Counts Per Minute (CPM) Electronic Calculator

External Peer Review Record

October 30, 2013-January 14, 2014

CONTENTS:

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Peer Review Charge for:
U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator."

Background:
EMS, under contract EP-W-13-016 with the U.S. Environmental Protection Agency's (EPA) Office of Solid Waste and Emergency Response, has been requested to obtain external, independent reviews of the draft "Counts Per Minute (CPM) Electronic Calculator." The purpose of this peer review is to identify any technical problems, omissions, or inconsistencies in the draft CPM calculator, and to obtain expert opinion as to the calculator's usefulness and appropriateness for its intended function. Your comments and recommendations will be used to revise the draft calculator so that the final version will reflect sound technical information and guidance.

Currently, there is no EPA guidance on correlating CPM field survey readings back to risk, dose, or other applicable or relevant and appropriate requirements (ARAR)-based concentrations for Superfund sites (sites regulated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, or CERCLA). EPA developed the CPM calculator to help risk assessors, remedial project managers, and others involved with risk assessment and decision making at radioactively contaminated sites.

The electronic calculator provides a method for correlating real-time survey results—often expressed as CPM—to contaminant concentrations used in risk assessments and cleanup levels at Superfund sites (typically provided in units of pCi/g or pCi/m^2). The intent of the CPM calculator is to facilitate more real-time measurements within a Superfund response framework. It also may standardize the process of converting laboratory data to real-time measurements and thus lessen the amount of laboratory sampling needed for site characterization and confirmation surveys. However, it will not eliminate the need for sampling.

The CPM calculator was developed as a stand-alone device, but in the future it will be incorporated into all of EPA's Superfund models for risk and dose assessment. The CPM calculator should help focus sampling efforts in the site evaluation and final status survey phases to ensure that response objectives are being met during the conduct of the site remediation, and provide better estimates of risk posed at initial site surveys.

Peer Review Charge:

Review the web site (instructions for accessing the site can be found on p. 3) to become familiar with its structure, organization, subpages, and links. The CPM calculator, for purposes of this peer review, includes:

- The Radiation Conversion Home page, with introduction and links to subpages
- The Area User's Guide and Volume User's Guide, which include instructions, explanations, equations, default data, assumptions, and sources
- The Area Calculator and Volume Calculator
- Frequently Asked Questions (FAQs)

We request that you review the overall web site; user's guides; and the area and volume calculators, and answer the charge questions below. You should focus your review on the user's guides, which provide a complete overview, explanation, and instructions, together with supporting data, models, equations, and references and citations. Please note any inconsistencies between the user's guides and calculators.

Charge Questions:

A. Overall Web Site
   1. Is the web site clearly organized, described, easy to navigate, and generally "user friendly?" If not, what do you recommend?
   2. Have the objectives of the CPM calculator, as stated in the documentation, been realized? If not, what do you recommend?
   3. Does the documentation (user's guides) match the online CPM calculator tools and vice-versa? If not, what do you recommend?
   4. Do you have any other recommendations to improve the usability of the web site?

B. User's Guides
   1. Are the tool and web site clearly explained?
      a. Are the assumptions clear and reasonable? If not, what do you recommend?
      b. Does it adequately describe the calculator's limitations? If not, what do you recommend?
      c. Is it well written and clearly organized? If not, what do you recommend?
      d. Is the technical support documentation complete, well organized, and easy to follow? If not, what do you recommend?
   2. Are the sources and citations appropriate, and do they represent the current state of knowledge? If not, what do you recommend?
   3. Are the models for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? If not, what do you recommend?
      a. Area (surface) contamination?
      b. Volumetric contamination?
   4. Are the equations for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations or derivations? Are the equation variables adequately explained in terms of relative sensitivities? Are the equation constants adequately explained and sourced? If not, what do you recommend?
      a. Area (surface) contamination?
      b. Volumetric contamination?
   5. Are the source material and photonic energy data used for the volume calculator comprehensive, appropriate, and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? Are they appropriate for residential and worker exposures? If not, what do you recommend?
   6. Are the choice of detectors and detector heights appropriate and based on supportable reasoning? If not, what do you recommend?
   7. Are the choice of radionuclides and how decay chains are addressed appropriate and based on supportable reasoning? If not, what do you recommend?

8. Are the standard recommended default factors adequately explained, sourced, and reasonable?
9. Is there anything else you recommend for the user's guides to improve them for their stated purpose?

C. Calculator
1. Are the results clearly explained and presented? If not, what do you recommend?
2. Are the results appropriately described and qualified (to the extent that they may be relied upon and defended)? If not, what do you recommend?
3. Do the results provide defensible explanation of how they were derived, or are they the result of a "black box"? Do you recommend anything different?
4. Are there aspects of other Superfund guidance that should have been used or incorporated into the calculator?
5. Are the radionuclides appropriate, and do the results adequately explain the variability among radionuclides? If not, what do you recommend?
6. Is there anything else you recommend for the calculator to improve it for its stated purpose?

D. Anything Else?
Is there anything else you would recommend to improve the CPM's utility, accuracy, completeness, or supportability?

When your review is complete, e-mail your comments to EMS's Project Manager (Mary Kazantseva, mary.kazantseva@emsus.com, 301-589-5318) on or before December 13, 2013. An annotated copy of the user's guide document in Microsoft Word may be submitted as well. *Please do not hand write your comments.*

How to Use the Calculator:

The draft CPM calculator is available for review at https://epa-cpm.ornl.gov/. To access the calculator, enter the user name "prg" and the password "development." Click "no" **every time** when prompted by a security alert asking "Do you want to view only the webpage content that was delivered securely?"

The CPM calculator has two major sub-calculators based on the field survey scenario: (1) ground-based scanning of surface contamination; and (2) ground-based scanning of volumetric contamination.

The CPM calculator includes 783 gamma emitting radionuclides that can be selected. There are some important caveats that users should be aware of, including: (1) the CPM tool is intended to facilitate use of real-time measurement techniques to supplement, not replace physical sampling; (2) the CPM tool only addresses gamma emitters; (3) the CPM tool assumes uniform contamination; (4) the source surface should not be shielded by water or other material; and (5) the CPM tool does not account for backscatter or build-up in the surface.

Detector Data

Detector data is based on four sizes of gamma scintillation detectors by Ludlum Measurements Inc. By default, the CPM calculator estimates the detector response for the primary radionuclide in secular equilibrium with its daughters. This is meaningful, especially in the common case of Cs-137 (the well-known 662 keV gamma of Cs-137 is actually produced by its metastable daughter, Ba-137m). However, this feature can be deactivated by deselecting the check box beneath the radionuclide selection list. The three main natural decay chain series have been truncated for use with manmade or purified radionuclides of U-238, U-235 and Th-232. For example, selecting U-238 will only include the immediate three daughters. The next sequential daughter, U-234, being so long lived, is considered a new radionuclide. To calculate for the natural state of the above three chains, as in calculating for uranium ore, select from the radionuclide list the natural instance of the parent radionuclide, denoted by the suffix, n: U-238n, U-235n, and Th-232n. Selecting one of these radionuclides will include the contribution of the entire natural chain.

Model Geometry

The geometry of the model is a disc source above which a detector is suspended. The height (h) of the detector is the user's estimate of the distance in centimeters between the detector and the source of contamination.

Volume Calculator

When using the Volume calculator, there are six different options for source material, which are soil, concrete, plate glass, wood, steel, and drywall. The model for soil, concrete, plate glass, wood, and steel is based on a uniformly contaminated cylindrical slab source of varying thickness.

MATRIX OF PEER REVIEW COMMENTS: Charge questions for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*						
Commenter	**Charge Question**	**Guidance Section**	**Line Number**	**Details**	**Comment**	**EPA Resolution**
Spreng	A1				I found the web site to be generally well-organized and easy to navigate. I feel that there are some places in the documentation that could be improved by moving or eliminating text to reduce redundancy and to be more internally consistent.	
Spreng	A2				Yes – The calculator should allow decision makers at Superfund sites to benefit from the advantages of real-time surveys. The process of correlating field measurements with lab analyses should become more standardized.	
Spreng	A3				Generally, yes. Some of the instructions within the calculator differ from the step-by-step instructions in the User's Guides. The texts are not conflicting, but they should be consistent.	
Spreng	A4				See suggested redline-strikeout changes and comments to the calculator documents.	
Spreng	B1a				Assumptions are clear and reasonable, but are potentially so limiting that results may not always be representative. It might be useful to explain whether the overall effect of these assumptions is likely to be conservative – or not.	
Spreng	B1b				The limitations are adequately described. Ludlum gamma detectors apparently are the presumed detectors. Variability among other types/brands of field detectors, beyond the detector sensitivity and energy response factor mentioned in 3.4.3, may be another limitation.	
Spreng	B1c				Generally yes. As mentioned above, there are places where the text clarity suffers from redundancy and inconsistent used of terms.	
Spreng	B1d				No response.	
Spreng	B2				Yes – I am not aware of any newer superseding sources.	
Spreng	B3a				Yes.	
Spreng	B3b				Yes. Should/could a link to the MCNP software documentation be provided?	
Spreng	B4a				N/A - My background and experience are not adequate enough to respond.	
Spreng	B4b				N/A - My background and experience are not adequate enough to respond. Should/could a link to the MCNP software documentation be provided?	
Spreng	B5				My background and experience are not adequate enough to respond regarding source material and photonic energy data.	
Spreng	B6				No guidance or reference is provided for determining appropriate detector height. It might be useful to explain the sensitivity of this parameter.	
Spreng	B7				Yes, the rationale seems reasonable especially for the purpose of estimating detector readings.	
Spreng	B8				Yes.	
Spreng	B9				See suggested redline-strikeout changes and comments to the calculator documents.	
Spreng	C1				Yes. The results can be copied and printed out, but it might be helpful to include a print option in the calculator.	
Spreng	C2				No response.	
Spreng	C3				The derivation of the Area Calculator results is fairly straightforward. The Volume Calculator results, however, depend on the MCNP black box. The explanation for this model is adequate for the purposes of the User's Guide, but a link to documentation for MCNP software might be useful.	
Spreng	C4				No.	
Spreng	C5				The variability among the radionuclides is adequately explained.	
Spreng	C6				Add titles on the pages of the Calculator that correspond to the titles in Section 2 of the User's Guide to help connect the Guide to the Calculator (e.g., Radionuclides of Interest, Activity Concentrations, etc.). Highlight the statement, "**I have read and understand the limitations of this model set forth in the User Guide and FAQ**", which must be checked in order to move to page 2 of the calculator.	
Spreng	D				See suggested redline-strikeout changes and comments to the calculator documents.	
King	A1				The web site is well organized, described, easy to navigate, and can be user friendly (there are several bugs, as stated), though a deeper review might leave the user with questions. The site is similar to PRG calculators, and that familiarity is helpful. There are some minor issues to consider that could be addressed by a thorough technical editor. For example: • Consistent use of acronyms (e.g., cpm v. CPM) • Consistent use of proper units (e.g., CF = cpm/pCi/g v. CPM/pCi) • Light blue text difficult to see on a green header	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
King	A2				Does the calculator provide source concentration to CPM conversions? The answer is yes. Would I use the calculator as presented? The answer is maybe. The site works well enough (though there are lots of bugs), so there is hope that the calculator will eventually provide investigators with useful information. The bottom line is that if an investigator assumes the detector will respond as the Calculator predicts, there is a risk of overlooking contamination. The higher than expected Calculator generated values are probably geometry related (from a semi-infinite plane or contamination). If the CPM result is supposed to represent the average measurement across the exposure unit, then that should be stated.	
King	A3				The calculator seems to match the documentation, though some of the information cannot be verified. For example, the gamma energies and yields cannot be verified (no values given), some of the output is inconsistent with input, and the documentation needs to be edited.	
King	A4				• Bottom line is that the investigator should be able to use the Calculator to reasonably predict what one would find in the field. Results should be similar to those presented in MARSSIM Table 6.7 or as described in Abelquist 2001 (*Decommissioning Health Physics – A Handbook for MARSSIM Users*). Values do not have to match – they just need to be reasonably close to give investigators a comfort level. As calculated the values are consistently higher (non-conservative) than expected, though not grossly so. • The Area Calculator may not be needed at all. The Volume Calculator already provides results for a 1-cm thick source.	
King	B1a				Assumptions are clear and reasonable.	
King	B1b				Limitations are adequately described.	
King	B1c				The Guides are written well enough, but they do need a thorough scrubbing by a technical editor. As detailed below, some of the definitions need to be revised.	
King	B1d			Part 1 of 3	• Area CPM Calculator User's Guide, 2nd paragraph. "This calculator…minimizes the use of more expensive sample collection and laboratory analysis" needs to be resolved with the apparent contradiction in Sect. 3.5.1, which states, "The Area CPM Calculator does not replace the need for lab-based sampling…" The Calculators may be used for MARSSIM (or similar) classification decisions and judgmental sample location placement, but the former statement implies a greater value in CPM estimates than the latter statement declares. • Area CPM Calculator User's Guide, Sect. 2.1. Why consider decay products ("+D") based on half-lives of hundreds or thousands of years when the common threshold is 6 month? • Area CPM Calculator User's Guide, Sect. 2.2. The TAC example of 5 pCi/g does not fit for an area calculation. Suggest finding an example with area in the denominator. Also, suggest adding the option to use process knowledge (in addition to laboratory analysis) in FAC development. Analytical data are not always available…or sometimes not enough are available. • Area CPM Calculator User's Guide, Sect. 3.3. What is the "outer circumference" of a disk with (per Sect. 3.5.2) infinite lateral extent? The R is infinite h^2 + R^2 = infinity = (7/u)^2, this u = 0. That would be the case in a vacuum. There seems to be some logic breakdown here. The gammas are assumed to be attenuated, but by what? • Area CPM Calculator User's Guide, Sect. 3.3. It is unclear how the mean free path is applied. The surface has no depth (atom thick), so there is no attenuation from the source. Is this the mean free path in air at STP? This does not appear to be the case.	
King	B1d			Part 2 of 3	• Area CPM Calculator User's Guide, Sect. 3.4.3. It is assumed S comes from the manufacturer. If that is the case, suggest adding that fact, or otherwise let the reader know where the information resides. S values are not provided as inputs or outputs. • Area CPM Calculator User's Guide, Sect. 3.4.4&5. FAC, SAC, or TAC? It is unclear whether or not CPM_FAC is the same as CPM_SAC, and if CPM_SAC_J is the same as TAC_j, why not say CPM_TAC_j? Radionuclide is misspelled in the last line (missing r). • Area CPM Calculator User's Guide, Sect. 3.5.5. How would the user subtract background from the GDR? Unless background is 0, subtraction would result in a negative number. • Area CPM Calculator User's Guide, Sect. 3.6. It is unclear what is meant by "a few" lab analyses. Correlations are very difficult in general and one might argue that uncertainty in the correlation is inversely proportional to the number of data points used in the analysis. • Area CPM Calculator User's Guide, Sect. 4. There is not a non-gaseous form of radon – suggest deleting gaseous. Re. units, becquerels, curies, etc. are lower case when spelled out unless used in reference to the person for which the unit in named. Might also note that 1 curie is the rate of decay from 1 gram of Ra-226. The definition for gross detector response is very weak and adds no value. Suggest simplifying isotope definition to "…the same number of protons in the nucleus but with…" If nuclide is term used to describe the full range of elements, should radionuclide be defined as nuclides that are radioactive? How does a TAC meet the cumulative risk assessment (meets risk goals, perhaps)?	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
King	B1d			Part 3 of 3	• Area CPM Calculator User's Guide, Sect. 6. MARSSIM should be EPA 2000. • It is unclear why the area calculator is needed. Surface area decisions would more likely be associated with alpha or beta/gamma measurements (GM, gas proportional, etc.) and not a pure gamma measurement. The 1-cm-thick option in the Volume Calculator should be good enough for thin sources. • Volume CPM calculator. Source depth does not show values other than 100 cm. CPM values do change with entered value, so the results are probably calculated per the inputs. • Volume CPM calculator. The back button leads to a "Webpage has expired" page. The back button *sometimes* works on the Area Calculator page. • Volume CPM calculator. The hyperlink to listed photons (e.g., 4 photons from Th-234) does not work. Specifically, no photon energies or yield data are presented. Several radionuclides were tried. Same comment for Area Calculator. • Volume CPM Calculator User's Guide, Sect. 3.5. The equation implies the user can enter a source area (e.g., 10 m^2). This is not the case, thus the assumption is the source represents a semi-infinite plane. Adjustments for surface area would be a nice and useful addition.	
King	B2				Sources and citations are appropriate, though authors should make sure results are comparable to values generated via standard (e.g., MARSSIM) guidance. Some calculations could not be verified given the lack of input/output information. Results do seem reasonable based on scale.	
King	B3a				The area model assumes an infinite source extent (though the text is inconsistent) without air attenuation. This should model an over-response and could leave investigators with the false assumption that the area is acceptable when it is not. The Area Calculator may not be necessary at all.	
King	B3b				No response.	
King	B4a				As stated in earlier comments, both methods seem to produce over-responses, and the Calculators do not provide all inputs (e.g., S) or outputs (e.g., gammas used). The equations and constants, as presented, as adequately explained and cited, except as already noted.	
King	B4b				As stated in earlier comments, both methods seem to produce over-responses, and the Calculators do not provide all inputs (e.g., S) or outputs (e.g., gammas used). The equations and constants, as presented, as adequately explained and cited, except as already noted. The Volume Calculator guide implies that the user can adjust source size, though this is not the case. It should be, however, because investigators are unlikely to encounter an actual or effectively-equivalent semi-infinite plane of contamination.	
King	B5				The Calculator would not show energies or yields (blank page each time attempted). Models need to be calibrated to produce values similar to those generated by standard methods. Differences are likely geometry related. Results should have nothing to do with receptor. The detector response in CPM from a source in pC/g or pC/cm^2 is independent of actual or hypothetical past, present, or future occupants.	
King	B6				Choice of detectors is reasonable, though MARSSIM also presents results for 1.25x1.5. Results for a FIDLER would be nice. CPM estimates for a NaI and surface source combination is limited.	
King	B7				The presented choices are reasonable, though the addition to decay products using the 6-month rule would be more consistent with industry.	
King	B8				Defaults are adequately explained, sourced, and reasonable.	
King	B9				See previous comments.	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
King	C1				See previous comments. The major black box issue is how the CPMs are combined to achieve an action level associated with the desired remedial activity. This had to be studied a bit. It eventually became clear that CPM is a stand-in for clean-up level, but it is unclear whether the Calculator is working. Consider the following example for soil, 100 cm depth, 2x2, 10 cm from the source: Radionuclide pCi/g_i f_i CPM_i K-40 15 0.8798 1667 Th-232nat 1.0 0.0587 1406 U-235nat 0.05 0.0029 60 U-238nat 1.0 0.0587 1554 pCi/g_T: 17.05 =sum(pCi/gi) f_i varies =pCi/gi / pCi/g_T GDR: 1524 =1/(f_1/CPM_1+…f_4/CPM_4) The Calculator produces a GDR value of 1761 CPM. Could be this example (table) calculation is off. The results for the 2x2/Unat combination produces the same response no matter what source depth is selected.	
King	C2				See response for C1.	
King	C3				See response for C1.	
King	C4				See response for C1.	
King	C5				See response for C1.	
King	C6				See response for C1.	
King	D				See previous comments.	
Bronson	General			Part 1 of 2	The concept is good. However, this review seems premature, given the state of the software and the document. This tool creates the expected CPM in the instrument. The instrument only reads counts that are above some threshold of energy [pulse height] – perhaps 30-40 keV. Those instruments are very difficult to determine the threshold in energy units. Nowhere in the document does it specify the energy threshold of the instrument. And this threshold varies from instrument to instrument, depending upon how it is adjusted by the user. For large sources there is a lot of scatter and therefore most of the counts are down at low energies. It is not stated what energy the calculations assume that a photon is counted. The referenced Monte Carlo document does calculations all the way down to 1 keV, which is far too low to be useful here. The above two issues make this a very dubious application tool for energies down in the few hundred keV or lower, unless the instrument is calibrated in a standard way, which must be described in this document. There is NO validation that this works. No independent testing with different models. No testing with sources. That is a very critical flaw if you want users to believe this. If a user developed such a tool and used it on a site they were trying to measure, NRC and EPA would certainly demand such proof that it worked, along with reliability estimates – TPU estimates.	
Bronson	General			Part 2 of 2	I don't understand why the two tools [area, volume] use completely different methods to compute the results. Both should use the MCNP method. Having a Government Furnished [which implies Government Approved] that only addresses a single vendor's instruments seems inappropriate. What is the plan and mechanism for others to get entered into here? That should be stated somewhere, and the tool should be designed assuming that will happen. The Volume Technical Reference also needs serious review. I don't see anything that is obviously wrong, the document isn't clearly written. E.g. Gail dePlanque's name is spelled wrong both in the Reference table, and spelled wrong in a different way in page 1 of the text.	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Bronson	A1				General, or both tools: The software tool is very easy to use, and the input is rather obvious. Using the Back arrow is very annoying; the previous page takes 2 clicks to get to, and nothing is remembered. When clicking on the number of photons button, the Photon Yield and Photon Energy headers show up but the table doesn't populate. The nuclide list is very inconvenient for 90% of the users. Have the dozen nuclides most commonly used displayed on the screen with check-boxes to select. Use a conventional method for the Help. E.g. a button on each screen that gives you the information for that screen; rather than a single place on the first page that is not even labeled Help.	
Bronson	A4				Volume Tool: Entering material wood or entering a depth of 1cm doesn't work; the result page always shows Soil at 100cm. This is such an obvious flaw in a very simple program that it causes much concern about the quality of the calculations.	
Davies	A1				The web site is reasonable well presented – although the style is pretty old-fashioned and may look archaic to younger readers. See A4.	
Davies	A2				'… to help risk assessors, remedial project managers, and others involved with risk assessment and decision making …' appears to be the objective. In which case, the calculators will help, but their place needs to be understood	
Davies	A3				Yes, the guides match the calculators.	
Davies	A4				• The web pages look like I wrote them. I know I'm not a good web author and thus I ask experienced designers to create web pages for me. • Secure/insecure content warnings appear repeatedly – puts me off and would do others. • The requirement to acknowledge the 'I have read and understand the limitations of this model set forth in the User Guide and FAQ' for every visit to the site is tedious – couldn't this be handled by 'cookies'? • I'm not sure why the Nuclide entry, Target Activity and other Selection entries are on separate pages – a clumsy implementation. • The radionuclide selector table has a footnote that says ' n = second metastable state nat = naturally occuring' This does not appear to be correct, as 'n' is used for natural series. • The 'No. of photons' feature in the final results tables does not work – always yields an empty table. • The 'Back' button always requires a page re-send – surely this can be avoided in 2014?	
Davies	B1a				• Assumptions are not specifically listed in the user guides – however, the text describes the limitations. • The inherent limitation that the calculators only work for a semi-infinite (lateral) source are not discussed and should be. The use of the CPM calculator for sources which are not semi-infinite could lead to underestimation of the specific activity(s) for smaller sources. • Sections 2.1: '… secular equilibrium in a hundred to a thousand years'. I'm not sure how this has been discussed anywhere in the documentation. Does this mean that decay chains that reach equilibrium in ten years will not be automatically added? Perhaps a phraseology problem. • The calculator cannot (let's be fair) know about gaseous radionuclides that may escape from a matrix (especially for U-238n, Ra-226 etc) – but perhaps that assumption should be stated.	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Davies	B1b				• The exclusion of 'build-up' from the Volume calculations appears to be a serious flaw. This *will* generate differences in between instrumental measurements and laboratory analysis – see next note. While excluding build-up will produce 'safer' results, this is can increase waste volumes and thus costs substantially. • The Area CPM user manual states 'A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.' This implies that these types of correction factor should be expected and are acceptable. The wording also implies that the measurements can be expected to be 'wrong' when in fact the both the sampling and analytical measurements, and the Calculator may be 'wrong'. The use of correction factors should be avoided at all costs – when such factors appear to be required by discrepancies in results, the cause should be sought, not an arbitrary fix. • Both manuals, in section 2.2, state 'The FAC is based on laboratory analysis'. I think this should read '… should be based on …' to make the reader understand that they are providing this information, and that it is not pre-defined in the calculator.	
Davies	B1c				The User Guides are well presented. Perhaps the calculators could have used more up-to-date features of web programming.	
Davies	B1d				No response.	
Davies	B2				I don't think the manuals require more referencing. The References covered most of my queries.	
Davies	B3a				I'm not sure why MCNP or similar codes were not used for the complete calculation – effectively to determine the CPM results in one process. These codes are ideal and proven for Sodium Iodide detectors and will properly account for 'build-up' etc. The use of a series of analytical calculations and assumptions is certainly not the current state of knowledge for environmental radiation measurements.	
Davies	B3b				I'm not sure why MCNP or similar codes were not used for the complete calculation – effectively to determine the CPM results in one process. These codes are ideal and proven for Sodium Iodide detectors and will properly account for 'build-up' etc. The use of a series of analytical calculations and assumptions is certainly not the current state of knowledge for environmental radiation measurements. The Volume user guide states 'The Volume CPM Calculator model was developed using 248 case runs of MCNP to simulate the spectrum of the desired radionuclide(s).' Why, if it was so important that everything else had to be determined analytically?	
Davies	B4a				• I believe that the calculation of CPM through dose/flux is inherently flawed: • Even if it was, the calculation of dose/flux using a (2D) surface tally in MCNP does not appear logical, as the detectors are 3D. • The 'back-end' calculations in relation to mixed radionuclides are appropriate. • I have compared the CPM results for Cs-137, Co-60 and Ra-226 with previous calculations I have done. While the Area and shallow Volume results are in good agreement, the thicker Volume result appear to be underestimates potentially by a factor of 2 (compared to my MCNP calculations, of course, which I don't state as definitive). To my mind, this is due to the lack of 'build-up' in the calculations.	
Davies	B4b				• I believe that the calculation of CPM through dose/flux is inherently flawed: • Even if it was, the calculation of dose/flux using a (2D) surface tally in MCNP does not appear logical, as the detectors are 3D. • The 'back-end' calculations in relation to mixed radionuclides are appropriate. • I have compared the CPM results for Cs-137, Co-60 and Ra-226 with previous calculations I have done. While the Area and shallow Volume results are in good agreement, the thicker Volume result appear to be underestimates potentially by a factor of 2 (compared to my MCNP calculations, of course, which I don't state as definitive). To my mind, this is due to the lack of 'build-up' in the calculations.	
Davies	B5				• Material definitions (in the MCNP report) appear ok – but it would have been nice to have more detailed references, for example, 'Steel' appears to be Stainless 316. • Unfortunately, I was unable to check photonic data as this feature of the web site ('Number of photons' see earlier) was broken.	
Davies	B6				• I'm not quite sure about the usability of the smallest detector (0.5x1), except in areas which are grossly contaminated. • I am confused by the absolute limitation of detector height for the Drywall material to 0.5cm height – surely measurements might be taken at other heights? Unless this height is mandated by legislation?	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Davies	B7				• The documentation should include some reference(s) to the detection of beta radiation by gamma detectors. While for the detectors quoted, which have relative thick aluminium cases, detection will be quite small, there may be detection of direct beta radiation from, say, Sr-90/Y-90 and of Bremsstrahlung from shallow sources. • The documentation might be changed to note that the decay of certain radionuclides may include gases which will escape from an un-sealed matrix such as soil or dryboard. For example, for U-238n or Ra-226, this may reduce the total gamma signal by 30% - enough to want to know about.	
Davies	B8				I'm not sure I can see any have been used.	
Davies	B9				Some comments above about assumptions etc, but otherwise they are ok.	

