

**SCIENTIFIC NOTEBOOK**

**SN 844E Vol. 1**

**Title:** Colloidal Transport in the Engineered Barrier Systems  
**Project Number:** 14002.01.354

by

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## INITIAL ENTRIES

**Scientific Notebook:** 844 E Vol. 1

**Issued to:** Hakan Basagaoglu

**Title:** Colloidal Transport in the Engineered Barrier Systems

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This volume of the scientific notebook documents:

**Section 1:** The changes in the implementation of flow and transport of radionuclides and colloids in Engineered Barriers Systems (EBS) in TSPA. Section 1 used to support (1) KTI agreements- Evaluation of the near-field environment 4.06 additional information need and TSPA 3.17 additional information need; and (2) Key messages drafted by David Pickett (CNWRA) and Tae Ahn (NRC) on January 30, 2007.

**Section 2:** A schematic representation of colloidal facilitated radionuclide transport in the EBS (accompanied with Table on the specification of radionuclides) was provided is in Section. Section 2 is the basis for the letter transmitted to NRC on the status of the colloid release evaluation.

**Section 3:** Independent calculations to evaluate risk-significance of different colloids in the EBS. These calculations were used, in particular, to assist the center staff's review of the colloid-facilitated radionuclide transport in the EBS of the Yucca Mountain License Application (YMLA).

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January 30, 2007 (underwent multiple revisions)

**Section 1 : Write-up for the KTI agreements- Evaluation of the near-field environment 4.06 additional information need and TSPAI 3.17 additional information need**

After reviewing the report entitled EBS Radionuclide Transport Abstraction (SNL 2005 and ACN-001), I have provided the following write-up to David Pickett as an input for the KTI Agreements and Key Messages.

4.1.1 Technical basis for radionuclide transport abstraction

The analysis model report (SNL 2005 and ACN-001) describes the structure and function of the engineered barrier system radionuclide transport abstraction within the total system performance assessment model. In the abstraction, the waste package is the main source of radionuclides and corrosion products colloids, and is capable of reducing radionuclide outflux to the invert by irreversibly retaining a portion of radionuclides at limited sorptive sites in the corrosion products domain. The major assumptions underlying the conceptual model are presented in Section 5 of the AMR (with particular emphasis on reversible and irreversible sorption of radionuclides onto mobile and immobile collector surfaces, negligence of film straining at air-water interfaces, existence of radionuclide and colloid transport through continuous film flows at in-drift temperatures below 100°C, and negligence of filtration and gravitational settling of colloids). A complete description of the mathematical model is discussed in Section 6.5.1.2 (including mass-balance equations for waste form colloids and radionuclides, and estimated masses of corrosion products given in Table 6.3-4) and additional assumptions are underlined in Section 6.5.1.2 (e.g., irreversible sorption of only Am and Pu onto mobile iron oxide colloids in the waste package and the use of the same rate constant for the mobile and stationary iron oxide colloids).

In this review, NRC staff focused on those aspects of SNL (2005 and ACN-001) that addressed irreversible attachment of radionuclides onto stationary and mobile surfaces in a breached waste package and in the invert. Some of the key attributes of the abstraction are significantly different from previous descriptions, which involve (1) elimination of reversible sorption of radionuclides onto stationary corrosion products in the waste package; and (2) consideration of irreversible sorption of radionuclides onto limited sites on stationary corrosion products in the breached waste package that promotes the greater quantity of unretarded radionuclides in the solution. These changes were implemented by (1) calculating the capacity of irreversible sorptive sites on stationary corrosion via the product of an available surface area, adsorbed site densities, and the percentage of high affinity sites; and (2) reducing the upper bounds for  $K_d$  values of Pu and Am by a factor of 100 to promote their irreversible sorption onto stationary corrosion products and reversible sorption onto mobile colloids (which would be in competition with each other) in a breached waste package (page 96 of SNL (2005 and ACN-001)). The irreversible (forward) rate constant was treated as a fitting parameter, whose value was determined from the mass-outflux ratio of the colloid-associated radionuclides to the total radionuclides at the exit end of the corrosion product domain (Equation B-72 of V). Although this may seem to be a practically reasonable approach, treatment of the irreversible rate coefficient as a fitting parameter does not necessarily honor the conceptual model proposed for calculating the limited irreversible sites in the

corrosion product domain in terms of the product of an available surface area, adsorbed site densities, and the percentage of high affinity sites, because these measures are simply lumped into the fitting reversible rate coefficient (and hence the effect of such measures can not be accounted for explicitly) .

