GENERAL

RADIOLOGICAL CONSEQUENCES OF BRINE RELEASE BY HUMAN INTRUSION INTO WIPP

WESTINGHOUSE ELECTRIC CORPORATION
WIPP PROJECT, ADVANCED ENERGY SYSTEMS DIVISION
ALBUQUERQUE, NEW MEXICO

by
S. W. Woolfolk
W. Baer

ABSTRACT

This paper presents an analysis of the impact of the release of radioactivity by the establishment of a conduit between a pressurized brine pocket through a transuranic (TRU) waste storage area to the surface. The scenarios evaluated the maximum credible long term release scenario for a TRU repository in bedded salt. Based on the results of these analyses, it is apparent that the potential long term releases from a bedded salt TRU disposal site have minimal impact on the public's health and safety.

INTRODUCTION

The WIPP Site is located in southeastern New Mexico about 26 miles from the city of Carlsbad and is planned as a geological disposal site for defense TRU-waste. The storage area will be located about 2150 below ground in a bedded salt formation. Due to the intersection of a brine reservoir by a borehole located about one mile north of the site center, the presence of a brine reservoir extending beneath the storage area is assumed in these analyses. The human intrusion drilling scenarios analyzed at WIPP assume that a brine pocket is located beneath the section of the storage area involved in these intrusion scenarios.

These types of scenarios would be applicable to any bedded salt repository where there is a significant potential for pressurized brine pockets beneath the storage area. With the exception of the WIPP-Site specific data, these analyses may be directly applicable to other sites in bedded salt.

To assure the adequacy of the analyses, two limiting potentially credible low probability scenarios were chosen for evaluation. The analysis of these two scenarios is described in detail in Reference 1. The only inadvertent human intrusion scenarios considered credible at the WIPP Site are drilling activities associated with mineral exploration or oil and gas recovery. Analyses of similar scenarios have been reported by others.[2,3]

Each scenario evaluated considers an inadvertent human intrusion into the storage area 250 years after closure of the facility. Such occurrences are deemed extremely unlikely since this would require the loss of information on the location of the WIPP Site within 250 years.

This analysis does not consider human intrusion, based on a cognitive decision by society, to be relevant to this analysis. Therefore, the intentional unconditional release of this site by the government or the relaxation of control of this area by the government are not considered as possible precursors for occurrence of the postulated scenarios. Such actions imply a decision by the then existing government that the level of risk associated with such a release of this area is acceptable.

SCENARIO I

Description of Scenario I

This scenario assumes the existence of a brine pocket beneath the WIPP site (see Figure 1). After loss of control of the site, 250 years after closure, it is assumed that a 15-inch hydrocarbon recovery/exploration drill hole is drilled through the storage area. The material removed during drilling is released to a drilling fluid pond. In addition, the drill hole strikes a brine pocket located beneath the site which flows brine for approximately 24 hours before the flow is stopped by action of the drilling crew. Any radioactive material brought to the surface by the flowing brine is deposited in the drilling fluid pond. Following termination of drilling activities, the drilling fluid pond is allowed to dry and, during this period, radioactive material is resuspended from its surface. Once the drilling fluid pond has dried, it is covered with soil.

It is assumed that the maximum individual lives on a self-sufficient farm located at the worst case location. The maximum individual's potential 50 year dose commitment was determined in this analysis. The potential fifty year dose commitment to the workers at the site and the surrounding population is also evaluated. No changes in climate, activities, or population of the areas within 50 miles of the site are assumed, since the results of these analyses will be used for comparison with existing operational accident analyses.

Geotechnical Analyses

The geotechnical analysis of this intrusion was completed in "Analysis of Potential Impacts of Brine Flow Through Boreholes Penetrating the WIPP Storage Facility" by D'Appolonia Consulting Engineers, Inc.[4] This analysis indicated, that due to

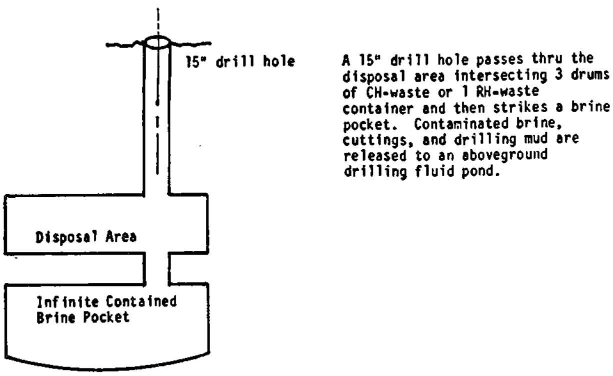


Fig. 1. Brine Scenario I.

