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NOTE TO: T. Speis, DD/RES

FROM: S. Yaniv, RPHEB/DRA/RES

SUBJECT: RISKS ASSOCIATED WITH THYROID IRRADIATION

I. Lifetime risk following ^{131}I exposure.

a) Thyroid cancer

The best estimate of lifetime thyroid cancer risk for U.S. population following ^{131}I exposure is 24 cases per 10^6 person.rad. This is the central estimate in NUREG/CR-4214. Rev. 1, 1989, and is based on linear non-threshold dose response model. The mortality from thyroid cancer is believed to be 10 percent

b) Benign thyroid nodules

The estimate of lifetime risk of benign thyroid nodules following exposure to ^{131}I for U.S. population is 54 cases per 10^6 person.rad.

c) Hypothyroidism

Hypothyroidism is most certainly a threshold effect. The best estimate for threshold in case of ^{131}I exposure is 1000 rad. The lifetime risk, above threshold, is estimated as 17 cases per 10^6 person.rad.

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II. Lifetime risk following exposure to external radiation or to ^{132}I, ^{133}I, or ^{135}I.

a) Thyroid cancer

The risk of thyroid cancer is three times higher than from I^{131} i.e., 72 cases per 10^6 person.rad.

b) Benign thyroid nodules

The risk of thyroid nodules is five times higher than from ^{131}I i.e., 268 cases per 10^6 person.rad.

c) Hypothyroidism

The risk of hypothyroidism is five times higher than from ^{131}I i.e.,

threshold: 200 rad and
83 cases per 10^6 person.rad above threshold

The above risk values apply to population composed of both genders and all ages. In general, children are more sensitive than adults and females more sensitive than males.

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Simplified Cost-Benefit Analysis Regarding Stockpiling of KI

1. Using WASH-1400 (Ref. 1), it is estimated that the probability of a large accidental release is about 10^{-5} per reactor -yr.

2. Assume 100 reactors in U. S.

3. Therefore, the probability of a large release per year somewhere in the U. S. is 10^{-5}/RY x 100 reactors = 10^{-3} per year.

4. From data in the Strip report (NUREG/CR-2723) (Ref. 2) a large release is calculated to result in a whole body dose of about 10^{7} man-rem, for a typical U. S. site.

5. From staff experience with preparation of environmental impact statements (EIS), the thyroid dose is about an order of magnitude greater than the whole body dose, for a large release. Therefore, a large release will result in 10^{8} man-rem to the thyroid for a typical site.

6. The average thyroid dose is then

   $$10^{8}\,\frac{\text{man-rem}}{\text{release}} \times 10^{-3}\,\frac{\text{release}}{\text{yr.}} = 10^{5}\,\frac{\text{man-rem}}{\text{yr.}}$$

7. The above estimate is based upon the release fractions of WASH-1400, which estimated releases averaging 50% of the core iodine inventory for core-melt atmospheric releases (equivalent to core-melt with early containment failure). NUREG-1150 (Ref. 3) has estimated that such releases would be lower and would average about 10 to 20% of the core iodine inventory. This is about a factor of three lower. Consequently, using the NUREG-1150 release fractions which are based upon the best available research information to date, the average thyroid dose is estimated to be

   $$\frac{1}{3} \times 10^{5} = 3.3\text{x}10^{4}\,\frac{\text{man-rem}}{\text{yr.}}$$

8. WASH-1400 used risk coefficients of 334 thyroid nodules per 10^{6} man-rem, 200 of which were benign thyroid nodules and 134 were thyroid cancers. WASH-1400 also assumed that 10% of the cancers would result in fatalities. The thyroid cancer risk coefficient of WASH-1400 is no longer considered valid. Instead, the values given in NCRP Report No. 80 (Ref. 4), namely, 74 thyroid cancers per 10^{6} man-rem (thyroid) is regarded as the best available data.

