CHANGING PERCEPTIONS OF HEALTH CONSEQUENCES WITH REDUCED SOURCE TERMS

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INTRODUCTION

Since the accident at Three Mile Island, there has been heightened interest in source terms from reactor accidents. (The source term is a description of the amount and kind of radioactive material postulated to be released to the environment following an accident.) Of special importance was the negligible amount of Iodine-131 released compared to that expected from WASH-1400 (NRC75) and the increased relative importance of the noble gases, although at a much reduced absolute level (Ke79). Such observations have led to this work as well as that of other groups (Wa83). In general, the work indicates that the consequences of a severe nuclear accident are much less serious than those that would be predicted from the source term assumptions currently in use. However, this work should not be viewed as a complete and conclusive study since research in source term and analytical models is ongoing.

Post-accident health consequences are dependent on reactor and site characteristics through site-specific population distributions, and acute consequences are also dependent on assumed health effects models because of the "No Observed Effect Level" (NOEL) or threshold doses of such models.

Sensitivity analyses performed in the past were based on comparisons of offsite health consequences, but, even though these are useful for a particular site, they do not lend themselves to generalized conclusions about source terms and consequence models. The present work was done in a different manner using comparisons of calculated whole body, bone marrow, and thyroid doses to allow such generalization and to decouple the effects of models and assumptions from site-specific data.

ANALYSES-DOSES

For a reference 3412 MW_t PWR (Al82), the computer code CRAC2 (Ri82) and hourly meteorological data obtained from National Weather Service stations were used to calculate acute whole body, thyroid, and bone marrow dose distributions as a function of distance. Dose distributions were calculated for current source terms, represented by the WASH-1400 PWR2, and reduced source terms, represented by a current revision of the Interim Source Term (RIST) proposed by Stone & Webster Engineering Corporation (SWEC) (Wa84). The total dose was broken down into contributions from individual radionuclide groups. Since such calculated doses are not subject to thresholds and site-specific population distributions, some understanding can be obtained as to the importance of specific nuclide groups and analytical model uncertainties. The source terms used for the comparison and their composition are given in Table 1.

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Time prior to release and duration of release were assumed to be 2 hours. Doses were calculated assuming the unrealistic but general case of an exposed individual standing on an open infinite smooth plain at the time of the accident and for the next 24 hours. The release was assumed to be at ground elevation with no sensible heat.

Mean acute whole body doses, from the dose frequency distributions generated by CRAC2, are presented in Figure 1 for distances up to 10 miles. The "noble gases only" case is included as a reference point, since there is general agreement that noble gases would be released in an accident that produced any source term at all, i.e., a major accident with multiple equipment failures and breach of containment.

Based on the CRAC2 results, the importance of each radionuclide group seems to be insensitive to distance, with the exception of the noble gases. Furthermore, the order of importance is different between the source terms. This order of importance for whole body, thyroid, and bone marrow doses is summarized in Figure 2 in terms of the fractional contribution to the total dose.

Based on these changes, both in absolute value and relative radionuclide importance, it is evident that our thinking about dose/effect models may need revision.

- As can be seen, noble gases are the major contributor to acute doses in the case of RIST, whereas they are a minor contributor in the case of PWR2 with the exception of the thyroid doses which, as expected, are dominated by iodine (though at a much lower absolute level).

- Early mortality was of paramount importance on the basis of WASH-1400.

- The effect of the source term change is to virtually eliminate early deaths, i.e., the risk of early mortality becomes low and, for many power stations, would be zero.

- The risk of thyroid cancer due to the irradiation of the thyroid by Iodine-131 decreases markedly with the new source term. External irradiation of the thyroid, as of the whole body, is lower and is dependent on several of the radionuclide groups, e.g., the lanthanum group and the noble gases.

- Protective sheltering by typical homes would reduce the external doses to individuals by a factor of 4 to 6, and basements and heavier construction would further reduce the consequences in all radiation health categories. With the range of doses predicted for the reduced source terms, it is clear that sheltering is a viable alternative to evacuation for persons close to as well as remote from the release point.

