GG-1: RADIOLYSIS OF BRINE
Summary Memo of Record

Date: October 10, 1995

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Subject: FEP Screening Issue GG-1

STATEMENT OF SCREENING DECISION

FEP Screening Issue GG-1 need not be included in future system-level performance assessment calculations.

STATEMENT OF SCREENING ISSUE

This screening effort evaluates the need for inclusion of radiolytic gas generation in future system-level performance assessment calculations. The production of gas in the WIPP disposal rooms will occur as a result of corrosion processes, microbial activity, and radiolysis. Although corrosion processes and microbial activity have the greatest potential to produce significant volumes of gas, radiolysis of brine in the disposal rooms and radiolysis of water in the waste will lead to additional gas production. Prior performance assessment calculations have not included this additional gas production. Disposal system performance may be adversely affected if radiolytic gas generation leads to significantly greater pressures. Significantly greater fluid pressures will influence the porosity of the waste-filled regions, inhibit room closure, and/or cause fractures to be created or reopened in the interbeds within the Salado. An associated screening issue is uncontrolled fluid flow to the surface (blowout) during an intrusion into the repository. The volume of uncontrolled releases to the surface due to cuttings, spalling, and blowout during drilling is influenced by the prevailing pressure, permeability, and saturation conditions in the disposal room at the time of intrusion.

APPROACH

A model was implemented in BRAGFLO to estimate disposal region radiolytic gas generation. This model accounts for the formation of H_2 and O_2 by radiolysis of H_2O according to the conservation equation:

$$\text{Energy} + 2H_2O \rightarrow 2H_2 + O_2$$

The energy required to separate water comes from ejected alpha particles. Alpha particles have energies of approximately 5 MEV and the approximate number of molecules of H_2O separated per EV is 1.25×10^{-2}. Therefore, each alpha decay particle splits approximately 6×10^4 molecules of water (Brush, 1993). Since gas generation is limited by the availability of H_2O, gas generation is limited by the quantity and distribution of brine in the waste resulting from initial brine saturation, brine flow into and out of the disposal region, and brine consumption due to corrosion and microbial action. Radiolysis of H_2O by 15 isotopes of thorium, plutonium, uranium, and Am241 was considered in the calculations. The formation O_2 gas during radiolysis was not included in the gas generation calculations. This treatment is based on the assumption that all of the produced oxygen will react with metal materials and other contents of the waste disposal region. Physical properties of all gas components in BRAGFLO correspond to those of H_2.

A series of BRAGFLO simulations were performed to assess the magnitude of the influence of the radiolysis of brine on contaminant migration to the accessible environment. Effects of all other FEP issues were disabled in the simulations. Two basic scenarios were considered in the screening analysis, undisturbed performance and disturbed performance. Both scenarios included a 1.0 degree formation dip downward to the south. Intrusion event E1 is considered in the disturbed scenario and consists of a borehole that penetrates the repository and pressurized brine in the underlying Castile Formation. Two variations of intrusion event E1 are examined, E1 Up-Dip and E1 Down-Dip. In the E1 Up-Dip event the modeled panel region is located on the up-dip (north) side of the borehole, whereas in the E1 Down-Dip event the modeled panel region is located on the down-dip side (south) of the borehole. These two E1 events permit evaluation of the possiblity of increased brine flow into the panel region down dip of the borehole and the potential for subsequent impacts on contaminant migration. To incorporate the effects of uncertainty in each case (E1 Up-Dip, E1 Down-Dip, and undisturbed), a Latin hypercube sample size of 20 was used resulting in a total of sixty simulations. To assess the sensitivity of system performance on gas generation by radiolysis, conditional complementary cumulative distribution functions (CCDFs) of normalized contaminated brine releases to the Culebra via human intrusion and shaft system, as well as releases to the subsurface boundary of the accessible environment, were constructed and compared to the corresponding baseline model CCDFs. These comparisons provide direct information about how the inclusion of radiolysis may influence repository performance. In addition, blowout related performance measures were examined and included volume averaged brine pressures, brine saturations, porosity, and permeability in the waste disposal area.