MATRIX OF PEER REVIEW COMMENTS: Welcome, Introduction, and FAQs for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		Welcome			Paragraphs and sentences re-arranged into a more logical sequence.	
Spreng		Welcome	Para 1	Sentences 2-4	Move to Welcome, as Para 3. Change to read [deleted items crossed out, new text in bold]: This tool is provided to help calculate the ~~radiation~~ gamma detector reading**s** in counts per minute (cpm) that corresponds to the level of radioactivity in a surface or volume of medium by converting radioactivity in either pCi/cm2 or pCi/g to cpm. The CPM calculator h~~as two major sub calculators based on the field survey scenario~~ **addresses two types of field surveys:** (1) ~~ground-based~~ scanning ~~of~~ surface contamination, and (2) ~~ground-based~~ scanning ~~of~~ volumetric contamination.	
Spreng		Welcome			Insert as Para 4: Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.	
Spreng		Introduction		Heading	Delete heading	
Spreng		Introduction	Para 1		Move to Welcome, Para 1, as Sentences 2-3.	
Spreng		Introduction	Para 2	Sentences 1-2	Move to Welcome as Para 2, Sentences 1-2.	
Spreng		Introduction	Para 2	Sentence 3	Delete	
Spreng		Introduction	Para 3	Sentences 1-2	Delete	
Spreng		Introduction	Para 3	Sentence 3	Move to Welcome, Para 2 as sentence 3.	
Spreng		FAQs			I'm not sure these would be my most pressing questions. Some of these paragraphs are more complete than the corresponding paragraphs in the User's Guides. I'd suggest integrating these paragraphs into the User's Guides, then deleting this FAQs sheet. If the FAQs sheet is a requirement, I'd at least integrate these paragraphs into the User's Guides, then the FAQs sheet can be abridged by referencing the appropriate sections in the User's Guides.	

MATRIX OF PEER REVIEW COMMENTS: Area CPM User's Guide for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		1			The Introduction in the User's Guide is somewhat redundant with the Introduction on the calculator home (Welcome) page and the two could be combined in one place or the other. If not combined, they should be better integrated. I would move the last sentence of the 2nd paragraph to follow the highlighted warning in the 3rd paragraph. Shouldn't the ultimate caution be, "The user should always verify real-time survey results with lab analyses."? See the end of Section 3.7.	
Spreng		1	Para 1		Replace Para 1 with: Data collection at radioactively-contaminated sites determines whether areas require remediation and then whether an area has been remediated to acceptable levels. Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.	
Spreng		1	Para 1-2		Delete paragraph break to create one paragraph.	
Spreng		1	Para 2	Sentence 1	Insert bolded terms: The Area CPM Calculator is a web-based calculator that estimates a gamma **scintillation** detector response **in cpm** for a target level of **radiological** contamination on a surface.	
Spreng		1	Para 2	Sentence 2	Delete: provides a rapid, exceptionally cost-effective assessment of contamination and cleanup standards based on	
Spreng		1	Para 2	Sentence 2	Insert after "calculator": supports the acquisition of	
Spreng		1	Para 2	Sentence 2	Comment: The calculator does not assess "contamination" or "cleanup standards". Cost effective?? It's free.	
Spreng		1	Para 2	Sentence 3	Move to follow first sentence of Para 3: A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.	
Spreng		1	Para 2-3		Delete paragraph break to create one paragraph.	
Spreng		1	Para 3	Sentence 1	Replace "sampling" with "analyses"	
Spreng		1	Bullet list	Bullet 3	Insert bolded item: • choice of target activity **concentration**	
Spreng		2			The step-by-step instruction in Section 2 makes it the most important part of these Guides. It is the "how to" that most users will rely on when first using the calculator. The rest is supplemental, support, or background information.	
Spreng		2.1			These instructions should match the instructions for this page in the calculator.	
Spreng		2.1	Bullet	Sentence 2	This next-to-last sentence is different in the instructions for this page in the calculator ("To calculate the parent and daughter activities manually…"). Both sentences could be included in both places	
Spreng		2.1	Para 1		Regarding sentence: "Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators." Doesn't belong here. See section 2.2 below.	
Spreng		2.2			These instructions should match the instructions for this page in the calculator. More information on how to derive FACs is needed here or in Section 3.4.	
Spreng		2.2	Bullet list	Bullets 1-2	These instructions should match the instructions for this page in the calculator.	
Spreng		2.3			How sensitive is the input of the distance from detector to source? Should that be mentioned here?	
Spreng		2.3	Bullet list	Bullet 2	Regarding sentence: "Enter the estimated distance between the source and the detector in centimeters. Click "Next"." Guidance on an appropriate estimate for this parameter would be useful.	
Spreng		2.4		Results table in calculator	The results table can be copied and then printed. Can a "print page" option be added?	
Spreng		3.1	Para 2	Sentence 3	Replace "three" with "four"	
Spreng		3.2	Section name		Insert bolded term: Daughters and **Decay** Chains	
Spreng		3.4			More information on how FACs should be derived could be included. I assume that the FAC inputs could be an average of activity measurements for each radionuclide over the area of interest with the assumption that field ratios are uniform over that area. The ratios of some radionuclides are fairly precise (e.g., Pu and its daughter Am) and can be used to determine contaminant source areas in the field. Variations in the isotopic ratios for U are also used to determine contaminant sources: DU, EU, and natural U.	

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		3.4	Para 1	Sentence 2	Typo (correction in bold): **e**stablished	
Spreng		3.4.5	Para 2		Typo (correction in bold): **r**adionuclide	
Spreng		3.5			Could variability among different types/brands of field detectors, beyond the detector sensitivity and energy response factor mentioned in 3.4.3, be a limitation?	
Spreng		3.5.3			I'd prefer to have the more complete explanation provided in the FAQs included here in the User's Guide. The FAQs section could reference this section for greater detail.	
Spreng		3.6	Para 1	Sentence 1	Replace: "designed and applied to correlate" with "developed by correlating"	
Spreng		3.6	Para 1	Sentence 1	Delete: sampling	
Spreng		3.6	Para 1	Sentence 1	Replace: "to" with "with"	
Spreng		3.7	Para 1	Sentence 1	Replace: "methods" with "surveys"	
Spreng		3.7	Para 1	Sentence 1	Insert: "(EPA 1999)" after "*Radiation Risk Assessment At CERCLA Sites: Q&A*"	
Spreng		3.7	Para 1	Sentence 2	Typo (correction in bold): measur**e**ments	
Spreng		3.7	Bullet list	Bullet 2, Sentence 2	Typo (correction in bold): measur**e**ments	
Spreng		3.7	Bullet list	Bullet 2, Sentence 2	Replace: "should" with "does"	
Spreng		4			Possible additional terms: photon spectrum, scintillation detector (rather than "detector").	
Spreng		4		MARSSIM definition	Insert hyphen: dose-	
Spreng		6		ITRC, 2006	Insert bolded letter: Radionuclide**s** [in "Real-Time Radionuclide Team"]	
Spreng		6		ITRC, 2006	Delete: "Real-Time" [from "Real-Time Radionuclide Team"] The existing citation is the one suggested at the front of the document. The actual team name, however, is simply Radionuclides Team.	
Bronson		General			The guide should be divided into different sections: - How to use the software - Technical reference - Regulatory applications	
Bronson		2.1	Para 2	Sentence 1	What defines "reaching" secular equilibrium ?	
Bronson		2.1	Para 2	Sentence 1	What happens to those daughters that are <100 or >1000 y ??	
Bronson		2.1	Para 2	Sentence 4	??? don't understand this sentence .	
Bronson		2.4	Para 3	Sentence 1	?? isn't it really "above"; all decays have X-rays that are lower than the detection range, and I didn't see any notes. I didn't' see any notes for Cs137, and the 36 keV photon is also likely outside the range of the detectors.	
Bronson		2.4	Para 3	Sentence 2	Doesn't work.	
Bronson		3.1	Para 3	3x3 graph	The 3x3 graph is considerably different from the others, and I don't understand why; something is not right.	

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Bronson		3.2	Para 1	Sentence 1	I don’t understand the 100-1000y part of this. The user wants to know the instrument response on the date of measurement, not what it will be 100-1000 y from now. How is the case of freshly processed Thorium handled, where most of the easily-measured daughters are removed and take 20-40y to mostly grow back ??	
Bronson		3.3	Para 1	Sentence 3	Regarding "seven mean free paths (7/μ):" MFP in Air ??? if so, then state it	
Bronson		3.3	Para 1	Sentence 3	This is far too much information for the user. Just say that the model is an infinite diameter planar disc source.	
Bronson		3.4.1		Definition of gamma coefficient	Where does this come from ? Reference; Where does “μ” come from ??	
Bronson		3.4.1			Regarding "is designed so that the range from the detector to the boundary is 7 mean free paths:" Why 7 ? Just pick a big number and use it for everything.	
Bronson		3.5.2	Para 1	Sentences 1-2	?? not sufficient; you really mean that each individual radionucide has a uniform concentration everywhere on the surface	
Bronson		3.5.2	Para 1	Sentence 3	Regarding "radionuclide ratios:" concentration, not ratios	
Bronson		3.5.3	Para 1	Sentence 1	?? still pure alphas and pure betas there; seems like the list	
Bronson		3.5.3	Para 2	Sentence 1	Regarding "between 40 keV and 2 MeV:" why a high energy cutoff ? the instrument only has a lower energy threshold, it still counts photons with energies >2MeV.	
Bronson		3.5.3	Para 2	Sentence 2	Seems that you should put all the energies in the library and let the analysis software figure out which ones to use. The cutoff will not always be 40 keV, and I doubt that it is that here for all detectors. And might not be for other detectors that it has been claimed that will be added sometime in the future.	
Bronson		3.7	Bullet list	Bullet 2, Sentence 2	These instruments are NOT exposure rate instruments, they are count-rate instruments.	
Bronson		4		Detector definition	Sensor, not instrument	
Bronson		4		Fractivity definition	??? Did you guys just make up this word ??	
Bronson		4		Fractivity definition	I thought that in secular equilibrium, the daughter activity is equal to the parent activity ??	
Bronson		4		Gamma radiation definition	Regarding "Gamma rays are very penetrating and require dense materials:" Actually they require massive materials, density must makes the mass smaller.	
Bronson		4		Mean free path definition	Regarding "completely attenuated:" It is actually only attenuated 1000x; if it started out really strong, the beam still might not be “negligible”. When the technical reference document is completed, it should prove that 7mfp in these calculations is sufficiently close to infinite mfp.	
Bronson		4		Yield definition	Insert bolded text: particles emitted **at a specific energy** per radionuclide decay.	
Bronson		6			There are no citation marks in the document showing where these references were referenced.	

MATRIX OF PEER REVIEW COMMENTS: Volume CPM User's Guide for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		1			The Introduction in the User's Guide is somewhat redundant with the Introduction on the calculator home page and the two could be combined in one place or the other. If not combined, they should be better integrated. I would move the last sentence of the 2nd paragraph to follow the highlighted warning in the 3rd paragraph. Shouldn't the ultimate caution be, "The user should always verify real-time survey results with lab analyses."? See the end of Section 3.7.	
Spreng		1	Para 1		Replace with: Data collection at radioactively-contaminated sites determines whether areas require remediation and then whether an area has been remediated to acceptable levels. Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.	
Spreng		1	Para 2	Sentence 1	Insert bolded term: target level of **radiological** contamination in a source	
Spreng		1	Para 2	Sentence 2	Replace pCi/area with pCi/volume	
Spreng		1	Para 2	Sentence 4	Delete sentence ["A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances."]	
Spreng		1	Para 3	Sentence 1	Replace "sampling" with "analyses"	
Spreng		1	Para 3	Sentence 1	Insert after Sentence 1: A correction factor to account for ground truthing and other field nuances can be derived from a correlation between this calculator's results and lab analyses.	
Spreng		1	Bullet list	Bullet 8	Typo: inlcuding	
Spreng		2			The step-by-step instruction in Section 2 makes it the most important part of these Guides. It is the "how to" that most users will rely on when first using the calculator. The rest is supplemental, support, or background information.	
Spreng		2	Para 1		These instructions should match the instructions for this page in the calculator.	
Spreng		2.1			These instructions should match the instructions for this page in the calculator.	
Spreng		2.1	Para 1		Regarding sentence: "Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators." Doesn't belong here. See section 2.2 below.	
Spreng		2.2			These instructions should match the instructions for this page in the calculator. More information on how to derive FACs is needed here or in Section 3.4.	
Spreng		2.3			How sensitive is the input of the distance from detector to source? Should that be mentioned here?	
Spreng		2.3	Bullet list	Bullet 4	Guidance on an appropriate estimate for this parameter would be useful.	
Spreng		2.4			The results table can be copied and then printed. Can a "print page" option be added?	
Spreng		3.3	Section name		Insert bolded term: Daughters and **Decay** Chains	
Spreng		3.7	Para 1		Replace: "designed and applied to correlate a few" with "developed by correlating"	
Spreng		3.7	Para 1		Delete: "sampling"	
Spreng		3.7	Para 1		Replace: "to" with "with"	
Spreng		3.8	Para 1	Sentence 1	Replace: "methods" with "surveys"	
Spreng		3.8	Para 1	Sentence 1	Insert: "(EPA 1999)" after "*Radiation Risk Assessment At CERCLA Sites: Q&A*"	
Spreng		3.8	Para 1	Sentence 2	Typo: measur**e**ments	
Spreng		3.8	Bullet list	Bullet 2, Sentence 2	Typo: measur**e**ments	
Spreng		3.8	Bullet list	Bullet 2, Sentence 2	Replace: "should" with "does"	
Spreng		4			Possible additional terms: photon spectrum, scintillation detector (rather than "detector").	
Spreng		4		MARSSIM definition	Insert hyphen: dose- [this comment was not in the reviewer's Volume CPM User's Guide review document; however, the reviewer made this comment regarding the MARSSIM definition in the review document for the Area CPM User's Guide; since the two definitions are identical, the comment is included in this matrix]	
Spreng		6		ITRC, 2006	Insert bolded letter: Radionuclide**s** [in "Real-Time Radionuclide Team"]	

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		6		ITRC, 2006	Delete: "Real-Time" [from "Real-Time Radionuclide Team"] The existing citation is the one suggested at the front of the document. The actual team name, however, is simply Radionuclides Team.	
Bronson		3.1			Why isn't the "more sophisticated" and "more rigorous" method used in both sections ?? The Area calculations are just thin weightless volumes.	
Bronson		3.1	Para 2	Sentence 2	Regarding "including attenuation:" didn't the Area CPM account for air attenuation?	
Bronson		3.1	Para 2	Sentence 2	Regarding "source shielding:" not accounted for because not relevant for thin sources	
Bronson		3.1	Para 2	Sentence 2	Regarding "scattering and buildup:" [this is really scattering], backscatter	
Bronson		3.2	Para 2		This paragraph isn't relevant to this document.	
Bronson		3.4	Para 1	Sentence 4	Diagram not linked	
Bronson		3.4	Para 2	Sentence 2	Too restrictive; what if the user wants to measure the drywall at 10 or 30 or 100cm like the others ?	
Bronson		3.5.1	Para 2	Sentence 1	Regarding "The output of the MCNP software is energy fluence per MCNP source particle, SP (Φ_E/cm^2 - SP):" Is the equation listed correct ??	
Bronson		3.5.1	Para 2	Equation for conversion factor	Explain all the terms in this equation; fix spelling [depth, not dept]	
Bronson		3.5.1	Para 3	Sentence 4	Regarding Technical Background Document: This document needs a lot of work	
Bronson		3.5.2	Para 1	Sentence 1	The equation uses pCi, not pCi/g	
Bronson		3.5.2	Para 1	Sentence 2	Same comment as before [the equation uses pCi, not pCi/g]	
Bronson		3.6.3	Para 3		The MC reference document says that bremsstrahlung IS included.	

MATRIX OF PEER REVIEW COMMENTS: Charge questions for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Spreng	A1				I found the web site to be generally well-organized and easy to navigate. I feel that there are some places in the documentation that could be improved by moving or eliminating text to reduce redundancy and to be more internally consistent.	
Spreng	A2				Yes – The calculator should allow decision makers at Superfund sites to benefit from the advantages of real-time surveys. The process of correlating field measurements with lab analyses should become more standardized.	
Spreng	A3				Generally, yes. Some of the instructions within the calculator differ from the step-by-step instructions in the User's Guides. The texts are not conflicting, but they should be consistent.	
Spreng	A4				See suggested redline-strikeout changes and comments to the calculator documents.	
Spreng	B1a				Assumptions are clear and reasonable, but are potentially so limiting that results may not always be representative. It might be useful to explain whether the overall effect of these assumptions is likely to be conservative – or not.	
Spreng	B1b				The limitations are adequately described. Ludlum gamma detectors apparently are the presumed detectors. Variability among other types/brands of field detectors, beyond the detector sensitivity and energy response factor mentioned in 3.4.3, may be another limitation.	
Spreng	B1c				Generally yes. As mentioned above, there are places where the text clarity suffers from redundancy and inconsistent used of terms.	
Spreng	B1d				No response.	
Spreng	B2				Yes – I am not aware of any newer superseding sources.	
Spreng	B3a				Yes.	
Spreng	B3b				Yes. Should/could a link to the MCNP software documentation be provided?	
Spreng	B4a				N/A - My background and experience are not adequate enough to respond.	
Spreng	B4b				N/A - My background and experience are not adequate enough to respond. Should/could a link to the MCNP software documentation be provided?	
Spreng	B5				My background and experience are not adequate enough to respond regarding source material and photonic energy data.	
Spreng	B6				No guidance or reference is provided for determining appropriate detector height. It might be useful to explain the sensitivity of this parameter.	
Spreng	B7				Yes, the rationale seems reasonable especially for the purpose of estimating detector readings.	
Spreng	B8				Yes.	
Spreng	B9				See suggested redline-strikeout changes and comments to the calculator documents.	
Spreng	C1				Yes. The results can be copied and printed out, but it might be helpful to include a print option in the calculator.	
Spreng	C2				No response.	
Spreng	C3				The derivation of the Area Calculator results is fairly straightforward. The Volume Calculator results, however, depend on the MCNP black box. The explanation for this model is adequate for the purposes of the User's Guide, but a link to documentation for MCNP software might be useful.	
Spreng	C4				No.	
Spreng	C5				The variability among the radionuclides is adequately explained.	
Spreng	C6				Add titles on the pages of the Calculator that correspond to the titles in Section 2 of the User's Guide to help connect the Guide to the Calculator (e.g., Radionuclides of Interest, Activity Concentrations, etc.). Highlight the statement, "**I have read and understand the limitations of this model set forth in the User Guide and FAQ**", which must be checked in order to move to page 2 of the calculator.	
Spreng	D				See suggested redline-strikeout changes and comments to the calculator documents.	
King	A1				The web site is well organized, described, easy to navigate, and can be user friendly (there are several bugs, as stated), though a deeper review might leave the user with questions. The site is similar to PRG calculators, and that familiarity is helpful. There are some minor issues to consider that could be addressed by a thorough technical editor. For example: • Consistent use of acronyms (e.g., cpm v. CPM) • Consistent use of proper units (e.g., CF = cpm/pCi/g v. CPM/pCi) • Light blue text difficult to see on a green header	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
King	A2				Does the calculator provide source concentration to CPM conversions? The answer is yes. Would I use the calculator as presented? The answer is maybe. The site works well enough (though there are lots of bugs), so there is hope that the calculator will eventually provide investigators with useful information. The bottom line is that if an investigator assumes the detector will respond as the Calculator predicts, there is a risk of overlooking contamination. The higher than expected Calculator generated values are probably geometry related (from a semi-infinite plane or contamination). If the CPM result is supposed to represent the average measurement across the exposure unit, then that should be stated.	
King	A3				The calculator seems to match the documentation, though some of the information cannot be verified. For example, the gamma energies and yields cannot be verified (no values given), some of the output is inconsistent with input, and the documentation needs to be edited.	
King	A4				• Bottom line is that the investigator should be able to use the Calculator to reasonably predict what one would find in the field. Results should be similar to those presented in MARSSIM Table 6.7 or as described in Abelquist 2001 (*Decommissioning Health Physics – A Handbook for MARSSIM Users*). Values do not have to match – they just need to be reasonably close to give investigators a comfort level. As calculated the values are consistently higher (non-conservative) than expected, though not grossly so. • The Area Calculator may not be needed at all. The Volume Calculator already provides results for a 1-cm thick source.	
King	B1a				Assumptions are clear and reasonable.	
King	B1b				Limitations are adequately described.	
King	B1c				The Guides are written well enough, but they do need a thorough scrubbing by a technical editor. As detailed below, some of the definitions need to be revised.	
King	B1d			Part 1 of 3	• Area CPM Calculator User's Guide, 2nd paragraph. "This calculator…minimizes the use of more expensive sample collection and laboratory analysis" needs to be resolved with the apparent contradiction in Sect. 3.5.1, which states, "The Area CPM Calculator does not replace the need for lab-based sampling…" The Calculators may be used for MARSSIM (or similar) classification decisions and judgmental sample location placement, but the former statement implies a greater value in CPM estimates than the latter statement declares. • Area CPM Calculator User's Guide, Sect. 2.1. Why consider decay products ("+D") based on half-lives of hundreds or thousands of years when the common threshold is 6 month? • Area CPM Calculator User's Guide, Sect. 2.2. The TAC example of 5 pCi/g does not fit for an area calculation. Suggest finding an example with area in the denominator. Also, suggest adding the option to use process knowledge (in addition to laboratory analysis) in FAC development. Analytical data are not always available…or sometimes not enough are available. • Area CPM Calculator User's Guide, Sect. 3.3. What is the "outer circumference" of a disk with (per Sect. 3.5.2) infinite lateral extent? The R is infinite h^2 + R^2 = infinity = (7/u)^2, this u = 0. That would be the case in a vacuum. There seems to be some logic breakdown here. The gammas are assumed to be attenuated, but by what? • Area CPM Calculator User's Guide, Sect. 3.3. It is unclear how the mean free path is applied. The surface has no depth (atom thick), so there is no attenuation from the source. Is this the mean free path in air at STP? This does not appear to be the case.	
King	B1d			Part 2 of 3	• Area CPM Calculator User's Guide, Sect. 3.4.3. It is assumed S comes from the manufacturer. If that is the case, suggest adding that fact, or otherwise let the reader know where the information resides. S values are not provided as inputs or outputs. • Area CPM Calculator User's Guide, Sect. 3.4.4&5. FAC, SAC, or TAC? It is unclear whether or not CPM_FAC is the same as CPM_SAC, and if CPM_SAC_J is the same as TAC_j, why not say CPM_TAC_j? Radionuclide is misspelled in the last line (missing r). • Area CPM Calculator User's Guide, Sect. 3.5.5. How would the user subtract background from the GDR? Unless background is 0, subtraction would result in a negative number. • Area CPM Calculator User's Guide, Sect. 3.6. It is unclear what is meant by "a few" lab analyses. Correlations are very difficult in general and one might argue that uncertainty in the correlation is inversely proportional to the number of data points used in the analysis. • Area CPM Calculator User's Guide, Sect. 4. There is not a non-gaseous form of radon – suggest deleting gaseous. Re. units, becquerels, curies, etc. are lower case when spelled out unless used in reference to the person for which the unit in named. Might also note that 1 curie is the rate of decay from 1 gram of Ra-226. The definition for gross detector response is very weak and adds no value. Suggest simplifying isotope definition to "…the same number of protons in the nucleus but with…" If nuclide is term used to describe the full range of elements, should radionuclide be defined as nuclides that are radioactive? How does a TAC meet the cumulative risk assessment (meets risk goals, perhaps)?	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
King	B1d			Part 3 of 3	• Area CPM Calculator User's Guide, Sect. 6. MARSSIM should be EPA 2000. • It is unclear why the area calculator is needed. Surface area decisions would more likely be associated with alpha or beta/gamma measurements (GM, gas proportional, etc.) and not a pure gamma measurement. The 1-cm-thick option in the Volume Calculator should be good enough for thin sources. • Volume CPM calculator. Source depth does not show values other than 100 cm. CPM values do change with entered value, so the results are probably calculated per the inputs. • Volume CPM calculator. The back button leads to a "Webpage has expired" page. The back button *sometimes* works on the Area Calculator page. • Volume CPM calculator. The hyperlink to listed photons (e.g., 4 photons from Th-234) does not work. Specifically, no photon energies or yield data are presented. Several radionuclides were tried. Same comment for Area Calculator. • Volume CPM Calculator User's Guide, Sect. 3.5. The equation implies the user can enter a source area (e.g., 10 m^2). This is not the case, thus the assumption is the source represents a semi-infinite plane. Adjustments for surface area would be a nice and useful addition.	
King	B2				Sources and citations are appropriate, though authors should make sure results are comparable to values generated via standard (e.g., MARSSIM) guidance. Some calculations could not be verified given the lack of input/output information. Results do seem reasonable based on scale.	
King	B3a				The area model assumes an infinite source extent (though the text is inconsistent) without air attenuation. This should model an over-response and could leave investigators with the false assumption that the area is acceptable when it is not. The Area Calculator may not be necessary at all.	
King	B3b				No response.	
King	B4a				As stated in earlier comments, both methods seem to produce over-responses, and the Calculators do not provide all inputs (e.g., S) or outputs (e.g., gammas used). The equations and constants, as presented, as adequately explained and cited, except as already noted.	
King	B4b				As stated in earlier comments, both methods seem to produce over-responses, and the Calculators do not provide all inputs (e.g., S) or outputs (e.g., gammas used). The equations and constants, as presented, as adequately explained and cited, except as already noted. The Volume Calculator guide implies that the user can adjust source size, though this is not the case. It should be, however, because investigators are unlikely to encounter an actual or effectively-equivalent semi-infinite plane of contamination.	
King	B5				The Calculator would not show energies or yields (blank page each time attempted). Models need to be calibrated to produce values similar to those generated by standard methods. Differences are likely geometry related. Results should have nothing to do with receptor. The detector response in CPM from a source in pC/g or pC/cm^2 is independent of actual or hypothetical past, present, or future occupants.	
King	B6				Choice of detectors is reasonable, though MARSSIM also presents results for 1.25x1.5. Results for a FIDLER would be nice. CPM estimates for a NaI and surface source combination is limited.	
King	B7				The presented choices are reasonable, though the addition to decay products using the 6-month rule would be more consistent with industry.	
King	B8				Defaults are adequately explained, sourced, and reasonable.	
King	B9				See previous comments.	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
King	C1				See previous comments. The major black box issue is how the CPMs are combined to achieve an action level associated with the desired remedial activity. This had to be studied a bit. It eventually became clear that CPM is a stand-in for clean-up level, but it is unclear whether the Calculator is working. Consider the following example for soil, 100 cm depth, 2x2, 10 cm from the source: Radionuclide pCi/g_i f_i CPM_i K-40 15 0.8798 1667 Th-232nat 1.0 0.0587 1406 U-235nat 0.05 0.0029 60 U-238nat 1.0 0.0587 1554 pCi/g_T: 17.05 =sum(pCi/gi) f_i varies =pCi/gi / pCi/g_T GDR: 1524 $=1/(f_1/CPM_1+\ldots f_4/CPM_4)$ The Calculator produces a GDR value of 1761 CPM. Could be this example (table) calculation is off. The results for the 2x2/Unat combination produces the same response no matter what source depth is selected.	
King	C2				See response for C1.	
King	C3				See response for C1.	
King	C4				See response for C1.	
King	C5				See response for C1.	
King	C6				See response for C1.	
King	D				See previous comments.	
Bronson	General			Part 1 of 2	The concept is good. However, this review seems premature, given the state of the software and the document. This tool creates the expected CPM in the instrument. The instrument only reads counts that are above some threshold of energy [pulse height] – perhaps 30-40 keV. Those instruments are very difficult to determine the threshold in energy units. Nowhere in the document does it specify the energy threshold of the instrument. And this threshold varies from instrument to instrument, depending upon how it is adjusted by the user. For large sources there is a lot of scatter and therefore most of the counts are down at low energies. It is not stated what energy the calculations assume that a photon is counted. The referenced Monte Carlo document does calculations all the way down to 1 keV, which is far too low to be useful here. The above two issues make this a very dubious application tool for energies down in the few hundred keV or lower, unless the instrument is calibrated in a standard way, which must be described in this document. There is NO validation that this works. No independent testing with different models. No testing with sources. That is a very critical flaw if you want users to believe this. If a user developed such a tool and used it on a site they were trying to measure, NRC and EPA would certainly demand such proof that it worked, along with reliability estimates – TPU estimates.	
Bronson	General			Part 2 of 2	I don’t understand why the two tools [area, volume] use completely different methods to compute the results. Both should use the MCNP method. Having a Government Furnished [which implies Government Approved] that only addresses a single vendor’s instruments seems inappropriate. What is the plan and mechanism for others to get entered into here? That should be stated somewhere, and the tool should be designed assuming that will happen. The Volume Technical Reference also needs serious review. I don’t see anything that is obviously wrong, the document isn’t clearly written. E.g. Gail dePlanque’s name is spelled wrong both in the Reference table, and spelled wrong in a different way in page 1 of the text.	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Bronson	A1				General, or both tools: The software tool is very easy to use, and the input is rather obvious. Using the Back arrow is very annoying; the previous page takes 2 clicks to get to, and nothing is remembered. When clicking on the number of photons button, the Photon Yield and Photon Energy headers show up but the table doesn't populate. The nuclide list is very inconvenient for 90% of the users. Have the dozen nuclides most commonly used displayed on the screen with check-boxes to select. Use a conventional method for the Help. E.g. a button on each screen that gives you the information for that screen; rather than a single place on the first page that is not even labeled Help.	
Bronson	A4				Volume Tool: Entering material wood or entering a depth of 1cm doesn't work; the result page always shows Soil at 100cm. This is such an obvious flaw in a very simple program that it causes much concern about the quality of the calculations.	
Davies	A1				The web site is reasonable well presented – although the style is pretty old-fashioned and may look archaic to younger readers. See A4.	
Davies	A2				'… to help risk assessors, remedial project managers, and others involved with risk assessment and decision making …' appears to be the objective. In which case, the calculators will help, but their place needs to be understood	
Davies	A3				Yes, the guides match the calculators.	
Davies	A4				• The web pages look like I wrote them. I know I'm not a good web author and thus I ask experienced designers to create web pages for me. • Secure/insecure content warnings appear repeatedly – puts me off and would do others. • The requirement to acknowledge the 'I have read and understand the limitations of this model set forth in the User Guide and FAQ' for every visit to the site is tedious – couldn't this be handled by 'cookies'? • I'm not sure why the Nuclide entry, Target Activity and other Selection entries are on separate pages – a clumsy implementation. • The radionuclide selector table has a footnote that says ' n = second metastable state nat = naturally occuring' This does not appear to be correct, as 'n' is used for natural series. • The 'No. of photons' feature in the final results tables does not work – always yields an empty table. • The 'Back' button always requires a page re-send – surely this can be avoided in 2014?	
Davies	B1a				• Assumptions are not specifically listed in the user guides – however, the text describes the limitations. • The inherent limitation that the calculators only work for a semi-infinite (lateral) source are not discussed and should be. The use of the CPM calculator for sources which are not semi-infinite could lead to underestimation of the specific activity(s) for smaller sources. • Sections 2.1: '… secular equilibrium in a hundred to a thousand years'. I'm not sure how this has been discussed anywhere in the documentation. Does this mean that decay chains that reach equilibrium in ten years will not be automatically added? Perhaps a phraseology problem. • The calculator cannot (let's be fair) know about gaseous radionuclides that may escape from a matrix (especially for U-238n, Ra-226 etc) – but perhaps that assumption should be stated.	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Davies	B1b				• The exclusion of 'build-up' from the Volume calculations appears to be a serious flaw. This *will* generate differences in between instrumental measurements and laboratory analysis – see next note. While excluding build-up will produce 'safer' results, this is can increase waste volumes and thus costs substantially. • The Area CPM user manual states 'A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.' This implies that these types of correction factor should be expected and are acceptable. The wording also implies that the measurements can be expected to be 'wrong' when in fact the both the sampling and analytical measurements, and the Calculator may be 'wrong'. The use of correction factors should be avoided at all costs – when such factors appear to be required by discrepancies in results, the cause should be sought, not an arbitrary fix. • Both manuals, in section 2.2, state 'The FAC is based on laboratory analysis'. I think this should read '… should be based on …' to make the reader understand that they are providing this information, and that it is not pre-defined in the calculator.	
Davies	B1c				The User Guides are well presented. Perhaps the calculators could have used more up-to-date features of web programming.	
Davies	B1d				No response.	
Davies	B2				I don't think the manuals require more referencing. The References covered most of my queries.	
Davies	B3a				I'm not sure why MCNP or similar codes were not used for the complete calculation – effectively to determine the CPM results in one process. These codes are ideal and proven for Sodium Iodide detectors and will properly account for 'build-up' etc. The use of a series of analytical calculations and assumptions is certainly not the current state of knowledge for environmental radiation measurements.	
Davies	B3b				I'm not sure why MCNP or similar codes were not used for the complete calculation – effectively to determine the CPM results in one process. These codes are ideal and proven for Sodium Iodide detectors and will properly account for 'build-up' etc. The use of a series of analytical calculations and assumptions is certainly not the current state of knowledge for environmental radiation measurements. The Volume user guide states 'The Volume CPM Calculator model was developed using 248 case runs of MCNP to simulate the spectrum of the desired radionuclide(s).' Why, if it was so important that everything else had to be determined analytically?	
Davies	B4a				• I believe that the calculation of CPM through dose/flux is inherently flawed: • Even if it was, the calculation of dose/flux using a (2D) surface tally in MCNP does not appear logical, as the detectors are 3D. • The 'back-end' calculations in relation to mixed radionuclides are appropriate. • I have compared the CPM results for Cs-137, Co-60 and Ra-226 with previous calculations I have done. While the Area and shallow Volume results are in good agreement, the thicker Volume result appear to be underestimates potentially by a factor of 2 (compared to my MCNP calculations, of course, which I don't state as definitive). To my mind, this is due to the lack of 'build-up' in the calculations.	
Davies	B4b				• I believe that the calculation of CPM through dose/flux is inherently flawed: • Even if it was, the calculation of dose/flux using a (2D) surface tally in MCNP does not appear logical, as the detectors are 3D. • The 'back-end' calculations in relation to mixed radionuclides are appropriate. • I have compared the CPM results for Cs-137, Co-60 and Ra-226 with previous calculations I have done. While the Area and shallow Volume results are in good agreement, the thicker Volume result appear to be underestimates potentially by a factor of 2 (compared to my MCNP calculations, of course, which I don't state as definitive). To my mind, this is due to the lack of 'build-up' in the calculations.	
Davies	B5				• Material definitions (in the MCNP report) appear ok – but it would have been nice to have more detailed references, for example, 'Steel' appears to be Stainless 316. • Unfortunately, I was unable to check photonic data as this feature of the web site ('Number of photons' see earlier) was broken.	
Davies	B6				• I'm not quite sure about the usability of the smallest detector (0.5x1), except in areas which are grossly contaminated. • I am confused by the absolute limitation of detector height for the Drywall material to 0.5cm height – surely measurements might be taken at other heights? Unless this height is mandated by legislation?	

