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Subject: Update to the calculation of the minimum brine volume for a direct brine release

Executive Summary

The minimum brine volume in the repository for a direct brine release (DBR) calculation was updated to increase consistency with the DBR conceptual model. The calculated volume increased by ~26%, from 13,700 m^3 with the previous method to a value of 17,400 m^3. The higher minimum brine volume for a DBR is likely to result in slightly lower actinide solubilities, as the constituent concentrations are more diluted in a larger brine volume.

Introduction

The concentration of various constituents in brine is used as an input for the actinide solubility calculation for the Waste Isolation Pilot Plant (WIPP) Performance Assessment (PA). With known quantities of the various constituents, the concentration is based on the volume of brine into which the constituents dissolve. The minimum volume of brine is defined as the lowest amount of brine required to be in the repository in order for a direct brine release (DBR) to occur. Using the minimum brine volume is a conservative estimate in terms of actinide releases, since larger volumes would dilute the constituents and lower the actinide solubility.

Prior to the 1996 Compliance Certification Application (CCA), the minimum brine volume required for a DBR was provided in a memo by Kurt Larsen (Larsen 1996). The value from Larsen's calculation (29,800 m^3) was used for the CCA, as well as for several subsequent calculations up to and including the 2004 Compliance Recertification Application (CRA-2004) PA. Following the CRA-2004 PA, the minimum brine volume calculation was updated based on new information and important changes that had been made to the way the repository is modeled using the CRA-2004 PA results (10,000 m^3, Stein 2005). The minimum brine volume was then updated using the results from the subsequent PA, denoted as the CRA-2004 Performance Assessment Baseline Calculation (PABC), following the same procedure used by Stein (13,700 m^3, Clayton 2006). This memo documents an update to the procedure proposed by Stein and how that affects the minimum brine volume.

Consolidated Void Volume

Stein (2005) recommended using the consolidated void volume which results from the lowest pressure realization at 10,000 years. This is inconsistent with the conceptual model for DBR. In order for a DBR to occur, two criteria must be met (Stoelzel and O'Brian 1996):

1. Volume averaged pressure in the vicinity of the repository encountered by drilling must exceed drilling fluid hydrostatic pressure (assumed to be 8 MPa).
2. Brine saturation in the repository must exceed the residual saturation of the waste material (Sampled from a uniform distribution ranging from 0.0 to 0.552).

If both of these criteria are met, a DBR can occur. If either of these conditions is not satisfied, no DBR can occur.

The lowest pressure realization at 10,000 years is generally not equal to the minimum pressure required for a DBR to occur. Therefore, it is appropriate to update the minimum brine volume calculations so that they are consistent with the conceptual model for DBR. For the determination of the consolidated void volume it is recommended to use the minimum pressure of 8 MPa, as is required for a DBR to occur.

Clayton (2006) used a minimum pressure of 6.18 MPa at 10,000 years which was determined from the CRA-2004 PABC calculations, and is ~29% lower than the minimum pressure required for a DBR to occur. The consolidated void volume is calculated below using the 8 MPa minimum pressure required for a DBR.

Following the procedure in Stein (2005), the results from SANTOS were used to determine the consolidated void volume that is associated with the 8 MPa minimum pressure. SANTOS is run using several gas generation rates (f-Factors). Table 1 shows the SANTOS results at 10,000 years for the pressure (P_i, i=1 to 4) and consolidated void volume (V_i, i=1 to 4) versus f-Factor (SNL, 1996), which results have not changed and were used previously to calculate the consolidated void volume (Stein 2005; Clayton 2006).

Table 1. SANTOS Results at 10,000 years for Pressure and Consolidated Void Volume versus f-Factor (SNL 1996).

f-Factor	Pressure (MPa)	Void Volume (m^3)
0.025	P_1=2.825	V_1=240.3
0.05	P_2=4.371	V_2=310.6
0.1	P_3=6.382	V_3=425.4
0.2	P_4=9.158	V_4=593.0

To choose an appropriate consolidated void volume (V) associated with the minimum pressure (P = 8 MPa), linear interpolation is used as shown below using the values in Table 1:

$$V = V_3 + \frac{(P-P_3)(V_4-V_3)}{(P_4-P_3)} = 425.4 + \frac{(8-6.382)(593.0-425.4)}{(9.158-6.382)} = 523.1 m^3.$$

This consolidated void volume is ~26% higher than the value calculated from the CRA-2004 PABC results (414.0 m^3, Clayton 2006).

Number of Equivalent Rooms in the Repository

The volume of the waste-filled region of the repository is equivalent to a certain number of room volumes times the waste-filled region of a room. As recommended in Stein (2005), this number of equivalent rooms is determined by the total excavated volume divided by the excavated volume of a single room. The excavated volume of the waste-filled region of the repository is stored in the WIPP parameter database as REFCON:VREPOS (4.3840608×10^5). The volume of a single room is stored in the parameter database as REFCON:VROOM (3.6443780×10^3). These parameters are the same as were used in Stein (2005). The number of equivalent rooms in the repository is:

$$\frac{REFCON:VREPOS}{REFCON:VROOM}=\frac{4.3840608\times10^5}{3.6443780\times10^3}=120.3$$

which is the same value as calculated in Stein (2005).

