MEMO

To:
Andy O'Hare
The Fertilizer Institute

From:
Douglas Chambers

Copies:

Arcadis Canada Inc.
121 Granton Drive, Suite 12
Richmond Hill, Ontario L4B 3N4
Tel 905 764 9380
Fax 905 764 9386
www.arcadis.com

ENVIRONMENT

Date:
April 3, 2020

ARCADIS Project No.:
30006877

Subject:
Responses to Second Set of USEPA Questions - Reclaimer

This memorandum responds to the technical comments and questions to TFI dated March 6, 2020 from the United States Environmental Protection Agency (USEPA). The questions from the USEPA relate to the Reclaimer calculations described in the risk assessment report submitted in October 2019[1] as support to the petition for beneficial use of phosphogypsum. For each paragraph provided by USEPA in their questions, Arcadis has provided a response below.

However, initially, this Response provides the relevant background, the probability of abandoning a road constructed with PG, an assessment of whether the USEPA BID Reclaimer Scenario is a reasonable maximum exposure (RME), and the Hypothetical Reclaimer Scenario in the October 2019 Risk Assessment.

Background

The USEPA BID risk assessment considered a scenario with exposures from gamma radiation and radon over a 70-year period, in which just the road surface is removed, no land preparation is performed, and a house is directly built directly upon PG amended road base material.

The October 2019 Risk Assessment concluded:

> The RME for ultimate disposition of a new road constructed with PG is that it serves as an established part of municipal (county, state and/or federal) infrastructure and as such would require periodic repair and expansion as needed. These activities could include removing the surface, grinding and reusing or disposing of the materials consistent with federal and state and local regulations. Exposures and risks associated with maintenance of roads and reuse of

[1] Arcadis 2019. *Radiological Risk Assessment in Support of Petition for Beneficial Use of Phosphogypsum*, Report to The Fertilizer Institute, October.

construction materials are expected to be comparable or less than those detailed in the risk assessment for road construction. It is also noted that as part of road construction, no excess PG is expected to be left over. Road builders avoid transporting extra material to a construction site and would mix in any remaining PG to avoid additional handling.

TFI had Arcadis include a “Reclaimer” scenario in the October 2019 Risk Assessment in the risk assessment in part to document the reasons it was not a RME ultimate disposal option and because USEPA requested that we perform an assessment of the risk for this extreme scenario. It is TFI’s understanding that USEPA requested this scenario because it was used by EPA in 1992.

The Probability of Abandoning a Road Constructed with PG

The initial question is, what is the probability of a road constructed with PG will be abandoned.

The Revised Petition includes a summary of the legal framework involved in abandoning a road. This Response include a summary of that legal background to provide context). There are legal, practical, and economic obstacles to abandoning a road.

First, federal regulations govern abandoning a federal road and state transportation laws govern abandoning state and local roads. Since roadways serve a public use (i.e., providing access of citizens of each state to the broader community), these laws, regulations and policies are designed to make it difficult to abandon roads.

Second, roads act as preferential pathways for placement of utilities and other economically important services. Abandoning a road effectively abandons those other societal benefits.

Third, Federal, State, and local roads are sited and maintained to support the federal, state, and local land use requirements. Abandoning a road ignores those broader societal goals.

Finally, the Reclaimer scenario of building a house on top of an abandoned roadway is not consistent with typical land re-use and sustainability policies, is limited by the legal constraints on abandoned public roads, is extremely rare (research has found few, if any, examples. Therefore it is not a reasonably anticipated land use).

Assessing Whether the USEPA BID Reclaimer Scenario Is an RME

The next question is whether the USEPA BID Reclaimer scenario is an RME. The RME is the exposure level utilized in USEPA risk assessments (see the TFI Revised Petition which summarizes the USEPA requirement for using high end, but realistic scenarios).

Even on the face of the 1992 USEPA BID, a 70-year period for the duration of residential exposure is beyond the RME, because the 1992 USEPA BID used 25 years as the duration of a resident’s exposure for the nearby resident. Additionally, USEPA’s current RME for the duration of residential exposure is 26 years (specifically a 90th percentile of exposure), precisely because “USEPA has been criticized for too often assuming that future use will be residential" and other unrealistic assumptions.[1] As described above, road abandonment is rare and requires a formal legal process.

In summary, the 1992 BID risk assessment's so called reclaimer scenarios is an extreme scenario well beyond an RME assumption and represents an extreme situation that is unlikely to even occur as described.

The Ultimate Disposition Scenarios Is Repair of the Road

The use of this extreme scenario does not mean it is a RME for ultimate disposition. More realistic situations for the ultimate disposition of the road include continued use of the road as a road, or reuse of the PG road base for a new road, if the road was to be relocated or realigned.