Commenter	Charge Question	Guidance Section	Line Number	Details	Comment	EPA Resolution
Davies	B7				• The documentation should include some reference(s) to the detection of beta radiation by gamma detectors. While for the detectors quoted, which have relative thick aluminium cases, detection will be quite small, there may be detection of direct beta radiation from, say, Sr-90/Y-90 and of Bremsstrahlung from shallow sources. • The documentation might be changed to note that the decay of certain radionuclides may include gases which will escape from an un-sealed matrix such as soil or dryboard. For example, for U-238n or Ra-226, this may reduce the total gamma signal by 30% - enough to want to know about.	
Davies	B8				I'm not sure I can see any have been used.	
Davies	B9				Some comments above about assumptions etc, but otherwise they are ok.	

MATRIX OF PEER REVIEW COMMENTS: Welcome, Introduction, and FAQs for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*						
Commenter	**Charge Question**	**Guidance Section**	**Paragraph Number**	**Details**	**Comment**	**EPA Resolution**
Spreng		Welcome			Paragraphs and sentences re-arranged into a more logical sequence.	
Spreng		Welcome	Para 1	Sentences 2-4	Move to Welcome, as Para 3. Change to read [deleted items crossed out, new text in bold]: This tool is provided to help calculate the ~~radiation~~ gamma detector reading**s** in counts per minute (cpm) that corresponds to the level of radioactivity in a surface or volume of medium by converting radioactivity in either pCi/cm2 or pCi/g to cpm. The CPM calculator h~~as two major sub calculators based on the field survey scenario~~ **addresses two types of field surveys:** (1) ~~ground-based~~ scanning ~~of~~ surface contamination, and (2) ~~ground-based~~ scanning ~~of~~ volumetric contamination.	
Spreng		Welcome			Insert as Para 4: Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.	
Spreng		Introduction		Heading	Delete heading	
Spreng		Introduction	Para 1		Move to Welcome, Para 1, as Sentences 2-3.	
Spreng		Introduction	Para 2	Sentences 1-2	Move to Welcome as Para 2, Sentences 1-2.	
Spreng		Introduction	Para 2	Sentence 3	Delete	
Spreng		Introduction	Para 3	Sentences 1-2	Delete	
Spreng		Introduction	Para 3	Sentence 3	Move to Welcome, Para 2 as sentence 3.	
Spreng		FAQs			I'm not sure these would be my most pressing questions. Some of these paragraphs are more complete than the corresponding paragraphs in the User's Guides. I'd suggest integrating these paragraphs into the User's Guides, then deleting this FAQs sheet. If the FAQs sheet is a requirement, I'd at least integrate these paragraphs into the User's Guides, then the FAQs sheet can be abridged by referencing the appropriate sections in the User's Guides.	

MATRIX OF PEER REVIEW COMMENTS: Area CPM User's Guide for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		1			The Introduction in the User's Guide is somewhat redundant with the Introduction on the calculator home (Welcome) page and the two could be combined in one place or the other. If not combined, they should be better integrated. I would move the last sentence of the 2nd paragraph to follow the highlighted warning in the 3rd paragraph. Shouldn't the ultimate caution be, "The user should always verify real-time survey results with lab analyses."? See the end of Section 3.7.	
Spreng		1	Para 1		Replace Para 1 with: Data collection at radioactively-contaminated sites determines whether areas require remediation and then whether an area has been remediated to acceptable levels. Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.	
Spreng		1	Para 1-2		Delete paragraph break to create one paragraph.	
Spreng		1	Para 2	Sentence 1	Insert bolded terms: The Area CPM Calculator is a web-based calculator that estimates a gamma **scintillation** detector response **in cpm** for a target level of **radiological** contamination on a surface.	
Spreng		1	Para 2	Sentence 2	Delete: provides a rapid, exceptionally cost-effective assessment of contamination and cleanup standards based on	
Spreng		1	Para 2	Sentence 2	Insert after "calculator": supports the acquisition of	
Spreng		1	Para 2	Sentence 2	Comment: The calculator does not assess "contamination" or "cleanup standards". Cost effective?? It's free.	
Spreng		1	Para 2	Sentence 3	Move to follow first sentence of Para 3: A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.	
Spreng		1	Para 2-3		Delete paragraph break to create one paragraph.	
Spreng		1	Para 3	Sentence 1	Replace "sampling" with "analyses"	
Spreng		1	Bullet list	Bullet 3	Insert bolded item: • choice of target activity **concentration**	
Spreng		2			The step-by-step instruction in Section 2 makes it the most important part of these Guides. It is the "how to" that most users will rely on when first using the calculator. The rest is supplemental, support, or background information.	
Spreng		2.1			These instructions should match the instructions for this page in the calculator.	
Spreng		2.1	Bullet	Sentence 2	This next-to-last sentence is different in the instructions for this page in the calculator ("To calculate the parent and daughter activities manually…"). Both sentences could be included in both places	
Spreng		2.1	Para 1		Regarding sentence: "Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators." Doesn't belong here. See section 2.2 below.	
Spreng		2.2			These instructions should match the instructions for this page in the calculator. More information on how to derive FACs is needed here or in Section 3.4.	
Spreng		2.2	Bullet list	Bullets 1-2	These instructions should match the instructions for this page in the calculator.	
Spreng		2.3			How sensitive is the input of the distance from detector to source? Should that be mentioned here?	
Spreng		2.3	Bullet list	Bullet 2	Regarding sentence: "Enter the estimated distance between the source and the detector in centimeters. Click "Next"." Guidance on an appropriate estimate for this parameter would be useful.	
Spreng		2.4		Results table in calculator	The results table can be copied and then printed. Can a "print page" option be added?	
Spreng		3.1	Para 2	Sentence 3	Replace "three" with "four"	
Spreng		3.2	Section name		Insert bolded term: Daughters and **Decay** Chains	
Spreng		3.4			More information on how FACs should be derived could be included. I assume that the FAC inputs could be an average of activity measurements for each radionuclide over the area of interest with the assumption that field ratios are uniform over that area. The ratios of some radionuclides are fairly precise (e.g., Pu and its daughter Am) and can be used to determine contaminant source areas in the field. Variations in the isotopic ratios for U are also used to determine contaminant sources: DU, EU, and natural U.	

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		3.4	Para 1	Sentence 2	Typo (correction in bold): **e**stablished	
Spreng		3.4.5	Para 2		Typo (correction in bold): **r**adionuclide	
Spreng		3.5			Could variability among different types/brands of field detectors, beyond the detector sensitivity and energy response factor mentioned in 3.4.3, be a limitation?	
Spreng		3.5.3			I'd prefer to have the more complete explanation provided in the FAQs included here in the User's Guide. The FAQs section could reference this section for greater detail.	
Spreng		3.6	Para 1	Sentence 1	Replace: "designed and applied to correlate" with "developed by correlating"	
Spreng		3.6	Para 1	Sentence 1	Delete: sampling	
Spreng		3.6	Para 1	Sentence 1	Replace: "to" with "with"	
Spreng		3.7	Para 1	Sentence 1	Replace: "methods" with "surveys"	
Spreng		3.7	Para 1	Sentence 1	Insert: "(EPA 1999)" after "*Radiation Risk Assessment At CERCLA Sites: Q&A*"	
Spreng		3.7	Para 1	Sentence 2	Typo (correction in bold): measur**e**ments	
Spreng		3.7	Bullet list	Bullet 2, Sentence 2	Typo (correction in bold): measur**e**ments	
Spreng		3.7	Bullet list	Bullet 2, Sentence 2	Replace: "should" with "does"	
Spreng		4			Possible additional terms: photon spectrum, scintillation detector (rather than "detector").	
Spreng		4		MARSSIM definition	Insert hyphen: dose-	
Spreng		6		ITRC, 2006	Insert bolded letter: Radionuclide**s** [in "Real-Time Radionuclide Team"]	
Spreng		6		ITRC, 2006	Delete: "Real-Time" [from "Real-Time Radionuclide Team"] The existing citation is the one suggested at the front of the document. The actual team name, however, is simply Radionuclides Team.	
Bronson		General			The guide should be divided into different sections: - How to use the software - Technical reference - Regulatory applications	
Bronson		2.1	Para 2	Sentence 1	What defines "reaching" secular equilibrium ?	
Bronson		2.1	Para 2	Sentence 1	What happens to those daughters that are <100 or >1000 y ??	
Bronson		2.1	Para 2	Sentence 4	??? don't understand this sentence .	
Bronson		2.4	Para 3	Sentence 1	?? isn't it really "above"; all decays have X-rays that are lower than the detection range, and I didn't see any notes. I didn't' see any notes for Cs137, and the 36 keV photon is also likely outside the range of the detectors.	
Bronson		2.4	Para 3	Sentence 2	Doesn't work.	
Bronson		3.1	Para 3	3x3 graph	The 3x3 graph is considerably different from the others, and I don't understand why; something is not right.	

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Bronson		3.2	Para 1	Sentence 1	I don't understand the 100-1000y part of this. The user wants to know the instrument response on the date of measurement, not what it will be 100-1000 y from now. How is the case of freshly processed Thorium handled, where most of the easily-measured daughters are removed and take 20-40y to mostly grow back ??	
Bronson		3.3	Para 1	Sentence 3	Regarding "seven mean free paths (7/μ):" MFP in Air ??? if so, then state it	
Bronson		3.3	Para 1	Sentence 3	This is far too much information for the user. Just say that the model is an infinite diameter planar disc source.	
Bronson		3.4.1		Definition of gamma coefficient	Where does this come from ? Reference; Where does "μ" come from ??	
Bronson		3.4.1			Regarding "is designed so that the range from the detector to the boundary is 7 mean free paths:" Why 7 ? Just pick a big number and use it for everything.	
Bronson		3.5.2	Para 1	Sentences 1-2	?? not sufficient; you really mean that each individual radionucide has a uniform concentration everywhere on the surface	
Bronson		3.5.2	Para 1	Sentence 3	Regarding "radionuclide ratios:" concentration, not ratios	
Bronson		3.5.3	Para 1	Sentence 1	?? still pure alphas and pure betas there; seems like the list	
Bronson		3.5.3	Para 2	Sentence 1	Regarding "between 40 keV and 2 MeV:" why a high energy cutoff ? the instrument only has a lower energy threshold, it still counts photons with energies >2MeV.	
Bronson		3.5.3	Para 2	Sentence 2	Seems that you should put all the energies in the library and let the analysis software figure out which ones to use. The cutoff will not always be 40 keV, and I doubt that it is that here for all detectors. And might not be for other detectors that it has been claimed that will be added sometime in the future.	
Bronson		3.7	Bullet list	Bullet 2, Sentence 2	These instruments are NOT exposure rate instruments, they are count-rate instruments.	
Bronson		4		Detector definition	Sensor, not instrument	
Bronson		4		Fractivity definition	??? Did you guys just make up this word ??	
Bronson		4		Fractivity definition	I thought that in secular equilibrium, the daughter activity is equal to the parent activity ??	
Bronson		4		Gamma radiation definition	Regarding "Gamma rays are very penetrating and require dense materials:" Actually they require massive materials, density must makes the mass smaller.	
Bronson		4		Mean free path definition	Regarding "completely attenuated:" It is actually only attenuated 1000x; if it started out really strong, the beam still might not be "negligible". When the technical reference document is completed, it should prove that 7mfp in these calculations is sufficiently close to infinite mfp.	
Bronson		4		Yield definition	Insert bolded text: particles emitted **at a specific energy** per radionuclide decay.	
Bronson		6			There are no citation marks in the document showing where these references were referenced.	

MATRIX OF PEER REVIEW COMMENTS: Volume CPM User's Guide for *U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator"*						
Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		1			The Introduction in the User's Guide is somewhat redundant with the Introduction on the calculator home page and the two could be combined in one place or the other. If not combined, they should be better integrated. I would move the last sentence of the 2nd paragraph to follow the highlighted warning in the 3rd paragraph. Shouldn't the ultimate caution be, "The user should always verify real-time survey results with lab analyses."? See the end of Section 3.7.	
Spreng		1	Para 1		Replace with: Data collection at radioactively-contaminated sites determines whether areas require remediation and then whether an area has been remediated to acceptable levels. Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.	
Spreng		1	Para 2	Sentence 1	Insert bolded term: target level of **radiological** contamination in a source	
Spreng		1	Para 2	Sentence 2	Replace pCi/area with pCi/volume	
Spreng		1	Para 2	Sentence 4	Delete sentence ["A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances."]	
Spreng		1	Para 3	Sentence 1	Replace "sampling" with "analyses"	
Spreng		1	Para 3	Sentence 1	Insert after Sentence 1: A correction factor to account for ground truthing and other field nuances can be derived from a correlation between this calculator's results and lab analyses.	
Spreng		1	Bullet list	Bullet 8	Typo: inlcuding	
Spreng		2			The step-by-step instruction in Section 2 makes it the most important part of these Guides. It is the "how to" that most users will rely on when first using the calculator. The rest is supplemental, support, or background information.	
Spreng		2	Para 1		These instructions should match the instructions for this page in the calculator.	
Spreng		2.1			These instructions should match the instructions for this page in the calculator.	
Spreng		2.1	Para 1		Regarding sentence: "Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators." Doesn't belong here. See section 2.2 below.	
Spreng		2.2			These instructions should match the instructions for this page in the calculator. More information on how to derive FACs is needed here or in Section 3.4.	
Spreng		2.3			How sensitive is the input of the distance from detector to source? Should that be mentioned here?	
Spreng		2.3	Bullet list	Bullet 4	Guidance on an appropriate estimate for this parameter would be useful.	
Spreng		2.4			The results table can be copied and then printed. Can a "print page" option be added?	
Spreng		3.3	Section name		Insert bolded term: Daughters and **Decay** Chains	
Spreng		3.7	Para 1		Replace: "designed and applied to correlate a few" with "developed by correlating"	
Spreng		3.7	Para 1		Delete: "sampling"	
Spreng		3.7	Para 1		Replace: "to" with "with"	
Spreng		3.8	Para 1	Sentence 1	Replace: "methods" with "surveys"	
Spreng		3.8	Para 1	Sentence 1	Insert: "(EPA 1999)" after "*Radiation Risk Assessment At CERCLA Sites: Q&A*"	
Spreng		3.8	Para 1	Sentence 2	Typo: measur**e**ments	
Spreng		3.8	Bullet list	Bullet 2, Sentence 2	Typo: measur**e**ments	
Spreng		3.8	Bullet list	Bullet 2, Sentence 2	Replace: "should" with "does"	
Spreng		4			Possible additional terms: photon spectrum, scintillation detector (rather than "detector").	
Spreng		4		MARSSIM definition	Insert hyphen: dose- [this comment was not in the reviewer's Volume CPM User's Guide review document; however, the reviewer made this comment regarding the MARSSIM definition in the review document for the Area CPM User's Guide; since the two definitions are identical, the comment is included in this matrix]	
Spreng		6		ITRC, 2006	Insert bolded letter: Radionuclide**s** [in "Real-Time Radionuclide Team"]	

Commenter	Charge Question	Guidance Section	Paragraph Number	Details	Comment	EPA Resolution
Spreng		6		ITRC, 2006	Delete: "Real-Time" [from "Real-Time Radionuclide Team"] The existing citation is the one suggested at the front of the document. The actual team name, however, is simply Radionuclides Team.	
Bronson		3.1			Why isn't the "more sophisticated" and "more rigorous" method used in both sections ?? The Area calculations are just thin weightless volumes.	
Bronson		3.1	Para 2	Sentence 2	Regarding "including attenuation:" didn't the Area CPM account for air attenuation?	
Bronson		3.1	Para 2	Sentence 2	Regarding "source shielding:" not accounted for because not relevant for thin sources	
Bronson		3.1	Para 2	Sentence 2	Regarding "scattering and buildup:" [this is really scattering], backscatter	
Bronson		3.2	Para 2		This paragraph isn't relevant to this document.	
Bronson		3.4	Para 1	Sentence 4	Diagram not linked	
Bronson		3.4	Para 2	Sentence 2	Too restrictive; what if the user wants to measure the drywall at 10 or 30 or 100cm like the others ?	
Bronson		3.5.1	Para 2	Sentence 1	Regarding "The output of the MCNP software is energy fluence per MCNP source particle, SP (Φ_E/cm^2 - SP):" Is the equation listed correct ??	
Bronson		3.5.1	Para 2	Equation for conversion factor	Explain all the terms in this equation; fix spelling [depth, not dept]	
Bronson		3.5.1	Para 3	Sentence 4	Regarding Technical Background Document: This document needs a lot of work	
Bronson		3.5.2	Para 1	Sentence 1	The equation uses pCi, not pCi/g	
Bronson		3.5.2	Para 1	Sentence 2	Same comment as before [the equation uses pCi, not pCi/g]	
Bronson		3.6.3	Para 3		The MC reference document says that bremsstrahlung IS included.	

Frazier Bronson

General Comments

The concept is good. However, this review seems premature, given the state of the software and the document.

This tool creates the expected CPM in the instrument. The instrument only reads counts that are above some threshold of energy [pulse height] – perhaps 30-40 keV. Those instruments are very difficult to determine the threshold in energy units. Nowhere in the document does it specify the energy threshold of the instrument. And this threshold varies from instrument to instrument, depending upon how it is adjusted by the user.

For large sources there is a lot of scatter and therefore most of the counts are down at low energies. It is not stated what energy the calculations assume that a photon is counted. The referenced Monte Carlo document does calculations all the way down to 1 keV, which is far too low to be useful here.

The above two issues make this a very dubious application tool for energies down in the few hundred keV or lower, unless the instrument is calibrated in a standard way, which must be described in this document.

There is NO validation that this works. No independent testing with different models. No testing with sources. That is a very critical flaw if you want users to believe this. If a user developed such a tool and used it on a site they were trying to measure, NRC and EPA would certainly demand such proof that it worked, along with reliability estimates – TPU estimates.

I don't understand why the two tools [area, volume] use completely different methods to compute the results. Both should use the MCNP method.

Having a Government Furnished [which implies Government Approved] that only addresses a single vendor's instruments seems inappropriate. What is the plan and mechanism for others to get entered into here? That should be stated somewhere, and the tool should be designed assumint that will happen.

The Volume Technical Reference also needs serious review. I don't see anything that is obviously wrong, the document isn't clearly written. E.g. Gail dePlanque's name is spelled wrong both in the Reference table, and spelled wrong in a different way in page 1 of the text.

Frazier Bronson

Comments on Calculator Software

General, or both tools:

The software tool is very easy to use, and the input is rather obvious.

Using the Back arrow is very annoying; the previous page takes 2 clicks to get to, and nothing is remembered.

When clicking on the number of photons button, the Photon Yield and Photon Energy headers show up but the table doesn't populate.

The nuclide list is very inconvenient for 90% of the users. Have the dozen nuclides most commonly used displayed on the screen with check-boxes to select.

Use a conventional method for the Help. E.g. a button on each screen that gives you the information for that screen; rather than a single place on the first page that is not even labeled Help.

Volume Tool

Entering material wood or entering a depth of 1cm doesn't work; the result page always shows Soil at 100cm.   This is such an obvious flaw in a very simple program that it causes much concern about the quality of the calculations.

