

~~WPP 39406~~

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Formation and Transport of Radioactive Gases

Qualitative screening argument for Side Efforts GG-8 and RNT-26

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For Review

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DR Anderson

Recommended Screening Decisions

Formation and transport of radioactive gases has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Screening Issue

The formation and transport of radioactive gases could potentially result in releases of radioactivity to the accessible environment.

Basis for Recommended Screening Decision

Based on the composition of the anticipated waste inventory as considered by Sanchez (1996), the radioactive gases that will be generated in the repository are carbon dioxide (CO_2) and methane (CH_4) containing ^{14}C , and radon (Rn).

According to Sanchez (1996) a small amount of ^{14}C , 2.88 grams, or 12.85 Ci, will be disposed in the WIPP. This amount is insignificant in comparison with the 40 CFR § 191.13 cumulative release limit for ^{14}C , estimated by Sanchez (1996) to be 525 Ci.

Notwithstanding this comparison, consideration of transport of radioactive gases could potentially be necessary in respect of the 40 CFR § 191.15 individual protection requirements. ^{14}C may partition into carbon dioxide and methane formed during microbial degradation of cellulosic and other organic wastes (e.g., rubbers and plastics). However, total fugacities of carbon dioxide in the repository are expected to be very low because of the action of the MgO chemical conditioner which will lead to incorporation of carbon dioxide in solid MgCO_3 . Similarly, interaction of carbon dioxide with cementitious wastes will limit carbon dioxide fugacities by the formation of solid CaCO_3 . Thus, because of the formation of solid carbonate phases in the repository, significant transport of ^{14}C as $^{14}\text{CO}_2$ has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Potentially significant volumes of methane may be produced during the microbial degradation of cellulosic waste. However, volumes of $^{14}\text{CH}_4$ will be small given the low total inventory of ^{14}C , and the incorporation of ^{14}C into solid carbonate phases in the repository. Therefore, although transport of ^{14}C could occur as $^{14}\text{CH}_4$, this effect has been eliminated from the current

performance assessment calculations on the basis that previous performance analyses for the WIPP have shown no releases under undisturbed conditions.

Radon gas will contain proportions of the alpha emitters ^{219}Rn , ^{220}Rn , and ^{222}Rn . All of these have short half-lives, but ^{222}Rn is potentially the most important because it is produced from the abundant waste isotope, ^{238}Pu , and because it has the longest half-life of the radon isotopes (≈ 4 days). ^{222}Rn will exhibit secular equilibrium with its parent ^{226}Ra , which has a half-life of 1.6×10^3 years. Consequently, ^{222}Rn will be produced throughout the 10,000-year period of interest. Conservative analysis of the potential ^{222}Rn inventory suggests activities of less than 716 Ci at 10,000 years (Attachment 1).

Direct comparison of the estimated level of ^{222}Rn activity with the release limits specified in 40 CFR § 191.13 cannot be made because the release limits do not cover radionuclides with half-lives less than twenty years. For this reason production of radon gas can be eliminated from the performance assessment calculations on regulatory grounds. Notwithstanding this regulatory argument, the small potential radon inventory means that the formation and transport of radon gas can also be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

References

L.C. Sanchez. 1996. *Identification of Important Radionuclides Used in WIPP Performance Assessment*. Memo to John F. Suermann [DEO/CAO/NTP] March 6, 1996. SWCF-A:WBS:1.1.6.2;PA;PBWAC - WIPP ACTIVITY

Attachment 1 to: Formation and Transport of Radioactive Gases

Qualitative screening argument for Side Efforts GG-8 and RNT-26

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This attachment documents an analysis of the potential activity of ^{222}Rn in the WIPP.

^{222}Rn is generated during decay down the following series:

^{242}Pu	$T_{1/2} = 3.76 \times 10^5$ years
^{238}U	$T_{1/2} = 4.47 \times 10^9$ years
^{234}Th	$T_{1/2} = 24.1$ days
^{234}Pa	$T_{1/2} = 1.17$ minutes or 6.7 hours (two decay modes)
^{234}U	$T_{1/2} = 2.45 \times 10^5$ years
^{230}Th	$T_{1/2} = 7.7 \times 10^4$ years
^{226}Ra	$T_{1/2} = 1.6 \times 10^3$ years
^{222}Rn	$T_{1/2} = 3.824$ days

In addition, the decay of ^{238}Pu augments ^{234}U activities and subsequently contributes to ^{222}Rn concentrations via:

^{238}Pu	$T_{1/2} = 87.7$ years
^{234}U	$T_{1/2} = 2.45 \times 10^5$ years
^{230}Th	$T_{1/2} = 7.7 \times 10^4$ years
^{226}Ra	$T_{1/2} = 1.6 \times 10^3$ years
^{222}Rn	$T_{1/2} = 3.824$ days

If a daughter isotope has a sufficiently short half-life in comparison with its parent, the parent-daughter couple will, after a period of time, attain secular equilibrium. When secular equilibrium is attained the activities of the parent and its daughter isotope are equal. ^{222}Rn has a sufficiently short half-life (3.824 days) in comparison with its parent ^{226}Ra (1600 years) that on the regulatory time-scale they will attain secular equilibrium. Based on this, and other simplifying assumptions discussed below, a conservative analysis has been made of the potential activity of ^{222}Rn :

- The decay chains have been simplified by the omission of short-lived isotopes (e.g., ^{234}Th and ^{234}Pa) which will exist in secular equilibrium with their parents. ^{238}U and its parent ^{242}Pu have also been omitted because the long half-life of ^{238}U (4.47×10^9 years) means that it approximates to a stable isotope over the regulatory period and will not contribute appreciably to generation of ^{222}Rn .

- Starting at the top of the simplified decay chain with ^{238}Pu , the generation of the daughter nuclide, in this case ^{234}U , over the 10,000-year regulatory period has been calculated using:

$$n_{t_2} = n_{t_1} e^{-\lambda(t_2 - t_1)}$$

where n_t = number of atoms at time t , and λ is the decay constant. λ is related to the half-life by:

$$\lambda = \frac{\ln 2}{T_{1/2}}$$

- The maximum potential amount of the daughter nuclide has then been calculated by summing its initial disposal inventory with the 10,000-year ingrowth from its parent. It has then been assumed that this inflated inventory was present at the initial time, t_1 , and the generation of the next daughter nuclide calculated as above.
- The calculational procedure has been propagated down the simplified decay chain and the activity of ^{222}Rn calculated assuming secular equilibrium with its parent ^{226}Ra .

This calculation is conservative in that it overestimates the potential activity of ^{222}Rn . This is because it assumes that the inflated inventory resulting from ingrowth is present at the time of disposal. In reality, ingrowth will not be instantaneous but will occur at rates dependent on the half-lives of the isotopes involved throughout the regulatory period.

The following table summarizes the results of the calculation.

Nuclide	Half Life (Years)	Initial Inventory (Ci)	Ingrowth from parent(s) over 10,000 years (Ci)	Inflated Inventory (Ci)
^{238}Pu	8.77E+01	3.80E+06	None	N/A
^{234}U	2.45E+05	5.53E+02	1.36E+03	1.91E+03
^{230}Th	7.7E+04	9.76E-02	1.70E+02	1.70E+02
^{226}Ra	1.6E+03	1.17E+01	7.04E+02	7.16E+02

From this table, the activity of ^{226}Ra , and therefore also of ^{222}Rn , can be seen to be less than 7.16E+02 Ci.