our profession is consistent globally, minor differences, units of measurement and regulations specifically, had to be addressed.

There were many challenges associated with this pursuit and the one absolute was that both examinations, US and Canadian, absolutely had to support the exact same level of qualification for all RRPTs.

Beyond the obvious, the Board of Directors had to:

- Identify qualified Canadian representatives for positions on the Board of Directors and the Panel of Examiners.
- Challenge the Panel of Examiners to review the entire bank of examination questions and determine which questions were unique to the United States and develop questions for the Canadian exam that would present the exact same level of knowledge.
- Introduce the benefit of Technologist registration to the Canadian industry.
- Verify that none of these actions would compromise our existing registration charter.

In 2005, all of these issues had been addressed and the first Canadian examination was administered on February 27, 2006. Fifteen candidates sat for this initial examination and of these 15, ten passed the examination. Since that initial examination there have been a total of 3 examinations and 36 candidates

with 18 candidates passing the examination. These results are consistent with the historical results with the US examination and demonstrated good consistency between the 2 exams.

Please join me and the rest of the Board of Directors and the Panel of Examiners in welcoming these Technologists from Canada into the registry as well celebrating the expansion of the Registry to International status.

Dwaine Brown, Ed.

A General Review of Health Physics Calculations

By Augustinus Ong

The purpose of this review, in the format of questions and answers, is to remind ourselves of some of the basic aspects of health physics calculations.

(1) The limit on occupational exposure is 5 mSv/yr. Suppose that a radiation worker in a hot lab receives the equivalent of a whole-body exposure of 5 mSv in 2000. According to ICRP risk estimate assessment, what is the total excess risk that this would induce a fatal cancer in this worker? What if he receives this amount each year over his 40-year working lifetime? Assuming radiation risk factor for public is estimated to be 5×10^{-2} (risk/Sv).

Exposure of the average radiation worker to a uniform, whole-body dose equivalent of D that would result in the probability of his dying of a radiation-induced cancer is

$$\text{Risk} = (\text{Risk / Sv})\, D$$

$$\begin{aligned}\text{The risk for one year} &= (5 \times 10^{-2}\ \text{Sv}^{-1})(0.005\ \text{Sv}) \\ &= 5 \times 10^{-4} \text{ or} \\ &= 2.5 / 10{,}000 = 0.025\%\end{aligned}$$

If he received 5 mSv per year for 40 years, his total excess risk would be 1%.

(2) One million people receive a whole-body exposure of 1 mSv. How many fatal lung cancers would this induce, assuming the linear, no-threshold dose-response relationship and the ICRP probability of 5×10^{-2} risk/Sv for members of the public? Assuming ICRP-60 Organ Weighting Factor for lung is 0.12.

If N members of a population assumed to have the same cancer risk, then the expected number of fatalities is

$$\text{Fatalities} = \text{risk} \times N$$

$$\text{Risk} = (\text{Risk / Sv})\, D$$

The expected number of cancers of all type is

$$\begin{aligned}\text{Fatalities} &= (5 \times 10^{-2}\ \text{per person Sv}^{-1})(0.001\ \text{Sv}) \times (10^{6}\ \text{people}) \\ &= 50\end{aligned}$$

Of those 50 people, the fraction 0.12 (from ICRP-60 for lung) 6 persons would die of lung cancer.

(3) One million people receive 7 mSv to both colon and the red bone marrow but none to the rest of the anatomy. How many excess cancer deaths are expected? Assuming the ICRP risk factors for colon of 0.12 and for the red bone marrow of 0.12.

The effect dose equivalent (EDE), designated as H, deals with non-uniform irradiation. It is an average dose that takes in account not only the doses to various organs but also their radiation sensitivities (w_T, tissue weighting factors).

$$\text{EDE} = \Sigma_T\, (w_T \times H_T)$$

$$\text{Risk} = (\text{Risk / Sv})\, D$$

$$= (\text{Risk / Sv})\, \text{EDE},$$

where total individual risk assumes to be proportional to the EDE.

For EDE of colon and red bone marrow:

$$\text{EDE} = (0.12 \times 0.007\ \text{Sv} + 0.12 \times 0.007\ \text{Sv})$$

$$= 0.0006\ \text{Sv}$$

For individual risk:

$$\begin{aligned}\text{Risk} &= (5 \times 10^{-2}\ \text{Sv}^{-1})(0.0006\ \text{Sv}) \\ &= 2.95 \times 10^{-5} \text{ or 29.5 deaths induced per one million people.}\end{aligned}$$

(4) A group of ten people each received a whole-body irradiation of 50 mSv; five others received 40 mSv to only the left half of the body; and third group of six persons received 10 mSv EDE each. What is the collective dose for the three groups?

The EDEs for the individuals in those three groups are 0.05, 0.02, and 0.01 Sv, respectively.

Collective dose = (0.05 Sv x 10 persons) + (0.02 Sv x 5 persons)
+ (0.01 Sv x 6 persons)

Collective dose = 0.66 person-Sv

(5) In an in vitro experiment, ten Gy of 250-kVp x-rays will kill 99% of the human fibroblast cells. Three Gy of 3-Mev neutrons will have the same killing effect. What is the RBE? What is the range of a 100-keV electron that is liberated by the x-rays interacting with soft tissue? Assuming the average LET for the electron in soft tissue is 1 keV/mm.