The rationale for neglecting reversible or irreversible sorption/attachment of radionuclides onto corrosion products in the invert (mainly due to localized and widely separated distribution of corrosion products in this zone) and reversible sorption of radionuclides (U, Np, Pu, Am, Pa, Cs, Sr, Ra, and Th) onto the crushed tuff in the invert have been clearly addressed. Partition coefficient ( $K_d$ ) values reported in Tables 8.2-3 and 6.5-6 of SNL (2005 and ACN-001) are consistent with the model assumptions regarding reversible and irreversible sorption of radionuclides onto colloidal particles, and the technical bases for parameter selections are clearly presented.

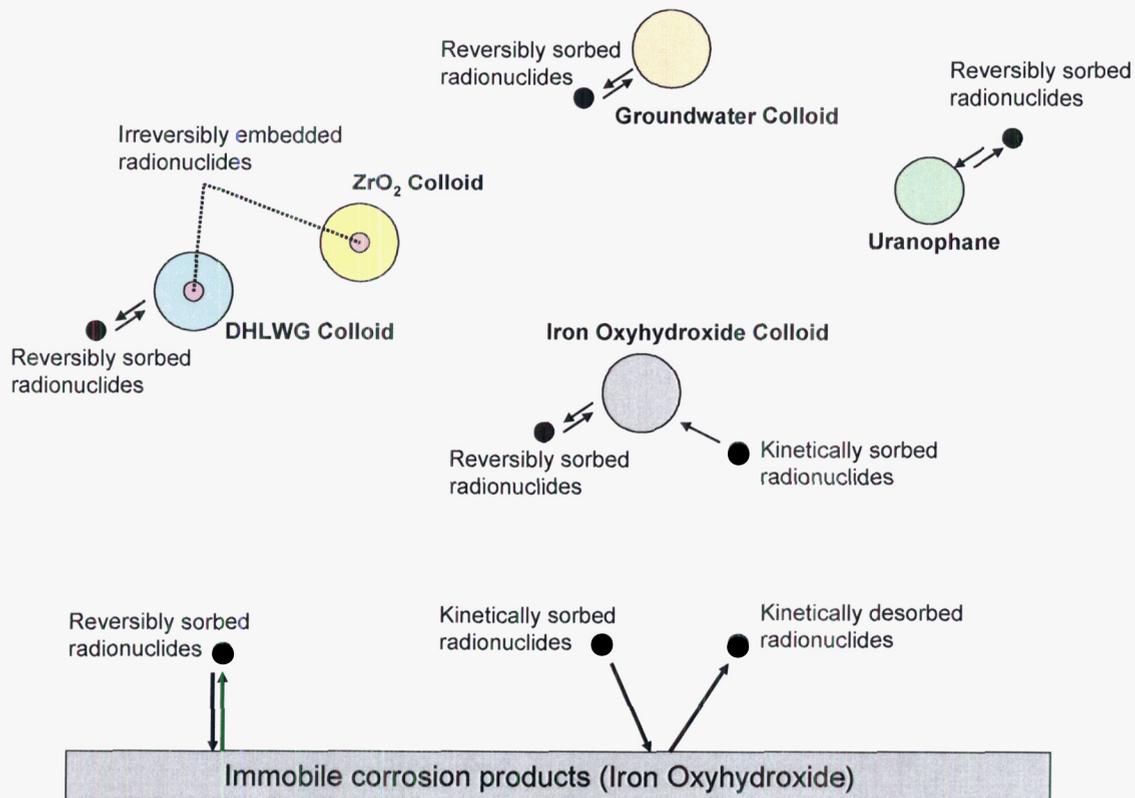
#### **Input to the Key Messages (drafted on January 30, 2007)**

