RAI Volume 3, Chapter 2.2.1.2.1, Seventh Set, Number 1:

Identify whether the effects of the evolution of unsaturated zone water chemistry due to microbial activity in the near-field condensation zone during the repository early thermal period have been addressed in a FEP listed in SAR Table 2.2-5. If these effects are considered to be part of an existing included FEP, then provide a technical basis for why the model abstractions that include the FEP adequately bound any potential impacts from microbial activity in the near-field condensation zone during the repository early thermal period. If the effects of the evolution of unsaturated zone water chemistry due to microbial activity in the near-field condensation zone during the repository early thermal period are addressed in an existing excluded FEP (SAR Table 2.2-5), then provide an updated FEP description, screening decision, and screening justification for the FEP that explicitly addresses the effects of the evolution of unsaturated zone water chemistry due to microbial activity in the near-field condensation zone during the repository early thermal period. Otherwise, provide an updated list of FEPs that includes the new FEP and provide a screening decision and screening justification for the new FEP. This information is needed to verify compliance with 10 CFR 63.114(a)(5)-(6).

Basis: DOE addresses microbial activity in multiple FEPs, including FEP 1.2.08.00.0A (Diagenesis), FEP 2.1.10.01.0A (Microbial Activity in the EBS), and FEP 2.2.09.01.0B (Microbial Activity in the UZ) (SNL, 2008). In the justification for FEP 1.2.08.00.0A, DOE states that the excluded FEP 2.2.09.01.0B addresses the effects of microbial activity in the unsaturated zone (SNL, 2008). DOE's description of FEP 2.2.09.01.0B (SNL, 2008) limits microbial effects to those that may affect radionuclide mobility. DOE excluded microbial activity in the EBS (FEP 2.1.10.01.0A), citing (i) high temperatures and dry conditions in the drifts during the early thermal period and (ii) low water activity and the scarcity of nutrients under ambient conditions as factors that would sharply limit any microbial activity within the drifts. In contrast, the condensation zone in the surrounding rock will have warm temperatures and a higher water content during the early thermal period, increasing its capability to support microbial activity beyond ambient conditions to an extent that could influence the composition of water in the condensation zone. Water from the condensation zone resaturates the dryout zone when the thermal period diminishes, potentially entering the repository drifts as seepage and influencing the corrosion of engineered barriers.

1. RESPONSE

As discussed at the October 15, 2009, clarification call with the NRC, this response identifies (a) the features, events, or processes (FEP), both primary and supporting, that address microbial activity in the unsaturated zone and how they interrelate; and (b) the specific technical bases from the report *Evaluation of Potential Impacts of Microbial Activity on Drift Chemistry* (BSC 2004) for the conclusion that no chemical effects beyond those in the ambient chemistry are expected in the condensation zone from microbial activity. The effects of microbial activity on chemistry in the unsaturated zone, including the condensation zone during the boiling period, are expected to be within the range of ambient unsaturated zone chemistry because microbial activity within the unsaturated host rock in the postclosure period is expected to stay within the range of the ambient microbial activity.

1.1 SUMMARY OF FEP DISCUSSIONS

Within SAR Table 2.2-5, the FEP listed as FEP 2.2.09.01.0B (Microbial Activity in the UZ, excluded—low consequence) is the primary FEP that addresses microbial effects on the chemistry of groundwater in the unsaturated zone. FEP 2.2.09.01.0B references the discussion within FEP 2.1.10.01.0A (Microbial activity in the EBS, excluded—low consequence) as an applicable supporting basis, because the rationale for many of the processes that limit microbial activity are developed from investigations of the ambient unsaturated zone microbial activity. Both of these FEPs refer to the report *Evaluation of Potential Impacts of Microbial Activity on Drift Chemistry* (BSC 2004) for the detailed technical bases of their justifications. A conclusion of that report is that the microbial activity within the unsaturated host rock in the postclosure period is bounded by the measured ambient microbial activity in the host rock units, and other similar rock units (BSC 2004, Section 6.5, first bullet, p. 6-36). Therefore, no chemical changes to the ambient unsaturated zone chemistry are expected from microbial activity during postclosure, unless they could be driven by changes within the Engineered Barrier System (EBS). Potential chemical changes to the unsaturated zone from direct microbial activity have been considered (BSC 2004, Section 6.1) and some have been evaluated in the context of nutrient additions within the emplacement drifts (BSC 2004, Section 6.5).

Introduction of materials into the emplacement drifts (both metallic materials and organic substances) represents a change to that environment different from the natural system. Thus, most of the analysis (BSC 2004) focuses on constraining the potential effects on microbial activity within the drifts. Microbial effects in the EBS are analyzed in a bounding manner accounting for uncertainties (BSC 2004, Section 6.6, p. 6-46) and are concluded to be excluded based on low consequence (FEP 2.1.10.01.0A). Any potential effects of additional materials in the EBS will be smaller in the host rock compared to directly within the emplacement drifts, and are, therefore, of even less consequence, as referenced within FEP 2.2.09.01.0B. Some of the limitations effective within the emplacement drifts (BSC 2004, Section 6.4) do not apply to the unsaturated zone (e.g., high radiation field) because of the rock mass. The primary limitations to microbial activity that do apply within the unsaturated zone are thermal effects within the boiling zone, limited water availability (lower relative humidity) within the boiling zone, and nutrient limitations throughout the unsaturated zone (BSC 2004). These limitations should provide a net decrease to the ambient microbial activity in the unsaturated host rock for some period of time,

but at the very least will not support any increase above ambient microbial activity (BSC 2004, Section 6.5).

