Attachment 1

IMPACT OF THE URANIUM FUEL CYCLE

5. Radioactive Effluents

Radioactive effluents estimated to be released to the environment from reprocessing and waste management activities and certain other phases of the fuel cycle process are set forth in Table S-3. Using these data, the staff has calculated the 100-year involuntary environmental dose commitment* to the U.S. population.

*The environmental dose commitment (EDC) is the integrated population dose for 100 years; that is, it represents the sum of the annual population doses for a total of 100 years. The population dose varies with time, and it is not practical to calculate this dose for every year.

These calculations estimate that the overall involuntary total-body gaseous dose commitment to the U.S. population from the fuel cycle (excluding reactor releases and the dose commitment due to radon-222) would be approximately 400 person-rems per year of operation of the model 1000-MWe LWR. Based on Table S-3 values, the additional involuntary total body-dose commitments to the U.S. population from radioactive liquid effluents due to all fuel cycle operations other than reactor operation would be approximately 100 person-rems per year of operation. Thus the estimated involuntary 100-year environmental dose commitment to the U.S. population from radioactive gaseous and liquid releases due to these portions of the fuel cycle is approximately 500 person-rems (whole body) per year of operation of the model 1000-MWe LWR.

At this time Table S-3 does not address the radiological impacts associated with radon-222 releases. Principal radon releases occur during mining and milling operations and as emissions from mill tailings. The staff has determined that releases from these operations for each year of operation of the model 1000-MWe LWR are as given in Table C-1.

The staff has calculated population dose commitments for these sources of radon-222 using the RABGAD computer code described in Appendix A of Chap. IV, Sec. J, of NUREG-0002.[2] The results of these calculations for mining and milling activities prior to tailings stabilization are listed in Table C-2.

When added to the 500 person-rems total-body dose commitment for the balance of the fuel cycle, the overall estimated total-body involuntary 100-year environmental dose commitment to the U.S. population from the fuel cycle for the model 1000-MWe LWR is approximately 640 person-rems. Over this period of time, this dose is equivalent to 0.00002% of the natural background dose of about 3 billion person-rems to the U.S. population.*

The staff has considered the health effects associated with the releases of radon-222, including both the short-term effects of mining and milling, and active tailings and the potential long-term effects from unreclaimed open-pit mines and stabilized tailings. The staff has assumed that, after completion of active mining, underground mines will be sealed, returning releases of radon-222 to background levels. For purposes of providing an upper bound impact assessment, the staff has assumed that open-pit mines will be unreclaimed and has calculated that if all ore were produced from open-pit mines, releases from them would be 110 Ci per year per reference reactor year (RRY). However, because the distribution of uranium ore reserves available by conventional mining methods is 66.8% underground and 32.2% open pit, the staff has further assumed that uranium to fuel LWRs will be produced by conventional mining methods in these proportions. This means that long-term releases from unreclaimed open-pit mines will be 0.332 x 110 or 37 Ci per year per RRY.

*Based on an annual average natural background individual dose commitment of 100 millirems and a stabilized U.S. population of 300 million.

Table C-1 Radon releases for each year of operation of the model 1000-MWe LWR*

Radon source	Quantity released	Source
Mining	4060 Ci	a
Milling and tailings (during active mining)	780 Ci	b
Inactive tailings (prior to stabilization)	350 Ci	b
Stabilized tailings (several hundred years)	1 to 10 Ci/year	b
Stabilized tailings (after several hundred years)	110 Ci/year	b

[a]R. Wilde, U.S. Nuclear Regulatory Commission transcript of direct testimony given "In the Matter of Duke Power Company Company (Perkins Nuclear Station)," Docket No. 50-488, April 17, 1978.

[b]P. Magno, U.S. Nuclear Regulatory Commission transcript of direct testimony given "In the Matter of Duke Power Company (Perkins Nuclear Station)," Docket No. 50-448, April 17, 1978.

*After three days of hearings before the Atomic Safety and Licensing Appeal Board (ASLAB) using the Perkins record in a "lead case" approach, the ASLAB issued a decision on May 13, 1981 (ALAB-640) on the radon-222 release source term for the Uranium Fuel Cycle. The decision, among other matters, produced new source term numbers based on the record developed at the hearings. These new numbers did not differ significantly from those in the Perkins record, which are the values set forth in this Table. Any health effects relative to radon-222 are still under consideration before the ASLAB. Because the source term numbers in ALAB-640 do not differ significantly from those in the Perkins record, the staff continues to conclude that "both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared to dose commitments and potential health effects to the U.S. population resulting from all natural background sources." (see page C-6)

Table C-2 Estimated 100-year environmental dose commitment per year of operation of the model 1000-MWe LWR

Radon Source	Releases (Ci)	Dosage (person-rems) Total Body	Bone	Lung (Bronchial epithelium)
Mining	4100	110	2800	2300
Milling and active tailings	1100	29	750	620
Total	5200	140	3600	2900

Based on the above, the radon released from unreclaimed open-pit mines over 100- and 1000-year periods would be about 3700 Ci and 37,000 Ci per RRY respectively. The total dose commitments for a 100- to 1000-year period would be as follows:

Time span (years)	Releases (Ci)	Population dose commitments (person-rems) Total body	Bone	Lung (bronchial epithelium)
100	3,700	96	2,500	2,000
500	19,000	480	13,000	11,000
1,000	37,000	960	25,000	20,000

The above dose commitments represent a worst case situation in that no mitigating circumstances are assumed. However, state and Federal laws currently require reclamation of strip and open-pit coal mines, and it is very probable that similar reclamation will be required for uranium open-pit mines. If so, long-term releases from such mines should approach background levels.