It was proposed in SNL (2005 and ACN-001; Section 6.3.4.2.3.2) that the site capacities for irreversible sorption of radionuclides onto stationary corrosion products in the waste package to be computed by the product of the total available surface area, adsorbed site densities, and the high-affinity (favorable) site density. Values for the site densities (in Table 6.3-4a) and low/high affinity site densities (in Table 6.3-4b) for Goethite were provided in the report based on a detailed literature survey. The proposed conceptual model can then calculate the total quantity of radionuclides that would irreversibly sorb onto corrosion products. However, in the model description (Section 6.5.3.4 of SNL (2005 and ACN-001), the forward rate constant describing the irreversible sorption of radionuclides onto iron corrosion products was treated as a 'fitting parameter' (for the seep case where the colloids are stable) to match the target release ratio (which was set to 0.95) of the colloid-associated radionuclides to the total radionuclides leaving the corrosion product domain. Furthermore, no site-limitation for the irreversible sorption was included in the mass-balance equation written for irreversibly adsorbed radionuclides onto stationary ironoxyhydroxide corrosion products (Eq. 6.5.1.2-31 in SNL (2005 and ACN-001). Although the treatment of the forward rate constant as a fitting-parameter might be a practically reasonable approach, its linkage to the conceptual model (described in Section 6.3.4.2.3.2) proposed to limit the capacity of the irreversible sorptive sites on the corrosion products is not clear. Specifically, the connections (a) between the forward rate constant and the total capacity of the irreversible sorptive sites; (b) between the total capacity of the irreversible sorptive sites and the target release rate of 0.95; and (c) between the forward rate constant and the values compiled from the literature for the site density and high-affinity site densities are vague in the report. Although it was not stated in model formulation in Section 6.5.1.2 of SNL (2004 and ACN-001), the conceptual model for the irreversible sorption onto corrosion products might have been proposed only for the no-seep case, where colloids are unstable (p. 6-178), for which the forward rate constant was treated as a sampled parameter constructed from a range of values for the adsorbed site densities and high-affinity site densities. This point needs to be clarified in Eqs. 6.5.1.2-13 and 6.5.1.2-31 and in Section 6.5.3.4.

**Section 2 : Letter transmitted to NRC on the status of colloid release evaluations**

This section includes the schematic representation of colloid-facilitated radionuclide transport in the EBS. This section forms the basis for the letter on letter transmitted to NRC on the status of colloid release evaluations. Details are presented in the letter report.

Briefly, Figure 2.1 schematically shows reversible or irreversible association of radionuclides to five different types of colloids and stationary corrosion products in the EBS in YMLA. Table 2.1 lists particular radionuclides that are reversibly or irreversibly associated with different colloid types in the EBS in YMLA. Figure 2.1 and Table 2.1 are based on center staff's understandings from SNL (2005 and CAN-001), SNL (2007a), SNL (2007b), and various teleconferences with DOE staff.



**Figure 2.1:** A schematic representation of radionuclides reversibly or irreversibly associated with different colloid types and stationary corrosion products. Types of radionuclides are given in Table 2.1.

Domain		Irreversible Association	Reversible Sorption	Kinetic Sorption	Kinetic Desorption
Mobile Colloid	Smectite (DHLWG)	Pu, Am	Pu, Am, Th, Pa, Cs		
	ZrO <sub>2</sub>	Pu, Am			
	Uranophane		Pu, Am, Th, Pa, Cs, Np, Ra, Sn		
	Iron Oxyhrdioxide		U, Th, Np	Pu, Am	
	Smectite (Groundwater)		U, Np, Sn, Ra		
Immobile Corrosion Products			U, Th, Np	Pu, Am	Pu, Am

**Table 2. 1:** Radionuclides reversibly or irreversibly associated with (or sorbed onto) different colloid types and stationary corrosion products.

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### Section 3: Independent Calculations for Colloid Releases from EBS

General modeling features:

1. No sorption and no filtration of colloids in the EBS
2. DOE noted that colloid-facilitated transport is not important to the EBS barrier capability
3. Tc99 does not sorb onto colloids
4. In TSPA, processes that limit colloid transport are the stability and transport mechanism (advection vs. diffusion). Diffusion limits colloid-facilitated radionuclide transport
5. High ionic strength and high temperature makes colloids unstable

#### Scenario: Igneous Intrusion

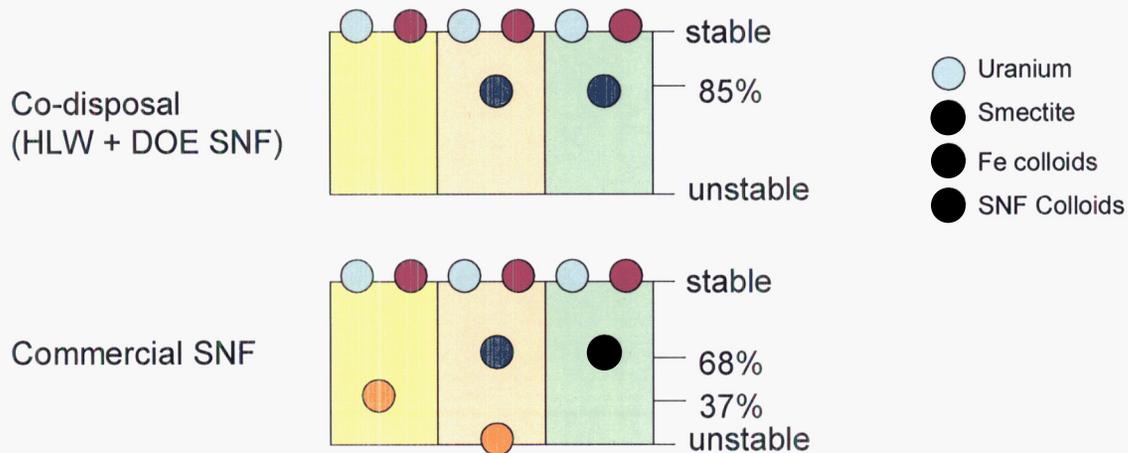
- Largest seepage rate through the EBS due to complete failure of drift wall and waste packages.
- No barrier effects
- Chemical conditions remain the same after 1,000 years
- There is no distinction between drip and no-drip case
- For advective flow case, chemical condition and colloid stability are the same in Corrosion Products (CP) and Invert (INV).
- No Fe colloids in WF