Comments on Area Calculator Users Guide

General

The guide should be divided into different sections
- How to use the software
- Technical reference
- Regulatory applications

Area CPM User's Guide

1. Introduction

Field sampling, a necessary step of environmental remediation, establishes areas of contamination before, during, and after cleanup in order to ensure acceptable residual levels of contamination. Sampling has the potential to be an extremely time-consuming and expensive portion of a radiological site remediation. Collected samples must be shipped to an off-site laboratory or counted in an on-site mobile unit in order to establish areas of contamination and to ensure that remainimg contaminants are of acceptable residual levels.

The Area CPM Calculator is a web-based calculator that estimates a gamma detector response for a target level of contamination on a surface. This calculator provides a rapid, exceptionally cost-effective assessment of contamination and cleanup standards based on field instrument data, which minimizes the use of more expensive sample collection and laboratory analysis. A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.

The user should verify calculator results with lab sampling.

Features of the Area CPM Calculator include:

- option to calculate the Gross Detector Response (GDR) for a single radionuclide or multiple radionuclide
- mixtures according to MARSSIM guidance
- option to include daughter (+D) ingrowth
- choice of target activity
- truncated decay chains, which allow for man-made decay spectrum
- inclusion of 3 natural decay series
- choice between 4 gamma NaI crystal detector sizes
- ability to specify the exact distance between the detector and the source

2. Step by Step User Guide

Section 2 provides the user with a step by step guide for each page of the Area CPM calculator and highlights potential issues that may be encountered. Links to the calculator data and outside sources are listed in the appendix.

2.1 Radionuclides of Interest

- Select primary (parent) radionuclides of interest by clicking on a radionuclide in the "Radionuclides (and daughter progeny)" list to highlight it and then click on the ">>" button to add it to the "Radionuclides of Interest" list. Multiple radionuclides can be moved together by highlighting while holding the shift or control keys. When one or all radionuclides have been selected, click "Next".

Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators.

Daughter products that reach secular equilibrium what defines "reaching" secular equilibrium ? in a hundred to a thousand years are automatically added. What happens to those daughters that are <100 or >1000 y ?? Adding a parent and its daughter will automatically deselect the daughter, as it is inherently included. To calculate the parent and daughter activities manually, deselect the box "Include daughter products." Chains with very long-lived daughters have been truncated at the typical 'parent' radionuclides for man-made purposes ??? don't understand this sentence . To select one of three natural decay series, find the parent with the suffix of 'n'. See Section 3.2 for more information.

2.2 Activity Concentrations

- Enter the target activity concentration (TAC) in pCi/cm^2 for each radionuclide.
- If multiple radionuclides are selected, enter the field activity concentration (FAC) for each radionuclide. Click "Next".

The TAC is the activity for which the result in cpm is desired. The TAC is analogous to PRGs and DCCs, which can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators. The TAC may also be based on an ARAR such as the 5 pCi/g over background standard from 40 CFR 192.

The FAC is based on laboratory analysis. The FAC is the activity of each primary radionuclide on the contaminated surface and is used to find the radionuclide ratios in mixtures.

2.3 Detector Information and Geometry of the Site

- Select the size of the gamma scintillation detector.
- Enter the estimated distance between the source and the detector in centimeters. Click "Next".

The CPM calculator was developed for use with 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystal detectors. For further guidance see Section 3.1.

2.4 Gross Detector Response

- The results are displayed. Click on the number of photons for a list of a radionuclide's photon energies and yields.
- Click the "Back" button to go back a page or click "Start Over" to begin another calculation.

The results table lists the primary selected radionuclides and their daughters, each daughter's fractional activity and the number of photons from each daughter. For reference, the field activity (if more than one primary is selected) and the TAC are reprinted next to their individual conversions to cpm. At the bottom, the detector size and distance are followed by the GDR in cpm.

A Field or Target Activity (CPM) result of \"-\" indicates that no photons are generated by the radionuclide's decay chain and thus cannot be detected by a gamma scintillation detector. Radionuclides with 0 photons do not contribute to the total GDR. This tool only works for gamma emitters.

If a radionuclide in the list emits one or more photons outside ?? isn't it really "above"; all decays have X-rays that are lower than the detection range, and I didn't see any notes. I didn't' see any notes for Cs137, and the 36 keV photon is also likely outside the range of the detectors. the range of the detector, a note will appear below the results table notifying the user that the selected spectrum has photons outside the range of the detector. A list of the photons excluded from the calculation of Gross Detector Response (GDR) will appear on the \"Photons\" page which can be accessed by clicking on the hyperlinked number of photons of a radionuclide. Doesn't work.

3. Design

Section 3 details the detector-specific and radionuclide-specific parameters utilized for the consequent calculation of GDR. Information required from the user about the radionuclides of interest, the detector used, and the geometry of the site are discussed in this section. Each step of the model is outlined in order to aid the user and ensure transparency.

3.1 Gamma Scintillation Detectors

Detector data is based on four sizes of gamma scintillation detectors by Ludlum Measurements Inc. The models are the 44-2, 44-10, 44-62, and the 44-20 NaI(Tl) crystal gamma scintillation detectors of sizes 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystals.

The detector sensitivity (S), a constant that converts exposure to cpm, and the detector response, a coefficient dependent on the detector's cataloged response to the photon energy, are fed into the Area CPM Calculator equations. The response coefficient is found in a graph of photon energy and response from the detector user manual. DataThief, a shareware program, was used to visually trace the graphs and convert the values to text for the three detector sizes. The graphs and text files for the detectors can be seen below:

0.5"x1" graph and text,
1"x1" graph and text,
2"x2" graph and text.
3"x3" graph and text. The 3x3 graph is considerably different from the others, and I don't understand why; something is not right.

3.2 Daughters and Chains

By default, the Area CPM Calculator estimates the detector response for the primary radionuclide in one hundred to one thousand years of secular equilibrium with its daughters. I don't understand the 100-1000y part of this. The user wants to know the instrument response on the date of measurement, not what it will be 100-1000 y from now. How is the case of freshly processed Thorium handled, where most of the easily-measured daughters are removed and take 20-40y to mostly grow back ?? This is meaningful, especially in the common case of Cs-137 (the well-known 662 keV gamma of Cs-137 is actually produced by its metastable daughter, Ba-37m). This feature, however, can be deactivated by deselecting the check box beneath the radionuclide selection list. The three main natural decay chain series have been truncated for use with manmade or purified radionuclides of U-238, U-235 and Th-232. For example, selecting U-238 will only include the immediate three daughters. The next sequential daughter, U-234, being so long lived, is considered a new radionuclide. To calculate for the natural state of the above three chains, as in calculating for uranium ore, select from the radionuclide list the natural instance of the parent radionuclide, denoted by the suffix, n: U-238n, U-235n, and Th-232n. Selecting one of these radionuclides will include the contribution of the entire natural chain. Isotopic decay chains can be found by using the Radionuclide Decay Chain Tool.

3.3 Model Geometry

The geometry of the model is a disc source above which a detector is suspended. The height (h) of the detector is the user's estimate of the distance in centimeters between the detector and the source of contamination. The maximum radius of the disc (R) is calculated such that the distance from the detector to the outer circumference of the circle is seven mean free paths (7/μ) MFP in Air ??? if so, then state it of the greatest photon energy, a distance at which the photon is safely assumed to be attenuated. This is far too much information for the user. Just say that the model is an infinite diameter planar disc source. See the exposure derivation.

3.4 Equations

The TAC is converted to detector response in cpm using an equation for exposure, the radionuclide-specific gamma constant and detector-specific parameters. If multiple primary radionuclides are selected, each TAC is converted separately and then summed with a risk-weighted equation using ratios stablished from the FAC, or FACs.

The FAC is the actual activity of each primary radionuclide in the contamination. FACs are used to establish field ratios for multiple radionuclides. The target detector responses, in cpm, are then figured together to obtain the GDR. First, the theoretical exposure rate at the detector is calculated for each TAC. The exposure rate is then multiplied by the detector sensitivity to convert to detector response in cpm and then corrected for the energy-specific detector response of the radionuclide's energy spectrum. Finally, a sum-ratio equation from MARSSIM that accounts for the contamination ratios and restrictive radionuclide concentrations is applied.

3.4.1 Exposure

The exposure rate at the detector is calculated as follows:

$$\dot{\mathrm{X}} = \Gamma * A * \pi * \ln\left(\frac{\mathrm{h}^2 + \mathrm{R}^2}{\mathrm{h}^2}\right)$$

where X is the exposure rate in μR/hr,
Γ is the gamma coefficient in μR hr^{-1} cm^2 pCi^{-1}, Where does this come from ? Reference; Where does "μ" come from ??
A is the surface activity in pCi/cm^2,
h is the distance from the detector to the surface in cm, and
R is the radius of the contamination boundary.
R is designed so that the range from the detector to the boundary is 7 mean free paths Why 7 ? Just pick a big number and use it for everything. and is defined:

$$R = \sqrt{\left(\frac{7}{\mu}\right)^2 - h^2}$$

thus,

$$\dot{\mathrm{X}} = \Gamma * A * \pi * \ln\frac{(7/\mu)^2}{\mathrm{h}^2}$$

3.4.2 Normalized, Weighted Response Factor

The detector response varies by the energy of the incident photon. A normalized and weighted detector response factor, RFnorm, is calculated to correct the response for the photon spectrum:

$$RF_{norm} = \sum \frac{Y * dfrac}{\sum Y * dfrac} RF$$

where Y is the yield of each photon of each radionuclide,
dfrac is the emitting radionuclide's fractional activity based on the primary parent's activity, and

RF is the response factor correlating to the energy of each photon.

3.4.3 CPM

The detector response in cpm is found by multiplying the exposure rate at the detector by the detector's sensitivity and response factor, RFnorm, resulting in cpm corrected for the spectrum's energy variance:

$$cpm = \dot{X} * S * RF_{norm}$$

where S is the sensitivity of the detector in cpm / (μR/hr), and
RF is the energy response factor of the detector.

For a single radionuclide of interest, the user may skip to section 3.4.5.

3.4.4 Relative Fraction

The relative fraction, f_i, is the fraction of the total activity contributed by each radionuclide, i. The FACs are used to find the relative fractions of each radionuclide, which are then applied to the GDR. See MARSSIM Chapter 4 (U.S. EPA, 2000).

$$f_i = \frac{cpm_{FAC\,i}}{cpm_{FAC\,1} + cpm_{FAC\,2} + \cdots + cpm_{FAC\,n}}$$

Where cpmFACj is the FAC of each radionuclide, j, in units of detector cpm.

3.4.5 Gross Detector Response

The GDR is the total calculated response of the detector in cpm for the desired remedial activity of the particular radionuclides in the soil. MARSSIM Equation 4-4 "Gross Activity DCGL" (U.S. EPA, 2000) is applied to find the gross detector response and can be seen in an edited form below:

$$GDR = \frac{1}{\frac{f_1}{cpm_{SAC_1}} + \frac{f_2}{cpm_{SAC_2}} + \cdots + \frac{f_n}{cpm_{SAC_n}}}$$

Where f_j is the relative fraction of each radionuclide, j, and $cpmSAC_j$ is the TAC for each radionuclide, j, in units of detector cpm.

3.5 Limitations

3.5.1 The Model

The Area CPM Calculator is designed around a model that converts surface activity in pCi/cm2 to detector response in cpm. The model is basic, involving a contaminated surface and a detector suspended a specified distance above. Differences between the model and field characteristics may introduce error into calculator estimates. The Area CPM Calculator does not replace the need for lab-based sampling or MARSSIM final status survey requirements; however, it may provide a reasonable starting point from which to work.

3.5.2 Uniformity

The model assumes uniform contamination on the source surface. In other words, the radionuclides of interest are in constant ratio ?? not sufficient; you really mean that each individual radionucide has a uniform concentration everywhere on the surface to each other on the surface and the source surface is infinite in lateral extent. Incongruity of the radionuclide ratios concentration, not ratios, such as separate spills or cross-contaminated sites, will diminish the effectiveness of the calculator.

3.5.3 Gamma Emitters

Radionuclides that emit alpha and beta radiation are difficult to measure with any accuracy in the field and are omitted ?? still pure alphas and pure betas there; seems like the list from this model unless the radionuclide also emits a qualifying gamma particle.

A qualifying gamma particle is one with energy between 40 keV and 2 MeV why a high energy cutoff ? the instrument only has a lower energy threshold, it still counts photons with energies >2MeV. and with a decay yield greater than 0.1%. The energy cutoff is due to the energy response curve given in the model detector Seems that you should put all the energies in the library and let the analysis software figure out which ones to use. The cutoff will not always be 40 keV, and I doubt that it is that here for all detectors. And might not be for other detectors that it has been claimed that will be added sometime in the future. manufacturer's specifications. For more information see the FAQs.

3.5.4 Shielding and Attenuation

The model assumes the source surface is free from all shielding from materials or substances coating or between the detector and source, such as and including paper, oil or moisture.

3.5.5 Background Radiation

The model does not account for background radiation. The user is responsible for adding or subtracting any background counts to the GDR.

3.5.6 Omitted Exposure Factors

The model does not account for backscatter or buildup in the surface material.

3.6 Correction Factors

A correction factor may be designed and applied to correlate a few lab sampling analyses to the results of this calculator.

3.7 Guidance

Guidance on circumstances where it may be appropriate to conduct real-time methods in addition to risk estimates based on slope factors is provided in *Radiation Risk Assessment At CERCLA Sites: Q&A*. Instances where it may be beneficial to also use direct measurments for assessing risk from external exposure to penetrating radiation include:

- During early site assessment efforts when the site manager is attempting to communicate the relative risk posed by areas containing elevated levels of radiation,
- As a real-time method for indicating that remedial objectives are being met during the conduct of the response action. The use of exposure rate measurments These instruments are NOT exposure rate instruments, they are count-rate instruments during the conduct of the response actions should not decrease the need for a final status survey.

Direct radiation exposure rate measurements may provide important indications of radiation risks at a site, particularly during early investigations, when these may be the first data available. Such data, however, may only reflect a subset of the radionuclides and exposure pathways of potential concern (e.g., only external exposure from gamma-emitting radionuclides in near-surface soil) and may present an incomplete picture of site risks (e.g., risk from internal exposures or potential increased future risk from radionuclides in subsurface soils). In most cases, more accurate estimation of radiation risks will require additional site characterization data, including concentrations of all radionuclides of concern in all pertinent environmental media. The principal benefits of utilizing direct exposure rate measurements is the speed and convenience of analysis and the elimination of potential modeling uncertainties. These data, however, should be used in conjunction with, rather than instead of, characterization data of radionuclide concentrations in environmental media to obtain a complete picture of potential site-related risks. **Exposure rate measurements should be correlated with actual scanned data by co-locating them to ensure that modeled assumptions about the correlation between exposure rate and sample concentrations is accurate.**

4. Glossary

- **activity concentration:** The activity per surface area (pCi/cm^2).

- **alpha particle:** A positively charged particle comprised of a helium nucleus emitted by some radioactive materials during radioactive decay. Alpha particles expend their energy quickly and are easily attenuated. They have a very short range in air and will not penetrate the dead skin layer. They are difficult to detect in the field. The main hazard due to alpha particles is from ingestion or inhalation, such as gaseous radon and its particulate daughters.

- **attenuation:** The loss of energy or intensity of a photon particle or beam as it passes through and interacts in a medium. The loss can be quantified with the use of the linear attenuation coefficient.

- **background radiation:** Surrounding radiation that is present in the environment, emitted from a variety of natural and artificial sources, including cosmic sources and fallout. The user must account for and add the background radiation to the GDR.

- **Becquerel (Bq):** The International System (SI) unit of radioactivity equal to one disintegration per second. 1 curie = 3.7×10^{10} Becquerels.

- **beta particle:** An electron emitted from the nucleus during radioactive decay. Beta particles have a relatively short range in air. Although very high energy betas can be easily measured, most beta radiation is difficult to measure with accuracy in the field. The main hazard from beta particles is exposure to eyes and skin.

- **counts per minute (cpm):** The number of counts a radiation detector records in a minute.

- **curie (Ci):** A unit of radioactivity defined as 3.7×10^{10} Becquerels, or decays per second, which is approximately equal to the decay rate of one gram of Ra-226.

- **detector:** An instrument Sensor, not instrument that detects radiation.

- **detector response curve:** A graph of a gamma detector response to photons of multiple energies.

- **detector response factor (RF):** A coefficient for correcting for a gamma detector's varied response due to incident photons of multiple energies.

- **exposure rate:** The amount of ionization produced per unit time in air by X-rays or gamma rays. The unit of exposure rate is Roentgen/hour (R/h).

- **Field Activity Concentration (FAC):** The current concentration of parent radionuclides in the field. This is used primarily to ascertain contaminant ratios.

- **fractivity:** **??? Did you guys just make up this word ??** The fractional activity of a daughter compared to the primary parent radionuclide in secular equilibrium. I thought that in secular equilibrium, the daughter activity is equal to the parent activity ?? This fraction is multiplied by the primary parent activity to find the daughter activity.

- **gamma constant/coefficient:** The gamma constant is a radionuclide-specific exposure rate due to photons. The gamma coefficient differs from the gamma constant in that the coefficient includes annihilation photons as contributing to exposure. The gamma coefficient was compiled from the output of the DECDATA software of ICRP Publication 107 (ICRP, 2008).

- **gamma radiation:** Penetrating high-energy, short-wavelength electromagnetic radiation emitted from the nucleus during radioactive decay. Gamma rays are very penetrating and require dense Actually they require massive materials, density must makes the mass smaller. materials, such as lead or steel, for shielding. Gamma particles are also called photons.

- **Gross Detector Response:** The final cpm result.

- **half-life ($T_{1/2}$):** The interval in which the activity of a radionuclide will decay to half of its initial value. The half-life is related to the decay constant λ as $T_{1/2} = \ln(2) / \lambda$.

- **isotope:** Atoms of the same atomic number with the same number of protons but with more or less neutrons, which often contributes to the stability, or radioactivity, of the atom.

- **linear attenuation coefficient:** A function of particle energy, the linear attenuation coefficient, μ, is the probability that a particle will interact or attenuate in a medium.

- **MARSSIM:** The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides guidance to federal agencies, states, site owners, contractors, and other private entities on how to demonstrate that their site is in compliance with a radiation dose or risk-based regulation, otherwise known as a release criterion.

- **mean free path:** The average distance traveled by a projectile prior to an interaction and the inverse of the linear attenuation coefficient, μ. The intensity of a beam of photons will be diminished to 37% in one mean free path of material. At seven mean free paths the intensity of the beam is negligible and considered to be completely attenuated. It is actually only attenuated 1000x; if it started out really strong, the beam still might not be “negligible”. When the technical reference document is completed, it should prove that 7mfp in these calculations is sufficiently close to infinite mfp.

- **nuclide:** A general term used to describe the full range of elements and their family of isotopes.

- **picocurie (pCi):** A unit of radioactivity defined as 1×10^{-12} curies.

- **primary radionuclide:** A term used to denote a radionuclide selected by the user as opposed to a daughter radionuclide. Not all primary radionuclides have daughter radionuclides.

- **radionuclide:** see nuclide.

- **relative fraction (f):** The fraction of the total activity contributed by one radionuclide of a mixture.

- **Roentgen (R):** The unit of photon exposure in air equivalent to 2.58 x 10^{-4} C/kg.

- **sensitivity (S):** The detector signal output per unit exposure (cpm / (µR/hr)).

- **shielding:** Any material or substance that blocks or attenuates radiation.

- **Target Activity Concentration (TAC):** The surface activity concentration that meets the cumulative risk assessment for a radionuclide of interest, although any level of surface activity can be used for investigative purposes.

- **yield:** particles emitted At a specific energy per radionuclide decay.

5. Appendix (data and links)

Preliminary Remediation Goal (PRG) Calculators
Tools for calculating the preliminary remediation goals for soil and water, inside buildings, and outdoor surfaces are available.

Dose Compliance Concentrations (DCC) Calculators
Tools for calculating the dose compliance concentrations for soil and water, inside buildings, and outdoor surfaces are available.

Nuclide Data File
This table was built from the data included in ICRP 107.

Response Curves
The detector response curves are generated from graphing the responses of a number of commonly used check sources. The curves can be found here.

6. References There are no citation marks in the document showing where these references were referenced

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U.S. EPA, 1999. Radiation Risk Assessment At CERCLA Sites: Q & A.

Comments on Volume CPM User's Guide

General Comments

Why are only fixed elevations used here ? The tool interpolates between energies. It can easily interpolate between elevations.

Much of the Volume document is the same as the Area document. If I pointed out issues in the Area document, I probably won't repeat them here. If you fix the issues I describe in one document, you should fix them in the other document.

Volume CPM User's Guide

1. Introduction

Field sampling, a necessary step of environmental remediation, establishes areas of contamination before, during, and after cleanup in order to ensure only acceptable residual levels of contamination remain. Sampling has the potential to be an extremely time-consuming and expensive portion of a radiological site remediation. Collected samples must be shipped to an off-site laboratory or counted in an on-site mobile unit in order to establish areas of contamination and to ensure that remaining contaminants are of acceptable residual levels.

The Volume CPM Calculator is a web-based calculator that estimates a gamma detector response for a target level of contamination in a source. This calculator can be used to determine screening levels in cpm that are based on pCi/area. Using handheld detectors measuring cpm can help reduce costly laboratory sampling. A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.

The user should verify calculator results with lab sampling.

Features of the Volume CPM Calculator include:

- option to calculate the Gross Detector Response (GDR) for a single radionuclide or multiple radionuclide mixtures according to MARSSIM guidance
- option to include daughter (+D) ingrowth
- choice of target activity
- truncated decay chains, which allow for man-made decay spectrum
- inclusion of 3 natural decay series
- choice between 4 gamma NaI crystal detector sizes.
- choice of 5 contamination depths
- choice of 6 source materials, inlcuding a special case of drywall
- exact data for 11 radionuclides most commonly found at remediation sites

2. Step by Step User Guide

Section 2 provides the user with a step by step guide for each page of the Volume CPM calculator and highlights potential issues that may be encountered. Links to calculator data and outside sources are listed in the appendix.

2.1 Radionuclides of Interest

- Select primary (parent) radionuclides of interest by clicking on a radionuclide in the "Radionuclides (and daughter progeny)" list to highlight it and then click on the ">>" button to add it to the "Radionuclides of Interest" list. Multiple radionuclides can be moved together by highlighting while holding the shift or control keys. When one or all radionuclides have been selected, click "Next".

Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators.

Daughter products that reach secular equilibrium in a hundred to a thousand years are automatically added. Adding a parent and its daughter will automatically deselect the daughter, as it is inherently included. To calculate the parent and daughter activities manually, deselect the box "Include daughter products." Chains with very long-lived daughters have been truncated at the typical 'parent' radionuclides for man-made purposes. To select one of three natural decay series, find the parent with the suffix of 'n'. See Section 3.3 for more information.

The following 11 radionuclides are the most common photon emitting nuclides found at Superfund remedial sites: Am-241, Cs-137, I-131, Ra-226, Ra-228, Rn-220, Th-230, Th-232, U-234, U-235, and U-238. These radionuclides were modeled with their exact photon spectrum, which is used rather than simulating the photon spectrum as is done with the other radionuclides.

2.2 Activity Concentrations

- Enter the target activity concentrations (TAC) in pCi/cm^2 for each radionuclide. The TAC is the activity for which the result in cpm is desired.
- If multiple radionuclides are selected, enter the field activity concentration (FAC) for each radionuclide. Click "Next".

The TAC is the activity for which the result in cpm is desired. The TAC is analagous to PRGs and DCCs, which can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators.

The FAC is based on laboratory analysis. The FAC is the activity of each primary radionuclide in the contaminated source and is used to find the radionuclide ratios in mixtures.

2.3 Detector Information and Materials

- Select the size of the gamma scintillation detector
- Select the material of interest
- Select the uniform depth of contamination in the source material
- Enter the distance between the detector and the source. Click "Next".

The CPM calculator was developed for use with 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystal detectors. For further guidance see Section 3.2.

2.4 Results - Gross Detector Response

- The results are displayed. Click on the number of photons for a list of a radionuclide's photon energies and yields.
- Click the "Back" button to go back a page or click "Start Over" to begin another calculation.

The results table lists the primary selected radionuclides and their daughters, each daughter's fractional activity and the number of photons from each daughter. For reference, the FACs (if more than one primary is selected) and the TACs are reprinted next to their individual conversions to cpm. At the bottom, the detector size and distance are followed by the GDR in cpm.

A Field or Target Activity (CPM) result of \"-\" indicates that no photons are generated by the radionuclide's decay chain and thus cannot be detected by a gamma scintillation detector. Radionuclides with 0 photons do not contribute to the total GDR. This tool only works for gamma emitters.

If a radionuclide in the list emits one or more photons outside the range of the detector, a note will appear below the results table notifying the user that the selected spectrum has photons outside the range of the detector. A list of the photons excluded from the calculation of Gross Detector Response (GDR) will appear on the \"Photons\" page which can be accessed by clicking on the hyperlinked number of photons of a radionuclide.

3. Design

3.1 Overview **Why isn't the "more sophisticated" and "more rigorous" method used in both sections ?? The Area calculations are just thin weightless volumes.**

The Volume CPM Calculator is more sophisticated than the Area CPM Calculator. While the Area CPM Calculator uses calculus to derive the exposure at a detector from a two-dimensional surface contamination, the Volume CPM Calculator estimates the exposure from a three-dimensional slab using Monte Carlo Neutron Particle (MCNP) (see RSICC) model case runs to simulate the photon spectrum of the selected radionuclide(s).

The Volume CPM Calculator is more rigorous and restrictive than the Area CPM Calculator. The MCNP computational model used by the Volume Calculator includes several factors that the Area Calculator does not account for, including attenuation didn't the Area CPM account for air attenuation, source shielding not accounted for because not relevant for thin sources, scattering and buildup [this is really scattering], backscatter. A limited set of spatial configurations have been preprogrammed and modeled with MCNP, so the user must choose parameters closest to his or her scenario. A correction factor may be needed to correlate the results to actual sampling.

The output of the MCNP model is energy fluence for fifty-two incident energy channels. This data is converted to detector response per specific contaminant activity (cpm per pCi/g) and then multiplied by the user's target activity to find the estimated detector response.

The user may select multiple radionuclides, in which case the tool will prompt for the FACs of the radionuclides. FACs are the actual activities of each contaminant, usually determined by laboratory analysis. The FACs establish the contaminant ratio, or relative fraction, that is used to correctly weigh the contaminants by their cpm contribution.

3.2 Gamma Scintillation Detectors

Detector data is based on four sizes of gamma scintillation detectors by Ludlum Measurements Inc. The models are the 44-2, 44-10, 44-62, and the 44-20 NaI(Tl) crystal gamma scintillation detectors of sizes 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystals.

This next paragraph isn't relevant to this document. The detector sensitivity is a detector-specific constant that converts exposure to cpm. The detector's energy response is a coefficient dependent on the detector's calibrated response to the incident photon energy. Both are used to convert the energy fluence into cpm. The energy response coefficients are found in a graph of photon energy and response in the detector user manual. A shareware program called DataThief was used to trace the graphs and convert the values to text. The graphs and text files for the detectors can be seen below:

0.5"x1" graph and text,
1"x1" graph and text,

2"x2" graph and text.
3"x3" graph and text.

3.3 Daughters and Chains
The Volume CPM Calculator calculates the detector response for the primary radionuclide in one-hundred to one-thousand years of secular equilibrium with its daughters. This is meaningful, especially in the common case of Cs-137 (the well-known 662 keV gamma of Cs-137 is actually produced by its metastable daughter, Ba-137m). This feature can be deactivated by deselecting the check box beneath the radionuclide selection list.

