

CONF-8709104--2-Vugraphs

ENVIRONMENTAL RADIATION STANDARDS\*

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TUTORIAL FOR PRESENTATION AT

ANS TOPICAL CONFERENCE ON POPULATION EXPOSURE

FROM THE NUCLEAR FUEL CYCLE

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## OUTLINE OF PRESENTATION

### (1) BASIC RADIATION PROTECTION STANDARDS FOR THE PUBLIC

RECOMMENDATIONS OF FEDERAL RADIATION COUNCIL, ICRP, AND NCRP

CURRENT AND PROPOSED STANDARDS OF NRC AND DOE

### (2) ENVIRONMENTAL RADIATION STANDARDS FOR SPECIFIC PRACTICES

CURRENT AND PROPOSED STANDARDS OF NRC, EPA, AND DOE FOR -

- OPERATIONS OF URANIUM FUEL-CYCLE FACILITIES
- RADIOACTIVITY IN DRINKING WATER
- URANIUM MILL TAILINGS AND RESIDUAL RADIOACTIVITY
- RADIOACTIVE WASTE DISPOSAL
- AIRBORNE RADIOACTIVITY

### (3) OTHER CONCERNS

ESTABLISHMENT OF DE MINIMIS DOSE AND EXEMPT LEVELS OF RADIOACTIVITY

CONSIDERATION OF AGE DEPENDENCE OF DOSE

DEVELOPMENT OF STANDARDS EXPRESSED AS LIMITS ON RISK

# BASIC RADIATION PROTECTION STANDARDS

FOR THE PUBLIC

## DEFINITION OF RADIATION PROTECTION STANDARD

A RADIATION PROTECTION STANDARD IS A STANDARD (USUALLY A LIMIT ON ANNUAL DOSE EQUIVALENT) THAT IS REGARDED AS NECESSARY FOR PROTECTION OF PUBLIC HEALTH, I.E., PROVIDES LIMIT ON ACCEPTABLE RISK OF STOCHASTIC (FATAL CANCERS OR GENETIC EFFECTS) OR NON-STOCHASTIC (ACUTE) RADIATION EFFECTS.

RADIATION PROTECTION STANDARDS ARE GENERALLY APPLICABLE TO ALL SOURCES OF EXPOSURE, EXCLUSIVE OF NATURAL BACKGROUND AND DELIBERATE MEDICAL PRACTICES.

RADIATION PROTECTION STANDARDS MUST BE MET, EXCEPT UNDER UNUSUAL CIRCUMSTANCES, REGARDLESS OF COST.

HISTORICAL PERSPECTIVE ON  
RADIATION PROTECTION STANDARDS FOR THE PUBLIC

UNTIL RECENTLY, NRC AND DOE RADIATION PROTECTION STANDARDS FOR  
THE PUBLIC HAVE BEEN BASED ON RECOMMENDATIONS OF -

- FEDERAL RADIATION COUNCIL (1960)
- ICRP PUBLICATIONS 1 AND 2 (1958, 1959)
- NCRP REPORT No. 39 (1971)

## HISTORICAL PERSPECTIVE

(CONTINUED)

RECOMMENDATIONS OF FEDERAL RADIATION COUNCIL (1960) -

LIMIT ON ANNUAL DOSE EQUIVALENT TO WHOLE BODY FOR  
INDIVIDUALS OF 0.5 REM (5 MSV)

LIMIT ON ANNUAL DOSE EQUIVALENT TO WHOLE BODY FOR AVERAGE  
INDIVIDUALS IN POPULATION OF 0.17 REM (1.7 MSV)

LIMIT ON DOSE EQUIVALENT TO GONADS FOR INDIVIDUALS IN LARGE  
POPULATION GROUPS OF 5 REM (50 MSV) IN 30 YEARS (LIMITATION  
OF GENETIC EFFECTS)

REDUCTION OF EXPOSURES AS LOW AS PRACTICAL (ALAP)

NOTE - DOSE TO "WHOLE BODY" MEANS DOSE FROM UNIFORM  
IRRADIATION OF THE WHOLE BODY.

## HISTORICAL PERSPECTIVE

(CONTINUED)

RECOMMENDATIONS IN ICRP PUBLICATIONS 1 AND 2 (1958, 1959) -

LIMITS ON ANNUAL DOSE EQUIVALENT FOR INDIVIDUALS OF -

- 0.5 REM (5 MSV) TO WHOLE BODY
- 3 REM (30 MSV) TO BONE, THYROID, OR SKIN
- 1.5 REM (15 MSV) TO ANY OTHER ORGAN

LIMITS APPLY TO SUM OF 50-YEAR COMMITTED DOSE EQUIVALENT FROM INTERNAL EXPOSURE AND DOSE EQUIVALENT FROM EXTERNAL EXPOSURE

LIMITS FOR THE PUBLIC ARE ONE-TENTH OF LIMITS FOR RADIATION WORKERS

HISTORICAL PERSPECTIVE  
(CONTINUED)

RECOMMENDATIONS IN NCRP REPORT No. 39 (1971) -

LIMIT ON ANNUAL DOSE EQUIVALENT TO WHOLE BODY OR CRITICAL ORGAN FOR INDIVIDUALS OF 0.5 REM (5 MSV)

LIMIT ON ANNUAL DOSE EQUIVALENT TO WHOLE BODY OR CRITICAL ORGAN FOR AVERAGE INDIVIDUALS IN POPULATION OF 0.17 REM (1.7 MSV)

LIMIT ON ANNUAL DOSE EQUIVALENT TO GONADS FOR AVERAGE INDIVIDUALS IN POPULATION OF 0.17 REM (1.7 MSV)

NOTE - CRITICAL ORGAN IS GENERALLY THE ORGAN RECEIVING THE HIGHEST DOSE, AND DOSE TO CRITICAL ORGAN IS OFTEN LIMITING FOR INTERNAL EXPOSURE INVOLVING NON-UNIFORM IRRADIATION OF THE WHOLE BODY.



## CURRENT RECOMMENDATIONS OF ICRP

### SYSTEM OF DOSE LIMITATION IN ICRP PUBLICATION 26 (1977) -

- (1) JUSTIFICATION OF PRACTICE
- (2) REDUCTION OF EXPOSURES AS LOW AS REASONABLY ACHIEVABLE (ALARA) - I.E., OPTIMIZATION OF POPULATION DOSE ON BASIS OF COST-BENEFIT ANALYSIS
- (3) LIMITATION OF DOSE TO INDIVIDUALS IN CRITICAL GROUPS

NOTE - DOSE LIMITS ARE INTENDED FOR APPLICATION TO AVERAGE EXPOSURE SITUATIONS AMONG INDIVIDUALS IN CRITICAL GROUPS.