Involves 5 colloid mass concentrations, but 4 colloid stability (the same colloid stability condition applies to HLWG and clay colloids, because both are represented by smectite colloids). A schematic showing the stability of different colloid types in EBS is given in Figure 3.1. According to this schematic,

#### Domains:

- Codisposal Domain (Glass + DOE SNF)
  - Smectite and uranium colloids are stable
  - 85 percent of Fe-colloids stable in CP and INV
- Commercial SNF
  - Smectite and uranium colloids are stable
  - 37 percent of SNF colloids are stable in WF, but unstable in CP domain
  - 68 percent of Fe-colloids stable in CP and INV

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**Figure 3.1:** Stability of colloids in the waste form (in yellow), corrosion product (in pale orange), and in invert (in green) subdomains of the co-disposal and commercial SNF domains under igneous intrusion case.

According to SNL (2007a), the releases of Pu embedded in waste form colloids are computed using (Eq. 6.5.1.2-9, p. 6-150),

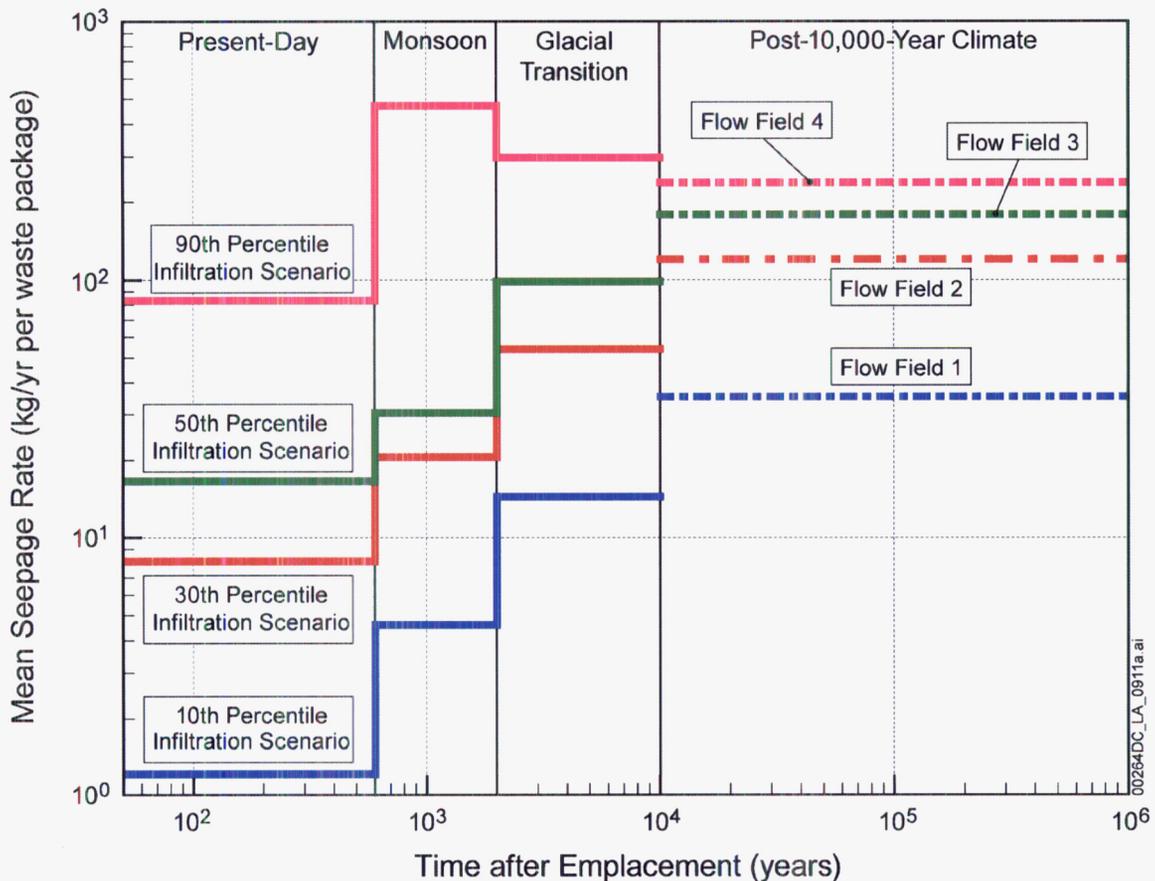
$$Q_{icm}^{embed} = \phi S_w \lambda_{Pu}^{embed} C_{Pu} \quad (1)$$