RESULTS AND DISCUSSION

CCDFs for releases to the Culebra and subsurface boundary of the accessible environment for E1 Up-Dip, E1 Down-Dip, and undisturbed cases are provided in Figure 4 in Appendix 1 of the records package entitled "FEPs Screening Analysis for FEPs GG-1 and S-7". Each figure compares CCDFs of normalized releases predicted by the baseline model and normalized releases predicted with radiolysis. Note that releases to the Culebra via the shaft and intrusion borehole are shown on the left side of the figure whereas releases to the subsurface boundary of the accessible environment are presented on the right side of the figure. In the E01-Down and E01-Up cases, the radiolysis curves for releases to the Culebra via the shaft and borehole are below and to the left of the baseline curves for their entire lengths. In the undisturbed case, the radiolysis and baseline CCDFs are essentially identical for their entire lengths. Releases to the accessible environment via the Marker Beds are on the right side of Figure 4. In the E01-Down case, the radiolysis CCDF coincides with the baseline CCDF for almost half of its length with the latter half located to the right of the baseline CCDF. Although in the E01-Down case the radiolysis model predicts higher releases to the subsurface boundary than the baseline model, the differences are not significant as indicated by the relative positions of the CCDFs. In the E01-Up case, the radiolysis and baseline CCDFs are again close to each other with the radiolysis CCDF located to the left of the baseline CCDF for the higher releases. In the undisturbed case, the radiolysis CCDF is above the baseline CCDF for only a short range of small releases, but is located to the left of the baseline CCDF for the larger releases. In summary, the CCDFs for releases to the Culebra and subsurface boundary of the accessible environment indicate that differences between predicted baseline and radiolysis releases are minor.

Blowout metrics including maximum, mean, medium, and minimum values of volume averaged brine pressures, brine saturations, porosity, and permeability in the waste region for undisturbed conditions at 100, 1000, and 10000 years are given in Table 3 of Appendix 1. Comparison of these table values with the baseline values given in Table 2 indicate that differences in brine pressures and saturations are minor for times of 100 and 1000 years. At 10000 years the radiolysis brine pressures tend to be higher with the difference between baseline and radiolysis maximum brine pressures being the only appreciable difference. These pressures exceed the regulatory limit of 15 MPa; pressures above this limit do not have to be considered for direct releases due to drilling activities. Therefore, baseline and radiolysis releases (for the maximum pressure tabulated) will be nearly equivalent since the differences between the other metrics (drivers) are insignificant. In addition, at other pressure values, mean and median brine saturations for radiolysis are to low to permit uncontrolled releases of appreciable brine due to blowout (See Records Package for FEP DR-4). In summary, the baseline model is conservative with respect to releases due to blowout, spallings, and cuttings.

It was noted above that the baseline and radiolysis maximum brine pressures at 10,000 years (see Table 2) are different. Blowout calculations were performed to determine if this difference impacted releases to the surface. CCDFs comparing brine releases due to blowout for the baseline and radiolysis models are shown in Figure 6. As shown, the baseline CCDF is above and to the right of the radiolysis CCDF for all releases. Therefore, the baseline model is conservative with respect to releases at 10,000 years.

Additional results comparing amounts of H_2 generated in the waste room due to radiolysis, biodegradation, and corrosion are presented in Figures 7-10. These results are based on conservative radionuclide solubilities. Additional analysis supporting the elimination of radiolytic gas generation from future system-level performance assessment calculations is provided in Appendix A.

BASIS FOR RECOMMENDED SCREENING DECISION

Results indicate that radiolysis does not significantly impact releases to the accessible environment. In addition, radiolysis does not significantly impact waste room conditions relevant uncontrolled release due to blowout, cuttings, and spalling. Therefore, radiolysis need not be included in system-level PA calculations.