Peer Review of EPA Building Preliminary Remediation Goals (BPRG) for Radionuclides Online Calculator and Information Resource

Objective

This peer review addresses the EPA Building Preliminary Remediation Goals (BPRG) for Radionuclides Online Calculator and Information Resource. It specifically follows the Charge Document provided by SRA International as a structuring guide for this peer review. Additional comments were incorporated in those charge questions believed to most closely deal with the topic.

General questions

1. **a). Are the purpose and scope of the guidance document clear?**

   Yes. Both purpose and scope of the BPRG website are adequately discussed in the BPRG Homepage, as well as in the User's Guide and Frequently Asked Questions pages.

   For the purposes of this review, all of the BPRG website information resources were reviewed under the lumped term "guidance document". In fact, there is no single identified "guidance document" underlying the BPRG website, but rather a detailed User's Guide together with additional information pages that can be found at the BPRG website (the point being that a User's Guide is in this reviewer's view not synonymous with a formal "guidance document" from either a statutory, legal, or regulatory perspective).

   However, as to scope there is one issue needing to be addressed. Specific mention is made in the last paragraph of the BPRG Homepage (https://epa-bprg.ornl.gov/) that "*…Non-carcinogenic effects are not considered for radionuclide analytes, except for uranium, for which carcinogenic and **non-carcinogenic effects are considered**….*". This statement seems to imply that the non-carcinogenic health effects of uranium isotopes are also considered in the BPRG calculations. However, both the Disclaimer found in the User's Guide ("*…It should also be noted that calculating human cancer risk from radiological contaminants **does not address** ecological risk or **noncancer toxicity**. Of the radionuclides generally found at CERCLA sites, only uranium has potentially significant noncancer toxicity. When assessing sites with radiological contaminants which include uranium, it may also be necessary to consider the noncancer toxicity of uranium**, using other tools**…*"), nor any indication (alternate equations or footnotes) in the BPRG Equations section of the User's Guide nor the Equations webpage point towards the inclusion of uranium's non-carcinogenic health effects in the BPRG calculator. Regardless of whether an additional calculation module is to be included in the BPRG calculator in the future for addressing uranium (which this reviewer highly recommends as a very large portion of radioactively-contaminated buildings, e.g. practically all FUSRAP buildings, contain uranium), the different statements regarding the scope for addressing non-carcinogenic effects must be brought into alignment.

   b). Does the document accurately represent existing guidance regarding risk-based PRGs and explain how it fits within this existing context?

   Yes. Existing guidance is accurately represented, albeit at times very much simplified to aid the end-user's ease of understanding. Explicit mention of existing guidance (RAGS, Part B) is made in the BPRG Homepage "…*This calculaor* **[typo: calculator]** *is based on Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) (RAGs Part B). RAGs Part B provides guidance on using EPA toxicity values and exposure information to calculate risk-based BPRGs*…", as well as addressing the guidance context in the Frequently Asked Questions. However, a succinct statement placing the BPRGs into the RAGS, Part B and other guidance context is missing from the User's Guide. At the risk of being repetitive, this reviewer recommends that the quoted sentence above be copied and inserted into the third or fourth paragraph of the Introduction section of the User's Guide.

Typo: The correct abbreviation for Risk Assessment Guidance for Superfund is RAGS. In the Introduction section of the BPRG Homepage it is twice referred to as "RAGs".

c). Does the document clearly state for what purposes it is applicable and for what purposes it should not be used? Please explain.

Yes. A detailed delineation of the purpose of the BPRG calculator is provided in the User's Guide as well as an overview in both the Homepage discussion and the Frequently Asked Questions.

However, it should be noted that the comment to Question 1.a). as to "addressing non-carcinogenic health effects" may be applicable here. Also, there is an underlying implication in the BPRG Homepage discussion "…*In addition, you are able to modify the input parameters to create site-specific BPRGs to meet the needs of your site…* [and] *…This calculation tool provides the ability to modify the standard default BPRG exposure parameters to calculate site-specific BPRGs…*" that the tool can be adjusted to fit **<u>any</u>** site-specific conditions. This is in stark contrast to the Disclaimer statement of the User's Guide that states "…*Alternative approaches for risk assessment may be found to be more appropriate at specific sites (e.g., where site circumstances do not match the underlying assumptions, conditions and models of the guidance)*…", as well as the statement in Section 3.1 Developing a Conceptual Site Model "…*When using BPRGs, the exposure pathways of concern and site conditions must match those taken into account by the screening levels…and additional tools or assessment methodologies may need to be considered*…". Clearly, it would be impractical to develop a tool that would handle **<u>any</u>** site-specific condition, but a more clearer mention that there are constraints on the ability to adjust to site-specific conditions should be mentioned in the BPRG Homepage discussion. For example, one could write "…*In addition, you are able to modify the input parameters to create site-specific BPRGs to meet the needs of your site,* **within the limitations of the underlying exposure scenarios, pathways, and routes**…*"* .