The three main natural decay chain series have been truncated for use with manmade or purified radionuclides of U-238, U-235 and Th-232. For example, selecting U-238 will only include the immediate three daughters. The next sequential daughter, U-234, being so long lived, is considered a new radionuclide.

To calculate for the natural state of the above three chains, as in calculating for uranium ore, select from the radionuclide list the natural instance of the parent radionuclide, denoted by the suffix 'nat': U-238nat, U-235nat, and Th-232nat. Selecting one of these radionuclides will include the contribution of the entire natural chain.

Isotopic decay chains can be found by using the Radionuclide Decay Chain Tool.

3.4 Model Geometry & Physics
The 6 different options for source material are soil, concrete, plate glass, wood, steel, and drywall. The model for soil, concrete, plate glass, wood, and steel is based on a uniformly contaminated cylindrical slab source of varying thickness. The exposure from the slab is calculated at a distance above the source in air, mimicking the geometry of a suspended detector. The geometry of this model is depicted in this diagram. Diagram not linked

The model for the drywall scenario is different from the model used for the other materials. This model assumes the drywall is 5/8" thick and that a 0.5 cm gap of air exists between the detector and the wall surface. Too restrictive; what if the user wants to measure the drywall at 10 or 30 or 100cm like the others ? This model can be seen in this diagram.

Both models were developed with the software package MCNP.

3.5 Equations
3.5.1 Calculating the Activity to CPM Conversion Factor
The photon spectra of a radionuclide or selection of radionuclides is simulated by rounding each photon in the radionuclide spectra to the closest of ten modeled photon energies. The modeled input energies were chosen for the even spacing of their detector energy responses.

The output of the MCNP software is energy fluence per MCNP source particle, SP $\left({}^{\varphi_E}/_{cm^2} - SP\right)$, Is the equation listed correct ?? for the mono-energetic input photon and is parsed into fifty-two evenly spaced energy channels. The energy fluence of these channels are converted and summed together to form the response of each emitted photon. The responses of each photon are weighted by photon yield and then weighted again with all radionuclides in the chain and the radionuclide's fractional activity of the parent when in secular equilibrium. This value is converted to cpm per activity for each radionuclide. The equation for this conversion factor, CF, for a radionuclide i can be seen below. Explain all the terms in this equation; fix spelling [depth, not dept]

$$CF_i\left(\frac{cpm}{\frac{pCi}{g}}\right) = (82.7)\left(\frac{Source}{Area}\right)\left(\frac{Source}{Dept}\right)\left(\frac{Source}{Dens}\right)\left(\frac{e}{\overline{w}_{air}}\right)(S_{det})\times\left\{(dfrac_i)\left[\sum_{\text{photons}}(Y)\left(\sum_{C}(\varphi_E)\left(\frac{\mu_{en}}{\rho_{air,E}}\right)(RF_{det,E})\right)\right]\right\}$$

Simulation of photon spectra is not used for the following 11 common radionuclides found in remediation sites: Am-241, Cs-137, I-131, Ra-226, Ra-228, Rn-220, Th-230, Th-232, U-234, U-235, and U-238. These radionuclides were modeled with their exact photon spectrum, rather than using the simulation process described above. A Technical Background Document (TBD) is available to view the MCNP output tables and learn more about the calculations performed to characterize the source to detector radiation transport. The TBD is available here. This document needs a lot of work

3.5.2 Calculating Field Acvitity and Target Activity in CPM

Field Activity in CPM, cpmFAC, and Target Activity in CPM, cpmTAC, are found by multiplying the cpm per activity conversion factor, CF, by the user's TAC in pCi/g [the equation uses pCi, not pCi/g] for a radionuclide. If multiple primary radionuclides were selected, the FACs in pCi/g same comment as before are also multiplied by the result. The equations for cpmFACi and cpmTACi for a radionuclide i may be seen below.

$$cpm_{FAC_i}(CPM) = FAC_i(pCi) \times CF_i\left({}^{CPM}/_{pCi}\right)$$

$$cpm_{TAC_i}(CPM) = TAC_i(pCi) \times CF_i\left({}^{CPM}/_{pCi}\right)$$

3.5.3 Calculating the Relative Fraction

The relative fraction, f, is the fraction of the total activity contributed by each radionuclide. The FACs are used to find the relative fractions of each radionuclide, which are then applied to the GDR. The equation for calculating the relative fraction for a radionuclide i may be seen below.

$$f_i = \frac{cpm_{FAC\,i}}{cpm_{FAC\,1} + cpm_{FAC\,2} + \cdots + cpm_{FAC\,n}}$$

Where

3.5.4 Calculating Gross Detector Response

The GDR is the total calculated response of the detector in cpm for the desired remedial activity of the particular radionuclides in the soil. MARSSIM Equation 4-4 "Gross Activity DCGL" (U.S. EPA, 2000) is applied to find the GDR and can be seen in an edited form below.

$$GDR = \frac{1}{\frac{f_1}{cpm_{TAC_1}} + \frac{f_2}{cpm_{TAC_2}} + \cdots + \frac{f_n}{cpm_{TAC_n}}}$$

Where f is the relative fraction of each radionuclide, and cpmTAC is the TAC of each radionuclide in units of detector cpm.

3.6 Limitations

3.6.1 The Model

The Volume CPM Calculator model was developed using 248 case runs of MCNP to simulate the spectrum of the desired radionuclide(s). The Volume CPM Calculator does not replace the need for lab-based sampling or MARSSIM final status survey requirements; however, it may provide a reasonable starting point from which to work. A correction factor for cpm analysis established between this calculator's results and lab sampling analysis should be applied to account for this simulation as well as ground truthing and other field nuances.

3.6.2 Uniformity
The model assumes uniform contamination on the source surface. In other words, the radionuclides of interest are in constant ratio to each other on the surface and the source surface is infinite in lateral extent. Incongruity of the radionuclide ratios, such as separate spills or cross-contaminated sites, will diminish the effectiveness of the calculator.

3.6.3 Gamma Emitters
Radionuclides that emit alpha and beta radiation are difficult to measure with any accuracy in the field and are omitted from this model unless the radionuclide also emits a qualifying gamma particle.

A qualifying gamma particle is one with energy between 40 keV and 2 MeV and with a decay yield greater than 0.1%. The energy cutoff is due to the energy response curve given in the model detector manufacturer's specifications. For more information, see the FAQs.

Bremsstrahlung radiation is electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged particle, typically an electron deflected by an atomic nucleus. The moving particle loses kinetic energy and is then converted into a photon. A study of the contribution of this radiation from the modeled materials is in progress. The MC reference document says that bremsstrahlung IS included.

3.6.4 Background Radiation
The model does not account for background radiation. The user is responsible for adding or subtracting any background counts to the GDR.

3.7 Correction Factors
A correction factor may be designed and applied to correlate a few lab sampling analyses to the results of this calculator.

3.8 Guidance
Guidance on circumstances where it may be appropriate to conduct real-time methods, in addition to risk estimates based on slope factors, is provided in *Radiation Risk Assessment At CERCLA Sites: Q&A*. Instances where it may be beneficial to also use direct measurments for assessing risk from external exposure to penetrating radiation include:

- During early site assessment efforts, when the site manager is attempting to communicate the relative risk posed by areas containing elevated levels of radiation,
- As a real-time method for indicating that remedial objectives are being met during the conduct of the response action.

The use of exposure rate measurments during the conduct of the response actions should not decrease the need for a final status survey. Direct radiation exposure rate measurements may provide important indications of radiation risks at a site, particularly during early investigations, when these may be the first data available. Such data, however may only reflect a subset of the radionuclides and exposure pathways of potential concern (e.g., only external exposure from gamma-emitting radionuclides in near-surface soil) and may present an incomplete picture of site risks (e.g., risk from internal exposures or potential increased future risk from radionuclides in subsurface soils). In most cases, more accurate estimation of radiation risks will require additional site characterization data, including concentrations of all radionuclides of concern in all pertinent environmental media. The principal benefits of utilizing direct exposure rate measurements is the speed and convenience of analysis and the elimination of potential modeling uncertainties. These data, however, should be used in conjunction with, rather than instead of, characterization data of radionuclide concentrations in environmental media to obtain a complete picture of potential site-related risks. **Exposure rate measurements should be correlated with actual scanned data by co-locating them to ensure that modeled assumptions about the correlation between exposure rate and sample concentrations is accurate.**

4. Glossary

- **alpha particle:** A positively charged particle comprised of a helium nucleus emitted by some radioactive materials during radioactive decay. Alpha particles expend their energy quickly and are easily attenuated. They have a very short range in air and will not penetrate the dead skin layer. They are difficult to detect in the field. The main hazard due to alpha particles is from ingestion or inhalation, such as gaseous radon and its particulate daughters.

- **attenuation:** The loss of energy or intensity of a photon particle or beam as it passes through and interacts in a medium. The loss can be quantified with the use of the linear attenuation coefficient.

- **background radiation:** Surrounding radiation that is present in the environment, emitted from a variety of natural and artificial sources, including cosmic sources and fallout. The user must account for and add the background radiation to the GDR.

- **Becquerel (Bq):** The International System (SI) unit of radioactivity equal to one disintegration per second. 1 curie =3.7 x 10^{10} Becquerels.

- **beta particle:** An electron emitted from the nucleus during radioactive decay. Beta particles have a relatively short range in air. Although very high energy betas can be easily measured, most beta radiation is difficult to measure with accuracy in the field. The main hazard from beta particles is exposure to eyes and skin.

- **counts per minute (cpm):** The number of counts a radiation detector records in a minute.

- **curie (Ci):** A unit of radioactivity defined as 3.7 x 10^{10} Becquerels, or decays per second, which is approximately equal to the decay rate of one gram of Ra-226.

- **detector:** An instrument that detects radiation.

- **detector response curve:** A graph of a gamma detector response to photons of multiple energies.

- **detector response factor (RF):** A coefficient for correcting for a gamma detector's varied response due to incident photons of multiple energies.

- **energy fluence:** The amount of energy delivered per unit area (J/m^2).

- **exposure rate:** The amount of ionization produced per unit time in air by X-rays or gamma rays. The unit of exposure rate is Roentgen/hour (R/h).

- **Field Activity Concentration (FAC):** The current concentration of parent radionuclides in the field. This is used primarily to ascertain contaminant ratios.

- **fractivity:** The fractional activity of a daughter compared to the primary parent radionuclide in secular equilibrium. This fraction is multiplied by the primary parent activity to find the daughter activity.

- **gamma radiation:** Penetrating high-energy, short-wavelength electromagnetic radiation emitted from the nucleus during radioactive decay. Gamma rays are very penetrating and require dense materials, such as lead or steel, for shielding. Gamma particles are also called photons.

- **Gross Detector Response:** The final cpm result.

- **half-life ($T_{1/2}$):** The interval in which the activity of a radionuclide will decay to half of its initial value. The half-life is related to the decay constant λ as $T_{1/2} = \ln(2) / \lambda$.

- **isotope:** Atoms of the same atomic number with the same number of protons but with more or less neutrons, which often contributes to the stability, or radioactivity, of the atom.

- **linear energy absorption coefficient:** A function of particle energy, the linear energy absorption coefficient, $\mu en/\rho$, is the probabliity that a particle will interact or attenuate in a medium.

- **MARSSIM:** The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides guidance to federal agencies, states, site owners, contractors, and other private entities on how to demonstrate that their site is in compliance with a radiation dose or risk-based regulation, otherwise known as a release criterion.

- **picocurie (pCi):** A unit of radioactivity defined as 1×10^{-12} curies.

- **primary radionuclide:** A term used to denote a radionuclide selected by the user as opposed to a daughter radionuclide. Not all primary radionuclides have daughter radionuclides.

- **radionuclide:** A general term used to describe the full range of elements and their family of isotopes.

- **relative fraction (f):** The fraction of the total activity contributed by one radionuclide of a mixture.

- **Roentgen (R):** The unit of photon exposure in air equivalent to 2.58×10^{-4} C/kg.

- **sensitivity (S):** The detector signal output per unit exposure (cpm / (μR/hr)).

- **shielding:** Any material or substance that blocks or attenuates radiation.

- **specific activity concentration:** The activity per source volume (pCi/g).

- **Target Activity Concentration (TAC):** The surface activity concentration that meets the cumulative risk assessment for a radionuclide of interest, although any level of surface activity can be used for investigative purposes.

- **yield:** particles emitted per radionuclide decay.

5. Appendix (data and links)

Preliminary Remediation Goal (PRG) Calculators

Tools for calculating the preliminary remediation goals for soil and water, inside buildings, and outdoor surfaces are available.

Dose Compliance Concentrations (DCC) Calculators
Tools for calculating the dose compliance concentrations for soil and water, inside buildings, and outdoor surfaces are available.

Nuclide Data File
This table was built from the data included in ICRP 107.

Response Curves
The detector response curves are generated from graphing the responses of a number of commonly used check sources. The curves can be found here.

6. References
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This site is maintained and operated through an Interagency Agreement between the EPA Office of Superfund and Oak Ridge National Laboratory. For questions or comments please contact Stuart Walker at the Office of Superfund Remediation and Technology Innovation.

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c. Education/Qualifications

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c. Relevant Experience

Currently exploring technologies and opportunities for long term research and development of new products. In addition, providing technical support for Canberra's assistance to the Japanese nuclear accident response.

Previously responsible for supervision of Canberra's Fundamental Research group and Applied Research group. This consists of approximately 20 technical personnel, about 2/3 with PhDs. This group is responsible for physics aspects of new product development and the physics aspects of customization and testing of special orders. The group also performs long term research to evaluate the potential of ideas that might become future products.

Previously responsible for the technical development of Canberra's applied spectroscopy products including mathematical efficiency calibrations, in-vivo counting hardware and software, low level waste assay systems, in-situ gamma spectroscopy environmental assay systems, computer programs for dosimetry calculations, mobile laboratories, and a wide variety of other products for specialized customer applications.

Designed, constructed and calibrated the following instruments: mobile whole body counters, fixed and mobile waste assay systems, various soil and contaminated object assay systems, computer-based multiple pulse height analyzer with alpha, beta, gamma scintillation, and gamma solid state detectors, thermoluminescent dosimetry system for environmental measurements, gamma calibration and exposure facility, automatic alpha and beta counting system, air flow calibration system, and high sensitivity counters for I-131 in milk .

Previously, at RMC was responsible for the operation and management of the largest USA non-government, radiological analytical laboratory for environmental, effluent, and bioassay samples. Developed radiological emergency accident and response scenarios for nuclear accidents at nuclear facilities; Performed training and audits for medical radiological accidents. In support of the TMI accident, was responsible for TMI emergency effluent and environmental measurements as GPU's prime subcontractor for those services. (1969-1980)

Created and managed a radiological services business element with 40 professional and technical employees in four cities. This group provided consulting services, environment and site assessment decommissioning surveys, mobile laboratories, mobile WBC services, and WBC products (1980-1985).

Started full-time career at Armed Forces Radiobiology Research Institute, as the Manager of the Counting Laboratory for the Radiation Safety department. (1965-1969)

d. Employment History

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1969 - 1984, Radiation Management Corp., General Manager, Lab & Services Divisions
1965 - 1969, Armed Forces Radiobiology Research Institute, Manager, Counting Laboratory
1964 - 1964, Newport News Shipbuilding and Dry Dock Company
1963 - 1963, Commonwealth of Massachusetts, Radiological Health Department

e. Professional Affiliations and Awards

Certified by the American Board of Health Physics, 1973 - present
Diplomate, American Academy of Health Physics, 1987 - present
Fellow, Health Physics Society, 2008 - present
American Board of Health Physics, Board Member 1985 - 1989, Chairman 1988 – 1989
American Academy of Health Physics, Executive Board member 2003-2006, President 2005
HPS representative to ANSI N13 Full Committee (Radiation Protection), 1987- 1993
Member, HPS Laboratory Accreditation Policy Committee, 1988 – 1998
Plenary member of Health Physics Society, 1966 - present
Plenary member of American Nuclear Society, 1970 – present
Board member ANS DD&R division, 2008 - 2011
Member of ANSI Working Group on Performance Criteria for Radiobioassay, N13.30
Member of ANSI Working Group on InSitu Calibration, N42.28
Member of ANSI Working Group on Low Level Survey Meter Calibration, N323
Member of ASTM Working Group on NDA Techniques C26.10
President, Delaware Valley Society for Radiation Safety [HPS Chapter], 1975-76
President, Midwest Chapter Health Physics Society, 1978-79
HPS Delegate to IRPA-12, 2008
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Peer Reviewer Conflict of Interest Certification

Peer Review: Counts Per Minute (CPM) Electronic Calculator

A conflict of interest or lack of impartiality exists when the proposed peer reviewer personally (or the peer reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the peer review; or may provide an unfair competitive advantage to the peer reviewer (or employer); or if the peer reviewer's objectivity in performing the peer review may be impaired due to other factors. When the Peer Reviewer knows that a reasonable person with knowledge of the facts may question the peer reviewer's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

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- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this peer review, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
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- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under peer review, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this peer review? ☒ No ☐ Yes

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Affiliation/Organization

Peer Review Charge for:
U.S. Environmental Protection Agency (EPA), "Counts Per Minute (CPM) Electronic Calculator."

Notes from the reviewer:

In general, I found that the documentation and presentation of the CPM calculator was adequate, but somewhat old-looking. The 'features' (sorry, they have to be treated as bugs) of the web pages involving security questions and re-displays are going to annoy many people and may stop them using the calculator. No excuses: 99.9% of the Internet does not have these special features ;-) and they would not be acceptable in the equivalent academic publication – imagine a thesis with an ink stain on every other page.

I was disappointed that the calculator appears to be biased towards analytical calculation of the results. The modeling code MCNP has been used for inappropriate calculations, when it might have been used (potentially at reduced cost to US taxpayers) for the entire calculation. MCNP and other codes have been used extensively for the modeling of the response of Sodium Iodide detectors and similar scintillation detectors – using a single process of calculation and NO conversion factors. The method applied in CPM first calculates dose and then converts dose to CPM. This process first discards valuable energy distribution information and then reapplies energy correction!!

I find the repeated references to an expectation of needing 'special conversions factors', to compare instrumental and analytical results, seriously dangerous – and leading to an expectation of needing 'kludging' to get comparable results. This leads to a potential for biased answers, based on a perception that physical sampling and laboratory analysis will always produce superior results. Both sampling and instrumental measurement processes have intrinsic flaws which need to be understood or each project.

Except for the flaws in the web implementation, the CPM calculator appears to do what it says, but the calculations may be inaccurate for thicker Volume sources.

MD January 2014

Charge Questions:

A. Overall Web Site	
1. Is the web site clearly organized, described, easy to navigate, and generally "user friendly?" If not, what do you recommend?	The web site is reasonable well presented – although the style is pretty old-fashioned and may look archaic to younger readers. See A.4.
2. Have the objectives of the CPM calculator, as stated in the documentation, been realized? If not, what do you recommend?	'… to help risk assessors, remedial project managers, and others involved with risk assessment and decision making …' appears to be the objective. In which case, the calculators will help, but their place needs to be understood.
3. Does the documentation (user's guides) match the online CPM calculator tools and vice-versa? If not, what do you recommend?	Yes, the guides match the calculators.
4. Do you have any other recommendations to improve the usability of the web site?	• The web pages look like *I* wrote them. I know I'm not a good web author and thus I ask experienced designers to create web pages for me. • Secure/insecure content warnings appear repeatedly – puts me off and would do others. • The requirement to acknowledge the 'I have read and understand the limitations of this model set forth in the User Guide and FAQ' for every visit to the site is tedious – couldn't this be handled by 'cookies'? • I'm not sure why the Nuclide entry, Target Activity and other Selection entries are on separate pages – a clumsy implementation. • The radionuclide selector table has a footnote that says ' n = second metastable state nat = naturally occuring' This does not appear to be correct, as 'n' is used for natural series. • The 'No. of photons' feature in the final results tables does not work – always yields an empty table.

	• The 'Back' button always requires a page re-send – surely this can be avoided in 2014?
B. User's Guides	
1. Are the tool and web site clearly explained?	
a. Are the assumptions clear and reasonable? If not, what do you recommend?	• Assumptions are not specifically listed in the user guides – however, the text describes the limitations. • The inherent limitation that the calculators only work for a semi-infinite (lateral) source are not discussed and should be. The use of the CPM calculator for sources which are not semi-infinite could lead to underestimation of the specific activity(s) for smaller sources. • Sections 2.1: '… secular equilibrium in a hundred to a thousand years'. I'm not sure how this has been discussed anywhere in the documentation. Does this mean that decay chains that reach equilibrium in ten years will not be automatically added? Perhaps a phraseology problem. • The calculator cannot (let's be fair) know about gaseous radionuclides that may escape from a matrix (especially for U-238n, Ra-226 etc) – but perhaps that assumption should be stated.
b. Does it adequately describe the calculator's limitations? If not, what do you recommend?	• The exclusion of 'build-up' from the Volume calculations appears to be a serious flaw. This *will* generate differences in between instrumental measurements and laboratory analysis – see next note. While excluding build-up will produce 'safer' results, this is can increase waste volumes and thus costs substantially. • The Area CPM user manual states 'A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.' This implies that these types of correction factor should

	be expected and are acceptable. The wording also implies that the measurements can be expected to be ‘wrong’ when in fact the both the sampling and analytical measurements, and the Calculator may be ‘wrong’. The use of correction factors should be avoided at all costs – when such factors appear to be required by discrepancies in results, the cause should be sought, not an arbitrary fix. • Both manuals, in section 2.2, state ‘The FAC *is* based on laboratory analysis’. I think this should read ‘… should be based on …’ to make the reader understand that *they* are providing this information, and that it is not pre-defined in the calculator.
c. Is it well written and clearly organized? If not, what do you recommend?	The User Guides are well presented. Perhaps the calculators could have used more up-to-date features of web programming.
d. Is the technical support documentation complete, well organized, and easy to follow? If not, what do you recommend?	
2. Are the sources and citations appropriate, and do they represent the current state of knowledge? If not, what do you recommend?	I don’t think the manuals require more referencing. The References covered most of my queries.
3. Are the models for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? If not, what do you recommend?	I’m not sure why MCNP or similar codes were not used for the complete calculation – effectively to determine the CPM results in one process. These codes are ideal and proven for Sodium Iodide detectors and will properly account for ‘build-up’ etc. The use of a series of analytical calculations and assumptions is certainly not the current state of knowledge for environmental radiation measurements.
a. Area (surface) contamination?	

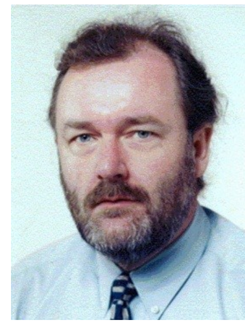
b. Volumetric contamination?	The Volume user guide states 'The Volume CPM Calculator model was developed using 248 case runs of MCNP to simulate the spectrum of the desired radionuclide(s).' Why, if it was so important that everything else had to be determined analytically?
4. Are the equations for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations or derivations? Are the equation variables adequately explained in terms of relative sensitivities? Are the equation constants adequately explained and sourced? If not, what do you recommend?	• I believe that the calculation of CPM through dose/flux is inherently flawed: • Even if it was, the calculation of dose/flux using a (2D) surface tally in MCNP does not appear logical, as the detectors are 3D. • The 'back-end' calculations in relation to mixed radionuclides are appropriate. • I have compared the CPM results for Cs-137, Co-60 and Ra-226 with previous calculations I have done. While the Area and *shallow* Volume results are in good agreement, the thicker Volume result appear to be underestimates potentially by a factor of 2 (compared to my MCNP calculations, of course, which I don't state as definitive). To my mind, this is due to the lack of 'build-up' in the calculations.
a. Area (surface) contamination?	
b. Volumetric contamination?	
5. Are the source material and photonic energy data used for the volume calculator comprehensive, appropriate, and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? Are they appropriate for residential and worker exposures? If not, what do you recommend?	• Material definitions (in the MCNP report) appear ok – but it would have been nice to have more detailed references, for example, 'Steel' appears to be Stainless 316. • Unfortunately, I was unable to check photonic data as this feature of the web site ('Number of photons' see earlier) was broken.
6. Are the choice of detectors and detector heights appropriate and based on supportable reasoning? If not, what do you recommend?	• I'm not quite sure about the usability of the smallest detector (0.5x1), except in areas which are grossly contaminated. • I am confused by the absolute limitation of detector

	height for the Drywall material to 0.5cm height – surely measurements might be taken at other heights? Unless this height is mandated by legislation?
7. Are the choice of radionuclides and how decay chains are addressed appropriate and based on supportable reasoning? If not, what do you recommend?	• The documentation should include some reference(s) to the detection of beta radiation by gamma detectors. While for the detectors quoted, which have relative thick aluminium cases, detection will be quite small, there may be detection of direct beta radiation from, say, Sr-90/Y-90 and of Bremsstrahlung from shallow sources. • The documentation might be changed to note that the decay of certain radionuclides may include gases which will escape from an un-sealed matrix such as soil or dryboard. For example, for U-238n or Ra-226, this may reduce the total gamma signal by 30% - enough to want to know about.
8. Are the standard recommended default factors adequately explained, sourced, and reasonable?	I'm not sure I can see any have been used.
9. Is there anything else you recommend for the user's guides to improve them for their stated purpose?	Some comments above about assumptions etc, but otherwise they are ok.
C. Calculator	
1. Are the results clearly explained and presented? If not, what do you recommend?	Yes, the results are presented tidily.
2. Are the results appropriately described and qualified (to the extent that they may be relied upon and defended)? If not, what do you recommend?	Although most users will be aware that the calculations relate to CPM above background, it might be worth emphasizing that in the GDR comment in the final table. See C4
3. Do the results provide defensible explanation of how they were derived, or are they the result of a "black box"? Do you recommend anything different?	The output (tables) contains enough information to confirm what radionuclide information has been used (assuming the 'Number of Photons' link was working).
4. Are there aspects of other Superfund guidance that should have been used or incorporated into the calculator?	It might be worth referencing the concept of Minimum Detectable Count Rate (MDCR) which is discussed in

	MARRSIM. Naïve users might not know about this concept, which is important in determining whether *an instrument is fit for use* for a project. An appropriate place would be in the 'Background radiation' sections of the manuals.
5. Are the radionuclides appropriate, and do the results adequately explain the variability among radionuclides? If not, what do you recommend?	It appears that strange half-life limits have been used in the selection list. While this is not a fault, it means that the list is quite extensive (long) and includes radionuclides with quite short half-lives (minutes) that are highly unlikely to be seen in environmental remediation. I see little point in short half-life radionuclides being included.
6. Is there anything else you recommend for the calculator to improve it for its stated purpose?	A next logical step might be to add features to give an indication of 'fitness for use' of a proposed instrument / contamination / survey scenario. The required calculations are straightforward, given user-provided background cpm and survey measurement times.
D. Anything Else?	
Is there anything else you would recommend to improve the CPM's utility, accuracy, completeness, or supportability?	

Curriculum Vitae
Mike Davies

Full Name:	Mike Davies
Date of Birth:	1953
Nationality:	British
Job Title:	Principal Consultant
Division / Department	Health Physics
Location:	Harwell
Security Clearance:	SC
Classified Status:	Classified Worker



Qualifications:

Graduate Diploma, Computer Science, Brunel University, -

Résumé

Large-scale radiological survey systems - Development and implementation of instrumental and data management methods for large-scale radiological survey of contaminated land, using Global Positioning Systems and Geographical Information Systems, notably the GROUNDHOG system.