## CURRENT RECOMMENDATIONS OF ICRP

(CONTINUED)

### DOSE LIMITS FOR INDIVIDUALS IN ICRP PUBLICATION 26 -

LIMIT ON ANNUAL DOSE EQUIVALENT FROM UNIFORM IRRADIATION OF WHOLE BODY OF 5 MSV (0.5 REM)

LIMIT WILL BE MET IF SUM OF ANNUAL COMMITTED EFFECTIVE DOSE EQUIVALENT FROM INTERNAL EXPOSURE AND ANNUAL EFFECTIVE DOSE EQUIVALENT FROM EXTERNAL EXPOSURE DOES NOT EXCEED 5 MSV (0.5 REM)

FOR LIFE-LONG EXPOSURES, IT WOULD BE PRUDENT TO LIMIT ANNUAL EFFECTIVE DOSE EQUIVALENT AVERAGED OVER A LIFETIME TO 1 MSV (0.1 REM)

LIMIT ON ANNUAL DOSE EQUIVALENT TO SKIN AND LENS OF THE EYE OF 50 MSV (5 REM) (PREVENTION OF NON-STOCHASTIC EFFECTS)

CURRENT RECOMMENDATIONS OF ICRP  
(CONTINUED)

STATEMENT OF APRIL 26, 1985 (ICRP PUBLICATION 45) -

PRINCIPAL LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 1 MSV  
(0.1 REM)

SUBSIDIARY LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF  
5 MSV (0.5 REM) FOR SOME YEARS, PROVIDED ANNUAL EFFECTIVE  
DOSE EQUIVALENT AVERAGED OVER A LIFETIME DOES NOT EXCEED  
1 MSV (0.1 REM)

LIMIT ON ANNUAL DOSE EQUIVALENT TO SKIN AND LENS OF THE EYE  
OF 50 MSV (5 REM)

## EFFECTIVE DOSE EQUIVALENT

EFFECTIVE DOSE EQUIVALENT IS DEFINED AS WEIGHTED SUM OF DOSE EQUIVALENTS TO DIFFERENT ORGANS OR TISSUES -

$$H_{\text{EFF}} = \sum_I w_I H_I, \quad I = \text{ORGAN INDEX}$$

WEIGHTING FACTOR  $w_I$  IS PROPORTION OF STOCHASTIC RISK RESULTING FROM ITH ORGAN TO TOTAL RISK, WHEN WHOLE BODY IS IRRADIATED UNIFORMLY

EFFECTIVE DOSE EQUIVALENT IS INTENDED TO BE PROPORTIONAL TO RISK FOR EITHER UNIFORM OR NON-UNIFORM IRRADIATION OF WHOLE BODY. EXPOSURES WITH EQUAL EFFECTIVE DOSE EQUIVALENTS SHOULD CORRESPOND TO EQUAL RISKS REGARDLESS OF DISTRIBUTION OF DOSE AMONG DIFFERENT ORGANS OR TISSUES.

## EFFECTIVE DOSE EQUIVALENT

(CONTINUED)

WEIGHTING FACTORS ( $w_T$ ) FOR DIFFERENT ORGANS OR TISSUES -

GONADS	0.25
BREAST	0.15
RED MARROW	0.12
LUNGS	0.12
THYROID	0.03
BONE SURFACES	0.03
REMAINDER	0.30

REMAINDER CATEGORY INCLUDES FIVE OTHER ORGANS (EXCLUDING SKIN, LENS OF THE EYE, AND BODY EXTREMITIES), EACH ASSIGNED WEIGHTING FACTOR OF 0.06

WHOLE BODY IS NOT A TISSUE AT RISK AND IS NOT INCLUDED IN REMAINDER CATEGORY

TOTAL RISK FROM UNIFORM WHOLE-BODY IRRADIATION:  $2 \times 10^{-2} \text{ Sv}^{-1}$   
( $2 \times 10^{-4} \text{ REM}^{-1}$ )

RISK FOR ANY ORGAN IS OBTAINED FROM TOTAL RISK FROM UNIFORM WHOLE-BODY IRRADIATION MULTIPLIED BY WEIGHTING FACTOR FOR SPECIFIC ORGAN.

DRAFT REVISIONS OF NCRP RECOMMENDATIONS

(JULY 25, 1985)

RECOMMENDED DOSE LIMITS FOR INDIVIDUALS -

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 1 MSV (0.1 REM)  
FOR CONTINUOUS OR REPEATED EXPOSURES

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 5 MSV (0.5 REM)  
FOR OCCASIONAL EXPOSURES

LIMITS ARE CONSISTENT WITH CURRENT ICRP RECOMMENDATIONS.

CURRENT NRC RADIATION PROTECTION STANDARDS  
(10 CFR PART 20)

NRC'S 10 CFR PART 20 IS ONLY LEGALLY BINDING RADIATION PROTECTION STANDARD IN U.S. FOR EXPOSURES OF THE PUBLIC TO ENVIRONMENTAL RADIOACTIVITY. CURRENT STANDARDS ARE BASED ON RECOMMENDATIONS IN ICRP PUBLICATIONS 1 AND 2.

PERMISSIBLE LEVELS OF RADIATION IN UNRESTRICTED AREAS FROM LICENSEE'S OPERATIONS AND OTHER SOURCES OF RADIATION -

LIMIT ON ANNUAL DOSE EQUIVALENT TO WHOLE BODY OF 0.5 REM  
(5 MSV)

LIMIT ON DOSE EQUIVALENT OF 2 MREM (0.02 MSV) IN ANY HOUR

LIMIT ON DOSE EQUIVALENT OF 0.1 REM (1 MSV) IN ANY  
7 CONSECUTIVE DAYS

LIMITS ON RADIOACTIVITY IN EFFLUENTS TO UNRESTRICTED AREAS  
FROM LICENSEE'S OPERATIONS -

MAXIMUM PERMISSIBLE CONCENTRATIONS (MPCs) OF RADIONUCLIDES  
IN AIR AND WATER (APPENDIX B), BASED ON ONE-TENTH OF VALUES  
IN ICRP PUBLICATION 2 FOR 168 HOURS PER WEEK OF OCCUPATIONAL  
EXPOSURE

RADIATION EXPOSURES AND RELEASES TO UNRESTRICTED AREAS SHOULD  
BE MAINTAINED ALARA

PROPOSED REVISIONS OF NRC'S 10 CFR PART 20

(JANUARY, 1986)

PROPOSED REVISIONS OF NRC'S RADIATION PROTECTION STANDARDS FOR THE PUBLIC ARE BASED ON RECOMMENDATIONS IN ICRP PUBLICATIONS 26 AND 30.