Furthermore, the User's Guide would benefit from a description of what, if any, "alternative approaches for risk assessment" there are and when specifically they should be used. As it stands, the user wishing to adjust the BPRG calculator to site-specific needs can effectively and efficiently undertake this task as long as the site-specific conditions of exposure principally match those of the BPRG calculator. If, for example, another exposure route such as dermal uptake is to be calculated, then the user is not provided any specific guidance on how to approach this task. [The issue of dermal uptake will be addressed in later comments]. Consequently, users – even professional risk assessors – may be reluctant to deviate from the BPRG calculator exposure scenarios and this could lead to a misapplication of the BPRG calculator, albeit that the User's Guide explicitly addresses this potential in sections 3.1, 3.3, and in the Disclaimer. An enhanced integration, or at least referential linkages, with other and "alternative approaches for risk assessment" of radioactively contaminated buildings could avoid this potential. Of course, this argument is for all intents and purposes moot if the overwhelming majority of radioactively contaminated buildings could be assessed using the BPRG calculator. No information is provided whether a sampling of a larger number of sites has been performed and what percentage was shown to fall under the constraints of the BPRG calculator's CSM. From experience, this reviewer would judge that a significant portion of radioactively contaminated buildings would NOT fall under the constraints of the BPRG calculator, for one because of the lack of the dermal route being calculated and the lack of a trespasser/visitor scenario, and also because of non-conforming building geometries (mostly larger buildings such as manufacturing facilities, school gyms, etc.), which will be addressed in later comments.

Typo: Tresspasser in section 3.1 should be trespasser.

2. a). Is the intended audience of the BPRG calculator clear?

Yes. Explicit mention of the intended audience is made in the discussion of the BPRG Homepage ("…*this BPRG calculation tool is to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at sites with contaminated buildings….*") as well as in the User's Guide ("…*The policies set out in the Building Preliminary Remediation Goal Electronic Calculator (BPRG) User's Guide provide guidance to EPA staff. It also provides guidance to the public and regulated community..* [and] …*This guidance provides a methodology for radiation professionals to calculate risk-based, site-specific, concentrations…* [and] … *WARNING: Using a dissipation rate constant or changing the value of t should only be done once a complete understanding of the mathematics involved in deriving the equation is gained and the site conditions have been fully investigated…*" It can be surmised that the BPRG Homepage discussion is more open to a broader intended audience, while the User's Guide specifically limits the actual execution of the BPRG calculator to "radiation professionals" and only provides guidance for the sake of transparency and informational value to the "public and regulated community". This seeming discrepancy should be addressed.

b). Can the calculator be effectively used as is currently presented for site-specific BPRG calculations?

Yes, but with recognized limitations. For one, it is limited to the underlying default exposure scenario and exposure routes, as well as being limited in the underlying building geometry. A further caveat for the above affirmative response relates to an issue of the inherent applicability of the distinction between soft and hard surfaces for transference of dust particulate matter to hand surface areas in adults and will be addressed further in later comments.

c). Does the supporting material provide the appropriate level of detail, technical content, and referencing for the intended audience? Please explain and identify specific recommendations for improving the BPRG calculation tool.

Yes, the supporting material provides the appropriate level of detail, technical content, and referencing for the intended audience, as long as the previously commented upon issues are resolved. Specifically, the following above mentioned issues should be resolved:

- the issue of "addressing non-carcinogenic health effects" mentioned in the comment to question 1.a). (see above).
- the issue of more clearly delineating the limitations of the BPRG calculator AND providing integration with or referential linkages to "alternative approaches for risk assessment" (see comment to question 1.c).).
- a clarification of the intended audience either in the BPRG Homepage discussion or in the User's Guide.

In addition, the following should be considered:

- in section 3.1, a stem-and-leaf CSM diagram of the default BPRG CSM should be provided. Note that a stylized graphical presentation of the CSM is shown on the BPRG Homepage, but is not of appropriate level of detail for the intended audience ("radiation professionals"). The stylized cartoon-like graphics presented in Section 4. also are informative, but do not allow for a holistic picture of the CSM to be made.
- In section 3.1, a referential link to EPA guidance(s) on developing CSMs (e.g. Planning Table 1 of RAGS-D, or Attachment A of the Soil Screening Guidance) should be included. Ideally, there should be a separate module of the BPRG website for aiding the user in the CSM development, tailored to building situations. That way, the boundaries of the default scenarios, pathways, and routes underlying the BPRG calculator can also be more quickly identified.
- In section 3.1, the phrase "…*The final CSM diagram represents* …" implies that CSMs must be graphical in nature. Although there are generally 3 types of CSMs recognized – stylized cartoon-like graphics, stem-and-leaf diagrams, and tabular – by far the majority belong to the first two types. Nevertheless, tabular CSMs (e.g. CSMs of RAGS-D) are possible.
- In section 3.2, a link to a journal article on radioactive materials naturally present in building materials is provided. No doubt this reference is very helpful and appropriate to the topic, but it might be more appropriate to provide an external link rather than offer an "extracted" version of the referenced file (http://nvl.nist.gov/pub/nistpubs/jres/105/2/j52hob.pdf).
- In section 4., the first sentence should read: "The BPRGs consider human exposure from direct contact with contaminated dust and air and external exposure to contaminated building materials."
- In section 4.1, the first sentence should read: "The BPRG equations for the residential exposure scenario, presented here, contain the following exposure pathways and exposure routes:". This change is recommended since the equations presented are not only related to dust exposure.
- In section 4.2, the first sentence should read: "The BPRG equations for the indoor worker exposure scenario, presented here, contain the ….".
- In both sections 4.1 and 4.2, reference should be made to Table 1 for identifying the factors presented in the equations.
- In section 4.3.8, last paragraph (just before the Exhibit 1), it is stated that the "…*dissipation term was modified from the original equation to reflect*…". It is unclear which original equation is meant nor how and to what extent the equation was modified. The referenced Exhibit 1 shows the previously presented dissipation term $(1-e^{(-kt)})/(kt)$.