Modelling of gamma radiation transport - Application of ’Monte Carlo’ modelling codes (MCBEND and MCNP) to determine the response of gamma radiation detectors to real-world contamination conditions.

Gamma radiation spectrometry systems - Development of highly automated spectrometry systems for laboratory and mobile use, including ’turn key’ systems.

Consultancy to RADIAC Project Office - On the operational use of radiation detection and spectrometry equipment in military field applications and risk assessments.

Information Systems projects - Management of a team providing system and software development and support to Health Physics projects and Analytical laboratories, working to ’TickIT’ guidelines.

Dosimetry Record Keeping systems and Epidemiological Database systems - Development of HSE-Approved Dosimetry Record Keeping database systems for a Radiation Dosimetry Service, alongside the development and management of in-house Epidemiology database systems supporting Nuclear Industry workforce health studies and Compensation Scheme record keeping.

Curriculum Vitae
Mike Davies

Career History:

Employer: Nuvia Limited
Dates: 2001 to Present
Location: Harwell
Position: Principal Consultant
Description: Development and management of advanced radiological survey systems for contaminated land surveys and recovery of radioactive particles from beaches. Consultancy on gamma radiation spectrometry systems; large scale surveys; gamma radiation transport modelling; and software development for instrumental applications.

Employer: AEA Technology
Dates: 1996 to 2001
Location: Harwell
Position: Senior Consultant
Description: Management and development of the GROUNDHOG radiological survey systems. Consultancy on gamma radiation spectrometry systems, large scale surveys and gamma radiation transport modelling.

Employer: AEA Technology
Dates: 1992 to 1996
Location: Harwell
Position: Team leader
Description: Management of a team maintaining and developing database systems and providing technical support to Health Physics operations and Analytical laboratories.

Employer: UKAEA
Dates: 1987 to 1992
Location: Harwell
Position: Senior Scientific Officer
Description: Management of development of Dosimetry Information Record Keeping systems, Epidemiology database system and maintenance Financial Information Systems.

Development of a 'portable' Gamma Radiation Spectrometry software system.

Employer: UKAEA
Dates: 1983 to 1987
Location: Harwell
Position: Higher Scientific Officer
Description: Development of a database for Bioassay analysis record keeping. Further development of NCEC database systems including down-sizing to a mini-computer. Management of laboratory and database computer systems.

Curriculum Vitae

Mike Davies

Employer: UKAEA
Dates: 1972 to 1983
Location: Harwell
Position: Scientific Officer
Description: Maintenance and development of database systems for the National Chemical Emergency Centre (NCEC). Development of high-speed communication links between mini- and mainframe computers. Management of laboratory instrumentation and computers systems.

Professional Links:

Member of British Computer Society.
Associate member of Health Physics Society.

Training & Courses:

Global Positioning Systems
Project Management
Financial and Business Management
Risk Assessment

Publications:

High-Density Gamma Radiation Spectrometry Surveys of Contaminated Land. 14th International Conference on Environmental Remediation and Radioactive Waste Management, September 2011, Reims, France

Problems and Experience of Detecting Particles in the Vicinity of the Dounreay Nuclear Site. 11th International Conference on Environmental Remediation and Radioactive Waste Management, Bruges, Belgium, September 2007

Site Characterization and Monitoring for Environmental Remediation. Adsley, Davies, Murley, Pearman, Harman, Proctor, Armitage and Beddow. 11th International Conference on Environmental Remediation and Radioactive Waste Management, Bruges, Belgium, September 2007

Experience of monitoring beaches for radioactive particles. Managing Historic Hot Particle Liabilities in the Marine Environment, Nairn, Scotland, September 2005.

Development and Evolution of a Site Survey System - Groundhog. The 9th International Conference on Radioactive Waste Management and Environmental Remediation, Oxford, England, September 2003

A system for monitoring the activities of gamma-emitting nuclides in drums of active waste. Nuclear Energy, 1996, 35, No. 6.

Towards Software Portability in On-line Gamma Radiation Spectrometry. AERE-R-12368 (1987).

SHIELD - A Novel Information System for Epidemiological Studies and Personnel Dose Records. Salmon, Venn and Davies. Application of Computer Technology to Radiation Protection, June 1987.

The Spectrometer User Interface for Computer Systems. Salmon, Davies, Fry and Venn. Computers in Activation Analysis and Gamma-ray Spectroscopy, May 1978.

Projects:

Dates: 2001 - present
Project: GROUNDHOG
Location: Harwell
Role: Development of instrumental and data management methods for large-scale radiological survey of contaminated land, using Global Positioning Systems and Geographical Information Systems, notably the GROUNDHOG system.

Project manager and/or survey designer and analyst for large area site surveys, including
• Project manager of pilot projects for UKAEA.
• Harwell and Winfrith delicensing surveys (1996 to present)
• Beach surveys for radioactive particles – Dounreay (1998 to present)
• Pickering Nuclear Power Plant, Canada, reassurance survey (1999)
• Rosyth Naval Dockyard delicensing surveys (2001, 2009)
• Beach surveys for radioactive particles – Sellafield (2006 to present)
• Oldbury Nuclear Power Station delicensing survey (2009)
• Low Level Waste Repository, delicensing survey (2012)
• Chalk River Laboratory, Canada, radiological survey (2012, 2013)

Language Skills:

Language	Speaking	Reading	Writing
-	0	0	0

Peer Reviewer Conflict of Interest Certification

Peer Review: <u>Counts Per Minute (CPM) Electronic Calculator</u>

A conflict of interest or lack of impartiality exists when the proposed peer reviewer personally (or the peer reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the peer review; or may provide an unfair competitive advantage to the peer reviewer (or employer); or if the peer reviewer's objectivity in performing the peer review may be impaired due to other factors. When the Peer Reviewer knows that a reasonable person with knowledge of the facts may question the peer reviewer's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

The following questions, if answered affirmatively, represent potential or apparent lack of impartiality (*any affirmative answers should be explained on the back of this form or in an attachment*):

- Did you contribute to the development of the document under peer review, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the document during its development? ☑ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this peer review, or any reason that your impartiality in the matter might be questioned? ☑ No ☐ Yes
- Have you had any previous involvement with the review document(s) under consideration? ☑ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☑ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☑ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☑ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under peer review, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this peer review? ☑ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this peer review:

(a) Peer Reviewer warrants, to the best of his/her knowledge and belief, that there are no relevant facts or circumstances that could give rise to an actual, apparent, or potential organizational or personal conflict of interest, or that Peer Reviewer has disclosed all such relevant information to EMS or to EPA.
(b) Peer Reviewer agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this peer review, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Peer Reviewer (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Peer Reviewer shall continue performance until notified by EMS of any contrary action to be taken.

[signature] 25/11/13

Signature Date

☐ Check here if any explanation is attached

R M DAVIES

Printed Name

NUVIA LIMITED, UK

Affiliation/Organization

The following responses are offered for charge questions.

Charge Questions and Embedded Responses:

A. Overall Web Site

1. Is the web site clearly organized, described, easy to navigate, and generally "user friendly?" If not, what do you recommend?

The web site is well organized, described, easy to navigate, and can be user friendly (there are several bugs, as stated), though a deeper review might leave the user with questions. The site is similar to PRG calculators, and that familiarity is helpful. There are some minor issues to consider that could be addressed by a thorough technical editor. For example:

- Consistent use of acronyms (e.g., cpm v. CPM)
- Consistent use of proper units (e.g., CF = cpm/pCi/g v. CPM/pCi)
- Light blue text difficult to see on a green header

2. Have the objectives of the CPM calculator, as stated in the documentation, been realized? If not, what do you recommend?

- Does the calculator provide source concentration to CPM conversions? The answer is yes. Would I use the calculator as presented? The answer is maybe. The site works well enough (though there are lots of bugs), so there is hope that the calculator will eventually provide investigators with useful information. The bottom line is that if an investigator assumes the detector will respond as the Calculator predicts, there is a risk of overlooking contamination. The higher than expected Calculator generated values are probably geometry related (from a semi-infinite plane or contamination). If the CPM result is supposed to represent the average measurement across the exposure unit, then that should be stated.

3. Does the documentation (user's guides) match the online CPM calculator tools and vice-versa? If not, what do you recommend?

- The calculator seems to match the documentation, though some of the information cannot be verified. For example, the gamma energies and yields cannot be verified (no values given), some of the output is inconsistent with input, and the documentation needs to be edited.

4. Do you have any other recommendations to improve the usability of the web site?

- Bottom line is that the investigator should be able to use the Calculator to reasonably predict what one would find in the field. Results should be similar to those presented in MARSSIM Table 6.7 or as described in Abelquist 2001 (*Decommissioning Health Physics – A Handbook for MARSSIM Users*). Values do not have to match – they just need to be reasonably close to give investigators a comfort level. As calculated the values are consistently higher (non-conservative) than expected, though not grossly so.

- The Area Calculator may not be needed at all. The Volume Calculator already provides results for a 1-cm thick source.

B. User's Guides

1. Are the tool and web site clearly explained?
   a. Are the assumptions clear and reasonable? If not, what do you recommend?
   b. Does it adequately describe the calculator's limitations? If not, what do you recommend?
   c. Is it well written and clearly organized? If not, what do you recommend?
   d. Is the technical support documentation complete, well organized, and easy to follow? If not, what do you recommend?

- Assumptions are clear and reasonable.
- Limitations are adequately described.
- The Guides are written well enough, but they do need a thorough scrubbing by a technical editor. As detailed below, some of the definitions need to be revised.
- Area CPM Calculator User's Guide, 2nd paragraph. "This calculator…minimizes the use of more expensive sample collection and laboratory analysis" needs to be resolved with the apparent contradiction in Sect. 3.5.1, which states, "The Area CPM Calculator does not replace the need for lab-based sampling…" The Calculators may be used for MARSSIM (or similar) classification decisions and judgmental sample location placement, but the former statement implies a greater value in CPM estimates than the latter statement declares.
- Area CPM Calculator User's Guide, Sect. 2.1. Why consider decay products ("+D") based on half-lives of hundreds or thousands of years when the common threshold is 6 month?
- Area CPM Calculator User's Guide, Sect. 2.2. The TAC example of 5 pCi/g does not fit for an area calculation. Suggest finding an example with area in the denominator. Also, suggest adding the option to use process knowledge (in addition to laboratory analysis) in FAC development. Analytical data are not always available…or sometimes not enough are available.
- Area CPM Calculator User's Guide, Sect. 3.3. What is the "outer circumference" of a disk with (per Sect. 3.5.2) infinite lateral extent? The R is infinite h^2 + R^2 = infinity = (7/u)^2, this u = 0. That would be the case in a vacuum. There seems to be some logic breakdown here. The gammas are assumed to be attenuated, but by what?
- Area CPM Calculator User's Guide, Sect. 3.3. It is unclear how the mean free path is applied. The surface has no depth (atom thick), so there is no attenuation from the source. Is this the mean free path in air at STP? This does not appear to be the case.
- Area CPM Calculator User's Guide, Sect. 3.4.3. It is assumed S comes from the manufacturer. If that is the case, suggest adding that fact, or otherwise let the reader know where the information resides. S values are not provided as inputs or outputs.
- Area CPM Calculator User's Guide, Sect. 3.4.4&5. FAC, SAC, or TAC? It is unclear whether or not CPM_FAC is the same as CPM_SAC, and if CPM_SAC_J is the same as TAC_j, why not say CPM_TAC_j? Radionuclide is misspelled in the last line (missing r).
- Area CPM Calculator User's Guide, Sect. 3.5.5. How would the user subtract background from the GDR? Unless background is 0, subtraction would result in a negative number.

- Area CPM Calculator User's Guide, Sect. 3.6. It is unclear what is meant by "a few" lab analyses. Correlations are very difficult in general and one might argue that uncertainty in the correlation is inversely proportional to the number of data points used in the analysis.
- Area CPM Calculator User's Guide, Sect. 4. There is not a non-gaseous form of radon – suggest deleting gaseous. Re. units, becquerels, curies, etc. are lower case when spelled out unless used in reference to the person for which the unit in named. Might also note that 1 curie is the rate of decay from 1 gram of Ra-226. The definition for gross detector response is very weak and adds no value. Suggest simplifying isotope definition to "…the same number of protons in the nucleus but with…" If nuclide is term used to describe the full range of elements, should radionuclide be defined as nuclides that are radioactive? How does a TAC meet the cumulative risk assessment (meets risk goals, perhaps)?
- Area CPM Calculator User's Guide, Sect. 6. MARSSIM should be EPA 2000.
- It is unclear why the area calculator is needed. Surface area decisions would more likely be associated with alpha or beta/gamma measurements (GM, gas proportional, etc.) and not a pure gamma measurement. The 1-cm-thick option in the Volume Calculator should be good enough for thin sources.
- Volume CPM calculator. Source depth does not show values other than 100 cm. CPM values do change with entered value, so the results are probably calculated per the inputs.
- Volume CPM calculator. The back button leads to a "Webpage has expired" page. The back button *sometimes* works on the Area Calculator page.
- Volume CPM calculator. The hyperlink to listed photons (e.g., 4 photons from Th-234) does not work. Specifically, no photon energies or yield data are presented. Several radionuclides were tried. Same comment for Area Calculator.
- Volume CPM Calculator User's Guide, Sect. 3.5. The equation implies the user can enter a source area (e.g., 10 m^2). This is not the case, thus the assumption is the source represents a semi-infinite plane. Adjustments for surface area would be a nice and useful addition.

2. Are the sources and citations appropriate, and do they represent the current state of knowledge? If not, what do you recommend?

- Sources and citations are appropriate, though authors should make sure results are comparable to values generated via standard (e.g., MARSSIM) guidance. Some calculations could not be verified given the lack of input/output information. Results do seem reasonable based on scale.

3. Are the models for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? If not, what do you recommend?
    a. Area (surface) contamination?
    b. Volumetric contamination?

- The area model assumes an infinite source extent (though the text is inconsistent) without air attenuation. This should model an over-response and could leave investigators with the false assumption that the area is acceptable when it is not. The Area Calculator may not be necessary at all.

4. Are the equations for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations or derivations? Are the equation variables adequately explained in terms of relative sensitivities? Are the equation constants adequately explained and sourced? If not, what do you recommend?
   a. Area (surface) contamination?
   b. Volumetric contamination?

- As stated in earlier comments, both methods seem to produce over-responses, and the Calculators do not provide all inputs (e.g., S) or outputs (e.g., gammas used). The equations and constants, as presented, as adequately explained and cited, except as already noted.
- The Volume Calculator guide implies that the user can adjust source size, though this is not the case. It should be, however, because investigators are unlikely to encounter an actual or effectively-equivalent semi-infinite plane of contamination.

5. Are the source material and photonic energy data used for the volume calculator comprehensive, appropriate, and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? Are they appropriate for residential and worker exposures? If not, what do you recommend?

- The Calculator would not show energies or yields (blank page each time attempted). Models need to be calibrated to produce values similar to those generated by standard methods. Differences are likely geometry related.
- Results should have nothing to do with receptor. The detector response in CPM from a source in pC/g or pC/cm^2 is independent of actual or hypothetical past, present, or future occupants.

6. Are the choice of detectors and detector heights appropriate and based on supportable reasoning? If not, what do you recommend?

- Choice of detectors is reasonable, though MARSSIM also presents results for 1.25x1.5. Results for a FIDLER would be nice. CPM estimates for a NaI and surface source combination is limited.

7. Are the choice of radionuclides and how decay chains are addressed appropriate and based on supportable reasoning? If not, what do you recommend?

- The presented choices are reasonable, though the addition to decay products using the 6-month rule would be more consistent with industry.

8. Are the standard recommended default factors adequately explained, sourced, and reasonable?

- Defaults are adequately explained, sourced, and reasonable.

9. Is there anything else you recommend for the user's guides to improve them for their stated purpose?

- See previous comments.

C. Calculator

1. Are the results clearly explained and presented? If not, what do you recommend?
2. Are the results appropriately described and qualified (to the extent that they may be relied upon and defended)? If not, what do you recommend?
3. Do the results provide defensible explanation of how they were derived, or are they the result of a "black box"? Do you recommend anything different?
4. Are there aspects of other Superfund guidance that should have been used or incorporated into the calculator?
5. Are the radionuclides appropriate, and do the results adequately explain the variability among radionuclides? If not, what do you recommend?
6. Is there anything else you recommend for the calculator to improve it for its stated purpose?

- See previous comments. The major black box issue is how the CPMs are combined to achieve an action level associated with the desired remedial activity. This had to be studied a bit. It eventually became clear that CPM is a stand-in for clean-up level, but it is unclear whether the Calculator is working. Consider the following example for soil, 100 cm depth, 2x2, 10 cm from the source:

Radionuclide	**pCi/g_i**	**f_i**	**CPM_i**
K-40	15	0.8798	1667
Th-232nat	1.0	0.0587	1406
U-235nat	0.05	0.0029	60
U-238nat	1.0	0.0587	1554
pCi/g_T:	17.05	$=sum(pCi/g_i)$	
f_i	varies	$=pCi/g_i$ / pCi/g_T	
GDR:	1524	$=1/(f_1/CPM_1+\ldots f_4/CPM_4)$	

The Calculator produces a GDR value of 1761 CPM. Could be this example (table) calculation is off.

- The results for the 2x2/Unat combination produces the same response no matter what source depth is selected.

D. Anything Else?

Is there anything else you would recommend to improve the CPM's utility, accuracy, completeness, or supportability?

- See previous comments.

David A. King, CHP, PMP

Health Physicist 4/Project Manager

Independent Environmental Assessment and Verification

Partnerships for Innovation

ORAU

OAK RIDGE ASSOCIATED UNIVERSITIES

Summary

David King is a Certified Health Physicist with over 19 years experience in human health risk/dose assessment, environmental studies, and project management. Relevant duties have included prospective carcinogenic risk and radiological dose analysis for the East Tennessee Technology Park, Oak Ridge National Laboratory, Paducah Gaseous Diffusion Plant, and Formerly Utilized Sites Remedial Action Program; retrospective dose assessments for the Nuclear Test Personnel Review program; sampling and analysis planning and characterization reporting for USACE, DOE, EPA and commercial clients; data assessments using the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM); and field team leadership for the characterization of various radiologically and chemically contaminated media. Highlights also include serving as project manager for a DOE/Oak Ridge landfill detection monitoring program and a MARSSIM-based experimental nuclear reactor decommissioning project.

Education

- M.S. in Radiological Engineering, University of Tennessee, Knoxville, Tennessee.
- B.S. in Physics, Middle Tennessee State University, Murfreesboro, Tennessee.

Certifications and Security Clearance

- Certified Health Physicist (certified in 1999, recertified through 2015)
- Project Management Professional (certified in 2012)
- U.S. Department of Energy Security “Q” Clearance

Related Experience

ORAU, Independent Environmental Assessment and Verification

Health Physicist 4 / Project Manager

July 2008 to Present

Plan, implement, and manage surveys for contaminated sites and verification of recently remediated DOE sites and NRC licensed sites. Responsibilities include technical review of site documentation, preparation of comprehensive survey plans, selection and procurement of supplies and equipment, and sub-contractor services. Direct teams of two to five survey technicians in conducting site surveys in accordance with established field measurement and sampling plans and program procedures. Assure proper maintenance, calibration, and operation of radiological and chemical detection and monitoring instrumentation and sampling equipment in accordance with established procedures. Interpret field and laboratory data collected during environmental surveys. Prepare survey reports describing procedures, results and conclusions, and compare conditions with applicable regulatory criteria. Recommend corrective actions as required. Review Decommissioning Plans and write Technical Evaluation Reports in support of license termination for the NRC. Provide technical input pertaining to licensing actions to the NRC.

Science Applications International Corporation, Oak Ridge, Tennessee

Health Physicist/ Risk Analyst/ Project Manager

January 1996 to July 2008

Served as a subject matter specialist supporting DOE operations in Oak Ridge, TN, and Paducah, KY, plus numerous FUSRAP sites under both DOE and USACE. Managed environmental studies (cost, schedule and scope in addition to addressing technical issues); conducted human health risk and radiological dose assessments; prepared sampling and analysis plans, final status survey plans (e.g., per MARSSIM), and characterization reports for various contaminated media; and provided general health physics consulting including radiological data interpretation, radiological instrumentation selection, etc. Managed MARSSIM-based final verification project at the Carolinas-Virginia Tube Reactor facility near Jenkinsville, South Carolina. Calculated derived concentration guideline levels (i.e., cleanup goals), performed prospective dose calculations, and prepared sample and analysis plans and verification reports. Managed data management, verification/validation, potentiometric mapping, and reporting effort for the EMWMF detection-monitoring program since the first waste shipments were received in 2002. Prepared monthly, quarterly and annual reports – the annual report was incorporated into the Oak Ridge Reservation Remediation Effectiveness Report. Planned and managed the collection of ~4.8 million gamma radiation measurements, 4350 systematic dose rate measurements, and over 1350 systematic and 500 biased soil samples as part of Oak Ridge's Melton Valley final verification effort. Prepared MARSSIM-based sampling and analysis plan and authored over 70 verification reports. The verification strategy relied heavily on real-time measurement technologies (including an on-site analytical laboratory) to optimize the site characterization, remediation and closure process, as per EPA's Triad approach.

CH2M Hill, Oak Ridge, Tennessee

Health Physicist/ Task Manager/ Field Team Leader

September 1993 to January 1996

Provided health physics support to four Superfund sites in West Chicago, IL. For the Residential Areas Superfund Site: measured indoor radon/thoron concentrations, operated an in situ gamma spectrometry system, and performed radiation walkover surveys using GPS technology. For the Kress Creek Superfund Site: planned and executed radiological characterization of impacted sediment along Kress Creek and the West Branch Dupage River. For the Reed-Keppler Park Superfund Site: managed radon/thoron sampling using E-PERM® detectors. For the Sewage Treatment Plant Superfund Site: collected groundwater, surface water, and sediment samples. Served as a health physics technician for the RI/FS in Oak Ridge's Melton Valley. Provided health and safety oversight for a Waste Area Grouping 5 deep well drill rig and screened potentially contaminated equipment at the project decontamination pad.

University of Tennessee, Knoxville, Tennessee

Graduate Teaching/ Research Assistant

January 1991 to September 1993

Served as a Graduate Teaching Assistant for the University of Tennessee Physics Department from August 1991 to May 1992. Conducted laboratories for General Physics courses and lead problem solving sessions with undergraduate students. Transferred to the Nuclear Engineering Department in May 1992 and became a Graduate Research Assistant: collected, compiled, analyzed, and documented radon data from detached single-family dwellings in Freehold, New Jersey – thesis based on this study. Coursework focused on physics, health physics, and applied mathematics.

Professional Associations

- Health Physics Society
- East Tennessee Chapter of the Health Physics Society
- Project Management Institute

Award and Accomplishments

- Health Physics Society Decommissioning Section Executive Board (expired 2012)
- 2004 Environmental Excellence Award (work on the DOE Oak Ridge Reservation)
- 2000 Environmental Excellence Awards (supporting USACE St. Louis/Buffalo Districts)

Selected Publications

Gammage, R.B., Dudney, C.S., Wilson, D.L., and King D.A., 1994. "Normal and Seasonally Amplified Indoor Radon Levels," Proceedings of Indoor Air: An Integrated Approach, Nov. 27-Dec. 1, Gold Coast, Australia.

Byrnes, M.E., King, D.A. and Tierno, P.M., 2003. *Nuclear, Chemical, and Biological Terrorism: Emergency Response and Public Protection*. ISBN 1-56670-651-3, Lewis Publishing, Boca Raton, Florida.

King, D.A., Byrnes, M.E. and Tierno, P.M., 2004. "Nuclear, Chemical, and Biological Terrorism: Emergency Response and Public Protection," Appendix A.3 to *Public Protection from Nuclear, Chemical, and Biological Terrorism*, edited by Brodsky, A. et al., ISBN 1-930524-23-4, Medical Physics Publishing, Madison, Wisconsin.

King, D.A. and Keil, K. 2006. "Comparison of Standard Radiological Risk Models and Using RESRAD to Derive Generic Risk-Based Area Factors for Final Status Surveys", *Risk Analysis*, Vol. 26, No. 1, pgs 175-183.

King, D.A., Haas, D.A., and Cange, J.B., 2006. "Final Verification Success Story Using the Triad Approach at the Oak Ridge National Laboratory's Melton Valley Soils and Sediment Project" paper presented at the 2006 Waste Management Conference in Tucson, AZ, February/March.

King, D.A., Altic, N., and Greer, C., 2012. "Minimum Detectable Concentration as a Function of Gamma Walkover Survey Technique," *Operational Radiation Safety*, Vol. 102, No. 2, pgs S22-S27, February.

Peer Reviewer Conflict of Interest Certification

Peer Review: Counts Per Minute (CPM) Electronic Calculator

A conflict of interest or lack of impartiality exists when the proposed peer reviewer personally (or the peer reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the peer review; or may provide an unfair competitive advantage to the peer reviewer (or employer); or if the peer reviewer's objectivity in performing the peer review may be impaired due to other factors. When the Peer Reviewer knows that a reasonable person with knowledge of the facts may question the peer reviewer's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

The following questions, if answered affirmatively, represent potential or apparent lack of impartiality (*any affirmative answers should be explained on the back of this form or in an attachment*):

- Did you contribute to the development of the document under peer review, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the document during its development? ☒ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this peer review, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
- Have you had any previous involvement with the review document(s) under consideration? ☐ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☒ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under peer review, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this peer review? ☒ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this peer review:

(a) Peer Reviewer warrants, to the best of his/her knowledge and belief, that there are no relevant facts or circumstances that could give rise to an actual, apparent, or potential organizational or personal conflict of interest, or that Peer Reviewer has disclosed all such relevant information to EMS or to EPA.
(b) Peer Reviewer agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this peer review, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Peer Reviewer (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Peer Reviewer shall continue performance until notified by EMS of any contrary action to be taken.

[signature] 11-05-13
Signature Date

☐ Check here if any explanation is attached

David A. King
Printed Name

ORAU
Affiliation/Organization

Counts Per Minute (CPM) Electronic Calculator

<u>Carl Spreng Responses to Charge Questions:</u>
(responses are in italics)

A. Overall Web Site
   1. Is the web site clearly organized, described, easy to navigate, and generally "user friendly?" If not, what do you recommend?
      I found the web site to be generally well-organized and easy to navigate. I feel that there are some places in the documentation that could be improved by moving or eliminating text to reduce redundancy and to be more internally consistent.
   2. Have the objectives of the CPM calculator, as stated in the documentation, been realized? If not, what do you recommend?
      Yes – The calculator should allow decision makers at Superfund sites to benefit from the advantages of real-time surveys. The process of correlating field measurements with lab analyses should become more standardized.
   3. Does the documentation (user's guides) match the online CPM calculator tools and vice-versa? If not, what do you recommend?
      Generally, yes. Some of the instructions within the calculator differ from the step-by-step instructions in the User's Guides. The texts are not conflicting, but they shold be consistent.
   4. Do you have any other recommendations to improve the usability of the web site?
      See suggested redline-strikeout changes and comments to the calculator documents.