9. Then, using risk coefficients of 200 benign thyroid nodules/10^6 man-rem, and 74 thyroid cancers/10^6 man-rem with 10% of the cancers resulting in fatalities, the average number of health effects per year becomes

$$200\ \frac{\text{benign nodules}}{10^6\ \text{man-rem}} \times 3.3 \times 10^4\ \frac{\text{man-rem}}{\text{yr.}} = 6.6\ \frac{\text{benign nodules}}{\text{yr.}}$$

plus

$$74\ \frac{\text{thyroid cancers}}{10^6\ \text{man-rem}} \times 3.3 \times 10^4\ \frac{\text{man-rem}}{\text{yr.}} = 2.44\ \frac{\text{thyroid cancers}}{\text{yr.}}$$

and 10% of the cancers, or 0.25 fatalities per year, are predicted.

10. In addition to these health effects, hypothyroidism must also be considered, as well. From information taken from NUREG/CR-4214 (Ref. 5), the risk coefficient for hypothyroidism is 17 cases per 10^6 man-rem (thyroid), with a threshold dose of 1000 rad (10 Gy) of occurrence.

11. Since hypothyroidism has a relatively high threshold for occurrence, it will occur over a limited area. NUREG-CR/1443 (Ref. 6) presents data showing that the average thyroid dose for a core-melt atmospheric release is equal to or greater than 1000 rem out to about 25 miles from the reactor. Since the analysis in NUREG-CR/1443 made use of WASH-1400 release fractions, the average doses should be reduced by about a factor of three to be in agreement with the results of NUREG-1150. With this correction, thyroid doses equal to or in excess of 1000 rem would be confined, on average, to distances of about 10 miles from the reactor.

12. Using demographic data from NUREG-0348 (Ref. 7), the average population within ten miles of a U. S. reator is 37,000 (1970 census). Adjusting for the 1980 census, this is estimated to be 40,000 persons.

13. The average number of cases of hypothyroidism per year can now be estimated. Given a large release, the average dose in the region from the reactor out to 10 miles is expected to be about 2000 rem to the thyroid (using data from Ref. 6 and adjusting for the reduced release fractions of NUREG-1150, Ref. 3). Although the average population within 10 miles is 40,000 persons, only a small fraction would be exposed to the plume of a release. Generally, estimates are that no more than about 3 sectors, each comprising 22 1/2 degrees, would

be exposed to the plume. Since there are a total of 16 such sectors, the affected population is $\frac{3}{16} \times 40{,}000 = 7500$ persons.

The total population dose is 7500 persons x 2000 rem = 15×10^6 man-rem and the number of cases of hypothyroidism, given a large release, is

$$\frac{17}{10^6 \text{ man-rem}} \times 15 \times 10^6 \text{ man-rem} = 255 \text{ cases}$$

Since the probability of a large release is 10^{-3} per yr., the average number per year is

$255 \times 10^{-3} = 0.255$ or 0.26 $\frac{\text{cases}}{\text{yr.}}$ hypothyroidism

(Actually, this is likely an overestimate. If a timely evacuation is carried out, the number of persons exposed would be much lower. Since this is difficult to estimate with precision, however, the above estimate will be used despite its conservatism.)

14. Taking values of $25,000 for the cost of treatment for benign nodules (Ref. 8); $50,000 for the cost of treatment of thyroid cancers (non-fatal); $50,000 for the cost of treatment for hypothyroidism (Ref. 9) and $1,000,000 for the cost of a cancer fatality, the average costs per year become

6.6 x $25,000 = $165,000 (benign nodules)

2.19 x $50,000 = $109,500 (non-fatal cancers)

0.25 x $1,000,000 = $250,000 (cancer fatalities)

0.26 x $50,000 = <u>$13,000</u> (hypothyroidism)

Total = $537,500 per year

15. The number of thyroid health effects predicted and the associated costs to society shown above assume that <u>no</u> protective measures are taken to reduce or avoid such exposures. However, a range of protective measures (other than use of KI), including evacuation, sheltering and avoiding the consumption of contaminated food and water are included in emergency plans, would likely be taken, and would significantly reduce radiation exposure not only to the

thyroid gland but to other body organs as well. Consequently, the thyroid costs shown above are significantly overestimated, probably by a factor of from two to ten times. Using a factor of two reduction, the total thyroid costs to society (assuming other protective measures) are estimated to be 1/2 x 537,500 \$/yr. = 270,000 \$/yr. (approx.)