For long-term radon releases from stabilized tailings piles, the staff has assumed that these tailings would emit (per RRY) 1 Ci per year for 100 years, 10 Ci per year for the next 400 years and 100 Ci per year for periods beyond 500 years. With these assumptions, the cumulative radon-222 release from stabilized tailings piles per RRY would be 100 Ci in 100 years, 4090 Ci in 500 years, and 53,800 Ci in 1000 years.[4] The total-body, bone, and bronchial epithelium dose commitments for these periods are as follows:

Time span (years)	Releases (Ci)	Population dose commitments (person-rems) Total body	Bone	Lung (bronchial epithelium)
100	100	2.6	68	56
500	4,090	110	2,800	2,300
1,000	53,800	1,400	37,000	30,000

If risk estimators of 136, 6.9, and 22.2 cancer deaths per million person-rems for total-body, bone, and lung exposures, respectively, are used, the estimated risk of cancer mortality resulting from mining, milling, and active tailings emissions of radon-222 is about 0.11 cancer fatalities per RRY. When this risk from radon-222 emissions from stabilized tailings over a 100-year release period is added, the estimated risk of cancer mortality over a 100-year period is unchanged. Similarly, a risk of about 1.2 cancer fatalities is estimated over a 1000-year release period per RRY. When potential radon releases from reclaimed and unreclaimed open-pit mines are included, the overall risks of radon induced cancer fatalities per RRY range as follows: 0.11 to 0.19 fatalities of a 100-year period, 0.19 to 0.57 fatalities for a 500-year period, and 1.2 to 2.0 fatalities for a 1000-year period.

To illustrate: a single-model 1000-MWe LWR operating at an 80% capacity factor for 30 years would be predicted to induce between 3.3 and 5.7 cancer fatalities in 100 yr, 5.7 and 17 in 500 yr, and 36 and 60 in 1000 yr as a result of releases of radon-222.

These doses and predicted health effects have been compared with those that can be expected from natural-background emissions of radon-222. Calculated using data from the National Council on Radiation Protection (NCRP)[5] the average radon-222 concentration in air in the contiguous United States is about 150 pCi/m^3, which the NCRP estimates will result in an annual dose to the bronchial epithelium of 450 millirems. For a stabilized future U.S. population of 300 million, this represents a total lung dose commitment of 135 million person-rems per year. If the same risk estimator of 22.2 lung cancer fatalities per million person-lung-rems used to predict cancer fatalities for the model 1000 MWe LWR is used, estimated lung cancer fatalities alone from background radon-222 in the air can be calculated to be about 3000 per year, or 300,000 to 3,000,000 lung cancer deaths over periods of 100 to 1000 years, respectively.

In addition to the radon-related potential health effects from the fuel cycle, other nuclides produced in the cycle, such as carbon-14, will contribute to population exposures. It is estimated that 0.08 to 0.12 additional cancer deaths may occur per RRY (assuming that no cure or prevention of cancer is ever developed) over the next 100 to 1000 years, respectively, from exposures to these other nuclides.

The latter exposures can also be compared with those from naturally occurring terrestrial and cosmic-ray sources. These average about 100 millirems. Therefore, for a stable future population of 300 million persons, the whole-body dose commitment would be about 30 million person-rems per year, or 3 billion person-rems and 30 billion person-rems for periods of 100 and 1000 years respectively. These dose commitments could produce about 400,000 and 4,000,000 cancer deaths during the same time periods. From the above analysis, the NRC staff concludes that both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared to dose commitments and potential health effects to the U.S. population resulting from all natural background sources.

6. Radioactive Wastes

The quantities of buried radioactive waste material (low-level, high-level, and transuranic wastes) are specified in Table S-3. For low-level waste disposal at land burial facilities, the Commission notes in Table S-3 that there will be no significant radioactive releases to the environment. The Commission notes that high-level and transuranic wastes are to be buried at a Federal repository and that no release to the environment is associated with such disposal. NUREG-0116,[6] which provides background and context for the high-level and transuranic Table S-3 values established by the Commission, indicates that these high-level and transuranic wastes will be buried and will not be released to the biosphere. No radiological environmental impact is anticipated from such disposal.

7. Occupational Dose

The annual occupational dose attributable to all phases of the fuel cycle for the model 1000-MWe LWR is about 200 person-rems. The NRC staff concludes that this occupational dose will not have a significant environmental impact.

