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BASE REALIGNMENT AND CLOSURE
PROGRAM MANAGEMENT OFFICE
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Ser BPMO/01
January 11, 2021

Mr. Enrique Manzanilla
U.S. Environmental Protection Agency, Region IX
75 Hawthorne Street, SDF-8
San Francisco, CA 94105-3901

Dear Mr. Manzanilla:

Thank you for your letter of December 22, 2020 requesting more information on the Department of the Navy's (DON's) Evaluation of Radiological Remedial Goals for Buildings at Hunters Point Naval Shipyard (HPNS) that was prepared as part of the Five Year Review.

We appreciate your agency's willingness to find a workable solution to retesting buildings at the HPNS and your openness to using RESRAD once your remaining concerns are resolved. Specifically, you stated your concerns are with the cancer risk slope factors, risk from an area source, risk from contaminated dust, and applicable building surfaces (floors and/or walls.) Since your August letter, EPA and DON staff have held several meetings to address those issues. Additionally, the DON provided a technical memorandum (Enclosure 1) to EPA on October 20, 2020. We believe that those technical meetings and the attached memorandum address the issues raised in EPA's August letter.

As mentioned in my previous letter, the DON's radiological experts have completed a technical review of the BPRG screening values EPA provided and determined the proposed values are not technically implementable and are derived using assumptions that are inconsistent with the conceptual site model for HPNS. Of specific concern are the proposed removable-contamination values for radium (1.2 dpm/100cm^2) and thorium (4.2 dpm/100cm^2). These values are below the background range of common building materials, cannot be measured accurately, and are not a valid representation of risk to future building users. Depending on the type of field instrument, accurate measurements can only be achieved at approximately 10-20 dpm/100cm^2 or higher. By way of example, the average activity measured from the concrete background area at HPNS is 15 dpm/100cm^2 for Alpha, with values collected as high as 41 dpm/100^2.

Despite diligent efforts by the DON and EPA since October of 2019, we have not reached consensus on building remedial goals. We agree with your recommendation to convene the

Dispute Resolution Committee to discuss and resolve any remaining issues so that our contactor can begin rescanning buildings at HPNS as soon as possible. I will contact you to coordinate such a meeting in the near future.

Sincerely,

Laura Duchnak

LAURA DUCHNAK
Director

Enclosure: 1. Technical Memorandum

Copy to: (via email)
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Terry Seward, Regional Water Quality Control Board
Anthony Chu, California Department of Public Health
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Technical Memorandum - Radiological Remediation Goals for Buildings

Section 1. Introduction

As requested by the Department of the Navy, Base Realignment and Closure Program Management Office West, this memorandum describes the methodologies used in two families of radiological pathway exposure models that are used to derive potential radiation doses and excess cancer risks to future residents that may occupy radiologically impacted buildings on Hunters Point Naval Shipyard (HPNS). US Environmental Protection Agency online calculators, maintained by Oak Risk National Laboratory (ORNL), include the Dose Compliance Concentrations for Radionuclides in Buildings (BDCC) Calculator (https://epa-bdcc.ornl.gov/) and the Building Preliminary Remediation Goals for Radionuclides (BPRG) Calculator (https://epa-bprg.ornl.gov/). These calculators may be used to calculate screening level concentrations under modeled conditions that would result in a selected dose limit or target risk level. They have also been used to estimate the dose or risk resulting from receptor exposures to selected contaminant concentrations under modeled conditions. RESRAD-BUILD (https://resrad.evs.anl.gov/codes/resrad-build/) is a member of a group of codes developed and maintained by Argonne National Laboratory (ANL) and is used to estimate both dose and risk resulting from receptor exposures to selected contaminant concentrations under modeled conditions. Generically, the EPA calculators output cumulative dose or risk over the exposure period and RESRAD models output integrated dose and risk at selected evaluation times.

Described in the following sections are the general methods used by the BDCC Calculator and RESRAD-BUILD to estimate resident dose from both indirect ingestion of, and external exposure to, settled, contaminated dust on building surfaces. Since both models use essentially the same methodology for both exposure pathways, additional discussion is provided to highlight both the differences in the default parameter values used as well as the observed limitations to using the BDCC and BPRG Calculators for dose and risk estimation at HPNS.