geotechnical properties of the backfilled waste and the storage room 250 years after emplacement, no waste material would be eroded from the storage area by the flow of brine through a drill hole. Thus the only material which will be released to the environment is the material brought to the surface during drilling activities. This material is that contained in the drill hole cross section, with a small percentage added to assure conservatism. Since drilling techniques would tend to compress the material in the storage area back into the waste matrix, these assumptions are clearly conservative.

"For the purposes of the consequence analysis, the conditions in existing wells in the area have been assumed. The brine reservoir is assumed to have the following characteristics, based on empirical data [where available]:

depth -- . . . [990.6 meters]
size -- infinite
pressure -- lithostatic before penetration . . . [(1.27×10^7 PA)]
content of brine -- saturated with salt
maximum potential discharge to well -- . . . [2.39×10^6 liters per day][4]

The intrusion is made during a hydrocarbon recovery/exploration operation. The drill hole characteristics are:

" . . .diameter -- . . . [3.81×10^1]
drilling methods -- normal or reverse circulation rotary ...."[4]

Source Term Characteristics

The source of activity for Scenario I is the radioactive material brought up during drilling and any radioactive material flushed out or dissolved from the storage area. As discussed in the Geotechnical Analyses Section, only material brought to the surface during drilling contributes significantly to this scenario. All released material flows into the drilling fluid pond at the drilling site. The waste is assumed to consist of 55-gallon drums of INEL defense TRU waste with external contact dose rates of less than 1×10^{-3} Sv/hr. The analysis assumes that there is no container integrity after 250 years in storage.

Once drilling is completed the drilling fluid pond is allowed to dry, which normally takes 0.5 to 2 years in the Carlsbad area. Once the drilling fluid pond has dried, it is assumed that standard *drilling practices* are followed and the pond is covered. When the drilling fluid pond is covered it will cease to be a significant source of release of radioactive material. Due to the complexity of the indirect pathways, a significant dilution of any release would occur, and the radiological impact of these pathways would be substantially less than those which are analyzed in this report. The only potentially significant release impact would be future direct human intrusion into the buried material. The consequences of this additional direct human intrusion would simply be a scaled-down version of this analysis, since only part of the material would be brought to the surface and then resuspended.

Activity Content

The source of all released activity will be the waste mixed with saturated brine and drilling mud in the drilling fluid pond. Only the material from the drill hole and 48.1 m^3 of brine from the reservoir which flowed through the drill hole contribute to the material in the drilling fluid pond. The contribution from 48.1 m^3 of brine is not significant since it contains several orders of magnitude less activity than the suspended material from the drill hole.

The isotopic inventory of the radioactive material within each container is based on the percentages given in Appendix E of the WIPP FEIS. The total radioactivity released is summarized in Table I.

TABLE I
Activity For the First Year (BQ)[5,6]

			RESUSPENDED ACTIVITY		
Isotope	Release of Activity	From Pond	From Drilling Mud (During Evaporation)	From Drilling Mud (During Recovery)	Total
Pu-238	2.58+9	2.58+2	3.26+5	2.97+7	3.00+7
Pu-239	2.16+11	2.19+4	2.76+7	2.52+9	2.52+9
Pu-240	5.25+10	5.25+3	6.62+6	6.07+8	6.14+8
Pu-241	2.56+6	2.56-1	3.23+2	2.95+4	2.99+4
Am-241	2.91+10	2.91+3	3.67+6	3.36+8	3.39+8

Erosion and Resuspension[5,6]

The radioactive material will be in a brine drilling mud matrix in the drilling fluid pond. Material will be resuspended from the liquid in the pond and from the evaporite and solidified drilling mud. It is assumed that the rate of evaporation is constant, so that during this period the applicable resuspension factors can be applied for the liquids for 1 year and for the solids for 1 year. The activity resuspended during the evaporation period is treated as though this activity is resuspended in a single year.