in which  $\phi$  is the porosity ;  $S_w$  is the water saturation ;  $\lambda_{Pu}^{embed}$  is the rate constant ( $yr^{-1}$ ) for mass conversion from dissolved state onto waste form colloids Pu.

However, DOE implemented transport of Pu irreversibly associated with SNF colloids differently in TSPA (SNL 2007b; Section 6.3.2.4). Pu concentrations associated with irreversible SNF colloids vary in the range of  $1 \times 10^{-10}$  to  $5 \times 10^{-6}$  mol/L [ $2.44 \times 10^{-8}$  to  $1.22 \times 10^{-3}$ g/L given that 1 mol Pu 244 g] or equivalently [ $2.44 \times 10^{-8}$  to  $1.22 \times 10^{-3}$ kg/m<sup>3</sup>] (Table 6-6b, p. 6-23, SNL 2007b).

DOE provided mean seepage estimates per waste package. For the igneous intrusion case:

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**Figure 3.2:** Estimated mean seepage rate at the Yucca Mountain Site, which is provided in SAR (2008; Figure 2.3.3-47).

The mean seepage rate can be computed from Figure 3.2 as follows:

$$1.2 \times \mathbf{0.62} + 8 \times \mathbf{0.16} + 18 \times \mathbf{0.16} + 82 \times \mathbf{0.06} = 9.9 \text{ kg/yr} \sim 0.01 \text{ m}^3/\text{yr} \text{ (Present)}$$

$$4.5 \times \mathbf{0.62} + 16 \times \mathbf{0.16} + 55 \times \mathbf{0.16} + 450 \times \mathbf{0.06} = 37.79 \text{ kg/yr} \sim 0.04 \text{ m}^3/\text{yr} \text{ (Monsoon)}$$

$$15 \times \mathbf{0.62} + 52 \times \mathbf{0.16} + 100 \times \mathbf{0.16} + 300 \times \mathbf{0.06} = 52.1 \text{ kg/yr} \sim 0.05 \text{ m}^3/\text{yr} \text{ (Glacier)}$$

(weights in bold are taken from SAR, 2008).

These numbers are **for per waste package**. Given that the subregion 3 encompasses 2,904 waste packages, the flux rates over the subregion 3 would be:

$$0.01 \times 2,904 \sim 29 \text{ m}^3/\text{yr} \text{ (Present)}$$

$$0.04 \times 2,904 \sim 110 \text{ m}^3/\text{yr} \text{ (Monsoon)}$$

$$0.05 \times 2,904 \sim 151 \text{ m}^3/\text{yr} \text{ (Glacier)}$$

Hence, the Pu releases irreversibly associated with SNF colloids becomes:

$$2.44 \times 10^{-8} \text{ to } 1.22 \times 10^{-3} \text{ kg/m}^3 \times 29 \text{ m}^3/\text{yr} = 2.4 \times 10^{-7} - 3.5 \times 10^{-2} \text{ kg/yr} \text{ (present)}$$

$$2.44 \times 10^{-8} \text{ to } 1.22 \times 10^{-3} \text{ kg/m}^3 \times 110 \text{ m}^3/\text{yr} = 9.2 \times 10^{-6} - 1.3 \times 10^{-1} \text{ kg/yr} \text{ (monsoon)}$$

$$2.44 \times 10^{-8} \text{ to } 1.22 \times 10^{-3} \text{ kg/m}^3 \times 151 \text{ m}^3/\text{yr} = 3.7 \times 10^{-6} - 1.8 \times 10^{-1} \text{ kg/yr} \text{ (glacier)}$$

Hence, if radioactive decay is neglected, releases of Pu irreversibly associated with **CSNF colloids** would be in the range of  $2.4 \times 10^{-7} - 1.8 \times 10^{-1} \text{ kg/yr}$ .

DOE in their response to RAI: RAI: 3.2.2.1.3.4-2-003 noted that all CSNF colloids are unstable in the corrosion products domain due to relatively a narrow range of pH, and hence all Pu irreversible associated with CSNF colloids settle out permanently (and gets removed from the inventory).