1.2 LIMITATIONS ON MICROBIAL ACTIVITY IN THE UNSATURATED ZONE

The unsaturated zone has limited nutrients for microbial activity, and this is not expected to change in the postclosure period (BSC 2004, Section 5, p. 5-1). The unsaturated zone primary sources of the elemental microbial building blocks carbon, nitrogen, sulfur, and phosphorous (nutrients) show that these nutrients are either readily available (sulfur and nitrogen), somewhat limited (phosphorous), or provide the major limitation (organic carbon) to microbial growth (BSC 2004, Section 6.4.5, pp. 6-30 to 6-32). The nutrient limitations for organic carbon in the host rock are not expected to change in the postclosure period in any way (i.e., no additional organic input is expected) that would affect the conclusions on limited microbial activity in the unsaturated zone (BSC 2004, Section 5, p. 5-1, and Section 6.4.5, p. 6-31). Repository-related introduced organic carbon effects on microbial activity and bulk chemistry within the emplacement drifts have been assessed and concluded to be insignificant (BSC 2004, Section 6.5.1, p. 6-37).

Thermal changes in the unsaturated rock will not be as large as those within the emplacement drifts because of distance from the heat source. However, there will be a zone of above-boiling temperatures within a portion of the rock, and the same thermal limitations to microbial activity that are applied within the drift (i.e., temperatures well above boiling; BSC 2004, Section 6.4.1, p. 6-20) will work to reduce microbial activity in this boiling zone for some period of time. In addition to the direct effect of temperature, the boiling zone in the unsaturated host rock will undergo a large reduction in relative humidity (BSC 2004, Section 6.4.1, p. 6-20, and Section 6.4.3), leading to limitations on microbial activity from low relative humidity (water availability) for at least some period of time.

Even though unsaturated, the rock units above the repository already have very high ambient water activity, as shown by the high relative humidity of the pore-water compositions (greater than 0.999 or 99.9%; e.g., see Figures 2b through 5b in the response to RAI 3.2.2.1.3.3-002). The ambient relative humidity values are already at the upper end of the range of optimal microbial activity (i.e., between 90% and 100%; BSC 2004, Section 7, p. 7-3, and Section 6.4.3, p. 6-26), so water availability conditions are virtually as conducive to microbial activity in the ambient unsaturated zone as possible. Even within an area of condensation outside the boiling zone, this high relative humidity (water availability) cannot be changed in any substantive way relative to microbial activity because increases from 99.9% to 100% relative humidity represent negligible increases compared to thresholds for limitations to microbial activity (i.e., water films readily form in the current ambient saturated zone conditions). The condensation zone may have slightly higher water content because water will condense in the fractures at 100% relative humidity, but this mass of water represents only an insignificant increase in the water content of the ambient host rock (SAR Section 2.3.2.2.2.6, p. 2.3.2-15). Although the fracture porosity may have higher water content (possibly saturated in the condensation zone), the fracture porosity in these rocks of the repository horizon is only about 1% (SAR Table 2.3.2-4). This additional water (even with imbibition into the pore space) does not represent a substantial increase in the water content of the host rock over the ambient water content that is contained in the ambient

host rock matrix pores, which are about 90% saturated (SAR Figure 2.3.2-34). Thus, the overall effect of boiling within the host rock (dry-out zone and condensation zone considered in an integrated fashion) is estimated to provide some reduction in microbial activity over the ambient condition, and at the very least provide no enhancement over ambient microbial activity.

It is only necessary to have a single limiting aspect to constrain microbial activity, whereas there are three primary limitations to microbial activity that apply within the unsaturated zone. These limitations are thermal effects within the boiling zone, limited water availability (lower relative humidity) within the boiling zone, and nutrient limitations throughout the unsaturated zone (BSC 2004). Because the condensation zone does not represent a zone of increased water availability for microbial activity during the postclosure period, these limitations indicate there should be a minor net reduction in microbial activity in the rock. This is the fundamental basis for the conclusion that microbial activity within the unsaturated zone rock is bounded by the measures of ambient microbial activity at the site and nearby similar lithologic units (BSC 2004, Section 6.5, p. 6-36, first bullet in the introduction), meaning that the ambient unsaturated system chemistry already encompasses any chemical effects from expected microbial activity in all aspects of the postclosure host rock. The postclosure changes to the unsaturated zone are not expected to enhance microbial activity; rather, they should provide additional limits on microbial activity beyond the limitations in the ambient system.

No chemical effects beyond those already captured in the ambient unsaturated system chemistry are expected in the unsaturated host rock. This is why the primary FEP screening justifications regarding microbial activity effects on chemistry focus on the potential additional perturbations within the emplacement drifts that may directly affect the EBS (e.g., FEP 2.1.10.01.0A, excluded—low consequence) and/or may directly contribute to physico-chemical changes in the unsaturated zone that relate most directly to radionuclide transport (e.g., FEP 2.2.09.01.0B, excluded—low consequence). In summary, the condensation zone will not represent increased water availability from the standpoint of microbial activity limitations, within the boiling zone thermal effects and limited water availability (lower relative humidity) will decrease microbial activity for a period of time in postclosure, and throughout the unsaturated zone nutrient limitations will constrain microbial activity. Therefore, microbial activity in the postclosure host rock (including the condensation zone) will remain at ambient levels, or less.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2004. *Evaluation of Potential Impacts of Microbial Activity on Drift Chemistry*. ANL-EBS-MD-000038 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041118.0005.

SNL (Sandia National Laboratories) 2008. *Features, Events, and Processes for the Total System Performance Assessment: Analyses*. ANL-WIS-MD-000027 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080307.0003.