B. User's Guides
   1. Are the tool and web site clearly explained?
      a. Are the assumptions clear and reasonable? If not, what do you recommend?
         Assumptions are clear and reasonable, but are potentially so limiting that results may not always be representative. It might be useful to explain whether the overall effect of these assumptions is likely to be conservative – or not.
      b. Does it adequately describe the calculator's limitations? If not, what do you recommend?
         The limitations are adequately described. Ludlum gamma detectors apparently are the presumed detectors. Variability among other types/brands of field detectors, beyond the detector sensitivity and energy response factor mentioned in 3.4.3, may be another limitation.
      c. Is it well written and clearly organized? If not, what do you recommend?
         Generally yes. As mentioned above, there are places where the text clarity suffers from redundancy and inconsistent used of terms.
      d. Is the technical support documentation complete, well organized, and easy to follow? If not, what do you recommend?
   2. Are the sources and citations appropriate, and do they represent the current state of knowledge? If not, what do you recommend?
      Yes – I am not aware of any newer superseding sources.

3. Are the models for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? If not, what do you recommend?
   a. Area (surface) contamination?
      Yes.
   b. Volumetric contamination?
      Yes. Should/could a link to the MCNP software documentation be provided?
4. Are the equations for the following scenarios comprehensive and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations or derivations? Are the equation variables adequately explained in terms of relative sensitivities? Are the equation constants adequately explained and sourced? If not, what do you recommend?
   a. Area (surface) contamination?
      N/A - My background and experience are not adequate enough to respond.
   b. Volumetric contamination?
      N/A - My background and experience are not adequate enough to respond.
      Should/could a link to the MCNP software documentation be provided?
5. Are the source material and photonic energy data used for the volume calculator comprehensive, appropriate, and accurate, and do they represent the current state of knowledge? Are they supported appropriately by citations? Are they appropriate for residential and worker exposures? If not, what do you recommend?
   My background and experience are not adequate enough to respond regarding source material and photonic energy data.
6. Are the choice of detectors and detector heights appropriate and based on supportable reasoning? If not, what do you recommend?
   No guidance or reference is provided for determining appropriate detector height. It might be useful to explain the sensitivity of this parameter.
7. Are the choice of radionuclides and how decay chains are addressed appropriate and based on supportable reasoning? If not, what do you recommend?
   Yes, the rationale seems reasonable especially for the purpose of estimating detector readings.
8. Are the standard recommended default factors adequately explained, sourced, and reasonable?
   Yes.
9. Is there anything else you recommend for the user's guides to improve them for their stated purpose?
   See suggested redline-strikeout changes and comments to the calculator documents.

C. Calculator
   1. Are the results clearly explained and presented? If not, what do you recommend?
      Yes. The results can be copied and printed out, but it might be helpful to include a print option in the calculator.
   2. Are the results appropriately described and qualified (to the extent that they may be relied upon and defended)? If not, what do you recommend?
   3. Do the results provide defensible explanation of how they were derived, or are they the result of a "black box"? Do you recommend anything different?

The derivation of the Area Calculator results is fairly straightforward. The Volume Calculator results, however, depend on the MCNP black box. The explanation for this model is adequate for the purposes of the User's Guide, but a link to documentation for MCNP software might be useful.

4. Are there aspects of other Superfund guidance that should have been used or incorporated into the calculator?
   No.
5. Are the radionuclides appropriate, and do the results adequately explain the variability among radionuclides? If not, what do you recommend?
   The variability among the radionuclides is adequately explained.
6. Is there anything else you recommend for the calculator to improve it for its stated purpose?
   *Add titles on the pages of the Calculator that correspond to the titles in Section 2 of the User's Guide to help connect the Guide to the Calculator (e.g., Radionuclides of Interest, Activity Concentrations, etc.). Highlight the statement, "**I have read and understand the limitations of this model set forth in the User Guide and FAQ**", which must be checked in order to move to page 2 of the calculator.*

D. Anything Else?
   Is there anything else you would recommend to improve the CPM's utility, accuracy, completeness, or supportability?
   See suggested redline-strikeout changes and comments to the calculator documents.

Peer Review of CPM Calculator – Spreng comments

Area CPM User's Guide

The step-by-step instruction in Section 2 makes it the most important part of these Guides. It is the "how to" that most users will rely on when first using the calculator. The rest is supplemental, support, or background information.

Section 1
The Introduction in the User's Guide is somewhat redundant with the Introduction on the calculator home (Welcome) page and the two could be combined in one place or the other. If not combined, they should be better integrated.

I would move the last sentence of the 2nd paragraph to follow the highlighted warning in the 3rd paragraph. Shouldn't the ultimate caution be, "The user should always verify real-time survey results with lab analyses."? See the end of Section 3.7.

Section 2.1
These instructions should match the instructions for this page in the calculator.

Section 2.2
These instructions should match the instructions for this page in the calculator.

More information on how to derive FACs is needed here or in Section 3.4.

Section 2.3
How sensitive is the input of the distance from detector to source? Should that be mentioned here?

Section 2.4
The results table can be copied and then printed. Can a "print page" option be added?

Section 3.4
More information on how FACs should be derived could be included. I assume that the FAC inputs could be an average of activity measurements for each radionuclide over the area of interest with the assumption that field ratios are uniform over that area. The ratios of some radionuclides are fairly precise (e.g., Pu and its daughter Am) and can be used to determine contaminant source areas in the field. Variations in the isotopic ratios for U are also used to determine contaminant sources: DU, EU, and natural U.

Section 3.5
Could variability among different types/brands of field detectors, beyond the detector sensitivity and energy response factor mentioned in 3.4.3, be a limitation?

Section 3.5.3
I'd prefer to have the more complete explanation provided in the FAQs included here in the User's Guide. The FAQs section could reference this section for greater detail.

Volume CPM User's Guide

The step-by-step instruction in Section 2 makes it the most important part of these Guides. It is the "how to" that most users will rely on when first using the calculator. The rest is supplemental, support, or background information.

Section 1
The Introduction in the User's Guide is somewhat redundant with the Introduction on the calculator home page and the two could be combined in one place or the other. If not combined, they should be better integrated.

I would move the last sentence of the 2nd paragraph to follow the highlighted warning in the 3rd paragraph. Shouldn't the ultimate caution be, "The user should always verify real-time survey results with lab analyses."? See the end of Section 3.7.

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These instructions should match the instructions for this page in the calculator.

Section 2.2
These instructions should match the instructions for this page in the calculator.

More information on how to derive FACs is needed here or in Section 3.4.

Section 2.3
How sensitive is the input of the distance from detector to source? Should that be mentioned here?

Section 2.4
The results table can be copied and then printed. Can a "print page" option be added?

FAQs sheet

I'm not sure these would be my most pressing questions. Some of these paragraphs are more complete than the corresponding paragraphs in the User's Guides. I'd suggest integrating these paragraphs into the User's Guides, then deleting this FAQs sheet. If the FAQs sheet is a requirement, I'd at least integrate these paragraphs into the User's Guides, then the FAQs sheet can be abridged by referencing the appropriate sections in the User's Guides.

Counts Per Minute (CPM)

Topic for Key OSWER Radiation Guidances and Reports

Welcome

Comment [CS1]: Paragraphs and sentences re-arranged into a more logical sequence.

Welcome to the EPA's Superfund Counts Per Minute (CPM) calculator. EPA developed the CPM calculator to help risk assessors, remedial project managers, and others involved with risk assessment and decision making at radioactively contaminated sites. The CPM electronic calculator provides a method for correlating real-time survey results, which are often expressed as counts per minute, to contaminant concentrations that are more typically provided in risk assessments or for cleanup levels, usually expressed in pCi/g or pCi/m^2, at Superfund sites (those regulated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, or CERCLA).

The intent of the CPM calculators is to facilitate more real-time measurements within a Superfund response framework. The CPM calculator may also standardize the process of correlating lab data with real-time measurements. Previously there was no EPA guidance for Superfund sites on correlating count per minute field survey readings back to risk, dose, or other ARAR-based concentrations.

This tool is provided to help calculate ~~the radiation~~ gamma detector readings in counts per minute (cpm) that corresponds to the level of radioactivity in a surface or volume of medium by converting radioactivity in either pCi/cm^2 or pCi/g to cpm. The CPM calculator ~~has two major sub calculators based on the field survey scenario~~ addresses two types of field surveys: (1) ~~ground-based~~ scanning ~~of~~ surface contamination, and (2) ~~ground-based~~ scanning ~~of~~ volumetric contamination. To ensure proper application of the radiation conversion tool, please see further guidance from the "Area User's Guide", "Volume User's Guide", and 'FAQ" links.

Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.

~~Introduction~~

~~EPA developed the CPM electronic calculator to help risk assessors, remedial project managers, and others involved with risk assessment and decision making at radioactively contaminated sites. The CPM electronic calculator provides a method for correlating real-time survey results, which are often expressed as counts per minute, to contaminant concentrations that are more typically provided in risk assessments or for cleanup levels, usually expressed in pCi/g or pCi/m^2, at Superfund sites (those regulated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, or CERCLA).~~

~~The intent of the CPM calculators is to facilitate more real-time measurements within a Superfund response framework. The CPM calculator may also standardize the process of converting lab data to real time measurements. It will thus lessen the amount of lab sampling that is needed for site characterization and confirmation surveys, but it will not remove the need for sampling.~~

~~Field sampling has the potential to be an extremely time-consuming and expensive portion of a radiological site remediation. Collected samples must be shipped to an off-site laboratory or counted in an on-site mobile unit in order to establish areas of contamination and to ensure that acceptable residual levels of contaminants remain. Previously there was no EPA guidance for Superfund sites on correlating count per minute field survey readings back to risk, dose, or other ARAR-based concentrations.~~

Highlights of this tool are provided here in a poster-style presentation.

This site is maintained and operated through an Interagency Agreement between the EPA Office of Superfund and Oak Ridge National Laboratory. For questions or comments please contact Stuart Walker at the Office of Superfund Remediation and Technology Innovation.

Topic for Key OSWER Radiation Guidances and Reports

Counts Per Minute (CPM)

Area CPM User's Guide

1. Introduction

~~Field sampling, a necessary step of environmental remediation, establishes areas of contamination before, during, and after cleanup in order to ensure acceptable residual levels of contamination. Sampling has the potential to be an extremely time-consuming and expensive portion of a radiological site remediation. Collected samples must be shipped to an off-site laboratory or counted in an on-site mobile unit in order to establish areas of contamination and to ensure that remainimg contaminants are of acceptable residual levels.~~ Data collection at radioactively-contaminated sites determines whether areas require remediation and then whether an area has been remediated to acceptable levels. Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.

The Area CPM Calculator is a web-based calculator that estimates a gamma scintillation detector response in cpm for a target level of radiological contamination on a surface. This calculator ~~provides a rapid, exceptionally cost-effective assessment of contamination and cleanup standards based on~~ supports the acquisition of field instrument data by converting the target levels to cpm, which minimizes the use of more expensive sample collection and laboratory analysis. ~~A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.~~

Comment [CS1]: The calculator does not assess “contamination” or “cleanup standards”. Cost effective?? It’s free.

Comment [CS2]: Moved to next paragraph.

The user should verify calculator results with lab ~~sampling~~ analyses. A correction factor to account for ground truthing and other field nuances can be derived from a correlation between this calculator's results and lab analyses.

Features of the Area CPM Calculator include:

- option to calculate the Gross Detector Response (GDR) for a single radionuclide or multiple radionuclide mixtures according to MARSSIM guidance
- option to include daughter (+D) ingrowth
- choice of target activity concentration
- truncated decay chains, which allow for man-made decay spectrum
- inclusion of 3 natural decay series
- choice between 4 gamma NaI crystal detector sizes
- ability to specify the exact distance between the detector and the source

2. Step by Step User Guide

Section 2 provides the user with a step by step guide for each page of the Area CPM calculator and highlights potential issues that may be encountered. Links to the calculator data and outside sources are listed in the appendix.

2.1 Radionuclides of Interest

- Select primary (parent) radionuclides of interest by clicking on a radionuclide in the "Radionuclides (and daughter progeny)" list to highlight it and then click on the ">>" button to add it to the "Radionuclides of Interest" list. Multiple radionuclides can be moved together by highlighting while holding the shift or control keys. When one or all radionuclides have been selected, click "Next".

Comment [CS3]: This next-to-last sentence is different in the instructions for this page in the calculator ("To calculate the parent and daughter activities manually..."). Both sentences could be included in both places

~~Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators.~~

Comment [CS4]: Doesn't belong here. See section 2.2 below.

Daughter products that reach secular equilibrium in a hundred to a thousand years are automatically added. Adding a parent and its daughter will automatically deselect the daughter, as it is inherently included. To calculate the parent and daughter activities manually, deselect the box "Include daughter products." Chains with very long-lived daughters have been truncated at the typical 'parent' radionuclides for man-made purposes. To select one of three natural decay series, find the parent with the suffix of 'n'. See Section 3.2 for more information.

2.2 Activity Concentrations

- Enter the target activity concentration (TAC) in pCi/cm^2 for each radionuclide.
- If multiple radionuclides are selected, enter the field activity concentration (FAC) for each radionuclide. Click "Next".

Comment [CS5]: These instructions should match the instructions for this page in the calculator.

The TAC is the activity for which the result in cpm is desired. The TAC is analogous to PRGs and DCCs, which can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators. The TAC may also be based on an ARAR such as the 5 pCi/g over background standard from 40 CFR 192.

The FAC is based on laboratory analysis. The FAC is the activity of each primary radionuclide on the contaminated surface and is used to find the radionuclide ratios in mixtures.

2.3 Detector Information and Geometry of the Site

- Select the size of the gamma scintillation detector.
- Enter the estimated distance between the source and the detector in centimeters. Click "Next".

Comment [CS6]: Guidance on an appropriate estimate for this parameter would be useful.

The CPM calculator was developed for use with 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystal detectors. For further guidance see Section 3.1.

2.4 Gross Detector Response

- The results are displayed. Click on the number of photons for a list of a radionuclide's photon energies and yields.
- Click the "Back" button to go back a page or click "Start Over" to begin another calculation.

The results table lists the primary selected radionuclides and their daughters, each daughter's fractional activity and the number of photons from each daughter. For reference, the field activity (if more than one primary is selected) and the TAC are reprinted next to their individual conversions to cpm. At the bottom, the detector size and distance are followed by the GDR in cpm.

A Field or Target Activity (CPM) result of \"-\" indicates that no photons are generated by the radionuclide's decay chain and thus cannot be detected by a gamma scintillation detector. Radionuclides with 0 photons do not contribute to the total GDR. This tool only works for gamma emitters.

If a radionuclide in the list emits one or more photons outside the range of the detector, a note will appear below the results table notifying the user that the selected spectrum has photons outside the range of the detector. A list of the photons excluded from the calculation of Gross Detector Response (GDR) will appear on the \"Photons\" page which can be accessed by clicking on the hyperlinked number of photons of a radionuclide.

3. Design

Section 3 details the detector-specific and radionuclide-specific parameters utilized for the consequent calculation of GDR. Information required from the user about the radionuclides of interest, the detector used, and the geometry of the site are discussed in this section. Each step of the model is outlined in order to aid the user and ensure transparency.

3.1 Gamma Scintillation Detectors

Detector data is based on four sizes of gamma scintillation detectors by Ludlum Measurements Inc. The models are the 44-2, 44-10, 44-62, and the 44-20 NaI(Tl) crystal gamma scintillation detectors of sizes 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystals.

The detector sensitivity (S), a constant that converts exposure to cpm, and the detector response, a coefficient dependent on the detector's cataloged response to the photon energy, are fed into the Area CPM Calculator equations. The response coefficient is found in a graph of photon energy and response from the detector user manual. DataThief, a shareware program, was used to visually trace the graphs and convert the values to text for the ~~three~~ four detector sizes. The graphs and text files for the detectors can be seen below:

0.5"x1" graph and text,
1"x1" graph and text,
2"x2" graph and text.
3"x3" graph and text.

3.2 Daughters and Decay Chains

By default, the Area CPM Calculator estimates the detector response for the primary radionuclide in one hundred to one thousand years of secular equilibrium with its daughters. This is meaningful, especially in the common case of Cs-137 (the well-known 662 keV gamma of Cs-137 is actually produced by its metastable daughter, Ba-137m). This feature, however, can be deactivated by deselecting the check box beneath the radionuclide selection list. The three main natural decay chain series have been truncated for use with manmade or purified radionuclides of U-238, U-235 and Th-232. For example, selecting U-238 will only include the immediate three daughters. The next sequential daughter, U-234, being so long lived, is considered a new radionuclide. To calculate for the natural state of the above three chains, as in calculating for uranium ore, select from the radionuclide list the natural instance of the parent radionuclide, denoted by the suffix, n: U-238n, U-235n, and Th-232n. Selecting one of these radionuclides will include the contribution of the entire natural chain. Isotopic decay chains can be found by using the Radionuclide Decay Chain Tool.

3.3 Model Geometry

The geometry of the model is a disc source above which a detector is suspended. The height (h) of the detector is the user's estimate of the distance in centimeters between the detector and the source of contamination. The maximum radius of the disc (R) is calculated such that the distance from the detector to the outer circumference of the circle is seven mean free paths ($7/\mu$) of the greatest photon energy, a distance at which the photon is safely assumed to be attenuated. See the exposure derivation.

3.4 Equations

The TAC is converted to detector response in cpm using an equation for exposure, the radionuclide-specific gamma constant and detector-specific parameters. If multiple primary radionuclides are selected, each TAC is converted separately and then summed with a risk-weighted equation using ratios established from the FAC, or FACs.

The FAC is the actual activity of each primary radionuclide in the contamination. FACs are used to establish field ratios for multiple radionuclides. The target detector responses, in cpm, are then figured together to obtain the GDR. First, the theoretical exposure rate at the detector is calculated for each TAC. The exposure rate is then multiplied by the detector sensitivity to convert to detector response in cpm and then corrected for the energy-specific detector response of the radionuclide's energy spectrum. Finally, a sum-ratio equation from MARSSIM that accounts for the contamination ratios and restrictive radionuclide concentrations is applied.

3.4.1 Exposure

The exposure rate at the detector is calculated as follows:

$$\dot{X} = \Gamma * A * \pi * \ln\left(\frac{h^2 + R^2}{h^2}\right)$$

where X is the exposure rate in μR/hr,
Γ is the gamma coefficient in μR hr^{-1} cm^2 pCi^{-1},
A is the surface activity in pCi/cm^2,
h is the distance from the detector to the surface in cm, and
R is the radius of the contamination boundary.

R is designed so that the range from the detector to the boundary is 7 mean free paths and is defined:

$$R = \sqrt{\left(\frac{7}{\mu}\right)^2 - h^2}$$

thus,

$$\dot{X} = \Gamma * A * \pi * \ln\frac{(7/\mu)^2}{h^2}$$

3.4.2 Normalized, Weighted Response Factor

The detector response varies by the energy of the incident photon. A normalized and weighted detector response factor, RF_{norm}, is calculated to correct the response for the photon spectrum:

$$RF_{norm} = \sum \frac{Y * dfrac}{\sum Y * dfrac} RF$$

where Y is the yield of each photon of each radionuclide,
dfrac is the emitting radionuclide's fractional activity based on the primary parent's activity, and
RF is the response factor correlating to the energy of each photon.

3.4.3 CPM

The detector response in cpm is found by multiplying the exposure rate at the detector by the detector's sensitivity and response factor, RF_{norm}, resulting in cpm corrected for the spectrum's energy variance:

$$cpm = \dot{X} * S * RF_{norm}$$

where S is the sensitivity of the detector in cpm / (μR/hr), and
RF is the energy response factor of the detector.

For a single radionuclide of interest, the user may skip to section 3.4.5.

3.4.4 Relative Fraction

The relative fraction, f_i, is the fraction of the total activity contributed by each radionuclide, i. The FACs are used to find the relative fractions of each radionuclide, which are then applied to the GDR. See MARSSIM Chapter 4 (U.S. EPA, 2000).

$$f_i = \frac{cpm_{FAC\,i}}{cpm_{FAC\,1} + cpm_{FAC\,2} + \cdots + cpm_{FAC\,n}}$$

Where cpm_{FACj} is the FAC of each radionuclide, j, in units of detector cpm.

3.4.5 Gross Detector Response

The GDR is the total calculated response of the detector in cpm for the desired remedial activity of the particular radionuclides in the soil. MARSSIM Equation 4-4 "Gross Activity DCGL" (U.S. EPA, 2000) is applied to find the gross detector response and can be seen in an edited form below:

$$GDR = \frac{1}{\frac{f_1}{cpm_{SAC_1}} + \frac{f_2}{cpm_{SAC_2}} + \cdots + \frac{f_n}{cpm_{SAC_n}}}$$

Where f_j is the relative fraction of each radionuclide, j, and cpm_{SACj} is the TAC for each radionuclide, j, in units of detector cpm.

3.5 Limitations

3.5.1 The Model

The Area CPM Calculator is designed around a model that converts surface activity in pCi/cm^2 to detector response in cpm. The model is basic, involving a contaminated surface and a detector suspended a specified distance above. Differences between the model and field characteristics may introduce error into calculator estimates. The Area CPM Calculator does not replace the need for lab-based sampling or MARSSIM final status survey requirements; however, it may provide a reasonable starting point from which to work.

3.5.2 Uniformity

The model assumes uniform contamination on the source surface. In other words, the radionuclides of interest are in constant ratio to each other on the surface and the source surface is infinite in lateral extent. Incongruity of the radionuclide ratios, such as separate spills or cross-contaminated sites, will diminish the effectiveness of the calculator.

3.5.3 Gamma Emitters

Radionuclides that emit alpha and beta radiation are difficult to measure with any accuracy in the field and are omitted from this model unless the radionuclide also emits a qualifying gamma particle.

A qualifying gamma particle is one with energy between 40 keV and 2 MeV and with a decay yield greater than 0.1%. The energy cutoff is due to the energy response curve given in the model detector manufacturer's specifications. For more information see the FAQs.

3.5.4 Shielding and Attenuation

The model assumes the source surface is free from all shielding from materials or substances coating or between the detector and source, such as and including paper, oil or moisture.

3.5.5 Background Radiation

The model does not account for background radiation. The user is responsible for adding or subtracting any background counts to the GDR.

3.5.6 Omitted Exposure Factors

The model does not account for backscatter or buildup in the surface material.

3.6 Correction Factors

A correction factor may be ~~designed and applied to correlate a few~~ developed by correlating lab ~~sampling~~ analyses ~~to~~with the results of this calculator.

3.7 Guidance

Guidance on circumstances where it may be appropriate to conduct real-time ~~methods~~ surveys in addition to risk estimates based on slope factors is provided in *Radiation Risk Assessment At CERCLA Sites: Q&A* (EPA 1999). Instances where it may be beneficial to also use direct measurements for assessing risk from external exposure to penetrating radiation include:

- During early site assessment efforts when the site manager is attempting to communicate the relative risk posed by areas containing elevated levels of radiation,
- As a real-time method for indicating that remedial objectives are being met during the conduct of the response action. The use of exposure rate measurements during the conduct of the response actions ~~should~~ does not decrease the need for a final status survey.

Direct radiation exposure rate measurements may provide important indications of radiation risks at a site, particularly during early investigations, when these may be the first data available. Such data, however, may only reflect a subset of the radionuclides and exposure pathways of potential concern (e.g., only external exposure from gamma-emitting radionuclides in near-surface soil) and may present an incomplete picture of site risks (e.g., risk from internal exposures or potential increased future risk from radionuclides in subsurface soils). In most cases, more accurate estimation of radiation risks will require additional site characterization data, including concentrations of all radionuclides of concern in all pertinent environmental media. The principal benefits of utilizing direct exposure rate measurements is the speed and convenience of analysis and the elimination of potential modeling uncertainties. These data, however, should be used in conjunction with, rather than instead of, characterization data of radionuclide concentrations in environmental media to obtain a complete picture of potential site-related risks. **Exposure rate measurements should be correlated with actual scanned data by co-locating them to ensure that modeled assumptions about the correlation between exposure rate and sample concentrations is accurate.**

4. Glossary

activity concentration: The activity per surface area (pCi/cm^2).

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Comment [CS7]: Possible additional terms: photon spectrum, scintillation detector (rather than "detector").

alpha particle: A positively charged particle comprised of a helium nucleus emitted by some radioactive materials during radioactive decay. Alpha particles expend their energy quickly and are easily attenuated. They have a very short range in air and will not penetrate the dead skin layer. They are difficult to detect in the field. The main hazard due to alpha particles is from ingestion or inhalation, such as gaseous radon and its particulate daughters.

attenuation: The loss of energy or intensity of a photon particle or beam as it passes through and interacts in a medium. The loss can be quantified with the use of the linear attenuation coefficient.

background radiation: Surrounding radiation that is present in the environment, emitted from a variety of natural and artificial sources, including cosmic sources and fallout. The user must account for and add the background radiation to the GDR.

Becquerel (Bq): The International System (SI) unit of radioactivity equal to one disintegration per second. 1 curie = 3.7×10^{10} Becquerels.

beta particle: An electron emitted from the nucleus during radioactive decay. Beta particles have a relatively short range in air. Although very high energy betas can be easily measured, most beta radiation is difficult to measure with accuracy in the field. The main hazard from beta particles is exposure to eyes and skin.

counts per minute (cpm): The number of counts a radiation detector records in a minute.

curie (Ci): A unit of radioactivity defined as 3.7×10^{10} Becquerels, or decays per second, which is approximately equal to the decay rate of one gram of Ra-226.

detector: An instrument that detects radiation.

detector response curve: A graph of a gamma detector response to photons of multiple energies.

detector response factor (RF): A coefficient for correcting for a gamma detector's varied response due to incident photons of multiple energies.

exposure rate: The amount of ionization produced per unit time in air by X-rays or gamma rays. The unit of exposure rate is Roentgen/hour (R/h).

Field Activity Concentration (FAC): The current concentration of parent radionuclides in the field. This is used primarily to ascertain contaminant ratios.

fractivity: The fractional activity of a daughter compared to the primary parent radionuclide in secular equilibrium. This fraction is multiplied by the primary parent activity to find the daughter activity.

gamma constant / coefficient: The gamma constant is a radionuclide-specific exposure rate due to photons. The gamma coefficient differs from the gamma constant in that the coefficient includes annihilation photons as contributing to exposure. The gamma coefficient was compiled from the output of the DECDATA software of ICRP Publication 107 (ICRP, 2008).

gamma radiation: Penetrating high-energy, short-wavelength electromagnetic radiation emitted from the nucleus during radioactive decay. Gamma rays are very penetrating and require dense materials, such as lead or steel, for shielding. Gamma particles are also called photons.

Gross Detector Response: The final cpm result.

half-life ($T_{1/2}$): The interval in which the activity of a radionuclide will decay to half of its initial value. The half-life is related to the decay constant λ as $T_{1/2} = \ln(2) / \lambda$.

isotope: Atoms of the same atomic number with the same number of protons but with more or less neutrons, which often contributes to the stability, or radioactivity, of the atom.

linear attenuation coefficient: A function of particle energy, the linear attenuation coefficient, μ, is the probability that a particle will interact or attenuate in a medium.