Section 2. Estimation of External Exposure Dose and Risk from Settled Dust

The methods used by RESRAD-BUILD and the BDCC Calculator to determine external doses from exposures to settled dust are nearly identical. To illustrate, using either the BDCC Calculator or RESRAD-BUILD, the dose to a resident from external exposure to settled dust would be estimated from the product of exposure duration, dust concentration and an applicable dose conversion factor (DCF). The dose is refined based on changes in the dust concentration due to physical and radiological decay, ingrowth of daughter products, the material and geometry of the source, the location of the resident relative to the source and shielding.

While the calculation of dose for each model is illustrated below, risk is generated by replacing DCFs with slope factors (risk coefficients), in units of (risk/yr)/(pCi/cm^2) for external exposure risk.

a. RESRAD-BUILD External Exposure Model. RESRAD-BUILD generates dose results at each user-selected evaluation time, t. An exposure duration, *ED*, of 365 days would result in the dose accumulated during each year for which there is an evaluation time. At *t*=0, this is the dose accumulated during the period *t* + *ED* or from Year 0 to Year 1, the first year. If *ED* = 26 years, the dose at *t*=0 for the first 26 years of exposure, while the dose at *t*=10 is the dose from Years 10 to 36. It will also output the average dose rate over the exposure duration at each evaluation time. Because the resident is not always home or exposed to the dust, *ED* is reduced by factors for time indoors (F_{in}) and time in the presence of the source (F_i). The dust concentration also varies with time and *C(t)* is adjusted for physical decay (called source lifetime), radioactive decay and ingrowth of radioactive daughters (progeny). The dose component that results from external exposure to a unit settled dust concentration is quantified by a published DCF. For an area source (contaminated building surface), external DCFs are derived for each radionuclide using a method that is described in the RESRAD-BUILD User's Manual, Appendix F (ANL 2003). This method is based on, and consistent with, the method outlined in US EPA Federal Guidance Report No. 12 (FGR 12, US EPA 1993). For example, the external DCF for Co-60 presented in Appendix F is 2.75 mrem/yr per pCi/cm^2 and that for Co-60 in FGR 12, Table III.3, is 2.74 mrem/yr per pCi/cm^2.

The equation used to determine external dose from an area source is adapted from the RESRAD-BUILD User's Manual, Equation F.1. Expressing the settled dust concentration in pCi/cm^2 and using the external DCFs described above yields:

$$D_{ext}\,(t, \mathrm{mrem}) = F_{in} \cdot F_i \cdot F_{CD} \cdot F_{AM} \cdot F_{OFF-SET} \cdot ED\,(\mathrm{d}) \cdot \frac{\mathrm{yr}}{365\ \mathrm{d}} \cdot C\left(t, \mathrm{pCi/cm^2}\right) \cdot DCF_{ext}\left(\frac{\mathrm{mrem/yr}}{\mathrm{pCi/cm^2}}\right)$$

Where:
D_{ext} *(t)* = total effective external dose equivalent at time, *t* (mrem)
F_{in} = fraction of receptor time spent indoors [default 0.5]
F_i = fraction of receptor time spent exposed to settled dust [default 1.0]
F_{CD} = cover-and-depth factor [radionuclide-specific]
F_{AM} = area and material factor [radionuclide-specific]
F_{OFF_SET} = off-set factor [default 0.5]
ED = exposure duration (d) [default 365]
C(t) = average settled dust concentration at time *t* (pCi/cm^2)
DCF_{ext} = external dose conversion factor (mrem/yr)/(pCi/cm^2)

b. BDCC Calculator External Exposure Model. The BDCC Calculator generates the dose for only the first year of exposure, t_{res}. Depending on whether radiological decay is selected as an output option, and whether physical decay is implemented by changing to a non-zero value of the dissipation rate constant, *k*, the dust concentration may be reduced during that year of exposure, thereby resulting in a lower dose. If so, the method is like that used in RESRAD-BUILD. The "*F*" factors are those taken from RESRAD-BUILD and the external DCFs are also derived by ORNL in the manner of FGR 12, as described in Section 2 of the ORNL 2014 report. For example, the ground plane external DCF from the master table (ORNL 2014 appendix) for Co-60 is 2.69 mrem/yr per pCi/cm^2.