BASIC DOSE LIMIT FOR THE PUBLIC -

LIMIT ON ANNUAL DOSE EQUIVALENT OF 0.5 REM (5 mSv) FROM ALL KNOWN SOURCES AND OPERATIONS, BOTH LICENSED AND UNLICENSED, EXCEPT FOR RADIOACTIVITY DISCHARGED INTO SANITARY SEWERAGE ACCORDING TO PROPOSED LIMITS

LIMIT APPLIES TO SUM OF DOSE EQUIVALENT TO WHOLE BODY FROM EXTERNAL EXPOSURE AND COMMITTED EFFECTIVE DOSE EQUIVALENT FROM INTERNAL EXPOSURE

RELEASES TO UNRESTRICTED AREAS SHALL BE KEPT ALARA



PROPOSED REVISIONS OF NRC'S 10 CFR PART 20  
(CONTINUED)

REFERENCE-LEVEL DOSE LIMITS FOR INDIVIDUAL LICENSEES -

COMPLIANCE WITH BASIC DOSE LIMIT WILL BE ACHIEVED IF SOURCES UNDER EACH LICENSEE'S CONTROL LIMIT ANNUAL DOSE EQUIVALENTS TO REFERENCE LEVEL OF 0.1 REM (1 MSV)

COMPLIANCE WITH REFERENCE-LEVEL DOSE LIMIT MAY BE DEMONSTRATED -

- IF ANNUAL DOSE EQUIVALENT TO INDIVIDUAL LIKELY TO RECEIVE HIGHEST EXPOSURE FROM SOURCES UNDER LICENSEE'S CONTROL DOES NOT EXCEED 0.1 REM (1 MSV), OR
- BY LIMITING ANNUAL AVERAGE CONCENTRATIONS OF RADIONUCLIDES IN AIR AND WATER AT BOUNDARY OF UNRESTRICTED AREAS TO VALUES IN TABLE 2 OF APPENDIX B AND LIMITING DOSE EQUIVALENTS IN UNRESTRICTED AREAS TO 2 MREM (0.02 MSV) IN AN HOUR AND 0.05 REM (0.5 MSV) IN A YEAR

PROPOSED REFERENCE-LEVEL CONCENTRATIONS IN AIR AND WATER ARE BASED ON ANNUAL DOSE EQUIVALENT FOR AN ADULT OF 0.05 REM (0.5 MSV). REDUCTION BY FACTOR OF 2 BELOW REFERENCE-LEVEL DOSE LIMIT IS INTENDED TO PROVIDE ADEQUATE PROTECTION OF OTHER AGE GROUPS.

DOE RADIATION PROTECTION ORDERS  
FOR THE GENERAL PUBLIC

PRIOR TO 1985, STANDARDS FOR DOE OPERATIONS (ORDER 5480.1A)  
WERE SIMILAR TO FRC GUIDANCE AND RECOMMENDATIONS IN NCRP  
REPORT No. 39 -

LIMITS ON ANNUAL DOSE EQUIVALENT FOR INDIVIDUALS OF 0.5 REM  
(5 MSV) TO WHOLE BODY, GONADS, OR RED BONE MARROW AND  
1.5 REM (15 MSV) TO OTHER ORGANS

LIMITS ON ANNUAL DOSE EQUIVALENT FOR AVERAGE INDIVIDUALS IN  
EXPOSED POPULATION OF ONE-THIRD THE VALUES FOR INDIVIDUALS  
IN CRITICAL GROUPS

CONCENTRATION GUIDES FOR RADIONUCLIDES IN AIR AND WATER IN  
UNCONTROLLED AREAS, BASED ON DOSE LIMITS FOR INDIVIDUALS AND  
168 HOURS PER WEEK OF EXPOSURE

EXPOSURES OF THE PUBLIC SHALL BE MAINTAINED ALARA

DOE RADIATION PROTECTION ORDERS  
FOR THE GENERAL PUBLIC  
(CONTINUED)

CURRENT RADIATION PROTECTION STANDARDS (AUGUST 5, 1985) -

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.5 REM (5 MSV)  
FOR OCCASIONAL EXPOSURES

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.1 REM (1 MSV)  
FOR EXPOSURES LASTING LONGER THAN 5 YEARS

LIMIT ON ANNUAL DOSE EQUIVALENT TO ANY ORGAN OF 5 REM  
(50 MSV)

EXPOSURES OF THE PUBLIC SHALL BE MAINTAINED ALARA

LIMITS ARE CONSISTENT WITH CURRENT ICRP RECOMMENDATIONS AND  
DRAFT NCRP REVISIONS. STANDARDS INVOLVE FIRST USE IN U.S. OF  
THE EFFECTIVE DOSE EQUIVALENT.

DOE RADIATION PROTECTION ORDERS  
FOR THE GENERAL PUBLIC  
(CONTINUED)

PROPOSED REVISIONS OF DOE STANDARDS (MARCH 31, 1987) -

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.1 REM (1 MSV)

FOR UNUSUAL CIRCUMSTANCES OR UNANTICIPATED OCCURRENCES,  
TEMPORARY LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF  
0.5 REM (5 MSV) MAY BE AUTHORIZED

LIMIT ON ANNUAL DOSE EQUIVALENT TO ANY ORGAN OF 5 REM  
(50 MSV)

REVISED CONCENTRATION GUIDES FOR RADIONUCLIDES IN AIR AND  
WATER, BASED ON DOSIMETRY MODELS IN ICRP PUBLICATIONS 30 AND  
48, PLUS CONCENTRATION GUIDES FOR EXTERNAL EXPOSURE TO  
CONTAMINATED ATMOSPHERIC CLOUD

EXPOSURES OF THE PUBLIC SHALL BE MAINTAINED ALARA

## RISKS ASSOCIATED WITH RADIATION PROTECTION STANDARDS

ESTIMATES OF RISK BASED ON ICRP RISK FACTOR FROM UNIFORM WHOLE-BODY IRRADIATION -

$7 \times 10^{-3}$  - LIFETIME RISK FOR ANNUAL DOSE EQUIVALENT TO WHOLE BODY OF 0.5 REM (5 mSv)

$1 \times 10^{-3}$  - LIFETIME RISK FOR ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.1 REM (1 mSv) FOR PROLONGED EXPOSURES

$1 \times 10^{-4}$  - ANNUAL RISK FOR EFFECTIVE DOSE EQUIVALENT OF 0.5 REM (5 mSv) FOR OCCASIONAL EXPOSURES

DOSE LIMITS IN RADIATION PROTECTION STANDARDS DO NOT INCLUDE CONTRIBUTIONS FROM NATURALLY OCCURRING SOURCES OF EXPOSURE.

ENVIRONMENTAL RADIATION STANDARDS  
FOR SPECIFIC PRACTICES

## DEFINITION OF ENVIRONMENTAL RADIATION STANDARD

AN ENVIRONMENTAL RADIATION STANDARD IS A STANDARD THAT APPLIES TO A SPECIFIC PRACTICE; IT IS A SOURCE-BASED STANDARD.

ENVIRONMENTAL RADIATION STANDARDS FOR SPECIFIC PRACTICES ARE BASED PRIMARILY ON -

- CONSIDERATIONS OF BEST AVAILABLE CONTROL TECHNOLOGIES, OR
- REDUCTION OF ENVIRONMENTAL RADIOACTIVITY TO LEVELS NEAR AMBIENT BACKGROUND.

THUS, ENVIRONMENTAL RADIATION STANDARDS ARE BASED ON APPLICATION OF ALARA PRINCIPLE TO STANDARD SETTING ITSELF, NOT LIMITATION OF RISK PER SE

ENVIRONMENTAL RADIATION STANDARDS HELP ENSURE THAT RADIATION PROTECTION STANDARDS FOR ALL SOURCES OF EXPOSURE WILL BE MET.

NRC RULEMAKING 10 CFR PART 50  
ALARA, DESIGN OBJECTIVES FOR NUCLEAR REACTORS

RELEASES OF RADIOACTIVITY FROM NUCLEAR REACTORS SHALL BE KEPT  
ALARA.