Minimum Brine Saturation

As described in the DBR conceptual model (Stoelzel and O'Brian 1996), in order for a DBR release to occur, the brine saturation in the repository must be above the sampled residual brine saturation for the waste (WAS_AREA:SAT_RBRN). As recommended in Stein (2005), the median value of the WAS_AREA:SAT_RBRN parameter (0.276) is a reasonable lower end estimate. The WAS_AREA:SAT_RBRN parameter did not change from the CRA-2004 PA to the CRA-2004 PABC and so the same median value is used.

The DBR volume as a function of brine saturation from the CRA-2004 PABC DBR calculations is shown in Figure 1. The vertical line in Figure 1 indicates the median value of the WAS_AREA:SAT_RBRN parameter (0.276). The S2 lower intrusion scenario was chosen for comparison as it results in the greatest frequency of non-zero DBR volumes, as well as the highest DBR volumes (Stein et al. 2005). The S2 lower intrusion scenario represents the second intrusion into the same waste panel in which the first intrusion had penetrated a brine pocket. Other scenarios have far fewer releases.

Examination of Figure 1 shows that non-zero DBR volumes become significant above a saturation of 0.276. This supports the selection of the median value of the WAS_AREA:SAT_RBRN parameter for use in the minimum brine volume for a DBR and shows that it remains applicable based on the results from the CRA-2004 PABC. The minimum value of the WAS_AREA:SAT_RBRN parameter is zero. Using the minimum value is unreasonable, as this would suggest that DBRs can occur at any brine saturation within the waste, which is inconsistent with the DBR conceptual model.

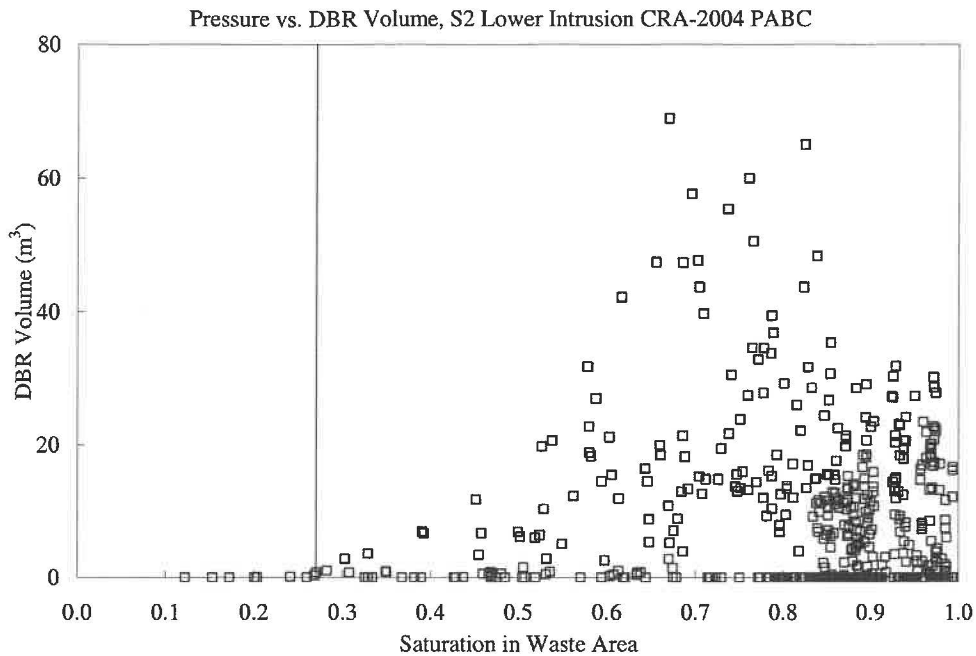

Figure 1. Scatter plot of DBR volume vs. brine saturation in the waste panel. The vertical line indicates the median value of the WAS_AREA:SAT_RBRN parameter.

Minimum Brine Volume in the Repository

Using the values discussed above for consolidated void volume, number of equivalent rooms in the repository and minimum brine saturation, a reasonable minimum volume of brine in the repository required for a DBR is:

$$523.1 \times 120.3 \times 0.276 = 17{,}400 \text{ m}^3$$

A comparison of the values from previous calculation using the CRA-2004 PABC results (Clayton 2006) versus the current values using the updated method is shown in Table 2, with the differences in bold and italicized.

Table 2. Comparison of the parameters from the CRA-2004 PABC results versus the updated method.

Parameter	CRA-2004 PABC	Updated Method
Pressure	6.183 (MPa)	***8.000 (MPa)***
Consolidated Void Volume	414.0 (m^3)	***523.1 (m^3)***
REFCON:VREPOS	4.3840608×10^5 (m^3)	4.3840608×10^5 (m^3)
REFCON:VROOM	3.6443780×10^3 (m^3)	3.6443780×10^3 (m^3)
# of Rooms in Repository	120.3	120.3
Minimum Brine Saturation	0.276	0.276
Minimum DBR Volume	13,700 (m^3)	***17,400 (m^3)***

As seen in Table 2, the updated method generated a minimum brine volume for a DBR (17,400 m^3) that is ~26% higher compared with the previous results (13,700 m^3), which arose from the higher consolidated void volume using the updated method. The higher pressure used in the updated method compared with the previous method produced the higher calculated consolidated void volume. The higher minimum brine volume for a DBR is likely to result in lower actinide solubilities, as the constituent concentrations are more diluted in a larger brine volume.

References

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