As required by USEPA, the October 2019 Risk Assessment assumed arbitrarily that a road which was constructed is reused for residential purposes, the land preparation activities will realistically result in blending and mixing of the road base to levels that are indistinguishable from background levels.

The October 2019 Risk Assessment, the Response to USEPA's Comments on January 16, 2020, and this Response document that the ultimate disposition is that the road serves as an established part of municipal (county, state and/or federal) infrastructure and as such would require periodic repair and expansion as needed. Below we address disposal of PG road material, if any.

The Hypothetic Reclaimer Scenario in the October 2019 Risk Assessment

To address USEPA's request, therefore, the Petition includes a hypothetical scenario which the risk analysis concludes is an extreme exposure (Extreme Reclaimer), i.e., the exposure is much higher than an RME exposure scenario. That hypothetical scenario assumes a home is built directly on an abandoned PG road, a construction scenario that would likely never occur under existing road construction practices and constraints on future land use for public infrastructure and therefore, the assumed scenario is not an RME scenario (N.B.: Note the distinction between an RME scenario and an individual assumption that is used to calculate the exposure in an RME scenario). The exposure assumptions utilized are more realistic, but high end, assumptions. As discussed above, this scenario does not occur with a sufficient frequency to qualify as a RME scenario, however, the October 2019 Risk Assessment utilized USEPA's 26 years of residence RME assumption (i.e., the 90th percentile). Although this scenario also meets the USEPA risk management limit of 3 in 10,000, it is not an RME and therefore should not represent a condition of approval.

<u>Comment-by-Comment Response</u>

USEPA:

1. One of the key assumptions for the Reclaimer Exposure Scenario identified in the TFI risk assessment, Section 3.4.1 is: *Site grading for construction will almost certainly reduce the*

[1] EPA Land Use in the CERCLA Remedy Selection Process at (OSWER Dir. No. 9344.7-04).

thickness of the layer containing PG; however, for present purposes, we have assumed that site preparation will reduce the PG layer to about 10 centimeters (cm) in thickness and the concentration of Ra-226 in the remaining layer to about 10 pCi/g. No justification is provided for either of these specific values, beyond the risk assessment's description of site grading as a means for reducing the PG layer thickness and concentration. Please provide either a technical justification of how the 10 cm thickness and 10 pCi/g values were derived, or a sensitivity analysis that shows why they are bounding.

Arcadis: As noted above the Reclaimer scenario is an unlikely extreme scenario. Despite this, the scenario was created applying current or future building practices. The Florida Building Code[1] for example requires that slab on grade homes are constructed to certain specifications. Footings are to be supported on undisturbed natural soils or engineered fill. Concrete slab-on-ground floors need to be a minimum 3½ inches (89 mm) thick. The area within the foundation walls under the floor shall have all vegetation, top-soil and foreign material removed. Fill material shall be free of vegetation and foreign material. The fill shall be compacted to ensure uniform support of the slab, and except where approved, the fill depths shall not exceed 24 inches (610 mm) for clean sand or gravel and 8 inches (203 mm) for earth. As a base below the fill material, the building code requires a 4-inch-thick (102 mm) base course consisting of clean graded sand, gravel, crushed stone, crushed concrete or crushed blast-furnace slag meeting specific engineered standards.

These building code requirements are deemed to be reasonable estimates of future requirements for slab-on-grade buildings. In the extremely unlikely event that a Reclaimer home were constructed on an abandoned road, the building code requirements would impose specific actions be taken to prepare the subsurface as described above. In practice, this is expected to eliminate all of the PG road base from beneath the home. Consequently, it is likely the dominant risk pathways associated with the Reclaimer would be eliminated.

For conservativeness and in an effort to respect the USEPA request to examine this scenario, it was assumed that a mixture of the PG in soil was re-introduced into the construction process beneath the floor. Admittedly subjective, the parameters for the PG amended layer and the associated concentration of radium-226, were set at 10 cm and 10 pCi/g which is nearly the maximum radium-226 concentration used for road base in the risk assessment. This estimate is still an extreme assumption, considering the discussion above concerning building code requirements.

USEPA:

2. Arcadis calculates external dose to the reclaimer (due to ground shine through the home foundation) using RESRAD, rather than MicroShield. A foundation thickness of 20 cm was specified in the RESRAD input (Arcadis 2019, pdf page 229), rather than the 10 cm specified on page 3-9. This appears to take credit for a 10 cm granular fill layer that is shown in Arcadis 2019, Figure 3.1, but is not otherwise discussed. Please provide a technical justification for the presence of clean fill.