16. Assume that KI is to be stockpiled at a number of locations throughout the U. S. and is to be distributed to the affected populace after an accident and that the number of locations is sufficient that KI could be distributed to the general public within a few hours after an accident.

17. Representatives of the American Thyroid Association have stated (Ref. 10) that clinically significant thyroid disease appears unlikely to result from individual thyroid exposures of less than 100 rads. To provide an added measure of protection for children and pregnant women, however, the authors of Ref. 10 suggest a radiation dose of 50 rads to the thyroid as a threshold for iodine blockade for this group.

18. Based on thyroid dose vs. distance data presented in Ref. 6 Table 3, (and with correction for NUREG-1150 reductions) doses in excess of about 50 rad for a child would be expected at distances up to about 100 miles from a reactor.

19. If KI is to be distributed to children and pregnant women, it is not likely that it could practically be withheld from the general population, in an emergency. It is assumed, therefore, that KI will be stockpiled in sufficient quantities to be distributed to the general population within 100 miles of a nuclear power reactor.

20. Based on the analysis of Ref. 11, it is estimated that 67 percent of the U. S. population resides within 100 miles of a nuclear power plant. Using 1980 census data, KI must be stockpiled for $0.67 \times 226 \times 10^6 = 151 \times 10^6$ persons.

21. Ref. 12 indicates that in a reactor emergency KI will be taken for a minimum of several days and for a maximum of ten days. Assuming stockpiling for a minimum of three days, with a usage of one KI tablet per day, the number of KI tablets to be stockpiled is $151 \times 10^6 \times 3 = 453 \times 10^6$.

22. The cost of KI is taken as \$0.05 per tablet (Ref. 13). (The actual costs are likely higher since this reflects only the cost of KI tablets in bulk. Not only have warehousing,

distribution and inventory control costs have neglected, but the need for rapid distribution at the time of an accident would suggest that KI tablets should be pre-packaged in readily dispensable individual packets containing 3 tablets each. The cost of such packaging has also been neglected.)

23. The cost of stockpiling KI then becomes 151 x 10^6 persons x

$$\frac{3\ \text{tablets}}{\text{person}} \times .05\ \frac{\$}{\text{tablet}} = 2.27 \times 10^7\ \$$$

Since the tablets should be replaced every 3 years (Ref. 12) the annual cost is one-third of this or 7.5 x 10^6 \$/yr.

24. Timing is critical in the effectiveness of KI as a blocking agent. If KI is given 4 hours after intake of radioiodine, then its effectiveness is sharply reduced (about 10-30% blocking). It is difficult to quantify the time delay associated with stockpiling. If KI is available to evacuees at relocation centers and other places within 3 to 4 hours after accident initiation, and if accident releases occur primarily after several hours warning, then this may be effective. For fast acting scenarios this may not be the case. Overall, it is estimated that stockpiling will result in a time delay sufficient to reduce the blocking effectiveness to 50% of what it would be if each individual had KI in his possession prior to an accident (predistribution). (For a blocking effectiveness of 50% to be achieved, KI must be received by individuals no later than about 2 hours after the release of iodine begins.)

25. The cost/benefit results are summarized below

Cost of KI = 7.5 x 10^6 \$/yr.

Benefit of KI = 1.4 x 10^5 \$/yr. (using a best estimate blocking value of 50%, and assuming other protective measures)

26. Additional calculations displaying the sensitivity of the benefits of KI to the assumptions used are shown on the following page.

Conclusion: Stockpiling of KI is not cost beneficial.

Cost/Benefit Summary for Stockpiling KI

Cost of KI = 7.5 x 10^6\$/yr.

Benefits	Reduced Blocking (50%)	Unreduced Blocking (100%)
NUREG-1150 release fractions	1.4 x 10^5\$/yr.* (2 x 10^5\$/yr.)**	2.7 x 10^5\$/yr. (4x10^5\$/yr.)
WASH-1400 release fractions	4.1 x 10^5\$/yr. (6 X 10^5\$/yr.)	8 x 10^5\$/yr. (1.2 x 10^6\$/yr.)