8. Transportation

The transportation dose to workers and the public is specified in Table S-3. This dose is small and not considered significant in comparison to the natural background dose.

9. Fuel Cycle

The staff's analysis of the uranium fuel cycle did not depend on the selected fuel cycle (no recycle or uranium-only recycle), because the data provided in Table S-3 include maximum recycle option impact for each element of the fuel cycle. Thus the staff's conclusions as to acceptability of the environmental impacts of the fuel cycle are not affected by the specific fuel cycle selected.

10. References

Documents marked with one asterisk (*) are available for inspection and copying for a fee in the NRC Public Document Room, 1717 H Street, NW, Washington, DC 20555. Those marked with two asterisks (**) may be ordered from the National Techinical Information Service (NTIS), Springfield, VA 22161. Those marked with three asterisks (***) may be ordered from NTIS and/or the NRC/GPO Sales Program, Washington, DC 20555. Except as specifically noted, other documents cited may be obtained through public technical libraries.

(1) Council on Environmental Quality, "The Seventh Annual Report of the Council on Environmental Quality," September 1976, Figures 11-27 and 11-28, pages 238-239.**

(2) U.S. Nuclear Regulatory Commission, "Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light-Water-Cooled Reactors, USNRC Report NUREG-002, August 1976.***

(3) U.S. Department of Energy, "Statistical Data of the Uranium Industry," Report GJO-100(8-78), January 1978.**

(4) R. Gotchy, U.S. Nuclear Regulatory Commission, transcript of direct testimony given "In the Matter of Duke Power Company" (Perkins Nuclear Station)," Docket No. 50-448, April 17, 1978.*

(5) National Council on Radiation Protection and Measurements, "Natural Background Radiation in the United States," Publication No. 45, November 1975.

(6) U.S. Nuclear Regulatory Commission, "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," USNRC Report NUREG-0116 (Supplement 1 to WASH-1248), October 1976.

Table 1. Update of the Potential Health Impacts of Radon-222 Releases from Uranium Mining and Milling per RRY

Source Term (Ci)	Perkins Testimony of R. L. Gotchy (p.18 of the January 25, 1978 Testimony)	NUREG-0757 (Tables 11, 15 & 16)[a]	ALAB-640 (Table 3)	NUREG-0757 Releases with Latest BEIR III Health Effects Estimates
1. Uranium Mines (active mining)	4,100	3,820	5,200	(Same as Before)
- For 100 years after mine shut down	-	1,500	2,000 - 9,000*	
- For 1,000 years after mine shut down	-	15,000	20,000 - 90,000*	
2. Uranium Mills				
- Active milling and drying of tailings prior to mill shut down	1,100	1,340	1,400	
- Releases from tailings piles for 100 years	100	200	100 - 14,000**	
- Releases from tailings piles for 1,000 years	53,800	10,800	1,000 - 140,000**	
3. Total Rn-222 Releases/RRY				
- 100 years	5,300	6,900	8,700 - 30,000	
- 1,000 years	59,000	31,000	28,000 - 240,000	
Population Dose Commitments (person-rem)				
1. Uranium Mines (Active Mining)				(Same as Before)
a. 100-yr Environmental Dose Commitment				
- Total Body	110	53	(To Be determined by future decision)	
- Lung***	2,300	520		
- Bone	2,800	720		
b. 1,000 yr. Environmental				
- Total Body	-	190		
- Lung	-	1,800		
- Bone	-	2,600		
2. Uranium Mills				
a. 100 yr Environmental Dose Commitment				
- Total Body	32	15		
- Lung	660	150		
- Bone	820	210		
b. 1,000-yr Environmental Dose Commitment				
- Total Body	1,400	120		
- Lung	30,000	1,200		
- Bone	37,000	1,700		
3. Total Rn-222 Population Dose Commitments				
a. 100-yr Environmental Dose Commitment				
- Total Body	140	68		
- Lung	3,000	670		
- Bone	3,600	930		
b. 1,000-yr. Environmental Dose Commitment				
- Total Body	1,500	310		
- Lung	33,000	3,000		
- Bone	41,000	4,300		
Potential Population Health Impacts				
a. Cancer Mortality - 100-yr Environmental Dose Commitment	0.11	0.070	(To Be determined by future decision)	0.032
- 1,000-yr " " "	1.2	0.32		0.20
b. Genetic Effects****				
- 100 yr Environmental Dose Commitment	0.036	0.018		0.015
- 1,000-yr " "	0.40	0.080		0.068

[a] NUREG-0757 represents the Staff's best estimates of radon-222 releases and potential population dose commitments. It will serve as the basis for proposed S-3 values for radon-222

* Upperbound of range is for unreclaimed and unsealed mines; lower bound assumes sealed and reclaimed mines

** Upperbound of range is for uncovered tailings piles, lower bound assumes tailings piles are stabilized to meet current NRC requirements

*** Bronchial epithelium

**** All serious defects over 5 generations