The BDCC User's Guide (https://epa-bdcc.ornl.gov/users_guide.html), Section 4.1.1 outlines the settled dust concentration limit associated with a given external exposure dose limit. Rearranging the User's Guide equation to solve for the external dose for a given settled dust concentration yields:

$$D_{ext}\,(\mathrm{mrem/yr}) = \frac{F \cdot EF\left(\frac{\mathrm{d}}{\mathrm{yr}}\right) \cdot \left(\frac{\mathrm{yr}}{365\ \mathrm{d}}\right) \cdot C_{ext}\left(\mathrm{pCi/cm^2}\right) \cdot DCF_{ext}\left(\frac{\mathrm{mrem/yr}}{\mathrm{pCi/cm^2}}\right) \cdot \left(\frac{1 - e^{-k \cdot t_{res}}}{k \cdot t_{res}}\right) \cdot \frac{(1 - e^{-\lambda \cdot t_{res}})}{\lambda\ (\mathrm{yr^{-1}})}}{t_{res}\ (\mathrm{yr})}$$

Where:
D_{ext} = average external dose equivalent rate (mrem/yr)
$F = F_{in} * F_i * F_{AM} * F_{OFF\text{-}SET}$
EF = exposure frequency (d/yr) [default 350 days for resident]
C_{ext} = average settled dust concentration (pCi/cm^2)
k = dissipation (physical decay) rate (yr^{-1}) [default 0]
t_{res} = resident exposure time (yr) [default 1]
λ = radioactive decay constant (yr^{-1})

Section 3. Estimation of Indirect Ingestion Dose and Risk from Settled Dust

The methods used by RESRAD-BUILD and the BDCC Calculator to determine indirect ingestion doses from exposures to settled dust are also nearly identical. To illustrate, using either the BDCC Calculator or RESRAD-BUILD, the dose to a resident from indirect ingestion to settled dust would be estimated from the product of exposure duration; surface loading; contact area and frequency; dust transfer efficiency and an applicable dose conversion factor (DCF). The dose is refined based on changes in the dust concentration due only to physical and radiological decay and the ingrowth of daughter products.

While the calculation of dose for each model is illustrated below, risk is generated by replacing DCFs with slope factors (risk coefficients), in units of risk/pCi for indirect ingestion risk.

a. RESRAD-BUILD Indirect Ingestion Model. The User's Guide for RESRAD-BUILD (ANL 2003), Equation E.2 provides the dose from the indirect ingestion of settled dust. This is consistent with Fig 8.3 and Equation 8.4 in ANL 2001. As with the external dose, this time-dependent dose is also corrected for physical and radiological decay, as well as progeny ingrowth, and integrated over the exposure duration at each evaluation time.

$$D_{ing}\ (t, \mathrm{mrem}) = 24\ (\mathrm{h/d}) \cdot ED\ (\mathrm{d}) \cdot F_{in} \cdot F_i \cdot SER\ (\mathrm{m^2/h}) \cdot C\ \left(t, \mathrm{pCi/m^2}\right) \cdot DCF_{ing}\ (\mathrm{mrem/pCi})$$

Where:
$D_{ing}(t)$ = total effective ingestion dose equivalent at time, t (mrem)
ED = exposure duration (d) [default 365]
F_{in} = fraction of receptor time spent indoors [default 0.5]
F_i = fraction of receptor time spent exposed to settled dust [default 1.0]
SER = indirect ingestion rate of settled dust (m^2/h) [default 0.0001]
$C(t)$ = average settled dust concentration at time t (pCi/m^2)
DCF_{ing} = ingestion dose conversion factor (mrem/pCi)

The indirect ingestion rate, *SER*, is the rate of transfer of deposited contamination from building surfaces to the mouth, expressed as the surface area contacted per time (m^2/h). The default value of 0.0001 m^2/h is primarily based on 16-hr per day exposures, adjusted for hand-to-mouth frequencies and the efficiency of dust transfer between the hand and mouth. A rate of 0.01 m^2/h implies mouthing an area equivalent to the inner surface of an adult hand each hour. Since adult ingestion rates can approach zero, the lower bound value of a probability density function was chosen as the default.