The relative biological effectiveness (RBE) is a measure of the ability of a type of ionizing radiation to cause cellular damage. It is defined as

$$RBE = Dose_{reference} / Dose_{test\ radiation}$$

$$= (10\ Gy) / (3\ Gy)$$

$$= 3.3$$

We assume that the electron dissipates its energy at a constant rate over its range, i.e., the linear energy transfer (LET), until it is captured by a positive ion.

$$Range = Energy\ (keV) / (LET)$$

$$= (100\ keV) / (1\ keV/\ mm)$$

$$= 100\ mm$$

(6) Technetium-99m is an important radionuclide that is used in the nuclear medicine department. Post 24 hr injection with Tc-99m, a patient was scanned with a G/M detector and the average net readings were 3 dps. What is the probability that in the next second the detector will read 5 dps?

We will use Poisson statistics for random events to estimate the probability:

$$Pm(n) = \mu^n \times e^{-\mu} / n!$$

where μ is the mean number of events and n is the value (must be an integer) of the next event.

$$Pm(n) = \mu^n \times e^{-\mu} / n!$$
$$= 3^5 \times e^{-3} / 5!$$

$$= 243 \times 0.0498 / 5!$$

$$= 0.101 \text{ or } 10.1\%$$

(7) A floor next to a radioactive-use bench measures 1.5 m. After a brief sprinkle of radioactive liquid drops from a leaky hose, a radiation worker reported that a total of 3000 drops landed on 20 small squared tiles. What is the probability that a typical tile, randomly chosen, will contain between 125 and 175 drops of radioactive liquid?

The mean N is 3000 / 20 = 150 drops.

The standard deviation is a direct measure of the width of the distribution of counts about that mean.

The standard deviation = SQRT (N)

$$= SQRT\ (150)$$

$$= 12.2$$

Since 125 and 175 are approximately two standard deviations below and above the mean, respectively, so there is about 95% chance (see the Table for a Poisson Distribution with large μ probability) that the number of drops in any tile will be between 125 and 175.

Continued on page 19

Professional Pool

Todd Davidson

In this feature, the author will present ideas and solutions for practical problems that professionals in the field of radiological protection and science have encountered. Feel free to share your particular experience with either problems or solutions. This is a forum for sharing experiences. Others in the field may have solved a problem that you have run into. Or you may have an elegant means to correct problems that others may not have considered.

You may contact me at t-davidson@sbcglobal.net. Please note "Professional Pool" in the subject line of the email.

Problem (restated)

The administration of a radiological protection program can be difficult, but there is a chaos at the beginning – and most particularly at the end – of a project. What is the most challenging problem that you or your colleagues have faced at the end of a project?

Response

In my most recent project, the problem that most dramatically caused difficulties at the end of the project was records management and retention. Below are some bulleted notes that list some of the challenges with this programmatic problem.

- *There are regulations and standards that determine the length that various types of records must be stored.*
- *Records management and its planning must occur long before the transfer of the records to the client or any storage facility.*
- *In cases where there is a team, partnership, LLC, joint venture, or even a subcontractor, it should be clear which of the business entities hold the responsibility for the management of records. This might be shared with each entity being responsible for different record types.*
- *At the end of the project, when records management is often hurried, it is difficult to find persons who have the knowledge of the entire project, particularly when the knowledge is not well documented (that is, when "tribal knowledge" is used).*
- *It is important to be aware of the format and setup that the client expects for any submittal of records early in the project.*
- *Whether records must be stored in hard copy format or as electronic records, considerable resources are expended as storage space, memory, and man-hours for administration.*
- *The long term storage of records is important for personal livelihood, corporate liability, government liability, and community health.*

Again, if you have experienced challenges with records or other difficulties at the end of a project, please share it with the author so that we can share it with the registry.

You're Invited!

NRRPT Board & Panel Meetings
February 5-8, 2011
Charleston, SC
Embassy Suites North Charleston - Airport/Hotel & Convention

** All NRRPT members are welcome and encouraged to attend **

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Continued from page 11

(8) The HVL of a monochromatic x-ray beam in matter is 5 cm. What fraction of the beam remains after passage through 12.5 cm?

$$\text{Intensity}(x) = \text{Intensity}(0) \times 2^{-N}$$

$$\text{Intensity}(x) / \text{Intensity}(0) = 2^{-(x / \text{HVL})}$$

$$= 2^{-(12.5\ \text{cm} / 5\ \text{cm})}$$

$$= 0.177 \text{ or } 17.7\%$$

(9) The linear attenuation coefficient μ of a monoenergetic beam in tissue is 0.244 cm^{-1}. What fraction of the intensity remains after penetrating through a 20 cm thick person?

$$\text{Intensity}(x) / \text{Intensity}(0) = e^{-(\mu)(x)}$$
$$= e^{-(0.244\ \text{cm}^{-1})(20\ \text{cm})}$$

$$= 0.00759 \text{ or } 0.759\%$$

(10) The characteristic attenuation distance, $1/\mu$, of a beam in tissue is 2 cm. What is the fraction of the beam remains after penetrating through a 0.05 cm?

$$\text{Intensity}(x) / \text{Intensity}(0) = e^{-(x) / (1/\mu)}$$
$$= e^{-(0.05\ \text{cm}) / (2\ \text{cm})}$$

$$= 0.9753 \text{ or } 97.53\%$$

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- "Board Meeting Update"

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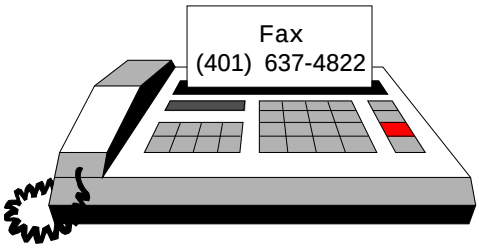

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