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* Best estimate value. The benefits would be increased by a factor of two if no other protective actions (evacuation, sheltering, food interdiction) are taken.

** The values in parentheses make use of the thyroid cancer risk estimates of Wash-1400, rather than those given in NCRP Report No. 80. See Note 1 for further details.

Note 1 - Risk of Thyroid Cancer

Wash-1400 used a risk coefficient of 334 thyroid nodules per 10^6 man-rem (to the thyroid). WASH-1400 also assumed that 60% of the nodules produced were benign, 40% were cancerous, and that 10% of the cancerous nodules (4% of the total nodules) would result in fatalities. The WASH-1400 risk coefficient for thyroid cancer is therefore 0.4 x 334 or 134 thyroid cancers per 10^6 man-rem (thyroid).

This value was re-examined in light of recent information that was unavailable to the authors of SECY-83-362. Two sources were used. The first was a Swedish study by Holm, et. al. "Thyroid Cancer after Diagnostic Doses of Iodine-131: A Retrospective Cohort Study", reported in the Journal of the National Cancer Institute, Vol. 80, No. 14, September 21, 1988. The second source was "Introduction of Thyroid Cancer by Ionizing Radiation," National Council on Radiation Protection and Measurements (NCRP), Report No. 80, March 30, 1985. Holm studied 35, 074 patients in Swedish hospitals receiving doses of I-131 and included a 20 year followup. The average thyroid dose per patient was stated to be 50 rads. The collective population dose was 35,074 x 50 or 1.75 x 10^6 person-rad. The total number of thyroid cancers observed in this therefore 29 thyroid cancers/10^6 man-rem, or about a factor of four less than that used in Wash-1400.

NCRP Report No. 80 gives an absolute thyroid cancer risk of about 72 to 74 cases per 10^6 person-rad. This value is stated to be based on population studies of North Americans exposed to external radiotherapy in childhood. This risk estimate is also considered to be applicable for thyroid doses in the range from 6 to 1500 rads. This value is about a factor of two less than that used in WASH-1400.

References

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

2. D. R. Strip, "Estimates of the Financial Consequences of Nuclear Power Reactor Accidents", Sandia National Laboratories, NUREG/CR-2723, September 1982.

3. USNRC, "Severe Accident Risks: An Assessment for Five U. S. Nuclear Power Plants", Second Draft for Peer Review, NUREG-1150, June 1989.

4. National Council on Radiation Protection and Measurements (NCRP)," Induction of Thyroid Cancer by Ionizing Radiation", NCRP Report No. 80, March 1985.

5. S. Abrahamson, et. al., "Health Effects Models for Nuclear Power Plant Accident Consequence Analysis", Part II: Scientific Bases for Health Effects Models, Sandia National Laboratories, NUREG/CR-4214, May 1989.

6. D. C. Aldrich, R. M. Blond, "Examination of the Use of Potassium Iodide (KI) as an Emergency Protective Measure for Nuclear Reactor Accidents", Sandia National Laboratories, NUREG/CR-1433, March 1980.

7. USNRC, "Demographic Statistics Pertaining to Nuclear Power Reactor Sites", NUREG-0348, October 1979.

8. Telephone call from A. K. Roecklein to D. Becker, Memorandum from Alan K. Roecklein to Themis Speis, November 9, 1989.

9. Personal communication, M. Fleishman to L. Soffer, November 30, 1989.

10. D. V. Becker, et. al., "The Use of Iodine as a Thyroidal Blocking Agent in the Event of a Reactor Accident", Journal of the American Medical Association, Vol. 252, No. 5, August 1984.

11. L. Soffer, personal analysis, November 29, 1989.

12. D. V. Becker, "Physiological Basis for the Use of Potassium Iodide as a Thyroid Blocking Agent-Logistic Issues in its Distribution", Bulletin of the New York Academy of Medicine, Second series, Vol. 59, No. 10, December 1983.

13. Telephone call from A. K. Roecklein to P. Hendrickson, Memorandum from Alan K. Roecklein to Themis Speis, November 9, 1989.