The indirect ingestion DCFs in RESRAD-BUILD are the largest effective DCF for a radionuclide taken from Table 2.2 in Federal Guidance Report No. 11 (US EPA 1988). For example, the default ingestion DCF for Co-60 is 2.69E-05 mrem/pCi which is derived from 7.28E-09 Sv/Bq * 3.7E+09 mrem-Sv/µCi-Bq * µCi/1E+06 pCi.

b. BDCC Calculator Indirect Ingestion Model: The BDCC User's Guide, Section 4.1.1 outlines the settled dust concentration limit associated with a given indirect ingestion dose limit. Rearranging the User's Guide equation to solve for the indirect ingestion dose for a given settled dust concentration yields:

$$D_{ing}\ (\text{mrem/yr}) = \frac{F_{in} \cdot F_i \cdot IFD\ (\text{cm}^2/\text{yr}) \cdot C(\text{pCi/cm}^2) \cdot DCF_{ing}(\text{mrem/pCi}) \cdot (\frac{1-e^{-k \cdot t_{res}}}{k \cdot t_{res}}) \cdot \frac{(1-e^{-\lambda \cdot t_{res}})}{\lambda\ (\text{yr}^{-1})}}{t_{res}\ (\text{yr})}$$

Where:
F_{in} = fraction of receptor time spent indoors [default 1.0]
F_i = fraction of receptor time spent exposed to settled dust [default 1.0]
IFD = ingestion rate of settled dust (cm^2/yr) [default 123,025]
C = settled dust concentration (pCi/cm^2)
t_{res} = resident exposure time (yr) [default 1]
k = dissipation (physical decay) rate (yr^{-1}) [default 0]

The indirect ingestion rate, *IFD*, in the BDCC Calculator is very similar to *SER* in RESRAD-BUILD. It is the surface to mouth transfer rate, expressed as cm^2/yr, and is age-weighted to account for different exposure times, hand surface areas, and hand-to-mouth frequencies between children and adult. The default value of 123,025 cm^2/yr is equivalent to 0.0014 m^2/h, a value 14 times higher than the RESRAD-BUILD default. This large increase is primarily due to the BDCC Calculator inclusion of toddler exposures for six of the 26-year exposure.

The default indirect ingestion DCFs in the BDCC Calculator are the per capita coefficients from International Commission on Radiological Protection (ICRP) Publication 107 (ICRP 2008) and provided by ORNL, as listed in Table 2.2 of the master table (ORNL 2014 appendix). Per capita coefficients are population-weighted considering the fractional distribution of all age groups. For example, the default ingestion DCF for Co-60 is 2.03E-05 mrem/pCi.

Section 4. EPA Calculator Limitations

This section discusses observed issues with each of EPA online calculators that limit the ability to accurately model site-specific conditions or that result in overly conservative estimates of receptor dose and risk.

a. Availability and Change Documentation. The EPA calculators are available only online. As such, users must have internet access and the calculator sites must be available for use. Changes made to the calculator functions or parameters are not sufficiently documented. The last documented change to the

BDCC and BPRG Calculators was in May 2018, however, many changes have been made that are not evident until comparison with past results or with other models.

b. Radioactive Decay and Progeny Ingrowth. As radioactive elements decay, their daughter products (progeny) are also often radioactive. In many cases, the contribution to dose or risk from the progeny exceeds that of the parent. For some long-lived radionuclides, their decay results in a series of radioactive progeny, each at different concentrations depending on their half-lives, until they potentially reach a state where all progeny concentrations equal that of the parent (i.e., secular equilibrium). The EPA calculators are incapable of accounting for this progeny ingrowth. Users have the following choices to handle radioactive decay and progeny in the calculators:

- Ignore radioactive decay and progeny ingrowth. The default, output option 1, places parent and progeny in secular equilibrium at time zero and ignores their subsequent decay. Input concentrations may be entered manually if the user-defined isotope information option is selected. This option greatly overestimates dose and risk, except for rare cases in which all radionuclides are very long-lived.
- Allow radioactive decay while ignoring progeny ingrowth. Output option 2 allows manually-input concentrations of parent and progeny and their subsequent decay of each according to their half-lives. It is also possible to change the half-lives of short-lived progeny to match those of their parents to prevent their rapid decay during a longer exposure period. Ingrowth of radioactive progeny from any radioactive parent is ignored. In most cases, where the exposure period exceeds the half-lives of the progeny, this option provides inaccurate dose and risk estimates. Each case varies with the radionuclides involved and their input concentrations.
- Allow parent radioactive decay while ignoring progeny. Output option 3 allows parent decay but omits progeny. This option provides slightly faster processing times over using option 2.