3. **a). Is the approach reflected in the BPRG calculator consistent with existing risk-based PRG guidance and practice and does the calculator adequately account for differences between: a) outdoor and indoor environments; and b) chemical and radiological contaminants?**

Yes, the approach reflected in the BPRG calculator is consistent with existing risk-based PRG guidance and practice. The Frequently Asked Questions section presents an accurate overview of the approach and how it is consistent with existing risk-based PRG guidance and practice.

Ad a) outdoor and indoor environments. The BPRG calculator is applicable only to indoor environments, as explicitly stated in the last paragraph of the BPRG Homepage discussion "…*BPRGs are presented for residential and indoor worker exposure*…". Admittedly, however, the distinction that only indoor environments are considered does not explicitly appear in the User's Guide until section 4.3.1, and then only as a corollary to the statement of the exposure times.

Ad b) chemical and radiological contaminants. The BPRG calculator explicitly states that it only considers radionuclides (very first sentence of the BPRG Homepage "…*Welcome to the EPA's Superfund **radionuclide** building preliminary remediation goal (BPRG) download and calculation website*…" or the first sentence of the Introduction in the User's Guide "…*Building Preliminary Remediation Goals (BPRGs) for **Radionuclides** are risk concentrations derived from standardized equations that combine exposure information and toxicity assessment as slope factors (SFs)…").*

b). What other important factors, if any, should be considered in the BPRG equations? Please explain.

As stated above in the comment to Question 1. a)., the non-carcinogenic health effects of uranium should be considered in the BPRG equations.

Also previously stated was that:

- calculation of the dermal route is lacking. There is a brief discussion of the dermal exposure in section 4.3.9, but the authors decided that the dermal route would be negligible in contrast to the other potential pathways already considered. However, this assessment by the authors is only valid if the currently presented assumptions for the dust transference and subsequent hand-to-mouth dust ingestion are considered. As this reviewer will discuss in the comment to Question 4.b)., the underlying assumptions for transference of dust from surfaces to hands and subsequent mouthing ingestion in adults are not believed to be realistic.
- A trespasser/visitor scenario is lacking. Most of the heavily radioactively-contaminated buildings requiring cleanup are typically abandoned or at least temporarily unoccupied (e.g. most FUSRAP buildings). In fact, many of these are placed under strict institutional control until such time as they can be returned to beneficial use after intensive decontamination or – more likely – be decommissioned. During this time of institutional control, neither a residential nor an indoor worker exposure scenario would be appropriate. Maintaining long-term active institutional control of buildings is expensive,

however, and might exceed the costs of a limited preliminary decontamination to reduce the radiological contamination to a level that would be protective of an occasional trespasser or visitor to the building. To provide decision-makers with another action alternative (limited preliminary decontamination until a final D&D decision is made), a trespasser/visitor scenario should be included in the BPRG calculator.

- Buildings with odd source geometries, finite sources, or unusual architecture should be accounted for through either a dynamic calculation of the Surfaces Factor, F_{SURF}, or by allowing the selection of the type of building under investigation from a pre-calculated set of building room sizes and source geometries. Many manufacturing buildings – pretty much any building containing a production line – will not have rooms that conform to the underlying range of 10 by 10 by 10 feet to 20 by 20 by 10 feet. Also whether school gymnasiums, theaters, restaurants, university lecture halls, hotel lobbies or conference rooms or indeed any building where larger numbers of people come together could be assessed at present by the BPRG calculator, is not clear. The supporting documentation (Dose rate in contaminated rooms, by K. Eckerman) discussed in Section 4.3.10 does claim that in regards to simple room size "…*that only at very low photon levels is the size of the room relevant*….". Underlying this last statement by the authors is the assumption that sources are uniformly distributed and that geometries and room architecture are standard. For rooms where the source material is not uniformly distributed and floor-to-wall and floor-to-ceiling relationships are unusual, this assumption may not hold.

Not previously commented upon are the following issues pertaining to the equations:

- The dissipation term, $(1-e^{(-kt)})/(kt)$, is provided in the denominator of the equations for exposure to settled dust on surfaces for both the residential and indoor worker exposure scenarios. Although there is a footnote that appears when site-specific BPRGs are calculated stating that "*4. When k = 0.0, the dissipation term is not included in the calculation to prevent division by zero which would result a PRG of zero*.", no mention of this "arbitrary dropping" of the dissipation term from the equation is provided in the sections 4.1 or 4.2 nor 4.3.8 of the User's Guide nor anywhere else in the User's Guide. Readers looking only at the equations for settled dust on surfaces without seeing the footnote in the site-specific input page would be puzzled how the dissipation term would be used since it would obviously "zero-out" the denominator. A caveat should be placed underneath the equations stating , "For values of k > 0.0".
- The dissipation term is apparently missing from the equations for the 3-D Direct External Exposure, which also calculates a BPRG for contaminated dust on walls, floor, and ceiling. It is unclear whether the underlying equations (see Dose rate in contaminated rooms, by K. Eckerman) can be adjusted to a finite source with a dissipating source term over time. At present, the underlying assumption of a constant, infinite planar source for 3-D direct external exposure to contaminated dust on walls, floor and ceiling is perhaps overly conservative, especially in light of the discussion presented in section 4.3.8 of the User's Guide.
- The BPRG for exposure to settled dust on surfaces, $PRG_{d\text{-}total}$, contains both contributions from ingestion of dust transferred to the skin of the hand and then ingested as a result of hand-to-mouth event, as well as external exposure