APPENDIX I - NUMERICAL GUIDES FOR DESIGN OBJECTIVES AND ALARA

LIQUID EFFLUENTS -

LIMIT ON ANNUAL DOSE EQUIVALENT OR COMMITTED DOSE  
EQUIVALENT OF 3 MREM (0.03 MSV) TO WHOLE BODY OR 10 MREM  
(0.1 MSV) TO ANY ORGAN

GASEOUS EFFLUENTS -

LIMIT ON ANNUAL DOSE EQUIVALENT OF 5 MREM (0.05 MSV) TO  
WHOLE BODY OR 15 MREM (0.15 MSV) TO SKIN

IODINE AND PARTICULATES -

LIMIT ON ANNUAL DOSE EQUIVALENT OR COMMITTED DOSE  
EQUIVALENT OF 15 MREM (0.15 MSV) TO ANY ORGAN FROM ALL  
EXPOSURE PATHWAYS

ALARA -

\$1,000 EXPENDED PER PERSON-REM AVOIDED TO WHOLE BODY OR  
THYROID FOR POPULATION WITHIN 50 MILES



NRC RULEMAKING 10 CFR PART 50  
ALARA, DESIGN OBJECTIVES FOR NUCLEAR REACTORS  
(CONTINUED)

NUMERICAL GUIDES IN APPENDIX I ARE DESIGN OBJECTIVES USED IN EVALUATING APPLICATIONS FOR CONSTRUCTION PERMITS, NOT AN ENVIRONMENTAL RADIATION STANDARD FOR OPERATING REACTORS.

DOSE LIMITS IN NUMERICAL GUIDES ESSENTIALLY DEFINE AN UPPER LIMIT TO ALARA FOR NUCLEAR REACTORS. ADDITIONAL CONTROL MEASURES SHALL BE USED IF COST IS LESS THAN \$1,000 PER PERSON-REM AVOIDED.

EPA RULEMAKING 40 CFR PART 190  
NUCLEAR FUEL-CYCLE OPERATIONS

STANDARDS APPLY TO NORMAL OPERATIONS IN MILLING OF ORE, CHEMICAL CONVERSION, FUEL FABRICATION, ELECTRICITY GENERATION, AND FUEL REPROCESSING BUT NOT TO MINING, WASTE DISPOSAL OPERATIONS, TRANSPORTATION, AND REUSE OF RECOVERED SPECIAL NUCLEAR AND BY-PRODUCT MATERIALS.

LIMITS ON ANNUAL DOSE EQUIVALENT FROM ALL RADIONUCLIDES EXCEPT RADON AND ITS DAUGHTERS OF -

- 25 MREM (0.25 MSV) TO WHOLE BODY
- 75 MREM (0.75 MSV) TO THYROID
- 25 MREM (0.25 MSV) TO ANY OTHER ORGAN

RELEASE LIMITS PER GW-YEAR OF ELECTRICAL ENERGY PRODUCED -

- 50,000 CI OF KR-85
- 5 MCI OF I-129
- 0.5 MCI COMBINED OF PU-239 AND OTHER ALPHA-EMITTING TRANSURANIC RADIONUCLIDES WITH HALF-LIVES GREATER THAN 1 YEAR

STANDARDS ARE BASED ON BEST AVAILABLE CONTROL TECHNOLOGIES, NOT RISK LIMITATION.

EPA RULEMAKING 40 CFR PART 141  
RADIOACTIVITY IN COMMUNITY DRINKING WATER SYSTEMS

STANDARDS APPLY TO PUBLIC OR PRIVATE WATER SYSTEMS WITH AT LEAST 15 SERVICE CONNECTIONS OR SERVING AT LEAST 25 INDIVIDUALS.

LIMITS ON CONCENTRATIONS OF RADIONUCLIDES AT THE IAP -

- 5 pCi/L FOR RA-226 PLUS RA-228
- 15 pCi/L FOR GROSS ALPHA-PARTICLE ACTIVITY, INCLUDING RA-226 BUT EXCLUDING RADON AND URANIUM

LIMIT ON ANNUAL DOSE EQUIVALENT FROM MAN-MADE, BETA/GAMMA-EMITTING RADIONUCLIDES AT THE IAP -

- 4 MREM (0.04 MSV) TO WHOLE BODY OR ANY ORGAN

STANDARDS FOR RADIUM AND GROSS ALPHA-PARTICLE ACTIVITY ARE BASED ON AMBIENT LEVELS IN COMMUNITY DRINKING WATER SYSTEMS AND COSTS OF REDUCING LEVELS BY WATER TREATMENT.

FOR INGESTION OF 2 L PER DAY OF WATER, 5 pCi/L FOR RA-226 PLUS RA-228 CORRESPONDS TO ANNUAL EFFECTIVE DOSE EQUIVALENT OF 5 MREM (0.05 MSV), NOT INCLUDING CONTRIBUTIONS FROM INTAKES OF RADIOACTIVE DAUGHTER PRODUCTS

DOSE LIMIT FOR BETA/GAMMA EMITTERS IS BASED ON LEVELS OF SR-90 AND Cs-137 FROM FALLOUT IN DRINKING WATER.

EPA RULEMAKING 40 CFR PART 141  
RADIOACTIVITY IN COMMUNITY DRINKING WATER SYSTEMS  
(CONTINUED)

REVISIONS OF EPA STANDARDS MAY INCLUDE -

SEPARATE CONCENTRATION LIMIT FOR RA-228 ABOUT 2-3 TIMES LESS  
THAN PRESENT LIMIT FOR RA-226

CONCENTRATION LIMIT FOR URANIUM ABOUT TWICE PRESENT LIMIT  
FOR RA-226

CONCENTRATION LIMIT FOR RADON ABOUT AN ORDER OF MAGNITUDE  
GREATER THAN LIMIT FOR RADIUM OR URANIUM

USE OF CONCENTRATION LIMIT FOR GROSS ALPHA-PARTICLE ACTIVITY  
ONLY AS SCREENING TOOL IN MONITORING REQUIREMENTS

EPA IS CONSIDERING ALTERNATIVE OF SINGLE LIMIT ON ANNUAL  
EFFECTIVE DOSE EQUIVALENT FOR ALL RADIONUCLIDES.

## DOE STANDARDS FOR DRINKING WATER

REQUIREMENTS IN PROPOSED REVISIONS OF DOE RADIATION PROTECTION STANDARDS (MARCH 31, 1987) -

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT FROM DRINKING WATER SUPPLIES OPERATED BY AND FOR DOE OF 4 MR/yr (0.04 MSV)

LIQUID EFFLUENTS FROM DOE ACTIVITIES WILL NOT CAUSE ANY PRIVATE OR PUBLIC DRINKING WATER SYSTEM DOWNSTREAM OF FACILITY DISCHARGE TO EXCEED CONCENTRATION AND DOSE LIMITS IN EPA DRINKING WATER STANDARD

EPA RULEMAKING 40 CFR PART 192  
URANIUM AND THORIUM MILL TAILINGS

STANDARDS FOR CONTROL AND CLEANUP OF RESIDUAL RADIOACTIVE MATERIALS FROM INACTIVE URANIUM PROCESSING SITES AND MANAGEMENT OF URANIUM AND THORIUM BY-PRODUCT MATERIALS -