---

[1] 2017 Florida Building Code - Residential, Sixth Edition. (https://codes.iccsafe.org/content/FRC2017)

Arcadis: As noted in the above question and response, the Florida Building Code represents a reasonable set of expectations for future building requirements. For slab-on-grade homes the foundation and sub-floor ground preparation requirements can reasonably be expected to essentially eliminate all the PG road base from beneath the home. Consequently, it is likely the risks associated with the Reclaimer would be eliminated.

If in the extreme case, a mixture of the PG in soil was reintroduced into the construction process beneath the floor, the building code requirements would result in approximately a 10 cm concrete slab supported upon approximately 10 cm of engineered fill.

USEPA:

3. No other reclaimer exposure pathways beyond indoor radon and gamma dose were analyzed, e.g., ground shine from time spent in the yard, inhalation and soil ingestion from working in the garden, consumption of vegetables grown in the garden, consuming water from an onsite well. For example, in addition to radon diffusing through the floor slab, the EPA in 1992 evaluated both of these latter two pathways as potentially contributing to the reclaimer's dose: *The reclaimer is assumed to build a house on the roadbed at some future time after the road is closed and the road surface has crumbled and been removed. In addition to living in a house at the site, the reclaimer drills a well for water and plants a vegetable garden in the contaminated soil. The vegetable garden provides 50 percent of the reclaimer's foodstuffs.* (EPA 1992, page 4-10) The EPA's risk assessment showed these pathways to be minor contributions to the overall dose. If numerical results are not included, these pathways should at least be discussed.

Arcadis: Based on USEPA's request to include the Reclaimer scenario, Arcadis assessed the external gamma and radon pathways. Arcadis focused on the most significant pathways for this scenario.

As indicated by USEPA, the USEPA's 1992 BID[2] demonstrated that almost all of the estimated risk from the hypothetical reclaimer scenario is from external gamma radiation and the inhalation of radon (and its short-lived decay products) indoors. To illustrate, the risks from these two pathways are more than 1,000 times larger than the risks from for example, drinking well water or consuming foods grown in the phosphate amended soils. The exposure pathways other than gamma and radon are for practical purposes trivial and do not require further assessment.

The pathways ground shine from time spent in the yard, inhalation and soil ingestion from working in the garden, consumption of vegetables grown in the garden, consuming water from an onsite well were not considered as their contribution can be considered de minimis. In order to have a yard or a garden topsoil to depth of approximately one foot is typically required to grow grass or vegetables. This negates inhalation and ingestion, reduces ground shine by a factor of close to ten. In addition, most vegetables are shallow root, there will be little radium uptake into the plants. As regards the on-site well, leaching of radium into ground water wells was discounted in the 1992 BID.

---

[2] United States Environmental Protection Agency. Potential Uses of Phosphogypsum and Associated Risks – Background Information Document. Air and Radiation (ANR-459), 402-R92-002, May 1992.

From 2019 risk assessment: NCRP 160 also indicates that typical outdoor levels of radon are about 15 Bq/m^3 or 0.4 pCi/L. Thus, the predicted incremental indoor radon level attributable to PG under the home is small by comparison to either the variation in indoor levels or the typical outdoor level of ambient radon.

USEPA:

4. On page 3-10 Arcadis reports an estimated radon flux into the home of .009 pCi/m^2-s. Several parameters were selected which could potentially lead to an underestimate of this value, and some errors are present in the spreadsheet calculation:

   - Radon surface flux is calculated by Arcadis in Figure 3.2. The calculation is performed using a radon diffusion coefficient for the foundation of 4×10^{-4} cm^2/s (from Chauhan and Kumar 2015), and an emanation factor of .062 (Rogers et al 1994 and Chauhan 2015) for intact concrete, and formulas found in US NRC Reg Guide 3.64. The RESRAD default radon diffusion coefficient is an order of magnitude higher, at $3\text{x}10^{-3}$ cm^2/s: *The 3.0 × 10^{-7} m^2/s default radon diffusion coefficient for the concrete slab is a conservative value compared with the value of 6.0 × 10^{-9} m^2/s used by the U.S. Nuclear Regulatory Commission (…). It is used to account for possible cracks and other penetrations that may develop in the foundation as the house ages.* (ANL 2001, p. C-12) The RESRAD default emanation factor is .25, half an order of magnitude higher. Using the RESRAD default values results in a radon flux at the surface that is approximately an order of magnitude higher than the value reported by Arcadis. Substituting these low numbers for default values requires additional technical justification.