Releases of radionuclides irreversibly associated with **mobile iron oxide corrosion** products are given by (Eq. 6.5.1.2-20; p. 6-152, SNL 2007a):

$$Q_{\text{Pu,Colloid}} = \theta S_w C_{\text{cFeOx}} \bar{s}_c k_{\text{Pu}} C_{\text{Pu}} \quad (2a)$$

Equation (2a) should have been (for consistency of dimensions):

$$Q_{\text{Pu,Colloid}} = \theta S_w C_{\text{cFeOx}} \bar{s}_c k_{\text{Pu}} \frac{1}{\theta} C_{\text{Pu}} \quad (2b)$$

$$Q_{\text{Pu,Colloid}} = \frac{\text{m}^3 \text{pore} \text{m}^3 \text{water} \text{kgcolloid} \text{m}^2 \text{colloid} \text{m}^3 \text{water} \text{m}^3 \text{bulk} \text{kg}_{\text{Pu}}}{\text{m}^3 \text{bulk} \text{m}^3 \text{pore} \text{m}^3 \text{water} \text{kgcolloid} \text{m}^2 \text{colloid} \text{m}^3 \text{water} \text{m}^3 \text{water}}$$

in which  $\bar{s}_c$  is specific surface area of mobile corrosion products colloids ( $\text{m}^2$  colloids  $\text{kg}^{-1}$  colloids), and  $k_{\text{Pu}}$  is the forward rate constant for irreversible sorption ( $\text{m}^3$  water  $\text{m}^{-2}$  Fe oxide colloids  $\text{yr}^{-1}$ ).

Similarly, Pu mass kinetically sorbed onto stationary corrosion products (sink term) is given by (Eq. 6.5.1.2-14; p. 6-151, SNL 2007a):

$$Q_{\text{Pu,stationary}} = \rho_b \bar{s}_{\text{cF}} k_{\text{Pu}} C_{\text{Pu}} \quad (3a)$$

Eq. (3a) should have been (for correct dimensions):

$$Q_{\text{Pu,stationary}} = \frac{\rho_b}{\theta S_w} \bar{s}_{\text{cF}} k_{\text{Pu}} C_{\text{Pu}} \quad (3b)$$

$$Q_{\text{Pu,stationary}} = \frac{\text{kgCP} \text{m}^3 \text{CP} \text{m}^2 \text{CP} \text{m}^3 \text{water} \text{kg}_{\text{Pu}}}{\text{m}^3 \text{CP} \text{m}^3 \text{water} \text{kgCP} \text{m}^2 \text{CP} \text{m}^3 \text{water}}$$

in which  $\bar{s}_{\text{cF}}$  is the specific surface area of corrosion products domain [ $\text{m}^2$  CP/kg CP] and  $\rho_b$  is the bulk density of the stationary corrosion products [ $\text{kg}/\text{m}^3$  CP bulk volume]. In these equations:

- Porosity,  $\theta$ , of the corrosion products domain: 0.4 (Table 8.2-1; SNL 2007a)
- Water saturation,  $S_w$ , in the corrosion products domain 1 (Table 8.2-1 in SNL 2007a)
- The forward rate constant  $k_{\text{Pu}}$  is bounded in the range of 0.002 – 0.05  $\text{m}^3 \text{m}^{-2} \text{yr}^{-1}$  (Table 6-24, p.6-116, SNL 2007b; DOE 2009a).

-- The mean of the sampled distributions for FeO colloids of 1.5 mg/L [ $1.5 \times (10^{-6} \text{ kg}/10^{-3} \text{ m}^3) = 1.5 \times 10^{-3} \text{ kg}/\text{m}^3$ ] when stainless steel is corroding and the colloids are stable (DOE Responses to RAI: 3.2.2.1.3.4-2-003).

-- Specific surface area of the mobile colloids is 1-22 m<sup>2</sup>/g [=1,000-22,000 m<sup>2</sup>/kg] (Table 6.5-6 in SNL, 2005).

However, no distinction is made about the specific surface area of the mobile iron oxide colloids and stationary corrosion products in SNL (2007a). In sample calculation on page B8 of SNL (2007a), the specific surface area of the mobile iron oxide colloids and stationary corrosion products were equal.