LIMIT ON (1) ANNUAL AVERAGE RELEASE RATE OF RN-222 TO ATMOSPHERE OF  $20 \text{ PCI}/\text{M}^2/\text{s}$  OR (2) ANNUAL AVERAGE CONCENTRATION OF RN-222 IN AIR ABOVE BACKGROUND OUTSIDE DISPOSAL SITE OF  $0.5 \text{ PCI}/\text{L}$

LIMIT ON RA-226 CONCENTRATION IN SOIL OF (1)  $5 \text{ PCI}/\text{G}$  AVERAGED OVER FIRST 15 CM BELOW SURFACE AND (2)  $15 \text{ PCI}/\text{G}$  AVERAGED OVER 15-CM THICK LAYERS MORE THAN 15 CM BELOW SURFACE

LIMIT ON RADON DECAY-PRODUCT CONCENTRATION (INCLUDING BACKGROUND) IN ANY OCCUPIED OR HABITABLE BUILDING OF  $0.03$  WORKING LEVELS (WL), WITH OBJECTIVE FOR REMEDIAL ACTION OF  $0.02$  WL

$1 \text{ WL} = 1.3 \times 10^5 \text{ MEV}$  OF ALPHA-PARTICLE ENERGY PER L OF AIR FROM SHORT-LIVED RADON DAUGHTER PRODUCTS

FOR SHORT-LIVED RN-222 DAUGHTER PRODUCTS IN EQUILIBRIUM IN AIR,  $1 \text{ WL} = 100 \text{ PCI}/\text{L}$

EPA RULEMAKING 40 CFR PART 192  
URANIUM AND THORIUM MILL TAILINGS  
(CONTINUED)

STANDARDS (CONTINUED) -

LIMIT ON GAMMA RADIATION LEVEL ABOVE BACKGROUND IN ANY OCCUPIED OR HABITABLE BUILDING OF 20  $\mu$ R/H

1 R = 0.6 REM (6 MSV) EFFECTIVE DOSE EQUIVALENT

LIMITS ON CONCENTRATIONS OF RA-226 PLUS RA-228 AND GROSS ALPHA-PARTICLE ACTIVITY, EXCLUDING RADON AND URANIUM, IN GROUND WATER GIVEN IN EPA DRINKING WATER STANDARD (40 CFR PART 141)

LIMIT ON ANNUAL DOSE EQUIVALENT FROM THORIUM PROCESSING OPERATIONS OF 25 MREM (0.25 MSV) TO WHOLE BODY, 75 MREM (0.75 MSV) TO THYROID, OR 25 MREM (0.25 MSV) TO ANY OTHER ORGAN

LIMITS FOR URANIUM, RN-222, AND RA-226 ALSO APPLY TO THORIUM, RN-220, AND RA-228, RESPECTIVELY

STANDARDS FOR CONTROL OF RADON EMISSIONS SHALL BE EFFECTIVE FOR UP TO 1,000 YEARS, TO EXTENT REASONABLY ACHIEVABLE, AND IN ANY CASE FOR AT LEAST 200 YEARS

EPA RULEMAKING 40 CFR PART 192  
URANIUM AND THORIUM MILL TAILINGS  
(CONTINUED)

STANDARDS ARE BASED PRIMARILY ON AMBIENT LEVELS OF RADIOACTIVITY IN WESTERN U.S. WHERE ORE DEPOSITS EXIST AND RESIDUAL MATERIALS WERE OBTAINED. THUS, PRIMARY BASIS FOR STANDARDS IS THAT MILL TAILINGS DISPOSAL SHOULD BE AS SAFE AS UNMINED ORE FROM WHICH TAILINGS WERE PRODUCED.

ESTIMATES OF LIMITS ON ANNUAL EFFECTIVE DOSE EQUIVALENT IMPLICIT IN STANDARDS -

OUTDOOR RN-222 CONCENTRATION OF 0.5 pCi/L - 0.02 REM (0.2 MSV) FOR SHORT-LIVED DAUGHTER PRODUCTS IN EQUILIBRIUM AND EXPOSURE OF 4 HOURS PER DAY

RA-226 CONCENTRATIONS IN SOIL - 0.08 REM (0.8 MSV) FOR DAUGHTER PRODUCTS IN EQUILIBRIUM AND CONTINUOUS EXPOSURE

INDOOR RADON DECAY-PRODUCT CONCENTRATION OF 0.03 WL FROM RN-222 - 0.6 REM (6 MSV) FOR EXPOSURE OF 20 HOURS PER DAY

INDOOR GAMMA RADIATION LEVEL OF 20  $\mu$ R/H - 0.08 REM (0.8 MSV) FOR EXPOSURE OF 20 HOURS PER DAY



NRC RULEMAKING 10 CFR PART 40, APPENDIX A  
URANIUM MILL TAILINGS

NRC HAS ISSUED REVISED STANDARDS TO CONFORM TO EPA STANDARDS.

REMAINING DIFFERENCES BETWEEN NRC AND EPA STANDARDS -

EXTERNAL PHOTON EXPOSURES SHOULD BE REDUCED TO BACKGROUND  
LEVELS

INDOOR CONCENTRATIONS OF RADON DECAY PRODUCTS ARE NOT  
ADDRESSED

CONFORMANCE WITH EPA'S GROUND-WATER PROTECTION REQUIREMENTS  
WILL BE ADDRESSED IN LATER RULEMAKING

NRC STANDARDS ALSO CONTAIN -

- TECHNICAL CRITERIA FOR SITING AND DESIGN OF DISPOSAL  
FACILITIES AND PROTECTION OF GROUND WATER
- REQUIREMENT THAT AIRBORNE EFFLUENTS FROM MILLING  
OPERATIONS SHALL BE ALARA

DOE GUIDELINES FOR RESIDUAL ACTIVITY AT  
FUSRAP AND REMOTE SFMP SITES  
(DRAFT REVISION, MARCH 1987)

GUIDELINES FOR RESIDUAL ACTIVITY AT FUSRAP AND REMOTE SFMP SITES ALSO APPLY TO RELEASE OF REAL PROPERTY AT ALL DOE SITES FOR UNRESTRICTED USE BY THE PUBLIC.

BASIC DOSE LIMITS FOR INDIVIDUALS -

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.1 REM (1 MSV)

UNDER UNUSUAL CIRCUMSTANCES, ANNUAL EFFECTIVE DOSE EQUIVALENTS UP TO 0.5 REM (5 MSV) MAY BE PERMITTED FOR EXPOSURES OF SHORT DURATION, PROVIDED ANNUAL EFFECTIVE DOSE EQUIVALENT AVERAGED OVER A LIFETIME IS NOT EXPECTED TO EXCEED 0.1 REM (1 MSV)

GUIDELINES FOR CONCENTRATIONS OF RESIDUAL RADIONUCLIDES IN SOIL, AIRBORNE RADON DECAY PRODUCTS, AND EXTERNAL GAMMA RADIATION GIVEN IN EPA URANIUM MILL TAILINGS STANDARD (40 CFR PART 192)

LIMITS ON RESIDUAL CONCENTRATIONS OF RADIONUCLIDES IN AIR AND WATER GIVEN IN DOE CONCENTRATION GUIDES

DOE GUIDELINES FOR RESIDUAL ACTIVITY AT  
FUSRAP AND REMOTE SFMP SITES  
(CONTINUED)

LIMITS ON REMOVABLE AND TOTAL RESIDUAL SURFACE CONTAMINATION FOR RELEASE OF MATERIALS AND EQUIPMENT FOR UNRESTRICTED USE GIVEN IN NRC GUIDELINES (JULY 1982).

