NUREG-0332

HEALTH EFFECTS ATTRIBUTABLE TO COAL AND NUCLEAR FUEL CYCLE ALTERNATIVES

Draft

Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission

Since publication of the draft NUREG in September, 1977, the Commission directed the staff to reevaluate the long-term impact of radon-222 from the uranium fuel cycle. The reevaluations have been included in the Perkins,Pebble Springs and Black Fox Hearings records in May and June, 1978. Health effects estimates from radon have been conservatively extended into an admittedly uncertain future to incorporate periods ranging from 100 to 1,000 years. Similarly, the staff also extended health effects estimates of carbon-14 releases for 100 to 1,000 years into the future.

These estimates have now been incorporated into the comparison of health effects for the coal and nuclear fuel cycles. The revised tables and Summary and Conclusion sections of the draft NUREG are attached.

Table 1. Current Energy Source Excess Mortality Summary per Year per 0.8 GWy(e)

	Occupational		General Public		Totals
	Accident	Disease	Accident	Disease	
Nuclear Fuel Cycle (all nuclear)	(a) 0.22	(b) 0.14	(c) 0.05	(b) 0.18-1.3	0.59-1.7 (1.0)*
(with 100% of electricity used in the fuel cycle produced by coal power (U.S. population for nuclear effects; regional population for coal effects)	(a,d) 0.24-0.25	(b,e) 0.14-0.46	(c,f) 0.10	(g) 0.77-6.3	1.2-6.8 (2.9)
Coal Fuel Cycle (Regional Population)	(d) 0.35-0.65	(e) 0-7	(f) 1.2	(g) 13-110	15-120(42)

Ratio of Coal to Nuclear (geometric means): 42 (all nuclear); 14 (with coal power) (h)

(a) Primarily fatal non-radiological accidents such as falls, explosions, etc.
(b) Primarily fatal radiogenic cancers and leukemias from normal operations at mines, mills, power plants and reprocessing plants.
(c) Primarily fatal transportation accidents (Table S-4, 10 CFR 51) and serious nuclear accidents.
(d) Primarily fatal mining accidents such as cave-ins, fires, explosions, etc.
(e) Primarily coal workers pneumoconiosis (CWP) and related respiratory diseases leading to respiratory failure..
(f) Primarily members of the general public killed at rail crossings by coal trains.
(g) Primarily respiratory failure among the sick and elderly from combustion products from power plants, but includes deaths from waste coal bank fires.
(h) 100% of all electricity consumed by the nuclear fuel cycle produced by coal power; amounts to 45 MWe per 0.8 GWy(e).

* Values in parentheses are the geometric means of the ranges; geometric mean = $\sqrt{ab}$

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Table 1a
(Breakdown of Table 1)

NUCLEAR — EXCESS MORTALITY per 0.8 GWy(e)

FUEL CYCLE COMPONENT	OCCUPATIONAL		GENERAL PUBLIC		TOTAL
	ACCIDENT (a)	DISEASE (b,c,d,)	ACCIDENT (d,e,)	DISEASE (b)	
RESOURCE RECOVERY (Mining, Drilling, etc.)	0.2	0.038	~0	0.085+	
PROCESSING (f)	0.005**	0.042	*	0.026-1.1(g)	
POWER GENERATION	0.01	0.061	0.04	0.016-0.20	
FUEL STORAGE	*	~0	*	~0	
TRANSPORTATION	~0	~0	0.01	~0	
REPROCESSING	*	0.003	*	0.054-0.062	
WASTE MANAGEMENT	*	~0	*	0.001	
TOTAL	0.22	0.14	0.05	0.18-1.3	0.59-1.7

+These effects are based on my affidavit of March 28, 1978 which indicates that the 4,060 Ci of Rn-222 released from mining the uranium necessary to produce the 0.8 GWy(e) would result in 0.085 excess deaths over all time.

*The effects associated with these activities are not known at this time. While such effects are generally believed to be small, they would increase the totals in this column.

**Corrected for factor of 10 error based on referenced value (WASH-1250)

(a) Ref. 1
(b) Ref. 7
(c) 10 CFR 51, Table S-3
(d) 10 CFR 51, Table S-4
(e) Ref. 8
(f) Includes milling, uranium hexafluoride production, uranium enrichment, and fuel fabrication.
(g) Long-term effects given by affidavit March 28, 1978 for radon-222 releases from mills and tailings piles account for all but 0.001 health effects here.