c. Resident Time. The default time over which radionuclide concentrations can decrease due to physical (dissipation) and radioactive decay is one year. Unless the radionuclide half-life exceeds the exposure duration, dissipation and decay significantly decrease the settled dust concentrations over the time in which the receptor is exposed. A t_{res} value of one cannot be changed by the user and therefore only accounts for dissipation or decay during the first year of exposure, regardless of the exposure duration (26 years default). For external exposures, this results in the maximum annual dose or risk but overestimates the dose or risk in subsequent years. For ingestion, the dust concentration is reduced for one year of dissipation and decay, but that concentration is assumed to be constant throughout the default 26-year exposure duration. Additionally, any indirect ingestion by the resident would result in a lower available surface dust concentration or transfer probability for the next contact. Both latter issues result in a gross overestimation of the indirect ingestion dose or risk. RESRAD-BUILD calculates the instantaneous dose or risk, based on time-dependent source conditions, a user-defined number of times (default of 17) per exposure duration (default 365 days).

d. Radon Emanation. Both uranium-238 and thorium-232 decay to a series of radioactive progeny in decay chains. These would also include radium-226 that is a progeny in the U-238 chain but is frequently a radionuclide of concern that also has a subsequent decay chain. In each chain, a radioactive gas is produced (radon-222 in the U-238 chain and radon-220 in the Th-232 chain). Especially for surface contamination, these gases escape the surface (emanate) and may be transported elsewhere before decaying. This means the particulate progeny of these gases are no longer part of the source dust and the receptor dose or risk should be reduced. The EPA calculators do not account for radon emanation losses and therefore overestimate the dose or risk from U-238 and Th-232 chain exposures. RESRAD-BUILD assumes a radon release fraction of 0.1, meaning 10% of the radon-222 or -220 are released to the air and therefore progeny remain at 90% of the radon parent concentration. EPA recommends use of residential equilibrium fractions of 40% and 2% for Rn-222 and Rn-220, respectively (US EPA 2014 #17). This means remaining progeny concentrations would be 40% of Rn-222 or 2% of Rn-220 concentrations.

Section 5. EPA Calculator Default Parameters

Several of the default parameters in the EPA calculators affect the dose or risk associated with settled dust exposures. The following parameters are related to the calculator limitations and warrant further description of how the default values overestimate dose and risk.

a. Dissipation. The calculators assume that contaminated dust on building surfaces is being continually replenished by radiological sources (i.e., a contaminant reservoir). The dust concentrations (radioactivity per area) are therefore assumed to be constant and the default dissipation rate constant, *k*, is 0.0. However, factors such as remediation, cleaning, radon emanation, resuspension, contact transfers and dilution with uncontaminated dust serve to reduce surface dust concentrations over time.

At HPNS, building contaminant reservoirs have been removed due to radioactive source license termination or remediation of residual surface contamination. Additionally, potentially contaminated surfaces were cleaned prior to surveys in impacted buildings and localized contamination was remediated. Many buildings have been in use for non-radiological purposes and surfaces have either been sealed or subject to continual factors that would remove dust from prior sources. Use of *k* = 0.0 is therefore overly conservative and inconsistent with EPA guidance and industry-standard values. The BDCC and BPRG User's Guides, Section 4.3.8, state "there is strong support for considering dissipation in setting criteria for building clean-ups." RESRAD-BUILD uses a dissipation rate, called source lifetime, with a default value of 365 days.

b. Fraction Transferred from Surface to Skin (FTSS). EPA calculators assume that 50% of surface contamination is transferred to the skin of the hand on contact with hard surfaces and that 10% is transferred from soft surfaces. As described in Resident Time above, the dust concentrations (surface load) are not constant and each surface -to-hand transfer event reduces the available source. Use of a static source concentration (after the first year) overestimates dose and risk.

Section 6. References

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ENCLOSURE 1

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