MARSSIM: The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides guidance to federal agencies, states, site owners, contractors, and other private entities on how to demonstrate that their site is in compliance with a radiation dose- or risk-based regulation, otherwise known as a release criterion.

mean free path: The average distance traveled by a projectile prior to an interaction and the inverse of the linear attenuation coefficient, μ. The intensity of a beam of photons will be diminished to 37% in one mean free path of material. At seven mean free paths the intensity of the beam is negligible and considered to be completely attenuated.

nuclide: A general term used to describe the full range of elements and their family of isotopes.

picocurie (pCi): A unit of radioactivity defined as 1×10^{-12} curies.

primary radionuclide: A term used to denote a radionuclide selected by the user as opposed to a daughter radionuclide. Not all primary radionuclides have daughter radionuclides.

radionuclide: see nuclide.

relative fraction (f): The fraction of the total activity contributed by one radionuclide of a mixture.

Roentgen (R): The unit of photon exposure in air equivalent to 2.58×10^{-4} C/kg.

sensitivity (S): The detector signal output per unit exposure (cpm / (μR/hr)).

shielding: Any material or substance that blocks or attenuates radiation.

Target Activity Concentration (TAC): The surface activity concentration that meets the cumulative risk assessment for a radionuclide of interest, although any level of surface activity can be used for investigative purposes.

yield: particles emitted per radionuclide decay.

5. Appendix (data and links)

Preliminary Remediation Goal (PRG) Calculators

Tools for calculating the preliminary remediation goals for soil and water, inside buildings, and outdoor surfaces are available.

Dose Compliance Concentrations (DCC) Calculators

Tools for calculating the dose compliance concentrations for soil and water, inside buildings, and outdoor surfaces are available.

Nuclide Data File

This table was built from the data included in ICRP 107.

Response Curves

The detector response curves are generated from graphing the responses of a number of commonly used check sources. The curves can be found here.

6. References

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ICRP, 2008. *Nuclear Decay Data for Dosimetric Calculations.* ICRP Publication 107. Ann. ICRP 38 (3).

ITRC (Interstate Technology and Regulatory Council), 2006. Real-Time Measurement of Radionuclides in Soil: Technology and Case Studies. RAD-4. Washington, D.C.: Interstate Technology and Regulatory Council, ~~Real-Time~~ Radionuclides Team.

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Comment [CS8]: The existing citation is the one suggested at the front of the document. The actual team name, however, is simply Radionuclides Team.

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Counts Per Minute (CPM)

Topic for Key OSWER Radiation Guidances and Reports

Volume CPM User's Guide

1. Introduction

~~Field sampling, a necessary step of environmental remediation, establishes areas of contamination before, during, and after cleanup in order to ensure only acceptable residual levels of contamination remain. Sampling has the potential to be an extremely time-consuming and expensive portion of a radiological site remediation. Collected samples must be shipped to an off-site laboratory or counted in an on-site mobile unit in order to establish areas of contamination and to ensure that remaining contaminants are of acceptable residual levels.~~ Data collection at radioactively-contaminated sites determines whether areas require remediation and then whether an area has been remediated to acceptable levels. Real-time (CPM) field measurements can supplement required sample collection and lab analysis efforts and can support decision making by reducing uncertainty. Other advantages of real-time surveys include reduced costs, greater flexibility, reduced remediation time frames, and a reduction of both characterization and remedial wastes.

The Volume CPM Calculator is a web-based calculator that estimates a gamma detector response for a target level of radiological contamination in a source. This calculator can be used to determine screening levels in cpm that are based on pCi/~~area~~volume. Using handheld detectors measuring cpm can help reduce costly laboratory sampling. ~~A correction factor for cpm analysis established between this calculator's results and lab sampling analysis may be needed to account for ground truthing and other field nuances.~~

The user should verify calculator results with lab ~~sampling~~ analyses. A correction factor to account for ground truthing and other field nuances can be derived from a correlation between this calculator's results and lab analyses.

Features of the Volume CPM Calculator include:

- option to calculate the Gross Detector Response (GDR) for a single radionuclide or multiple radionuclide mixtures according to MARSSIM guidance
- option to include daughter (+D) ingrowth
- choice of target activity
- truncated decay chains, which allow for man-made decay spectrum
- inclusion of 3 natural decay series
- choice between 4 gamma NaI crystal detector sizes.
- choice of 5 contamination depths
- choice of 6 source materials, in~~l~~cluding a special case of drywall

- exact data for 11 radionuclides most commonly found at remediation sites

2. Step by Step User Guide

Section 2 provides the user with a step by step guide for each page of the Volume CPM calculator and highlights potential issues that may be encountered. Links to calculator data and outside sources are listed in the appendix.

Comment [CS1]: These instructions should match the instructions for this page in the calculator.

2.1 Radionuclides of Interest

- Select primary (parent) radionuclides of interest by clicking on a radionuclide in the "Radionuclides (and daughter progeny)" list to highlight it and then click on the ">>" button to add it to the "Radionuclides of Interest" list. Multiple radionuclides can be moved together by highlighting while holding the shift or control keys. When one or all radionuclides have been selected, click "Next".

~~Remedial activity can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators.~~

Comment [CS2]: Doesn't belong here. See section 2.2 below.

Daughter products that reach secular equilibrium in a hundred to a thousand years are automatically added. Adding a parent and its daughter will automatically deselect the daughter, as it is inherently included. To calculate the parent and daughter activities manually, deselect the box "Include daughter products." Chains with very long-lived daughters have been truncated at the typical 'parent' radionuclides for man-made purposes. To select one of three natural decay series, find the parent with the suffix of 'n'. See Section 3.3 for more information.

The following 11 radionuclides are the most common photon emitting nuclides found at Superfund remedial sites: Am-241, Cs-137, I-131, Ra-226, Ra-228, Rn-220, Th-230, Th-232, U-234, U-235, and U-238. These radionuclides were modeled with their exact photon spectrum, which is used rather than simulating the photon spectrum as is done with the other radionuclides.

2.2 Activity Concentrations

- Enter the target activity concentrations (TAC) in pCi/cm^2 for each radionuclide. The TAC is the activity for which the result in cpm is desired.
- If multiple radionuclides are selected, enter the field activity concentration (FAC) for each radionuclide. Click "Next".

The TAC is the activity for which the result in cpm is desired. The TAC is analagous to PRGs and DCCs, which can be calculated using the PRG, BPRG, SPRG, DCC, BDCC, and SDCC calculators.

The FAC is based on laboratory analysis. The FAC is the activity of each primary radionuclide in the contaminated source and is used to find the radionuclide ratios in mixtures.

2.3 Detector Information and Materials

- Select the size of the gamma scintillation detector

- Select the material of interest
- Select the uniform depth of contamination in the source material
- Enter the distance between the detector and the source. Click "Next".

Comment [CS3]: Guidance on an appropriate estimate for this parameter would be useful.

The CPM calculator was developed for use with 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystal detectors. For further guidance see Section 3.2.

2.4 Results - Gross Detector Response

- The results are displayed. Click on the number of photons for a list of a radionuclide's photon energies and yields.
- Click the "Back" button to go back a page or click "Start Over" to begin another calculation.

The results table lists the primary selected radionuclides and their daughters, each daughter's fractional activity and the number of photons from each daughter. For reference, the FACs (if more than one primary is selected) and the TACs are reprinted next to their individual conversions to cpm. At the bottom, the detector size and distance are followed by the GDR in cpm.

A Field or Target Activity (CPM) result of \"-\" indicates that no photons are generated by the radionuclide's decay chain and thus cannot be detected by a gamma scintillation detector. Radionuclides with 0 photons do not contribute to the total GDR. This tool only works for gamma emitters.

If a radionuclide in the list emits one or more photons outside the range of the detector, a note will appear below the results table notifying the user that the selected spectrum has photons outside the range of the detector. A list of the photons excluded from the calculation of Gross Detector Response (GDR) will appear on the \"Photons\" page which can be accessed by clicking on the hyperlinked number of photons of a radionuclide.

3. Design

3.1 Overview

The Volume CPM Calculator is more sophisticated than the Area CPM Calculator. While the Area CPM Calculator uses calculus to derive the exposure at a detector from a two-dimensional surface contamination, the Volume CPM Calculator estimates the exposure from a three-dimensional slab using Monte Carlo Neutron Particle (MCNP) (see RSICC) model case runs to simulate the photon spectrum of the selected radionuclide(s).

The Volume CPM Calculator is more rigorous and restrictive than the Area CPM Calculator. The MCNP computational model used by the Volume Calculator includes several factors that the Area Calculator does not account for, including attenuation, source shielding, scattering and buildup. A limited set of spatial configurations have been preprogrammed and modeled with MCNP, so the user must choose parameters closest to his or her scenario. A correction factor may be needed to correlate the results to actual sampling.

The output of the MCNP model is energy fluence for fifty-two incident energy channels. This data is converted to detector response per specific contaminant activity (cpm per pCi/g) and then multiplied by the user's target activity to find the estimated detector response.

The user may select multiple radionuclides, in which case the tool will prompt for the FACs of the radionuclides. FACs are the actual activities of each contaminant, usually determined by laboratory analysis. The FACs establish the contaminant ratio, or relative fraction, that is used to correctly weigh the contaminants by their cpm contribution.

3.2 Gamma Scintillation Detectors

Detector data is based on four sizes of gamma scintillation detectors by Ludlum Measurements Inc. The models are the 44-2, 44-10, 44-62, and the 44-20 NaI(Tl) crystal gamma scintillation detectors of sizes 0.5"x1", 1"x1", 2"x2", and 3"x3" NaI crystals.

The detector sensitivity is a detector-specific constant that converts exposure to cpm. The detector's energy response is a coefficient dependent on the detector's calibrated response to the incident photon energy. Both are used to convert the energy fluence into cpm. The energy response coefficients are found in a graph of photon energy and response in the detector user manual. A shareware program called DataThief was used to trace the graphs and convert the values to text. The graphs and text files for the detectors can be seen below:

0.5"x1" graph and text,
1"x1" graph and text,
2"x2" graph and text.
3"x3" graph and text.

3.3 Daughters and Decay Chains

The Volume CPM Calculator calculates the detector response for the primary radionuclide in one-hundred to one-thousand years of secular equilibrium with its daughters. This is meaningful, especially in the common case of Cs-137 (the well-known 662 keV gamma of Cs-137 is actually produced by its metastable daughter, Ba-137m). This feature can be deactivated by deselecting the check box beneath the radionuclide selection list.

The three main natural decay chain series have been truncated for use with manmade or purified radionuclides of U-238, U-235 and Th-232. For example, selecting U-238 will only include the immediate three daughters. The next sequential daughter, U-234, being so long lived, is considered a new radionuclide.

To calculate for the natural state of the above three chains, as in calculating for uranium ore, select from the radionuclide list the natural instance of the parent radionuclide, denoted by the suffix 'nat': U-238nat, U-235nat, and Th-232nat. Selecting one of these radionuclides will include the contribution of the entire natural chain.

Isotopic decay chains can be found by using the Radionuclide Decay Chain Tool.

3.4 Model Geometry & Physics

The 6 different options for source material are soil, concrete, plate glass, wood, steel, and drywall. The model for soil, concrete, plate glass, wood, and steel is based on a uniformly contaminated cylindrical slab source of varying thickness. The exposure from the slab is calculated at a distance above the source in air, mimicking the geometry of a suspended detector. The geometry of this model is depicted in this diagram.

The model for the drywall scenario is different from the model used for the other materials. This model assumes the drywall is 5/8" thick and that a 0.5 cm gap of air exists between the detector and the wall surface. This model can be seen in this diagram.

Both models were developed with the software package MCNP.

3.5 Equations

3.5.1 Calculating the Activity to CPM Conversion Factor

The photon spectra of a radionuclide or selection of radionuclides is simulated by rounding each photon in the radionuclide spectra to the closest of ten modeled photon energies. The modeled input energies were chosen for the even spacing of their detector energy responses.

The output of the MCNP software is energy fluence per MCNP source particle, SP $\left({\varphi_E}/{cm^2 - SP}\right)$, for the mono-energetic input photon and is parsed into fifty-two evenly spaced energy channels. The energy fluence of these channels are converted and summed together to form the response of each emitted photon. The responses of each photon are weighted by photon yield and then weighted again with all radionuclides in the chain and the radionuclide's fractional activity of the parent when in secular equilibrium. This value is converted to cpm per activity for each radionuclide. The equation for this conversion factor, CF, for a radionuclide i can be seen below.

$$CF_i\left(\frac{cpm}{\frac{pCi}{g}}\right) = (82.7)\left(\frac{Source}{Area}\right)\left(\frac{Source}{Dept}\right)\left(\frac{Source}{Dens}\right)\left(\frac{e}{\overline{w}_{air}}\right)(S_{det}) \times \left\{(dfrac_i)\left[\sum_{photons}(Y)\left(\sum_{C}(\varphi_E)\left(\frac{\mu_{en}}{\rho_{air,E}}\right)(RF_{det,E})\right)\right]\right\}$$

Simulation of photon spectra is not used for the following 11 common radionuclides found in remediation sites: Am-241, Cs-137, I-131, Ra-226, Ra-228, Rn-220, Th-230, Th-232, U-234, U-235, and U-238. These radionuclides were modeled with their exact photon spectrum, rather than using the simulation process described above. A Technical Background Document (TBD) is available to view the MCNP output tables and learn more about the calculations performed to characterize the source to detector radiation transport. The TBD is available here.

3.5.2 Calculating Field Acvitity and Target Activity in CPM

Field Activity in CPM, cpm_{FAC}, and Target Activity in CPM, cpm_{TAC}, are found by multiplying the cpm per activity conversion factor, CF, by the user's TAC in pCi/g for a radionuclide. If multiple primary radionuclides were selected, the FACs in pCi/g are also multiplied by the result. The equations for cpm_{FACi} and cpm_{TACi} for a radionuclide i may be seen below.

$$cpm_{FAC_i}(CPM) = FAC_i(pCi) \times CF_i\left({}^{CPM}/_{pCi}\right)$$
$$cpm_{TAC_i}(CPM) = TAC_i(pCi) \times CF_i\left({}^{CPM}/_{pCi}\right)$$

3.5.3 Calculating the Relative Fraction

The relative fraction, f, is the fraction of the total activity contributed by each radionuclide. The FACs are used to find the relative fractions of each radionuclide, which are then applied to the GDR. The equation for calculating the relative fraction for a radionuclide i may be seen below.

$$f_i = \frac{cpm_{FAC\,i}}{cpm_{FAC\,1} + cpm_{FAC\,2} + \cdots + cpm_{FAC\,n}}$$

Where

3.5.4 Calculating Gross Detector Response

The GDR is the total calculated response of the detector in cpm for the desired remedial activity of the particular radionuclides in the soil. MARSSIM Equation 4-4 "Gross Activity DCGL" (U.S. EPA, 2000) is applied to find the GDR and can be seen in an edited form below.

$$GDR = \frac{1}{\frac{f_1}{cpm_{TAC_1}} + \frac{f_2}{cpm_{TAC_2}} + \cdots + \frac{f_n}{cpm_{TAC_n}}}$$

Where f is the relative fraction of each radionuclide, and cpm_{TAC} is the TAC of each radionuclide in units of detector cpm.

3.6 Limitations

3.6.1 The Model

The Volume CPM Calculator model was developed using 248 case runs of MCNP to simulate the spectrum of the desired radionuclide(s). The Volume CPM Calculator does not replace the need for lab-based sampling or MARSSIM final status survey requirements; however, it may provide a reasonable starting point from which to work. A correction factor for cpm analysis established between this calculator's results and lab sampling analysis should be applied to account for this simulation as well as ground truthing and other field nuances.

3.6.2 Uniformity

The model assumes uniform contamination on the source surface. In other words, the radionuclides of interest are in constant ratio to each other on the surface and the source surface is infinite in lateral extent. Incongruity of the radionuclide ratios, such as separate spills or cross-contaminated sites, will diminish the effectiveness of the calculator.

3.6.3 Gamma Emitters

Radionuclides that emit alpha and beta radiation are difficult to measure with any accuracy in the field and are omitted from this model unless the radionuclide also emits a qualifying gamma particle.

A qualifying gamma particle is one with energy between 40 keV and 2 MeV and with a decay yield greater than 0.1%. The energy cutoff is due to the energy response curve given in the model detector manufacturer's specifications. For more information, see the FAQs.

Bremsstrahlung radiation is electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged particle, typically an electron deflected by an atomic nucleus. The moving particle loses kinetic energy and is then converted into a photon. A study of the contribution of this radiation from the modeled materials is in progress.

3.6.4 Background Radiation

The model does not account for background radiation. The user is responsible for adding or subtracting any background counts to the GDR.

3.7 Correction Factors

A correction factor may be ~~designed and applied to correlate a few~~ developed by correlating lab ~~sampling~~ analyses ~~to~~ with the results of this calculator.

3.8 Guidance

Guidance on circumstances where it may be appropriate to conduct real-time ~~methods~~surveys, in addition to risk estimates based on slope factors, is provided in *Radiation Risk Assessment At CERCLA Sites: Q&A* ~~.~~ (EPA 1999). Instances where it may be beneficial to also use direct measurements for assessing risk from external exposure to penetrating radiation include:

- During early site assessment efforts, when the site manager is attempting to communicate the relative risk posed by areas containing elevated levels of radiation,
- As a real-time method for indicating that remedial objectives are being met during the conduct of the response action. The use of exposure rate measurements during the conduct of the response actions ~~should~~ does not decrease the need for a final status survey.

Direct radiation exposure rate measurements may provide important indications of radiation risks at a site, particularly during early investigations, when these may be the first data available. Such data, however may only reflect a subset of the radionuclides and exposure pathways of potential concern (e.g., only external exposure from gamma-emitting radionuclides in near-surface soil) and may present an incomplete picture of site risks (e.g., risk from internal exposures or potential increased future risk from radionuclides in subsurface soils). In most cases, more accurate estimation of radiation risks will require additional site characterization data, including concentrations of all radionuclides of concern in all pertinent environmental media. The principal benefits of utilizing direct exposure rate measurements is the speed and convenience of analysis and the elimination of potential modeling uncertainties. These data, however, should be used in conjunction with, rather than instead of, characterization data of radionuclide concentrations in environmental media to obtain a complete picture of potential site-related risks. **Exposure rate measurements should be correlated with actual scanned data by co-locating them to ensure that modeled assumptions about the correlation between exposure rate and sample concentrations is accurate.**

4. Glossary

Comment [CS4]: Possible additional terms: photon spectrum, scintillation detector (rather than "detector").

- **alpha particle:** A positively charged particle comprised of a helium nucleus emitted by some radioactive materials during radioactive decay. Alpha particles expend their energy quickly and are easily attenuated. They have a very short range in air and will not penetrate the dead skin layer. They are difficult to detect in the field. The main hazard due to alpha particles is from ingestion or inhalation, such as gaseous radon and its particulate daughters.
- **attenuation:** The loss of energy or intensity of a photon particle or beam as it passes through and interacts in a medium. The loss can be quantified with the use of the linear attenuation coefficient.
- **background radiation:** Surrounding radiation that is present in the environment, emitted from a variety of natural and artificial sources, including cosmic sources and fallout. The user must account for and add the background radiation to the GDR.
- **Becquerel (Bq):** The International System (SI) unit of radioactivity equal to one disintegration per second. 1 curie = 3.7 x 10^{10} Becquerels.

- **beta particle:** An electron emitted from the nucleus during radioactive decay. Beta particles have a relatively short range in air. Although very high energy betas can be easily measured, most beta radiation is difficult to measure with accuracy in the field. The main hazard from beta particles is exposure to eyes and skin.
- **counts per minute (cpm):** The number of counts a radiation detector records in a minute.
- **curie (Ci):** A unit of radioactivity defined as 3.7×10^{10} Becquerels, or decays per second, which is approximately equal to the decay rate of one gram of Ra-226.
- **detector:** An instrument that detects radiation.
- **detector response curve:** A graph of a gamma detector response to photons of multiple energies.
- **detector response factor (RF):** A coefficient for correcting for a gamma detector's varied response due to incident photons of multiple energies.
- **energy fluence:** The amount of energy delivered per unit area (J/m^2).
- **exposure rate:** The amount of ionization produced per unit time in air by X-rays or gamma rays. The unit of exposure rate is Roentgen/hour (R/h).
- **Field Activity Concentration (FAC):** The current concentration of parent radionuclides in the field. This is used primarily to ascertain contaminant ratios.
- **fractivity:** The fractional activity of a daughter compared to the primary parent radionuclide in secular equilibrium. This fraction is multiplied by the primary parent activity to find the daughter activity.
- **gamma radiation:** Penetrating high-energy, short-wavelength electromagnetic radiation emitted from the nucleus during radioactive decay. Gamma rays are very penetrating and require dense materials, such as lead or steel, for shielding. Gamma particles are also called photons.
- **Gross Detector Response:** The final cpm result.
- **half-life ($T_{1/2}$):** The interval in which the activity of a radionuclide will decay to half of its initial value. The half-life is related to the decay constant λ as $T_{1/2} = \ln(2) / \lambda$.
- **isotope:** Atoms of the same atomic number with the same number of protons but with more or less neutrons, which often contributes to the stability, or radioactivity, of the atom.
- **linear energy absorption coefficient:** A function of particle energy, the linear energy absorption coefficient, μ_{en}/ρ, is the probabliity that a particle will interact or attenuate in a medium.
- **MARSSIM:** The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides guidance to federal agencies, states, site owners, contractors, and other private entities on how to demonstrate that their site is in compliance with a radiation dose or risk-based regulation, otherwise known as a release criterion.
- **picocurie (pCi):** A unit of radioactivity defined as 1×10^{-12} curies.
- **primary radionuclide:** A term used to denote a radionuclide selected by the user as opposed to a daughter radionuclide. Not all primary radionuclides have daughter radionuclides.
- **radionuclide:** A general term used to describe the full range of elements and their family of isotopes.
- **relative fraction (f):** The fraction of the total activity contributed by one radionuclide of a mixture.

- **Roentgen (R):** The unit of photon exposure in air equivalent to 2.58 x 10^{-4} C/kg.
- **sensitivity (S):** The detector signal output per unit exposure (cpm / (μR/hr)).
- **shielding:** Any material or substance that blocks or attenuates radiation.
- **specific activity concentration:** The activity per source volume (pCi/g).
- **Target Activity Concentration (TAC):** The surface activity concentration that meets the cumulative risk assessment for a radionuclide of interest, although any level of surface activity can be used for investigative purposes.
- **yield:** particles emitted per radionuclide decay.

5. Appendix (data and links)

Preliminary Remediation Goal (PRG) Calculators

Tools for calculating the preliminary remediation goals for soil and water, inside buildings, and outdoor surfaces are available.

Dose Compliance Concentrations (DCC) Calculators

Tools for calculating the dose compliance concentrations for soil and water, inside buildings, and outdoor surfaces are available.

Nuclide Data File

This table was built from the data included in ICRP 107.

Response Curves

The detector response curves are generated from graphing the responses of a number of commonly used check sources. The curves can be found here.

6. References

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Comment [CS5]: The existing citation is the one suggested at the front of the document. The actual team name, however, is simply Radionuclides Team.

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This site is maintained and operated through an Interagency Agreement between the EPA Office of Superfund and Oak Ridge National Laboratory. For questions or comments please contact Stuart Walker at the Office of Superfund Remediation and Technology Innovation.

CARL SPRENG
RESUME

Colorado Department of Public Health & Environment
Hazardous Materials and Waste Management Division
4300 Cherry Creek Drive South, HMWMD-B2
Denver, CO 80246-1530

JOB TITLE: Rocky Flats Project Coordinator
(Environmental Protection Specialist III)

DATES OF EMPLOYMENT: April 1992 – July 1993; May 1994 – present

DUTIES: Provide technical lead and staff authority for development, implementation, and oversight of corrective action involving radioactive and chemical contamination at RCRA facilities; advise and provide technical guidance to management and external agencies on these issues. Assure and determine adequate treatment and environmental cleanup of hazardous waste facilities and contaminated sites by investigating, analyzing, and evaluating the chemistry, geology, hydrogeology, and geotechnical aspects of the sites. Evaluate laboratory analytical data, inspect facilities, oversee remediation activities and maintenance of work plans and permits. Regularly meet with local governments and stakeholders, and participate in technical working groups and public participation forums.

Team leader of several technical teams for the Interstate Technology and Regulatory Council, a nation-wide organization of state environmental regulators and representatives of federal agencies, industry, academia, and local and tribal stakeholders: *Radionuclides*; *Attenuation Processes for Metals and Radionuclides in Groundwater*; *Remediation Management of Complex Sites*.

Hart Publications, Inc.
Denver, CO

JOB TITLE: Managing Editor

DATES OF EMPLOYMENT: September 1990 – April 1992
August 1993 – May 1994

DUTIES: Oversaw and managed two publications targeting the oil & gas industry; compilation and editing of data; accounting for sales; developing advertising; hiring and other personnel duties; supervised 6 professional employees.

CARL SPRENG
RESUME (continued)

Spreng Geological Consulting
Thornton, CO

JOB TITLE: Independent Consulting Geologist

DATES OF EMPLOYMENT: January 1984 – April 1991

DUTIES: Developed and managed exploration projects; well-site supervision of oil and gas wells; economic/property evaluations; taught hydrogeology course at Front Range Community College; conducted/supervised corrosion engineering projects (cathodic protection of tanks, pipelines, etc.).

Berge Exploration, Inc.
Denver,CO

JOB TITLE: Manager – Special Projects

DATES OF EMPLOYMENT: November 1977 – December 1983

DUTIES: Developed and managed exploration projects (oil & gas, oil shale, tar sands, uranium, coal, etc.); supervised field exploration projects in the western U.S. including U.S. Dept. of Energy NURE project (*US DOE Report GJO-014(82)*); developed project proposals; wrote reports; compiled data, maps, etc.; hired and supervised professional geologists.

Occidental Oil Shale, Inc. (Occidental Petroleum, Inc.)
Grand Junction, CO

JOB TITLE: Geologist

DATES OF EMPLOYMENT: July – December 1975
April – August 1976

DUTIES: Directed fracture mapping program; computer data processing; conducted sampling study of in-situ retort; measured geologic sections; hydrologic well logging.

Seismograph Service Corporation
Tulsa, OK

JOB TITLE: Electronics repairman; jug crew lead

DATES OF EMPLOYMENT: April - August 1974

DUTIES: Electronic instrumentation repairs; led geophone crew on seismic exploration project in western U.S.

Petro-Nuclear, Ltd. (Consolidated Oil & Gas, Inc.)
Denver, CO

JOB TITLE: Geological Field Assistant

DATES OF EMPLOYMENT: June – August 1968

DUTIES: Surveying, mapping, scintillometer surveys in support of uranium exploration in central Wyoming.

EDUCATION

Bachelor of Science – Geology	Brigham Young University (1975)
Master of Science – Geology	Brigham Young University (1978)
Post-graduate courses:	
Geohydrology	University of Colorado
Geophysics	Colorado School of Mines

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(b) Peer Reviewer agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this peer review, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Peer Reviewer (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Peer Reviewer shall continue performance until notified by EMS of any contrary action to be taken.

Carl Spreng
Signature

November 13, 2013
Date

☑ Check here if any explanation is attached

Carl Spreng
Printed Name

Colorado Department of Public Health and Environment
Affiliation/Organization

From about 1998 to 2008 I served as the team leader for the Radionuclides Team of the Interstate Technology and Regulatory Council (ITRC). Some members of the team were with EPA's Office of Superfund Remediation and Technology Innovation (OSRTI). I became acquainted with radiation risk calculators that OSRTI was developing through those team members. There was no actual or apparent conflict of interest then and I do not believe that association creates one now.

Carl Spreng