INTERIM STORAGE OF RESIDUAL RADIOACTIVE MATERIAL AT FUSRAP AND REMOTE SFMP SITES -

LIMITS ON RN-222 CONCENTRATIONS IN AIR ABOVE BACKGROUND OF (1) 100 pCi/L AT ANY POINT WITHIN SITE, (2) 30 pCi/L AVERAGED OVER A YEAR AND OVER SITE, AND (3) 3 pCi/L AVERAGED OVER A YEAR AT ANY LOCATION OUTSIDE SITE

RN-222 CONCENTRATION OF 1 pCi/L GIVES ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.04 REM (0.4 MSV) FOR SHORT-LIVED DAUGHTER PRODUCTS IN EQUILIBRIUM AND EXPOSURE OF 4 HOURS PER DAY

LIMITS ON CONCENTRATIONS OF RADIONUCLIDES IN GROUND WATER OR QUANTITIES OF RESIDUAL RADIOACTIVE MATERIALS AS ESTABLISHED IN FEDERAL OR STATE STANDARDS

CONTROL AND STABILIZATION FEATURES DESIGNED TO ENSURE EFFECTIVE LIFE OF 50 YEARS, TO EXTENT REASONABLY ACHIEVABLE, AND IN ANY CASE OF AT LEAST 25 YEARS

DOE GUIDELINES FOR RESIDUAL ACTIVITY AT  
FUSRAP AND REMOTE SFMP SITES  
(CONTINUED)

LONG-TERM MANAGEMENT OF URANIUM, THORIUM, AND THEIR DECAY  
PRODUCTS -

LIMITS ON RN-222 EMANATION TO ATMOSPHERE GIVEN IN EPA  
URANIUM MILL TAILINGS STANDARD (40 CFR PART 192)

DESIGN LIFETIME FOR CONTROL AND STABILIZATION FEATURES GIVEN  
IN EPA STANDARD

PROTECTION OF GROUND WATER IN ACCORDANCE WITH FEDERAL AND  
STATE STANDARDS

EPA RULEMAKING 40 CFR PART 194  
CLEANUP OF RESIDUAL RADIOACTIVITY

EPA IS DEVELOPING PROPOSED CRITERIA FOR CLEANUP OF LAND AND FACILITIES CONTAMINATED WITH RESIDUAL RADIOACTIVE MATERIALS.

STANDARD WOULD APPLY TO -

- LICENSEES OF NRC OR AGREEMENT STATES
- SITES OWNED OR USED BY DOE, DOD, FORMER AEC, AND FORMER MANHATTAN ENGINEERING DISTRICT
- SITES WHERE NATURAL AND ACCELERATOR-PRODUCED RADIOACTIVE MATERIALS HAVE BEEN USED

## EPA GUIDANCE ON INDOOR RADON

EPA HAS RECOMMENDED MAXIMUM INDOOR RADON CONCENTRATION OF 4 PCI/L TO PROVIDE GUIDANCE ON NEED FOR MITIGATION OF INDOOR RADON.

FOR SHORT-LIVED DAUGHTER PRODUCTS IN EQUILIBRIUM, RN-222 CONCENTRATION OF 4 PCI/L GIVES ANNUAL EFFECTIVE DOSE EQUIVALENT OF 1 REM (10 MSV) FOR CONTINUOUS EXPOSURE.

EPA RULEMAKING 40 CFR PART 191  
MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES

STANDARDS APPLY TO SPENT FUEL, HIGH-LEVEL WASTE, AND  
TRANSURANIC WASTE.

STANDARDS FOR MANAGEMENT AND STORAGE OF WASTES -

FACILITIES REGULATED BY NRC OR AGREEMENT STATES -

LIMIT ON ANNUAL DOSE EQUIVALENT (1) FROM MANAGEMENT AND  
STORAGE AND (2) FROM ALL OPERATIONS COVERED BY 40 CFR PART  
190 OF 25 MREM (0.25 MSV) TO WHOLE BODY, 75 MREM  
(0.75 MSV) TO THYROID, OR 25 MREM (0.25 MSV) TO ANY OTHER  
ORGAN

FACILITIES OPERATED BY DOE BUT NOT REGULATED BY NRC OR  
AGREEMENT STATES -

LIMIT ON ANNUAL DOSE EQUIVALENT OF 25 MREM (0.25 MSV) TO  
WHOLE BODY OR 75 MREM (0.75 MSV) TO ANY ORGAN

UPON APPLICATION FOR ALTERNATIVE STANDARD, LIMIT ON ANNUAL  
DOSE EQUIVALENT FROM ALL SOURCES, EXCLUDING NATURAL  
BACKGROUND AND MEDICAL PRACTICES, OF 0.1 REM (1 MSV) FOR  
CONTINUOUS EXPOSURE AND 0.5 REM (5 MSV) FOR INFREQUENT  
EXPOSURE

EPA RULEMAKING 40 CFR PART 191  
MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES  
(CONTINUED)

STANDARDS FOR WASTE DISPOSAL -

CUMULATIVE RELEASES OF RADIONUCLIDES TO ACCESSIBLE ENVIRONMENT FOR 10,000 YEARS AFTER DISPOSAL SHALL HAVE A LIKELIHOOD OF (1) LESS THAN ONE CHANCE IN 10 OF EXCEEDING SPECIFIED LIMITS AND (2) LESS THAN ONE CHANCE IN 1,000 OF EXCEEDING TEN TIMES THE SPECIFIED LIMITS

ACCESSIBLE ENVIRONMENT - ATMOSPHERE, LAND SURFACE, SURFACE WATERS, OCEANS, AND ALL OF LITHOSPHERE MORE THAN 5 KM FROM OUTER BOUNDARY OF ORIGINAL LOCATION OF WASTES IN DISPOSAL SYSTEM

RADIONUCLIDE-SPECIFIC CUMULATIVE RELEASE LIMITS ARE BASED ON LIMIT ON POPULATION RISK OF 1,000 HEALTH EFFECTS PER REPOSITORY OVER 10,000 YEARS

FOR 1,000 YEARS AFTER DISPOSAL AND ASSUMING UNDISTURBED PERFORMANCE OF DISPOSAL SYSTEM, LIMIT ON ANNUAL DOSE EQUIVALENT IN ACCESSIBLE ENVIRONMENT OF 25 MREM (0.25 MSV) TO WHOLE BODY OR 75 MREM (0.75 MSV) TO ANY ORGAN

UNDISTURBED PERFORMANCE - PREDICTED BEHAVIOR ABSENT HUMAN INTRUSION OR OCCURRENCE OF UNLIKELY NATURAL EVENTS



EPA RULEMAKING 40 CFR PART 191  
MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES  
(CONTINUED)

STANDARDS FOR WASTE DISPOSAL (CONTINUED) -

GROUND-WATER PROTECTION REQUIREMENTS FOR 1,000 YEARS AFTER DISPOSAL AND ASSUMING UNDISTURBED PERFORMANCE OF DISPOSAL SYSTEM -