Liquid Resuspension

It is assumed that the dissolved species resuspend at the same rate as the plutonium in a plutonium nitrate solution. Based on existing experimental data, approximately 1×10^{-5} percent of the plutonium dissolved in the brine will be resuspended from the liquid during evaporation. This number is extremely conservative, since most of the plutonium in the drilling fluid pond will be associated with the suspended solids in the liquid which will sink rapidly to the bottom of the pond and will be unavailable for resuspension. The total resuspended material is summarized in Table I.

Solid Resuspension-Erosion

The solids produced during drying of the drilling fluid pond will be in the form of salt-evaporite and solidified drilling mud. The salt-evaporite is a crystalline material which would be extremely resistant to resuspension or wind erosion. The solidified drilling mud is very similar to claystone and is also resistant to resuspension or wind erosion. For purposes of this analysis, a resuspension factor of $4X10^{-11}$ sec^{-1} is used.[5] This value is in the lower range for soil, but very large for this material. In addition, it is assumed that only the top 1 centimeter of the 10 centimeters of deposited material is available for resuspension. The resuspended activity is summarized in Table I.

When the drilling fluid pond has dried it will be covered with soil using heavy equipment. The drilling fluid pond is covered by pushing the berm in from the outside so there will be little or no disturbance of the deposited material. However, to assure conservatism, it was assumed that the mechanically enhanced resuspension factor increases to $1X10^{-6}$ sec^{-1} during the 32 hours it takes to cover the pond (see Table I). It should be noted that the workers are present only during the two 8 hour shifts they are working, although the material will be exposed for 32 hours.

Failure to cover the drilling fluid pond was evaluated. Because of the conservative assumption discussed in the previous paragraph, this evaluation indicated that not covering the drilling fluid pond decreases the fifty year dose commitment by a factor of 3 compared to exposure from the covered pond. It is recognized that this is an artifact of the conservatism of the analyses and it is preferable to cover the drilling fluid pond.

Consequence Analysis

This scenario considers the release from the drilling fluid pond which is treated as a one acre circular source of resuspended radioactive material. The airborne concentration, ground deposition, inhalation doses, and ingestion doses are calculated using AIRDOS-EPA. The distances from the brine pond used in the analysis ranged from 20 to 80000 meters. The maximum individual's locations is the worst case location for the locations analyzed. This location is 500 meters from the brine pond.

Meteorology

Meteorological conditions are based on weighted averages for the WIPP site. These data are used as input to AIRDOS-EPA and generate the meteorological matrix with which the doses are evaluated.

Ingestion-Inhalation Pathway

The doses received by ingestion and inhalation are calculated by AIRDOS-EPA using the dose conversion factors from the work at Oak Ridge National Laboratory.[8] The balance of the input to the program generally comes from site specific data, Regulatory Guide 1.109[9] and the AIRDOS-EPA Manual. The site specific population data for humans, beef and dairy cattle, and the agricultural and water immersion data are based on the data reported in the WIPP FEIS.[10] A number of the environmental parameters are based on the published range of experimental results.[11]

For conservatism, the particle size distribution is assumed to consist entirely of $3x10^{-5}$ cm diameter particles. The ingestion pathway dose is not included in the doses specified for workers at the job site.

The doses are summarized in Table II. It should be noted that the inhalation pathway represents more than 99% of the dose for all significant doses to the various organs and the total body and at least 90% of the others.

Table II
Doses for Scenario I

	Total Body	Endostial Cells	Red Marrow	Lungs	Kidney	Testes/ Ovaries
	50-Year Dose Commitment (S_v)					
Maximum Individual	9.2-4	2.2-2	1.7-3	3.4-3	5.6-4	9.2-4
Worker	1.3-3	3.1-2	--	4.6-3	--	--
Natural Background (per individual)	5.0-2	--	5.0-2	9.0-2	--	--
	50-Year Dose Commitment (Person-S_v)					
Population (50 mile radius)	6.9-2	1.7+0	1.2-1	2.5-1	4.2-2	6.9-2

External Exposure

Based on previous analyses in the WIPP SAR[12] and the preliminary results of this analyses,[1] no external exposure is included for members of the public or workers since these numbers are not significant when compared with the inhalation and ingestion pathway doses.