     Arcadis: There are a number of published values for radon diffusion coefficients. As the reclaimer scenario is not considered to be a (realistically) credible scenario, a detailed evaluation of diffusion coefficients was not performed. However, we point out that Table 7.1 of Yu et. al. 1993[3] provides a review of radon diffusion coefficients. The value of 4×10^{-4} cm^2/s is central to the values reported by Yu et. al. (1993) and considered suitable for the screening analysis provided in the current risk assessment.

     There are considerable data on the emanation coefficient of 0.062 used in the current assessment (as captured in the radon flux calculations) and is in the range of published emanation coefficients. The emanation factor of 0.062 used in this assessment is from a paper

[3] ANUEAIS-8 Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil by C. Yu, C. Loureiro,* J.-J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia,* and E. Faillace, Environmental Assessment and Information Sciences Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.

by Vern Rogers[4], specific to concrete in Florida construction (experimentally determined) and in our view appropriate.

- In the spreadsheet provided by Arcadis, the term $\sqrt{a_b/a_f}$ from Reg Guide 3.64 Equation 12 was not included. By disregarding this term, Arcadis' calculation does not account for differences between the porosity, radon diffusion coefficient, and moisture content of the foundation and underlying layers.

  Arcadis: There are no terms in equation 12 "a_b" or "a_f". It is assumed the terms cited should be "a_t" and "a_c" the interface coefficients. As the basis for this case assumed approximately the same diffusion coefficient, porosity and moisture saturation fraction, the ratio is unity and this term can be ignored in the multiplication. Additionally , the screening analysis considered the effect of this factor which as USEPA notes is intended to adjust for the differences in media (a sort of "transition from one media to another) to be inconsequential and on the order of about 10% (and in any event if incorporated, would reduce the radon flux and not increase it).

- The spreadsheet contains an error. Cell 'Diffi Co 2 unit conc (2)'!F46:F55 does not correctly multiply all correct parts of the term by the exponential.

  Arcadis has checked this calculation and appreciates the identification of a missing bracket. We have made a modification to the spreadsheet to show the impact of this change. The revised spreadsheet is attached. The overall dose including external gamma is updated to be 4 mrem/yr as opposed to 3 mrem/yr. In total the dose for 26 years of exposure results in 104 mrem or a risk of 0.5 in 10,000.

- Rather than calculate the buildup of radon daughter products within the home, the TFI risk assumed an equilibrium factor of 0.4. This may be a reasonable assumption, but was not well documented and may explain some of the difference in indoor radon dose between TFI's risk assessment and EPA's 1992 risk assessment.

  Arcadis: The 0.4 indoor equilibrium factor is a widely used default (notional value) for such calculations and is considered suitable for such generic risk calculations as postulated for the hypothetical and extremely unlikely reclaimer scenario[5].

The most consequential of these issues is the calculated radon flux through the foundation. Using more conservative, and arguably more realistic, estimates of the emanation factor and radon diffusion coefficients, the radon air concentration in the home could be several orders of magnitude higher than the 0.013 pCi/L (13 pCi/m^3) reported by Arcadis, and the reclaimer's inhalation dose more than an order of magnitude higher than the 1.8 mrem/yr reported for the reclaimer. The conceptual treatment of the

---

[4] Rogers V., Nielson K., Lehto M., Rodger H. Radon Generation and Transport Through Concrete Foundations. United States Environmental Protection Agency, Air and Energy Engineering Research Laboratory, EPA/600/SR-94/175. November 1994.

[5] NCRP 160, or UNSCEAR 2008 Annex E

slab and sub slab should generally be better explained. As stated above, the treatment of indoor radon for the reclaimer should be thoroughly justified wherever it departs from model default values and/or USEPA's 1992 risk assessment.

Arcadis: Further discussion of the basis for the assumed characteristics of the slab-on-grade home postulated for the hypothetical reclaimer is provided earlier in the memorandum and is based on Florida Building Code guidance as previously indicated.

As previously indicated, we suggest that the assumptions and model parameters used in the risk assessment are appropriate for the screening analysis of a reclaimer scenario.

As an aside, the average indoor radon level in US homes is about 1.4 pCi/L and the average (notional perhaps) outdoor level of radon is about 0.4 pCi/L. Thus, while we consider the calculations performed to be reasonable, even if the predicted indoor radon levels were to increase by a factor of say 10 to 0.013 pCi/L, the incremental levels would be in the variability of natural back indoor levels and for that matter within the natural variability of natural background radon levels outdoors.[6]

[6] United Stated Environmental Protection Agency. A Citizen's Guide to Radon. EPA402/K-12/002|2016|www.epa.gov/radon