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MEMORANDUM FOR: Malcolm Knapp, Chief
Geotechnical Branch
Division of Waste Management

FROM: Richard Codell
Hydrology Section
Geotechnical Branch
Division of Waste Management

SUBJECT: COMPARISON OF CHEMICAL AND RADIOACTIVE HAZARD OF SPENT FUEL

At your request, I have compared the chemical and radioactive hazard of spent fuel. The radioactive hazard was quantified in Ref 1 in terms of the Radioactive Untreated Dilution Index (RUDI) which is the quantity of water which must be added per metric tonne of heavy metal (MTHM) in order to comply with 10 CFR 20 drinking water standards. I used 10-year old spent fuel (PWR) for this calculation.

A similar technique was developed to generate a Non-Radioactive Untreated Dilution Index (NUDI), using chemical water quality standards. The quantity of each element per MTHM of 10-year old PWR fuel was defined in Ref 1. Water quality standards were taken from 3 sources, Ref 2, 3, and 4. There were only a few elements for which I could find standards, however. A default value of 0.05 mg/l was chosen for all elements for which I could not find a standard. This value is probably conservatively small in practically all cases, since it is likely that there would be a defined standard if the element presented an unusually great hazard.

The computations are summarized in Table 1. Only elements present in quantities greater than 1.0 gram/MTHM were considered. The elements C, Al, Si, P, and S were also eliminated because they are ubiquetous in the biosphere and are unlikely to be hazardous in most situations.

The element Zr was eliminated because no standard has been set for it, and there is so much of it present in spent fuel (structural material and cladding) that using the default standard of 0.05mg/l would distort the results. It is also a corrosion-resistant material and unlikely to dissolve in the waste to any large degree.

The results of the calculations shown in Table 1 indicate that the ratio of the non-radioactive/radioactive hazard is only about 6.1×10^{-6} even with the choice of conservative non-radioactive water standards. At 10,000 years after burial, the chemical hazard would be expected to remain about the same because

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the largest contributors to the chemical hazard do not decay appreciably, and the decay products themselves are expected to be about as hazardous as the parents. The radiological hazard however would decrease, with a UDI of about 10^8 m^3/MTHM. The non-radiological/radiological hazard at 10,000 years is therefore expected to increase to 0.012, which is still an insignificant fraction.

The largest contributors to the non-radioactive hazard were Ni, U and Pu. Only Ni has a bona fide standard. There is no EPA standard for U or Pu, although there is a Wyoming water standard for U. The default standard of 0.05 mg/l was used for Pu.

Richard Codell
Hydrology Section
Geotechnical Branch
Division of Waste Management

References

1. U.S. Environmental Protection Agency, "Technical Support of Standards for High-Level Waste Management", EPA 520/4-79-007A, U.S. E.P.A., Washington, DC 20460, 1978

2. U.S. Government, Code of Federal Regulations, Title 40 Part 143.3, July 1, 1982

3. Federal Register, Vo. 45, No. 231, Nov. 28, 1980, pp. 79318-79341

4. Wyoming Water Quality Rules and Regulations, Chapter 8, Table 1, April 9, 1980, Summarized in "DES Related to the Operation of the Teton Project", NUREG-0925, June 1982

cc: M. Weber
M. Bell
R. Browning
J. Starmer
P. Justus
H. Miller

RC

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Table 1 - Untreated Dilution Index to Comply With Water-Quality Standards for Chemicals

Element	Grams/MTHM*	Standard mg/l	Reference**	Dilution, liters***
Ti	56	.05	D	1.1E6
V	2.8	.05	D	5.6E4
Cr	2000	.05	A,B,C	4E7
Mn	105	.05	D	2.1E6
Fe	3.97E3	. 3	B	1.3E7
Co	64	.05	D	1.3E6
Ni	3700	.0134	B	2.8E8
Cu	19	1	B,C	1.9E4
Sr	770	.05	D	1.5E7
Y	460	.05	D	9.2E6
Nb	323	.05	D	6.5E6
Mo	3670	.05	D	7.3E7
Tc	840	.05	D	1.7E7
Ru	2170	.05	D	4.34E7
Cd	90	.01	A,C	9E6
In	1.2	.05	D	2.5E4
Sn	1880	.05	D	3.8E7
Sb	1.7	.05	D	3.4E7
Te	580	.05	D	1.2E7
U	9.55E5	5	C	1.91E8
Np	470	.05	D	9.4E6
Pu	8970	.05	D	1.8E8
Am	600	.05	D	1.2E7

Element	Grams/MTHM*	Standard mg/l	Reference**	Dilution, liters***
Cm	17	.05	D	3.4E5
Se	52	.01	A,B,C	5.2E6
Br	15	.05	D	3.1E6
Rb	340	.05	D	6.8E6
Pd	1470	.05	D	2.9E7
Ag	62	.05	A,B	1.2E6
I	270	.05	D	5.4E6
Cs	2250	.05	D	4.5E7
Ba	1790	1.0	C	1.8E6
La	1270	.05	D	2.5E7
Ce	2480	.05	D	5.0E7
Pr	1190	.05	D	2.4E7
Pm	9	.05	D	1.7E5
Sm	900	.05	D	1.8E7
Eu	160	.05	D	3.2E6
Gd	150	.05	D	3E6
Tb	1.9	.05	D	3.7E4
Rh	390	.05	D	7.8E6
Nd	4100	.05	D	8.2E7
Total	1.4×10^6 gm			1.2×10^9 liters

*From EPA 52014-79-007A, Table A-IV-2, for 10-year old fuel. Only values greater than 1 g/MTHM reported. Elements C, Al, Si, P, S and Zr eliminated.

**References for water standards

A. 40 CFR 143.3
B. Federal Register, Vol 45, No. 231, Nov 28, 1980, pp 79318-79341
C. Wyoming Water Quality Rules and Regulations Chapter 8, Table 1, April 9, 1980
D. Default value

*** Dilution = (grams element)/(Standard, grams/liter) = liters

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Calculations

1. Nonradioactive Untreated Dilution Index = $1.2*10^9$ liters

2. Radioactive Untreated Dilution Index = $2x10^{11}$ m^3 for 10-year old PWR fuel (EPA-520/4-79-007A, Fig A6)

   so = (chemical/radioactive) hazard = $\frac{1.2x10^9}{2x10^{11}x1000} = 6.1x10^6$

3. At 10,000 years, UDI for chemical hazard will be about the same, but UDI for radiological hazard will decrease to about 10^8 m^2/MTHM.

   so (chemical/radiological) hazard = $\frac{1.2x10^9}{10^8x1000} = 0.012$

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