Inhalation Exposure of Workers

The maximum worker inhalation exposures use the same basic assumptions and methods used in assessing the maximum individual's dose except:

1. the worker is assumed to be at the job site 2500 hours per year;
2. the worker is located at an average distance of 20 meters from the drilling fluid pond;
3. the worker is present for 16 of the 32 hours during the covering of the drilling fluid pond; and
4. core inspection produces a 30 minute inhalation exposure.

The core inspection doses totally dominate worker exposures. The inclusion of this possible scenario is very conservative, since the storage area is well above strata which are normally cored in hydrocarbon exploration and below those normally cored for potash exploration.

Summary of Scenario I Consequence Analysis

As is clearly indicated, the 50 year dose commitments received by the maximum individual and the general population from the inadvertent human intrusion analyzed in this analysis are not significant when compared to existing natural background in this area (see Table II). It should be pointed out that the projected dose received by the maximum worker would be well within the acceptable yearly doses received by workers in the nuclear industry.

In addition, it is clear from the extremely unlikely events necessary to cause this intrusion that the probability of the occurrence of this scenario is extremely small.

Even if the events postulated to generate this scenario occurred, the probable actions or probable conditions after the event would substantially mitigate the consequences. For example:

1. when the drill strikes the waste storage area, it would become apparent to the drilling crew that they had hit an area which is not consistent with the existing geology, based on the behavior of the drill string and the loss of drilling fluid circulation; and

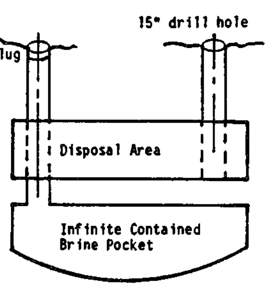
2. the drilling crew may be unable or unwilling to take the necessary action to maintain drill fluid circulation after they strike the storage area and may elect to abandon or case the hole.

The analysis indicates that the potential risk from this scenario is insignificant. Therefore, the impact of this scenario represents a minimal level of risk to transfer to future generations for the benefit of isolation from the biosphere of waste stored at WIPP.

SCENARIO II

Description of Scenario II

This scenario assumes the existence of a brine pocket beneath the WIPP site (see Figure 2). After loss of control of the site, 250 years after closure of the WIPP site, it is assumed that a 38.1 cm inch hydrocarbon recovery/exploration drill hole is drilled through a storage room and then into a brine pocket. This intrusion produces the same effects as Scenario I. The drill hole is plugged above the storage area and brine fills the storage area. When the brine reaches equilibrium concentration with the americium and plutonium dioxide present (less than 20 years after initial instrusion), a second hole is drilled through the same area. Brine will then flow through the first drill hole, through the storage area and finally will flow through the second hole to the surface. This flow is assumed to continue for 24 hours. The material removed by the drill and brought up by the brine is placed in the drilling fluid pond. The remaining assumptions for Scenario II are the same as those in Scenario I.



A drill hole is drilled through the storage areas and intersects a pressurized brine pocket.[2] This hole is then plugged above the storage room. After the system has re-established equilibrium, a 15" drill hole intersects the storage area. A quantity of contaminated brine is released to an aboveground pond.

Total container failure is assumed. In addition, the initial penetration constitutes a Scenario I event.

There would be substantial change in this scenario based on whether a plug is placed between the brine pocket and the facility when the first drill hole is plugged. Although this plug could exist, it is assumed not to be present. This would effectively limit the brine source so it would not flow to the surface when the storage area is struck or would flow for a substantially reduced period.

Fig. 2
Brine Scenario II

Geotechnical Assessment of the Total Brine Release to the Surface

The geotechnical analyses are described in Reference 4 with supporting information from Reference 13.

The geotechnical analyses indicate the following would be brought to the surface as a result of this intrusion.

"- contaminant-saturated brine - ... [3.19X10^3 m^3]
- crushed salt (disregarding settlement from the borehole after transient flow) - ... [8.61 m^3]
- waste (disregarding settlement from the borehole after transient flow) - ... [9.69 m^3]"[4]

Source Term Characteristics

The source terms for Scenario II will be the same as in Scenario I, except that the brine released to the drilling fluid pond will be saturated with dissolved plutonium and americium and 1500 liters of waste will be swept out by the brine flow. The activity released to the drilling fluid pond is summarized in Table III.