to the settled dust. However, the BPRG for 3-D direct external exposure to settled dust on indoor surfaces, $PRG_{3\text{-}D\_dust}$, also addresses the external exposure to dust pathway. The part of the $PRG_{d\text{-}total}$ equation dealing with external exposure is essentially the same as the equation of the $PRG_{3\text{-}D\_dust}$, with the exception of the gamma shielding factor, GSF, and the surfaces factor, F_{SURF}. This raises the question whether or not the $PRG_{d\text{-}total}$ is actually a total BPRG for settled dust on indoor surfaces. Furthermore, there is also no total BPRG that combines the ingestion and external exposure pathways with the inhalation and submersion pathways, although the source terms for both are linked. That is to say, if one were to cleanup the dust source term it would affect both the settled dust exposure calculation as well as the ambient air exposure calculations. More importantly, a receptor would be exposed to both the settled dust on indoor surfaces and the resuspended dust in the ambient air at the same time, thus requiring the consideration of a total $BPRG_{dust}$. Indeed, if this same receptor would also be exposed to a contaminated building materials source which acts as a continuously regenerating reservoir of the contaminated dust source term, then this would also need to be reflected in a total BPRG equation and value. Clearly, the individual BPRG values cannot be summed or otherwise combined to obtain a total $BPRG_{(dust\_total)}$ value, but rather a cumulative total $BPRG_{(dust\_total)}$ equation must be derived.

- Minor or typographical corrections of the equations include:
    - The conversion factors CF1 and CF2 are defined in Table 1, but do not appear in the equations as CF1 and CF2.
    - The variable t for time, in years, (without subscript as defined in section 4.3.8 and again presented in the equation given in section 4.3.11) does not appear to be defined in Table 1.
    - The equation for the age-adjusted dust ingestion rate, IF, discussed in section 4.3.6 "takes into account" but does not "…***average*** *the differences in hand to mouth behavior, hand surface area, and exposure to hard and soft surfaces over the exposure durations of an adult and child*…." Suggest replacing the word "average".
    - In the section 4.3.8 discussion of the Binghamton State office Building case, the second parenthetical statement should read "dissipation rate constant of 0.38 yr^{-1}" and not "decay rate".
    - In section 4.5.1, the units of the defined terms of the presented equation for the external exposure pathway dose are missing (see for example 4.5.1.1).
    - In section 4.5.1.1, for constraint #3, insert the word "as" before t_s ? zero, to indicate that source thickness is not assumed to be zero, but as it approaches zero, the DCF should match the contaminated surface DCF.
    - In section 4.5.1.2, the variables X and X' and t_s for source thickness (in the equations for $(X)^2$, $(X')^2$, and μ, t appears to be without subscript) do not appear to be defined.
    - In section 4.5.1.3, the variables f_i and F_A do not appear to be defined.

4. a). Are the BPRG equations, sources of toxicity information, and exposure parameter default variables and values supported by risk assessment literature, existing guidance, and/or site-specific BPRG experience?

In general, YES, the BPRG website provides for adequate support of the equations, sources of toxicity information, and exposure parameter default variables and values through reference to the risk assessment literature, existing guidance, and/or site-specific BPRG experience.

There are exceptions, however. As stated in the above comments (specifically to question 3.b).), there are a number of issues to be resolved for the equations. As to sources of toxicity information, these are adequately referenced, but some of the limitations of the underlying toxicity information itself (e.g. dose coefficients obtained from the Federal Guidance Report 12 assume geometries of infinite dimensions) has apparently been implicitly addressed, but hast not been explicitly discussed in the User's Guide. Similarly, no discussion appears why the external exposure slope factors available in HEAST, which themselves are derived from Federal Guidance Report 13, were not employed or adapted. Hereto, Table 1 of the User's Guide states that $SF_{d\text{-}ext}$ and SF_{sub} are based on risk coefficients from FGR 13, while the justification paper "Dose Rate in Contaminated Rooms" by K. Eckerman states that external dose coefficients from FGR 12 are used. In light of these seeming deficits in providing a thoroughly sufficient background discussion to help the user understand the issues, it is not conducive to gaining public trust to then state "*WARNING: … changing the value of t should only be done once a complete understanding of the mathematics involved in deriving the equation is gained*…".

Regarding exposure parameter default variables and values, these have been commented upon previously and will be discussed further in detail in subsequent comments on the individual exposure pathways. In general, however, the User's Guide provides for adequate support of the selected exposure parameter default variables and values in the section 4.3 Exposure Parameter Justification.

Minor comment: The discussion in section 4.3.8 of the User's Guide that "…*To determine whether dissipation is a factor at a given site, the site manager should establish whether a significant reservoir of contaminated dust is present.…The default value, in this BPRG calculator, for the dissipation rate constant is 0.0. This assumes that a contaminant reservoir is present. …. If a dissipation rate constant is used, it is assumed that the dust was deposited as a one time event (i.e.; dust cloud)*…" appears to be circular reasoning. One cannot argue that the default assumption is that a contaminant reservoir is present, and that if one chooses a non-default value that this is evidence of a contaminant reservoir not being present.

b). Does the BPRG calculator address the most important and appropriate exposure scenarios, exposure pathways, and exposure routes?