Differences such as these will have an impact on calculated health consequences for a given site and, further, they can impact the type and extent of protection that is needed in case of an accident.

ANALYSES-CONSEQUENCES

In an attempt to extend these conclusions for site-specific applications, a limited investigation was performed using four U.S. nuclear reactor sites identified as sites A, B, C, and D. These sites were chosen as being representative of the U.S., and the health consequences compared acute fatalities and injuries and latent cancer fatalities. (For delayed effects, dose vs effects relationships equivalent to the linear-quadratic curve of BEIR III (Na80) were used, i.e., a central estimate interpolation technique using BEIR 1972 data. However, effects were computed for a lifetime rather than for 30 years.) The data used for these analyses were site-specific in terms of power level, meteorology, and population distribution to 50 miles from the site. It was assumed that no evacuation took place following the accident. The nominal sheltering corresponding to normal activities was employed (NRC83).

Mean acute health consequences from the consequence distributions generated by CRAC2 for PWR2 and RIST are presented in Table 2. It should be noted that these consequences are conditional on the accident.

The acute consequences, shown in Table 2, are based on supportive medical treatment (NRC75) which implies allocation of fixed medical means to a large number of people. This, of course, was a valid assumption for the number of heavily exposed people involved in the case of PWR2, but would appear pessimistic, consequence-wise, for the small number of people in RIST to whom the total services could be allocated.

It is evident from Figure 3 and Table 3 that, for reduced source terms where a small number of people would be involved, more intensive medical treatment would be a more realistic and viable assumption. Under this assumption, the calculated fatalities would be zero at all four sites.

In terms of delayed effects, examination of the BEIR-III (Na80) response models in Table 4 reveals that, for dose ranges of interest in the case of reduced source terms, the differences in excess cancer mortality between the three models would be much less than the differences using current source terms.

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Al82 Aldrich, D.C. and Sprung, J.L. Technical Guidance for Siting Criteria Development. NUREG/CR-2239, Sandia National Laboratories, November 1982.

Ke79 Kemeny et al. Report of the President's Commission on the Accident at Three Mile Island, October 1979.

Na80 National Academy of Sciences (NAS)/National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiations. The Effects on Populations of Exposure to Low Levels of Ionizing Radiations (BEIR-III), Washington, D.C., NAS, 1980.

NRC75 Nuclear Regulatory Commission. Reactor Safety Study - An Assessment of Accident Risks in U.S. Commercial Nuclear Reactor Plants. WASH-1400 (NUREG-75/014), October 1975.

NRC83 Nuclear Regulatory Commission. PRA Procedures Guide. A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants, NUREG/CR-2300, January 1983.

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TABLE 1

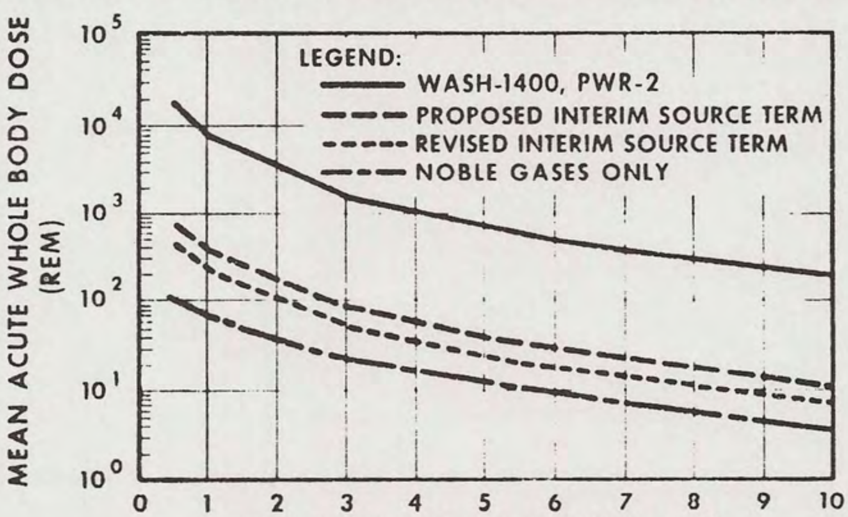
COMPARISON OF SEVERE ACCIDENT SOURCE TERMS