The specific surface area of Goethite (Goethite\_SA\_a in TSPA):  
14.7-110 m<sup>2</sup>/g (p. 8-17, SNL 2007a) -- truncated log-normal  
(mean value is: 51.43 and standard deviation is 30.04)

The specific surface area of HFO (HFO\_SA\_a in TSPA):  
68-600 m<sup>2</sup>/g (p. 8-17, SNL 2007a) -- truncated log-normal  
(mean value is: 275.6 and standard deviation is 113.4)

Both Goethite and HFO are considered in the stationary corrosion products. The relative abundance of Goethite is 0.45-0.80 (sampled from a uniform distribution) – This range was supplied by J. Mancillas

Hence the range of surface area of the stationary corrosion products would be:  
14.7×0.80+68×0.20=25.4 m<sup>2</sup>/g (min)  
110×0.45+68×0.55=380 m<sup>2</sup>/g (max)

Therefore, the specific surface area of stationary corrosion products (calculated above) and reported in SNL 2007a is ~15-25 times larger than the specific surface area reported for mobile corrosion products in SNL (2005).

The bulk density of Goethite is 4,260 kg/m<sup>3</sup> and the bulk density of HFO is 3,960 kg/m<sup>3</sup>. (p. 8-21 SNL 2007a)

Considering the relative abundance of Goethite in the range of 0.45-0.80, the bulk density of the stationary corrosion products will be

4,260×0.45+3,960×0.55=4,095 kg/m<sup>3</sup> (min)  
4,260×0.80+3,960×0.20=4,200 kg/m<sup>3</sup> (max)

The ratio of the Pu retained on stationary corrosion products (sink term) and carried (releases) by mobile iron oxide colloids can be computed by dividing Eq.(3) by Eq.(2),

$$\frac{Q_{\text{Pu,stationary}}}{Q_{\text{Pu,colloids}}} = \frac{\frac{\rho_b}{\theta S_w} \bar{s}_{cF} k_{\text{Pu}} C_{\text{Pu}}}{\theta S_w C_{\text{cFeOx}} \bar{s}_c k_{\text{Pu}} \frac{1}{\theta} C_{\text{Pu}}} = \frac{\frac{\rho_b}{S_w} \bar{s}_{cF}}{\theta S_w C_{\text{cFeOx}} \bar{s}_c} \quad (4)$$

Let's assume that the specific surface area for the mobile iron oxide colloids and stationary corrosion products are the same, the mean FeO colloid concentration is  $1.5 \times 10^{-3} \text{ kg/m}^3$ ,  $S_w = 1$ ,  $\theta = 0.4$ ,  $\rho_b = 4,100 \text{ kg/m}^3$ , Eq. (4) becomes,

$$\frac{Q_{\text{Pu,stationary}}}{Q_{\text{Pu,colloids}}} = \frac{4100}{6 \times 10^{-4}} \cong 7 \times 10^6 \quad (5)$$

Hence, Pu concentration associated with stationary corrosion products would be ~ 6 orders of magnitude larger than Pu mass associated with mobile iron oxide colloids. This suggests that the stationary corrosion products are more effective retaining Pu concentrations than releases by mobile colloids.

Using the bulk density of the corrosion products estimated on the previous page (just before Eq. (4)), Pu concentrations associated with the stationary corrosion products can be computed from Eq. (3),

$$Q_{\text{Pu,stationary}} = (4,095)(25)(0.002)C_{\text{Pu}} = 2.1 \times 10^2 C_{\text{Pu}} \quad (\text{min}) \quad (6a)$$

$$Q_{\text{Pu,stationary}} = (4,200)(380)(0.05)C_{\text{Pu}} \sim 8 \times 10^4 C_{\text{Pu}} \quad (\text{max}) \quad (6b)$$

Because, Pu associated with iron oxide colloids is  $\sim 7 \times 10^6$  is less than Pu associated with stationary corrosion products

$$Q_{\text{Pu,colloids,max}} \cong \sim 3 \times 10^{-5} C_{\text{Pu}} \quad (\text{min}) \quad (7a)$$

$$Q_{\text{Pu,colloids,max}} \cong \sim 1 \times 10^{-2} C_{\text{Pu}} \quad (\text{max}) \quad (7b)$$

$$3 \times 10^{-5} C_{\text{Pu}} \leq Q_{\text{Pu,colloids,max}} \leq 1 \times 10^{-2} C_{\text{Pu}} \quad (7b)$$

Hence only a small fraction (0.00003 – 0.01) of dissolved plutonium will be associated with iron-oxide colloids.