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Table 2. Current Energy Source Summary of Excess Morbidity and Injury per 0.8 GWy(e) Power Plant

	Occupational		General Public		Totals
	Morbidity	Injury	Morbidity	Injury	
Nuclear Fuel Cycle (all nuclear)	0.84 (a)	12 (b)	1.0-3.1 (c)	0.1 (d)	14-16 (15)*
(with 100% of electricity used by the fuel cycle produced by coal power) (U.S. population for nuclear effects; regional population for coal effects)	1.7-4.1 (e)	13-14 (b)	1.5-7.6 (g)	0.55 (h)	17-26 (21)
Coal Fuel Cycle (Regional population)	20-70 (e)	17-34 (f)	10-100 (g)	10 (h)	57-210 (109)

Ratio of Coal to Nuclear (geometric means): 7.3 (all nuclear); 5.2 (with coal power) (1)

(a) Primarily non-fatal cancers and thyroid nodules.
(b) Primarily non-fatal injuries associated with accidents in uranium mines such as rock falls, explosions, etc.
(c) Primarily non-fatal cancers, thyroid nodules, genetically related diseases, and non-fatal illnesses following high radiation doses such as radiation thyroiditis, prodromal vomiting, and temporary sterility.
(d) Transportation related injuries from Table S-4, 10 CFR Part 51.
(e) Primarily non-fatal diseases associated with coal mining such as CWP, bronchitis, emphysema, etc.
(f) Primarily injuries to coal miners from cave-ins, fires, explosions, etc.
(g) Primarily respiratory diseases among adults and children from sulfur emissions from coal-fired power plants, but includes waste coal bank fires.
(h) Primarily non-fatal injuries among members of the general public from collisions with coal trains at railroad crossings.
(1) 100% of all electricity consumed by the nuclear fuel cycle produced by coal power; amounts to 45 MWe per 0.8 GWy(e).
* Values in parentheses are the geometric means of the ranges.

Table 2a
(Breakdown of Table 2)

NUCLEAR FUEL CYCLE COMPONENT	MORBIDITY AND INJURY per 0.8 GWy(e)				
	OCCUPATIONAL		GENERAL PUBLIC		TOTAL
	MORBIDITY	INJURY (a)	MORBIDITY	INJURY (b)	
RESOURCE RECOVERY (Mining, Drilling, etc.)	**	10	***	~0	
PROCESSING (c)	**	0.6	***	~0	
POWER GENERATION	**	1.3	***	~0	
FUEL STORAGE	**	*	***	~0	
TRANSPORTATION	**	<1	***	0.1	
REPROCESSING	**	*	***	*	
WASTE MANAGEMENT	**	*	***	~0	
TOTAL	0.84	12	1.0-3.1	0.1	14-16

(a) Ref. 1
(b) Table S-4, 10 CFR 51
(c) Includes milling, uranium hexaflouride production, uranium enrichment, and fuel fabication.

*The effects associated with these activities are not known at this time. While such effects are generally believed to be small, they would increase the totals in this column.

**Non-fatal cancers ≤ fatal cancers (excluding thyroid) = 0.14
Non-fatal thyroid cancers and benign nodules = 3X fatal cancers = 0.42
Genetic defects 2X fatal cancers = 0.28

***Reactor accidents 10X fatalities = 0.40 non-fatal cases
Normal operations: Non-fatal cancers ≤ fatal cancers = 0.18-1.3
Non-fatal thyroid cancers and nodules = 3X fatal cancers (from Total-Body doses) = 3X(0.085-0.28) = 0.26-0.84
Genetic Effects = 2X fatal cancers (from Total-Body doses) = 2X(0.085-0.28) =

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In addition, some believe (Ref. 33) that when the physical and biological properties of the radium released from conventional coal powered plants burning coal (with 1-2 ppm uranium-238 and Th-232) are considered, such plants discharge relatively greater quantities of radioactive materials into the atmosphere than nuclear powered plants of comparable size. EPA has estimated radiation doses from coal and nuclear powered plants of early designs and reached similar conclusions (Ref. 16). Even if the health effects from radioactivity released by the coal fuel cycle are greater than the health effects from radioactivity released in the nuclear fuel cycle, the total health effects from coal would not change significantly since these effects would be only a small percentage of the total health effects from the coal cycle.

III. SUMMARY AND CONCLUSIONS

For the reasons discussed above, it is extremely difficult to provide precise quantitative values for excess mortality and morbidity, particularly for the coal fuel cycle. Nevertheless, estimates of mortality and morbidity have been prepared based on present day knowledge of health effects, and present day plant design and anticipated emission rates, occupational experience and other data. These are summarized in Tables 1 and 2, with some important assumptions inherent in the calculations of health effects listed in Appendix A.

While future technological improvements in both fuel cycles may result in significant reductions in health effects, based on current estimates for present day technology, it must be concluded that the nuclear fuel cycle is considerably less harmful to man than the coal fuel cycle. (Refs. 1,2,3, 4,5,10,11,27,28,33,34,35,36) As shown in Tables 1 and 2, the coal fuel cycle alternative may be more harmful to man by factors of 7.3 to 42 depending on the effect being considered, for an all nuclear economy, or factors of 5.5 to 14 with the assumption that all of the electricity used by the uranium fuel cycle comes from coal powered plants.

It should be noted that although there are large uncertainties in the estimates of most of the potential health effects of the coal cycle, the impact of transportation of coal is based on firm statistics; this impact alone is greater than the conservative estimates of health effects for the entire uranium fuel cycle (all nuclear economy), and can reasonably be expected to worsen as more coal is shipped over greater distances. In the case where coal generated electricity is used in the nuclear fuel cycle, primarily for uranium enrichment and auxiliary reactor systems, the impact of the coal power accounts for essentially all of the impact of the uranium fuel cycle.