No. At issue is the underlying exposure scenario assumptions for the ingestion of settled dust through transference to skin and then through hand-to-mouth activity in adults. No issue is taken with the other exposure pathways (air inhalation, nor with external exposures to dust, air (submersion), or contaminated building materials). Specifically, the issue is that the ingestion exposure pathway for settled dust on surfaces does not appear to be valid for adults. In particular, the duration and distinction of hand contact with hard and soft surfaces for adults does not appear to be realistic. The scenarios previously developed in other guidance and which were drawn upon when deciding on exposure pathways and routes for the BPRG were based on MEI receptors for RME scenarios of indoor residential exposures (see EPA Hubbard treatise on risk calculations based on surface wipes). The MEI receptor was typically a young child of toddler age, whose preferred mode of propulsion is on all fours, and who plays in direct contact with the floor a large portion of the day. Thus, a significant amount of dust will be transferred to the hands of the child. Here, differences in the transference of contaminated dust from different surface textures to the skin of the hand are very important. However, this assumes that the child will repeatedly touch the surface, which is a reasonable assumption.

Adults, however, do not touch carpeted floors (i.e. soft surfaces) more than a few times a day with their hands, usually only to pick things up that had fallen down. They will, nevertheless, make hand contact with hard surfaces quite often during the day, e.g. countertops, desktops, tables, production lines, etc. Therefore, in section 4.3.1 the base exposure scenario assumption states that "…. *assume that adult residents would spend 8 hr/d on carpets and 4 hr/d on hard surfaces. This totals 12 hr/d. Assuming that an individual sleeps 8 hr/d, the total time in a residence is 20 hr/d. For this calculator, the remaining for* **[typo: for]** *4 hr/d was equally divided between exposure to hard and soft surfaces. This results in default values of 10 hr/d on carpets and 6 hr/d on hard surfaces for adult and child residents*…". Thus, an adult may in fact be located on a carpeted area in the home or workplace (e.g. office building) for 10 hrs/d, but will not be in hand contact with the soft surface during that time. Instead the adult receptor will almost exclusively come into hand contact with hard surfaces during the day. Correcting this assumption could lead to an increase in the ingested dose because transference factors for hard surfaces are significantly higher than for soft surfaces, such as carpets. However, the relatively low frequency of hand to mouth events for adults and the relatively small skin surface area of the hand contacted by the mouth will limit the amount of contaminated dust ingested.

Adults, as well as children, will also be in dermal contact with dust through their heads, arms, and – if wearing shorts or skirts – through portions of their legs for most of the day. Although translocation/absorption of radionuclides from contaminated dust into the skin is relatively low, the fact that the dermal exposure occurs throughout the day seems to bear a larger potential for delivering an internal dose to a receptor than the infrequent and inefficient hand-to-mouth transfer. Prior personal experience of this reviewer suggests that the dermal exposure route is at least, if not more, significant for delivering an effective dose in adults than the hand-to-mouth ingestion route for adults (for children it is reversed and in accord with the base exposure scenario presented in the BPRG User's Guide). Thus, it appears that a dermal exposure pathway should also be calculated, which is in contrast to the statement in section 4.3.9 of the User's Guide.

c). Is the construction of the calculator appropriate and reasonable given the available methods, documented experience, and current practice? Please explain.

Yes, for the most part the construction of the calculator appears to be appropriate and reasonable given the assumptions presented and documented in the BPRG website. As stated above in the comment to question 4.b)., there are some issues regarding the basic exposure scenario assumptions that need to be resolved, as well as other issues presented in the previous comments, but – in general – the BPRG calculator is an extraordinarily helpful tool for EPA staff and professional risk assessors in providing a standardized methodological calculation and information tool for determining BPRGs.

Also, the construction of a site-specifically adjustable, online calculator is particularly helpful when needing to adjust generic BPRGs to site-specific conditions, within the limitations of the underlying exposure scenarios, pathways, and routes. The design of the website itself appears to be very functional and intuitive. The User's Guide could be structured a little better to ease transitions and could benefit from a hyperlinked table of contents.

5. a). In addition to comments provided in response to the above questions, are there any shortcomings of the guidance that diminishes its effectiveness?

No, the major issues have been addressed in the previous comments. There are some additional, minor issues that will be detailed in the subsequent comment to question 5.b).

b). Is anything missing that, if included, would improve its effectiveness? Please explain and identify specific recommendations for improving the calculator.