FISSION PRODUCT GROUP	WASH-1400 RELEASE CATEGORY PWR-2	INTERIM SOURCE TERM (NOV. 1982)*	REVISED INTERIM SOURCE TERM
XENON & KRYPTON	0.90	1.00	1.00
IODINE	0.70	0.01	0.01
CESIUM - RUBIDIUM	0.50	0.01	0.01
TELLURIUM - ANTIMONY	0.30	0.01	0.01
BARIUM - STRONTIUM	0.06	0.01	0.004
RUTHENIUM	0.02	0.01	0.0003
LANTHANUM	0.004	0.004	0.0002

* PRESENTED AT SECOND INTERNATIONAL CONFERENCE ON NUCLEAR TECHNOLOGY TRANSFER.

FIGURE 1

WHOLE BODY DOSE AS A FUNCTION OF DISTANCE FOR VARIOUS SOURCE TERMS



NOTE: WHOLE BODY DOSES BASED ON EXPOSURE TO PLUME WITH 2 HR. RELEASE @ 2 HR. FOLLOWED BY EXPOSURE TO GROUND CONTAMINATION FOR 24 HR. WITH NO SHELTERING

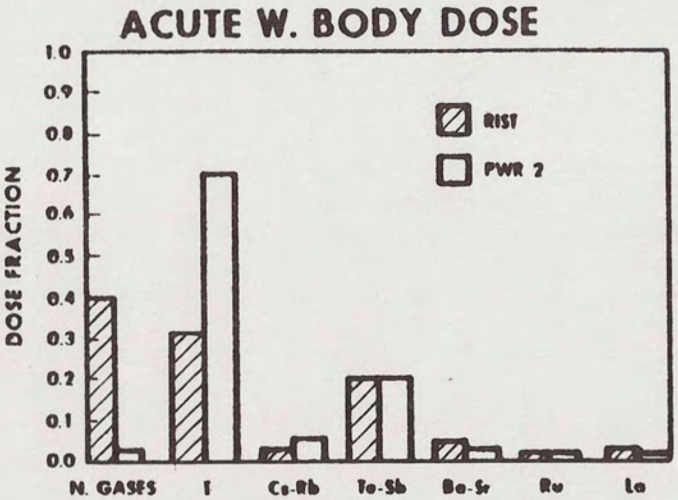
TABLE 2

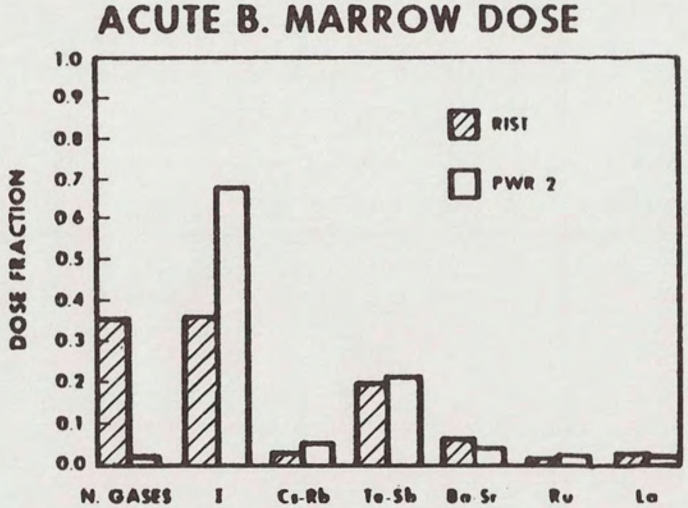
CONDITIONAL MEAN CONSEQUENCE MAGNITUDE

	PWR2 SITE				RIST SITE			
	A	B	C	D	A	B	C	D
ACUTE FATALITIES	566	312	372	89	1	0	0	0
ACUTE INJURIES	974	535	1150	245	23	<1	14	2