LIMITS ON ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN SPECIAL SOURCE OF GROUND WATER OF (1) 5 PC1/L FOR RA-226 AND RA-228 COMBINED, (2) 15 PC1/L FOR ALPHA-EMITTING RADIONUCLIDES, INCLUDING RA-226 BUT EXCLUDING RADON, AND (3) VALUES FOR ALL BETA/GAMMA-EMITTING RADIONUCLIDES THAT WOULD PRODUCE AN ANNUAL DOSE EQUIVALENT OF 4 MREM (0.04 MSV) TO WHOLE BODY OR ANY ORGAN

IF ANY RADIONUCLIDE CONCENTRATION IN SPECIAL SOURCE OF GROUND WATER BEFORE CONSTRUCTION OF DISPOSAL SYSTEM EXCEEDS SPECIFIED LIMIT, THEN EXISTING CONCENTRATION SHALL NOT BE INCREASED BY MORE THAN THE LIMIT

SPECIAL SOURCE OF GROUND WATER (1) LIES WITHIN 5 KM OF OUTER BOUNDARY OF ORIGINAL LOCATION OF WASTE IN DISPOSAL SYSTEM, (2) IS SUPPLYING DRINKING WATER FOR THOUSANDS OF PERSONS AT TIME OF SITE CHARACTERIZATION, AND (3) IS IRREPLACEABLE AS SOURCE OF DRINKING WATER FOR THAT POPULATION

EPA RULEMAKING 40 CFR PART 191  
MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES  
(CONTINUED)

STANDARDS FOR DISPOSAL ARE BASED ON BEST AVAILABLE TECHNOLOGY,  
NOT RISK LIMITATION.

LIMIT ON POPULATION RISK OF 1,000 HEALTH EFFECTS PER  
REPOSITORY OVER 10,000 YEARS, USED TO OBTAIN CUMULATIVE  
RELEASE LIMITS OF RADIONUCLIDES, CORRESPONDS TO LIFETIME RISK  
OF  $5 \times 10^{-8}$  FOR AVERAGE INDIVIDUAL IN CURRENT U.S. POPULATION.

NRC RULEMAKING 10 CFR PART 60  
DISPOSAL OF HIGH-LEVEL WASTES

STANDARD CONTAINS TECHNICAL CRITERIA, INCLUDING SITING AND DESIGN CRITERIA, INTENDED TO PROVIDE REASONABLE ASSURANCE THAT EPA STANDARD WILL BE MET.

DURING PRE-CLOSURE OPERATIONS, COMPLIANCE WITH DOSE LIMITS FOR MANAGEMENT AND STORAGE IN EPA STANDARD

POST-CLOSURE PERFORMANCE CRITERIA -

SUBSTANTIALLY COMPLETE CONTAINMENT OF WASTE WITHIN WASTE PACKAGES FOR 300-1,000 YEARS

LIMIT ON RELEASE RATE OF ANY RADIONUCLIDE FROM ENGINEERED BARRIER SYSTEM FOLLOWING CONTAINMENT PERIOD OF (1)  $10^{-5}$  PER YEAR OF INVENTORY OF THAT RADIONUCLIDE AT 1,000 YEARS FOLLOWING PERMANENT CLOSURE OR (2)  $10^{-5}$  PER YEAR OF INVENTORY OF ALL RADIONUCLIDES PLACED IN DISPOSAL FACILITY THAT REMAINS AFTER 1,000 YEARS OF DECAY

PRE-WASTE-EMPLACEMENT GROUND-WATER TRAVEL TIME ALONG FASTEST PATH OF LIKELY RADIONUCLIDE TRAVEL FROM EDGE OF DISTURBED ZONE TO ACCESSIBLE ENVIRONMENT OF AT LEAST 1,000 YEARS

DISTURBED ZONE - REGION WHERE MECHANICAL OR THERMAL DISTURBANCES MAY SIGNIFICANTLY AFFECT REPOSITORY PERFORMANCE

NRC RULEMAKING 10 CFR PART 61  
NEAR-SURFACE LAND DISPOSAL OF RADIOACTIVE WASTE

PERFORMANCE OBJECTIVES -

LIMIT ON ANNUAL DOSE EQUIVALENT BEYOND FACILITY BOUNDARY OF 25 MREM (0.25 MSV) TO WHOLE BODY, 75 MREM (0.75 MSV) TO THYROID, OR 25 MREM (0.25 MSV) TO ANY OTHER ORGAN

RELEASES BEYOND FACILITY BOUNDARY SHOULD BE MAINTAINED ALARA  
DESIGN, OPERATION, AND CLOSURE OF FACILITY MUST ENSURE PROTECTION OF INADVERTENT INTRUDERS INTO SITE AT ANY TIME AFTER ACTIVE INSTITUTIONAL CONTROLS ARE REMOVED

TECHNICAL REQUIREMENTS -

REQUIREMENTS ON SITE SUITABILITY, DESIGN, OPERATION AND CLOSURE, ENVIRONMENTAL MONITORING, AND WASTE CHARACTERISTICS

LIMITS ON CONCENTRATIONS OF RADIONUCLIDES THAT ARE GENERALLY ACCEPTABLE FOR NEAR-SURFACE LAND DISPOSAL, I.E., CLASS-A AND -C LIMITS FOR LONG-LIVED RADIONUCLIDES AND CLASS-A, -B, AND -C LIMITS FOR SHORT-LIVED RADIONUCLIDES

WASTE CLASSIFICATION SYSTEM PROVIDES PROTECTION OF INADVERTENT INTRUDERS AND IS BASED ON LIMIT ON ANNUAL DOSE EQUIVALENT OF 0.5 REM (5 MSV) TO WHOLE BODY AND BONE OR 1.5 REM (15 MSV) TO ANY OTHER ORGAN

DOE ORDER 5820.2  
MANAGEMENT OF LOW-LEVEL WASTE

INTERIM PERFORMANCE OBJECTIVE FOR OFF-SITE EXPOSURES FOR NEW  
LOW-LEVEL WASTE DISPOSAL FACILITIES (NOVEMBER 11, 1985) -

LIMIT ON ANNUAL DOSE EQUIVALENT OF 25 MREM (0.25 MSV)

PERFORMANCE OBJECTIVES IN PROPOSED REVISIONS OF ORDER  
(APRIL 17, 1987) -

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT BEYOND FACILITY  
BOUNDARY OF 25 MREM (0.25 MSV)

EXPOSURES OF THE PUBLIC SHOULD BE MAINTAINED ALARA

LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT FOR INADVERTENT  
INTRUDERS AFTER LOSS OF ACTIVE INSTITUTIONAL CONTROLS OF  
0.1 REM (1 MSV) FOR CONTINUOUS EXPOSURES OR 0.5 REM (5 MSV)  
FOR EXPOSURES OF LESS THAN 1 YEAR