The following comments address minor issues, typographical errors, and editing suggestion that could, if included, incrementally improve the effectiveness of the User's Guide and BPRG:

- In Section 1., the phrase "…*combine exposure information and toxicity assessment as slope factors (SFs)*…" should be changed to place exposure information on the same level as the toxicity information. Suggestion: "...combine exposure information and toxicity information in the form of slope factors (SFs)…"
- In Section 1., add ", as a screening tool" to the end of the sentence "*In general, generic PRGs are used before site-specific risk assessments*…."
- In section 1., change "at" to "for" in the sentence "…*buildings at which risk is being assessed*…"
- In Section 1., consider changing the word "appropriate" to "warranted" for the sentence "…*suggests that further evaluation of the potential risks is appropriate*…"
- In Section 3.2, name the document to which the word "here" links to (i.e. Dose Rate in Contaminated Rooms by K.F. Eckerman).
- In Section 4.3.1, the phrase "…*and whether the source is a hard or soft surface*…" appears to imply that the source is the surface substrate on which the contaminated dust settles and not the dust itself. Suggest changing to read: "…and whether the source is located on a hard or soft surface…".
- In Section 4.3.1, insert "…the estimated time spent …" into the sentence "…*Hard surface time is based on time in kitchen and bathroom*…".
- In Section 4.3.1, correct typo "…*remaining for 4 hr/d was equally* …" to read "… remaining 4 hr/d were equally…". Also, it is unclear why these 4 hours were equally divided and not proportionally, as would be expected for most exposure scenario developments. However, for the adult it is not applicable to consider surface-to-hand transference from soft surfaces (i.e. carpets), even if they spend 10 hr/d in rooms with carpeted surfaces.
- In Section 4.3.1, the statement that "… *dust doesn't collect between sheets*…" may be applicable, but significant ingestion of dust does occur during sleep. Specifically during sleep phases, inhaled dust particles are not expectorated in the mucus (phlegm) as during waking hours in form of wet coughing (or "clearing one's throat and spitting"), but rather is swallowed leading to a cross-over of inhaled particulate matter being ingested. Whether or not this is a significant contributor to the ingested radionuclide dose is unclear and practically no quantitative exposure data is available to properly assess this mechanism of ingestion.

- In Section 4.3.3, the statement "…*based on the area of a child's 3 fingers*…" may be factually correct, but sounds awkward. Suggest changing to read "…based on the surface area for 3 fingers that a child will most likely use for hand-to-mouth transfer…" .
- In Section 4.3.3, it is stated that the child's skin surface area of the hands is estimated from the adult's hand surface area and dividing by the total skin surface area increase factor (3 fold) for children from age 2 to adult. The increase in the size of the hands does not necessarily follow the same growth proportions as does the rest of the body. Also, 3 fingers out of 10, would not be equal to 5% of the total area of both hands, especially since the palms and back of the hands are not involved in the hand-to-mouth transfer. Quantitative estimates of the skin surface areas for different age cohorts should be available in the medical literature. It is suggested that the medical literature (e.g. size of skin grafts needed for burn victims) is queried to at least verify the basic premise of the linear proportional increase between child and adult hand skin surface area.
- In Section 4.3.4, it was stated that "…*It was decided to step down this frequency as follows*:…". Suggest replacing the phrase "*step down this*" with "group the age cohort-specific hand-to-mouth". Recognizing that there is very little quantitative exposure data available for this activity, what was the rationale for dividing the age cohorts into four non-standard, overlapping groups? In fact, there is probably a typo in the second and third age group, which are from 7 to 12 years and 8 to 18 years. The latter should probably be 13 to 18 years.
- Although not a typo in Section 4.3.8, the Dissipation Rate Constant is given in yr^{-1}. Because of the adjacent placement of the "r" in yr next to the superscripted –1, the minus sign is almost unreadable on the monitor. Suggest changing either the unit abbreviation to read "1/yr" or "years^{-1}".
- In Section 4.3.8, the sentence "…*By putting these variables in the denominator of the BPRG resident and worker ingestion of dust equations, a higher BPRG concentration* ***can*** *be calculated*.." sounds awkward and devil's advocates may say that it appears to imply that it is desirable to achieve higher BPRG concentrations. The word "can" should be substituted with "will".
- In Section 4.3.8, Exhibit 1 effectively shows that with the dissipation rate constant set at 0.38 years^{-1}, the calculated PRG will effectively increase by an order of magnitude over a 30 year time span. What is not shown or discussed is how sensitive the equation is for changes in the dissipation rate constant. This reviewer verified the calculated values in Exhibit 1 and observed that the BPRG is essentially linearly related to changing k values above 0.1.
- In Section 4.3.8, change the word "some" in the phrase "…*SF is some slope factor*…" to read "…SF is the radionuclide-specific slope factor…".
- In Section 4.3.9, insert "of" in the last sentence to read "…current version of this BPRG calculator.".
- In Section 4.3.10, insert the abbreviation of the Surfaces Factor in the title to read "4.3.10 Surfaces Factor (F_{SURF})". See section titles 4.3.1 to 4.3.8.
- In Section 4.3.10, second sentence, change "are" to "is" to read "…surfaces factor, … is based …".
- In Section 4.3.11, insert the abbreviation of the Radionuclide Decay Constant in the title to read "4.3.11 Radionuclide Decay Constant (?)". See section titles 4.3.1 to 4.3.8.