Table III
Activity Released In Scenario II (BQ)

	Activities Released to the Drilling Fluid Pond			Activity Released from the Drilling Fluid Pond			
Source	Brine	Waste	Total	Liquid	Mud	Pit Recovery	Total
Isotope							
Pu-238	3.70+8	1.48+10	1.52+10	1.52+3	1.92+6	1.74+8	1.78+8
Pu-239	3.15+10	1.26+12	1.30+12	1.30+5	1.63+8	1.48+10	1.52+10
Pu-240	7.77+9	3.30+11	3.10+11	3.11+4	4.07+7	3.58+9	3.63+9
Pu-241	3.70+5	1.48+07	1.52+7	1.51+0	1.92+3	1.74+5	1.78+5
Am-241	8.14+9	1.70+11	1.78+11	1.78+4	2.22+7	2.11+9	2.15+9

Consequence Analysis

The dose consequence analysis is identical to Scenario I's except that additional activity is released (see Table III). The relationship between dose and released activity is a direct proportionality. Thus, the doses for Scenario II (see Table IV) are simply the ratio of the released activity times the doses from Scenario I.

Summary of Scenario II Consequence Analysis

The 50 year dose commitments received by the general population and the maximum individual from the inadvertent human intrusions analyzed are not significant when the doses are compared to existing natural background in this area (see Table IV). The significance of the worker doses is the same as discussed in the Summary of Scenario I Consequence Analysis section.

The probability of occurrence of this scenario is substantially smaller than that for Scenario I, since:

1. two drill holes must be drilled into the same storage unit to obtain the maximum release; and
2. the scenario assumes that no plug between the brine pocket and the storage area exists for the first drill hole.

Therefore, based on this analysis, the potential risk from this scenario is clearly not significant and represents a minimal level of risk when compared to the benefits provided by WIPP.

Table IV
Doses for Scenario II

	Total Body	Endostial Cells	Red Marrow	Lungs	Kidney	Testes/ Ovaries
	50-Year Dose Commitment (S_v)					
Maximum Individual*	5.6-3	1.3-1	9.8-3	2.2-2	3.3-3	5.6-3
Worker	2.8-3	6.5-2	4.9-3	1.1-2	1.7-3	2.8-3
Natural Background (per individual	5.0-2	--	5.0-2	9.0-2	--	--
	50-Year Dose Commitment (Person-S_v)					
Population* (50 mile radius)	4.1-1	9.9+0	7.3-1	1.5+0	2.5-1	4.1-1

*This includes doses for both the 1st and 2nd drill holes and associated activities.

CONCLUSIONS

This analysis has evaluated the two limiting credible scenarios for human intrusion into the WIPP storage area after closure of the facility. The scenarios both involve intersection of a pressurized brine pocket. Based on the consequences and probability of these scenarios, it is apparent that the presence of a brine pocket beneath the site does not significantly increase the risk associated with the disposal of radioactive waste at WIPP.

The results of this analysis were also compared with the release limits specified for the first 10,000 years after closure in draft of 40 CFR 191.[14] Table V indicates that WIPP meets the proposed standard, since human intrusion scenarios describe the only mechanism which releases any activity to the accessible environment within 10,000 years after closure.[15] In fact, Scenario I would have to occur 14 times to exceed the proposed "reasonably foreseeable release" limit and 138 times to exceed the "very unlikely release" limit. Scenario II would have to occur 20 times to exceed the proposed applicable release limit for a very unlikely release (see Table V). This analysis indicates that WIPP is in compliance with the release limits proposed by the EPA in 40 CFR 191.

Table V
Activity Released to the Environment
In First 10,000 Years (BQ)

	PU-239	AM-241	PU-240
Brine Scenario I	2.22+11	2.96+10	5.18+10
Brine Scenario II	1.30+12	1.78+11	3.11+11
	Applicable 40 CFR 191 Limit (Draft 21)		
Reasonably Foreseeable Releases	1.03+13	1.03+12	1.03+13
Very Unlikely Releases	1.03+14	1.03+13	1.03+14

ACKNOWLEDGEMENT

This work was performed under DOE Contract DE-AC04-78AL5346 with the Westinghouse Electric Corporation.

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