FIGURE 2

FRACTIONAL DOSE CONTRIBUTIONS





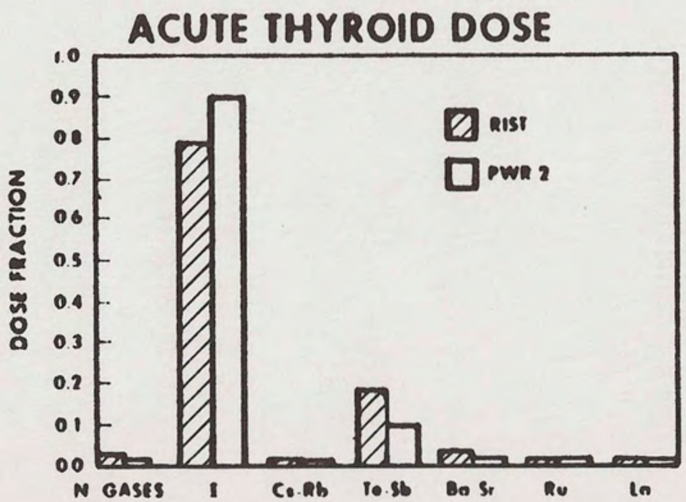


FIGURE 3

ESTIMATED DOSE RESPONSE CURVES FOR BONE MARROW DOSES

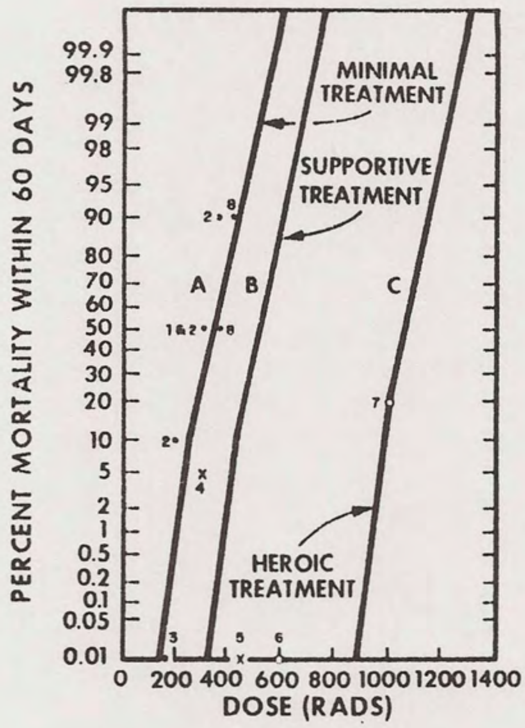


TABLE 3

IDENTIFICATION OF MEDICAL TREATMENT

CURVE	MEDICAL TREATMENT	LD 50/60 RADS	NO. OF PEOPLE
MINIMAL	NONE	340	(LARGE NUMBER)
SUPPORTIVE	BARRIER NURSING, COPIOUS ANTIBIOTICS, TRANSFUSIONS OF WHOLE BLOOD, PACKED CELLS AND PLATELETS. START WITHIN 20 DAYS.	510	2500-5000
HEROIC	SUPPORTIVE TREATMENT PLUS BONE MARROW TRANSPLANTATION. START WITHIN 10 DAYS.	1050	50-150

TABLE 4

ESTIMATED EXCESS INCIDENCE OF (AND MORTALITY FROM) LEUKEMIA AND BONE CANCER FROM LOW-LET RADIATION DOSE (D):

L-L MODEL

ESTIMATED DOSE-RESPONSE RELATIONSHIP:

LEUKEMIA: EXCESS RISK = 2.239D
BONE CANCER: EXCESS RISK = 0.05D

Q-L MODEL

ESTIMATED DOSE-RESPONSE RELATIONSHIP:

LEUKEMIA: EXCESS RISK = $0.01372D^2$
BONE CANCER: EXCESS RISK = $0.000306D^2$

LQ-L MODEL

ESTIMATED DOSE-RESPONSE RELATIONSHIP:

LEUKEMIA: EXCESS RISK = $0.9892D + 0.008508D^2$
BONE CANCER: EXCESS RISK = $0.02209D + 0.000190D^2$