- In Section 4.3.11, change the first sentence to read "…a decay constant term (?) which is based on the half-life of the isotope…" to avoid possible confusion that (?) refers to the half-life of the isotope.
- In Section 4.3.11, change the third sentence to read "…term is to derive realistic …".
- In the References after Table 1, there is a typo for the last reference "…*Potential* ***Concern***…".
- The references should also include citations for the Federal Guidance Reports 12 and 13, and URL links to them (http://www.epa.gov/radiation/docs/federal/402-r-99-001.pdf , http://www.epa.gov/radiation/docs/federal/402-r-93-081.pdf).
- In the Section 4.5, typo in sentence under "Exposure to ambient air equations:", "…*The* ***inhalation*** *equation*…".
- In Section 4.5.1, define D^{n}_{iv} and amend the units to the defined variables and factors.
- In Section 4.5.1.1, insert the full name of the Depth-and-cover Factor in front of the abbreviation in the title to read "4.5.1.1 Depth-and-Cover Factor (F_{CD})". See section titles 4.3.1 to 4.3.8.
- In Section 4.5.1.1, it is stated that the F_{CD} is not included in the equations for this calculator because either the dust layer is so thin (suggest changing "so thin" to read "typically extremely thin") and direct external exposure risk coefficients are not concerned with depth. Both the arguments for discounting a depth-and-cover factor are not fully developed. For one, dust layers on smooth, hard surfaces are typically very thin but dust layers on soft surfaces can reach appreciable depths. Secondly, the external exposure pathway is concerned with depth, for instance when direct external exposure from contaminated building materials is considered (e.g. Styrofoam sound isolation boards on top of contaminated concrete or building blocks). A more detailed justification of why the depth-and-cover factor is not considered in the BPRG calculator should be provided.
- In Section 4.5.1.1, it is stated in the next-to-last sentence that values for the four unknown parameters were found for 67 radionuclides. This represents probably less than 10% of the total number of radionuclides available in the BPRG calculator. The discussion should address that.
- In Section 4.5.1.2, insert the full name of the Area-and-Material Factor in front of the abbreviation in the title to read "4.5.1.2 Area-and-Material Factor (F_{AM})". See section titles 4.3.1 to 4.3.8.
- In Section 4.5.1.3, insert the full name of the Off-set Factor in front of the abbreviation in the title to read "4.5.1.3 Off-set Factor ($F_{off\text{-}set}$)". See section titles 4.3.1 to 4.3.8.
- In the reference support document "Dose Rate in Contaminated Rooms" by K.F. Eckerman, there is a typo in the sentence immediately following Equation (1). The "linear attention coefficients" should be "linear attenuation coefficients".
- On the BPRG Search webpage, clicking on the form button to "Select All" does not work.

Specific topics

6. Is the discussion of background sources of radionuclide contamination complete and are adequate guidance and citations provided to account for background in BPRG calculations? Please explain.

Yes, the discussion of background sources of radionuclide contamination is complete and adequate guidance and citations are provided. Although succinct, section 3.2 provides enough information to alert users to first check up on their site's radionuclide background values "…*prior to applying BPRGs as cleanup levels*…". Although adequate guidance and citations are provided, additional references might include EPA's Guidance for Comparing Background and Chemical Concentrations in soil for CERCLA Sites, EPA 540-R-01-003, 2002, and EPA EFI's Determination of Background Concentrations of Inorganics in soils and sediments at Hazardous Waste Sites, EPA/540/S-96/500, 1995.

The following peer review questions relate to BPRGs for specific exposure pathways.

7. BPRGs for Settled Dus t

a. Are the equations, default values, and other input parameters appropriate for establishing risk-based BPRGs for this pathway? Please explain.

As stated above, there are four primary issues with the BPRGs for settled dust. Firstly, the applicability of the BPRG's CSM to allow for repeated hand contact with soft surfaces (i.e. carpets) is not believed to be realistic for adults. Secondly, the equation for the $PRG_{d-total}$ considers both ingestion of contaminated dust and external exposure to dust, but does not follow the same dose equation for the external exposure contribution as that shown in the PRG_{3-D_dust} BPRG. Thirdly, the dermal contact exposure route was discounted by the authors, but perhaps should be included if this route's contribution increases when the previous issues are addressed. Finally, the settled dust source term in indoor situations is linked to the ambient air source term and a total $BPRG_{(dust\_total)}$ should consider the contribution of the settled dust on the ambient air BPRG and vic e versa. Besides these issues, and the others mentioned in the previous comments, the exposure scenario and the equations used to describe it are generally appropriate.

The default values are generally appropriate and most if not all default values are supported by referenced risk assessment literature or existing guidance. Specifically:

- The default value of 0.0 for the dissipation rate constant is conservative, but because of a division by zero resulting from this default value, the dissipation term must be stricken from the equation when k = 0.
- The default values for the exposure times are also conservative, with the above mentioned exception of the ingestion route for adults.
- The default values for the hand skin surface area for children should be verified through medical literature sources since it is properly derived, but the underlying assumptions of the derivation may be speculative.
- The default values for the frequency of hand-to-mouth activity are broken into non-standard, overlapping age cohort groups. Again, there is little quantitative exposure data available to support the estimates of the default values.
- The default value for the saliva extraction factor appears to be conservative but is supported by guidance and risk assessment literature.

- The age-adjusted dust ingestion rate for the resident receptor is a function of the above default values for exposure parameters and thus should also reflect a conservative approach.

b. Do the equations, default values, and other input parameters adequately account for risks to children? Please explain.

Yes, the above mentioned issues (see comment to Question 7.a).) with the distinction of the hand contact between hard and soft surfaces is fully applicable and appropriate for children. The issues of the dose equation for the external exposure contribution and of the a total $BPRG_{(dust\_total)}$, however, also apply for the assessment of the risks to children. Noteworthy are the issues of the hand skin surface area default value for the child and the age cohort grouping for the frequency of hand-to-mouth activity.

c. Is the use of the external ground plane slope factor appropriate? Please explain.