#### Irreversible HLGW Colloids:

The ratio of two TSPA parameters defines the HLGW colloid concentrations in the EBS. These parameters are the sampled Pu concentrations ( $\text{CPu\_Col\_Wf\_Embed\_Sampled\_a}$ ) and sampled colloid scaling factor ( $\text{CPu\_Per\_WF\_Embed\_Col\_a}$ ). In TSPA (SNL 2007b),

1.  $0 \times 10^{-11} \text{ mol/L} < \text{CPu\_Col\_Wf\_Embed\_Sampled\_a} < 1.0 \times 10^{-8} \text{ mol/L}$
5.  $0 \times 10^{-9} \text{ mol/L} < \text{CPu\_Per\_Wf\_Embed\_Col\_a} < 2.5.0 \times 10^{-8} \text{ mol/L} < (\text{mg/L})$

And hence, the range for

$$4 \times 10^{-4} \text{ mg/L} \leq \frac{\text{CPu\_Col\_Wf\_Embed\_Sampled}}{\text{CPu\_Per\_Wf\_Embed\_Col\_a}} \leq 2 \text{ mg/L}$$

which corresponds to mass concentration of irreversible HLGW colloids; DOE 2009b, p.5). When compared to iron oxide colloid concentrations in the EBS (which range from

0.001 to 30 mg/L), mass concentrations of irreversible HGLW colloids are **about an order of magnitude less** than mass concentrations of iron oxide colloids (SNL 2007b, p. 6-47).

Pu concentrations associated with irreversible HGLW colloids vary in the range of  $1 \times 10^{-11}$  to  $1 \times 10^{-8}$  mol/L [ $2.44 \times 10^{-9}$  to  $2.44 \times 10^{-6}$  g/L given that 1 mol Pu 244 g] or equivalently [ $2.44 \times 10^{-9}$  to  $1.22 \times 10^{-6}$  kg/m<sup>3</sup> or  $2.44 \times 10^{-6}$  to  $2.44 \times 10^{-3}$  g/L] (Table 6-6b in SNL 2007b).

Flow rates throughout the igneous intrusion case (as computed above) are:  
~ 0.01 m<sup>3</sup>/yr (Present); ~ 0.04 m<sup>3</sup>/yr (Monsoon); ~ 0.05 m<sup>3</sup>/yr (Glacier)

If we assume that all Pu (sampled concentration associated with the irreversible HGLW colloids are flushed out (advectively) of all EBS components, the release rates would be in the range of:

$$\begin{aligned} (2.44 \times 10^{-6} \text{ to } 2.44 \times 10^{-3} \text{ g/m}^3) \times 29 \text{ m}^3/\text{yr} &= 7.8 \times 10^{-5} \text{ to } 7.8 \times 10^{-2} \text{ g/yr (Present)} \\ (2.44 \times 10^{-6} \text{ to } 2.44 \times 10^{-3} \text{ g/m}^3) \times 110 \text{ m}^3/\text{yr} &= 2.7 \times 10^{-4} \text{ to } 2.7 \times 10^{-1} \text{ g/yr (Monsoon)} \\ (2.44 \times 10^{-6} \text{ to } 2.44 \times 10^{-3} \text{ g/m}^3) \times 151 \text{ m}^3/\text{yr} &= 3.7 \times 10^{-4} \text{ to } 3.7 \times 10^{-1} \text{ g/yr (Glacier)} \end{aligned}$$

Under different infiltration scenarios for the igneous intrusion case, the upper bounds for Pu-242 mass concentration (above) are on the same orders Pu-242 mass irreversibly transported by iron oxide colloids (which was assessed to be insignificant dose contributor) when CSNF colloids are unstable in the WF form (DOE 2009d, Fig. 5). Similarly, for the igneous intrusion case under each infiltration scenario, the upper bound of Pu-242 irreversibly associated with HLWG colloids is 2-3 orders of smaller than the dissolved Pu-242 concentrations during the compliance period and 1-2 orders of magnitude smaller (even when the decay process is neglected and source is assumed to be continuous in the calculations above) at 1M years (DOE 2009d; Fig. 3).

Hence, because (i) HGLW colloid mass concentrations are an order of magnitude smaller than the mass concentration of iron oxide colloids, (ii) the maximum Pu-242 releases (at 100K-year) associated with the (dose/risk-insignificant) iron oxide colloids are 3-4 orders magnitude higher than Pu-242 releases associated with the HGLW colloids during the compliance period and comparable at the 1M-year period, and (iii) Pu-242 releases associated with HGLW colloids is 1-2 orders of magnitude smaller than dissolved Pu-242 releases even when radioactive decay is neglected and colloid and radionuclide sources are assumed to be continuous (not limited in anyways) in our calculations, HGLW colloids are considered to be risk-insignificant. This is consistent with DOE (2009c; Fig. 1.1-26, shown by dashed red line).

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Abstraction and Summary.

This Scientific note **is closed** on June 4, 2010.

A handwritten signature in black ink, appearing to be 'M. B. ...'.