This question in essence addresses the same issue as mentioned above for the discrepancy between the external exposure contribution in the equation for the $PRG_{d\text{-}total}$ and the equation of the $PRG_{3\text{-}D\_dust}$. Overall, the use of the external ground plane slope factor is appropriate given the listed assumptions for the dust source term (extremely thin depth) and the derivation of the surfaces factor, F_{SURF}. This surfaces factor, together with the area-and-material factor and the off-set factor, allow for the appropriate consideration of the use of the external ground plane slope factor.

d. Is the use of the dissipation rate, including a default input parameter of 0, appropriate? Please explain.

This issue has been addressed at length in the comments to question 2.c)., 3.b)., 5.b)., and 7.a).

8. BPRGs for Indoor Air

a. Are the equations, default values, and other input parameters appropriate for establishing risk-based BPRGs for this pathway? Please explain.

Yes, there are no significant issues that were identified with this pathway. The default values are generally appropriate and most if not all default values are supported by referenced risk assessment literature or existing guidance. Specifically:

- The default values for the exposure times, the exposure frequencies, and exposure durations for the resident and indoor worker are well established default values.
- The derivation of the total annual air submersion effective dose equivalent (in mrem/yr) is presented in Section 4.5.2 of the User's Guide. However, this is not used in the BPRG air submersion calculation, but rather the air submersion dose conversion factor (in mrem/yr per pCi/m3) is employed. How this air submersion dose conversion factor is converted from mrem/yr per pCi/m3 into risk/yr per pCi/m3, or whether the SF_{sub} is directly taken from Federal Guidance Report 13, is not provided in the BPRG User's Guide.

b. Do the equations, default values, and other input parameters adequately account for risks to children? Please explain.

The equations are the same for the child as for the adult since there is no size- or age-specific difference in the equations for the inhalation and submersion pathway. However, there is a difference in the inhalation rate between children and adults. The standard default value for the adult inhalation rate for a resident or a worker is provided in the BPRG as 20 or 60 m3/day, respectively, while the child inhalation rate is not listed (it is typically given as 10 m3/day – see U.S. EPA. 1997a. Exposure Factors Handbook. Office of Research and Development, Washington, DC. EPA/600/P-95/002Fa. http://www.epa.gov/ncea/pdfs/efh/).

c. Is the use of the external submersion slope factor appropriate? Please explain.

Yes, the external submersion slope factor is appropriate and is detailed in Federal Guidance Report 13.

9. BPRGs for External Exposure

a. Are the equations, default values, and other input parameters appropriate for establishing risk-based BPRGs for this pathway? Please explain.

Here again, as already mentioned in the comment to Question 7.a). and previously, the equation underlying the external exposure of settled dust for the $PRG_{3\text{-}D\_dust}$ is slightly different from the external exposure equation contribution for the $PRG_{d\text{-}total}$ equation. Specifically, the $PRG_{3\text{-}D\_dust}$ considers the GSF and the derived values for F_{SURF} .

The equations and default values for the direct external exposure to contaminated building material appear to be identical to the external exposure of settled dust equation, with the one exception that the building material BPRG is calculated using soil volume risk coefficients from HEAST (which will account for internal shielding), while the settled dust BPRG is calculated using an adjusted ground planar risk coefficient derived from Federal Guidance Report 13 and a calculated, radionuclide-specific relative dose ratio, i.e. the surfaces factor, F_{SURF} .

Whether or not the supporting documentation ("Dose Rate in Contaminated Rooms", by K.F. Eckerman) is appropriate and sufficient to justify the use of a derived relative dose ratio coefficient (i.e. the surfaces factor, F_{SURF}) with the external dose coefficients of FGR 12 (which assumes an infinite planar source) to determine a dose rate coefficient that is applicable to rooms with either a surface or volume contamination, is not clear. A fully detailed analysis of all the underlying computations in the referenced supporting documents (specifically the "Dose Rate in Contaminated Rooms", by K.F. Eckerman, and the FGR 12 and 13) to discern if issues in the external exposure derivations are present, was not possible within the scope (and projected hours of effort) for this review. This reviewer, therefore, cannot definitively state with confidence if the underlying computational assumptions for the adjusted external exposure dose rate coefficients are appropriate and applicable.

The default values are generally appropriate and most if not all default values are supported by referenced risk assessment literature or existing guidance.

b. Do the equations, default values, and other input parameters adequately account

for risks to children? Please explain.

No distinction is made between the child and adult receptor for the external exposure pathways for either contaminated building material or settled dust. No distinction is warranted, albeit that the underlying assumption of the external dose rate coefficients in the Federal Guidance Reports are based on a dose determined for a height of 1m above an infinite plane of surface contamination. Thus, most of the children under the age of 7 yrs old will not even reach the hypothetical dose height. Whether or not this is a significant issue is not restricted to only the BPRG calculator, but to all risk equations utilizing the external dose rate coefficients of the Federal Guidance Reports

c. Is the adjusted dose rate in for using the external infinite source slope factor in a contaminated room appropriate? Please explain.

This issue has been addressed in the comment to Question 9.a). In general, yes, the use of the adjusted dose rate using the F_{SURF} surface factor for adjusting the external infinite source slope factor to a 3-dimensional contaminated room, is addressed and documented in the BPRG User's Guide and the supporting document ("Dose Rate in Contaminated Rooms", by K.F. Eckerman).