PROTECTION OF WATER RESOURCES ACCORDING TO APPLICABLE WATER  
QUALITY STANDARDS

EPA RULEMAKING 40 CFR PART 193  
DISPOSAL OF LOW-LEVEL WASTE

EPA IS DEVELOPING PROPOSED RULEMAKING ON LOW-LEVEL WASTE  
DISPOSAL THAT APPARENTLY WILL CONTAIN -

- LIMIT ON ANNUAL DOSE EQUIVALENT BEYOND FACILITY BOUNDARY  
OF 25 MREM (0.25 MSV)
- REQUIREMENTS FOR PROTECTION OF GROUND WATER AT DISPOSAL  
SITES
- NO OTHER DOSE OR CONCENTRATION LIMITS DIRECTLY RELATED TO  
PROTECTION OF INADVERTENT INTRUDERS

EPA RULEMAKING 40 CFR PART 61  
AIRBORNE EMISSIONS OF RADIONUCLIDES

STANDARDS FOR AIRBORNE RELEASES FROM DOE FACILITIES AND NRC-  
LICENSED AND NON-DOE FEDERAL FACILITIES, EXCEPT UNDERGROUND  
URANIUM MINES -

LIMIT ON ANNUAL DOSE EQUIVALENT OF 25 MREM (0.25 MSV) TO  
WHOLE BODY OR 75 MREM (0.75 MSV) TO ANY ORGAN, EXCLUSIVE OF  
DOSES FROM RADON AND DECAY PRODUCTS

UPON APPLICATION FOR ALTERNATIVE STANDARD, LIMIT ON ANNUAL  
EFFECTIVE DOSE EQUIVALENT FROM ALL SOURCES, EXCLUDING  
NATURAL BACKGROUND AND MEDICAL PRACTICES, OF 0.1 REM (1 MSV)  
FOR CONTINUOUS EXPOSURE AND 0.5 REM (5 MSV) FOR  
NONCONTINUOUS EXPOSURE

STANDARD FOR ELEMENTAL PHOSPHORUS PLANTS -

LIMIT ON ANNUAL EMISSIONS OF Po-210 TO AIR OF 21 CI

STANDARD FOR RN-222 EMISSIONS FROM UNDERGROUND URANIUM MINES -

REQUIREMENTS ON INSTALLATION AND MAINTENANCE OF BULKHEADS TO  
ISOLATE ABANDONED AND TEMPORARILY ABANDONED AREAS OF MINES

## SUMMARY OF ENVIRONMENTAL RADIATION STANDARDS

STANDARDS BASED ON BEST AVAILABLE CONTROL TECHNOLOGIES -

DESIGN OBJECTIVES FOR NUCLEAR REACTORS (10 CFR PART 50,  
APPENDIX I)

NUCLEAR FUEL-CYCLE OPERATIONS (40 CFR PART 190)

MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES (40 CFR PART  
191; 10 CFR PART 60)

NEAR-SURFACE LAND DISPOSAL OF RADIOACTIVE WASTE (10 CFR PART  
61; DOE ORDER 5820.2)

AIRBORNE EMISSIONS OF RADIONUCLIDES (40 CFR PART 61)

NOTE - A LIMIT ON ANNUAL EFFECTIVE DOSE EQUIVALENT OF 25 MREM  
(0.25 MSV) IS A DE FACTO ENVIRONMENTAL RADIATION  
STANDARD FOR MANY PRACTICES.



SUMMARY OF ENVIRONMENTAL RADIATION STANDARDS  
(CONTINUED)

STANDARDS BASED ON AMBIENT BACKGROUND LEVELS -

RADIOACTIVITY IN DRINKING WATER (40 CFR PART 141; DOE  
RADIATION PROTECTION ORDERS)

URANIUM AND THORIUM MILL TAILINGS (40 CFR PART 192; 10 CFR  
PART 40, APPENDIX A)

CLEANUP OF RESIDUAL RADIOACTIVITY (DOE RADIATION PROTECTION  
ORDERS)

## RISKS ASSOCIATED WITH ENVIRONMENTAL RADIATION STANDARDS

ESTIMATES OF LIFETIME RISK BASED ON ICRP RISK FACTOR FROM UNIFORM WHOLE-BODY IRRADIATION AND WEIGHTING FACTORS FOR SPECIFIC ORGANS -

- 1 x 10<sup>-2</sup> - EPA GUIDANCE ON INDOOR RADON
- 1 x 10<sup>-2</sup> - EPA URANIUM MILL TAILINGS STANDARDS
- 7 x 10<sup>-3</sup> - ANNUAL DOSE EQUIVALENT TO WHOLE BODY OF 0.5 REM
- 4 x 10<sup>-4</sup> - ANNUAL DOSE EQUIVALENT TO WHOLE BODY OR EFFECTIVE DOSE EQUIVALENT OF 25 MREM
- 7 x 10<sup>-5</sup> - CONCENTRATION OF RA-226 PLUS RA-228 IN DRINKING WATER OF 5 PCI/L
- 6 x 10<sup>-5</sup> - ANNUAL DOSE EQUIVALENT TO WHOLE BODY OR EFFECTIVE DOSE EQUIVALENT FROM DRINKING WATER OF 4 MREM
- 3 x 10<sup>-5</sup> - ANNUAL DOSE EQUIVALENT TO THYROID OF 75 MREM
- 1 x 10<sup>-5</sup> - ANNUAL DOSE EQUIVALENT TO BONE OF 25 MREM
- 5 x 10<sup>-6</sup> - ANNUAL DOSE EQUIVALENT TO BONE FROM SR-90 IN DRINKING WATER OF 4 MREM
- 2 x 10<sup>-6</sup> - ANNUAL DOSE EQUIVALENT TO THYROID FROM I-129 IN DRINKING WATER OF 4 MREM
- 5 x 10<sup>-8</sup> - EPA CONTAINMENT REQUIREMENTS FOR DISPOSAL OF HIGH-LEVEL WASTES

RISKS ASSOCIATED WITH ENVIRONMENTAL RADIATION STANDARDS  
(CONTINUED)

EPA STANDARDS FOR DRINKING WATER AND DISPOSAL OF HIGH-LEVEL WASTES LIMIT RISK TO AVERAGE INDIVIDUALS IN EXPOSED POPULATION; OTHER STANDARDS LIMIT RISK TO INDIVIDUALS IN CRITICAL GROUPS.

LIFETIME RISKS ASSOCIATED WITH DIFFERENT STANDARDS VARY BY ABOUT 5 ORDERS OF MAGNITUDE.

RISKS ASSOCIATED WITH EPA URANIUM MILL TAILINGS STANDARDS AND GUIDANCE ON INDOOR RADON EXCEED RISKS ASSOCIATED WITH GENERALLY APPLICABLE RADIATION PROTECTION STANDARDS BUT INCLUDE CONTRIBUTIONS FROM NATURALLY OCCURRING SOURCES.

DE MINIMIS DOSE AND EXEMPT

LEVELS OF RADIOACTIVITY

## DEFINITIONS

"EXEMPT" OR "BELOW REGULATORY CONCERN" -

LEVELS OF RADIOACTIVITY OR DOSE JUDGED BY REGULATORY AUTHORITIES TO BE ALARA FOR SPECIFIC PRACTICES AT ANY SITE

LEVELS ARE BASED ON GENERAL APPLICATION OF ALARA PRINCIPLE TO SPECIFIC PRACTICES AND MAY VARY FROM ONE PRACTICE TO ANOTHER

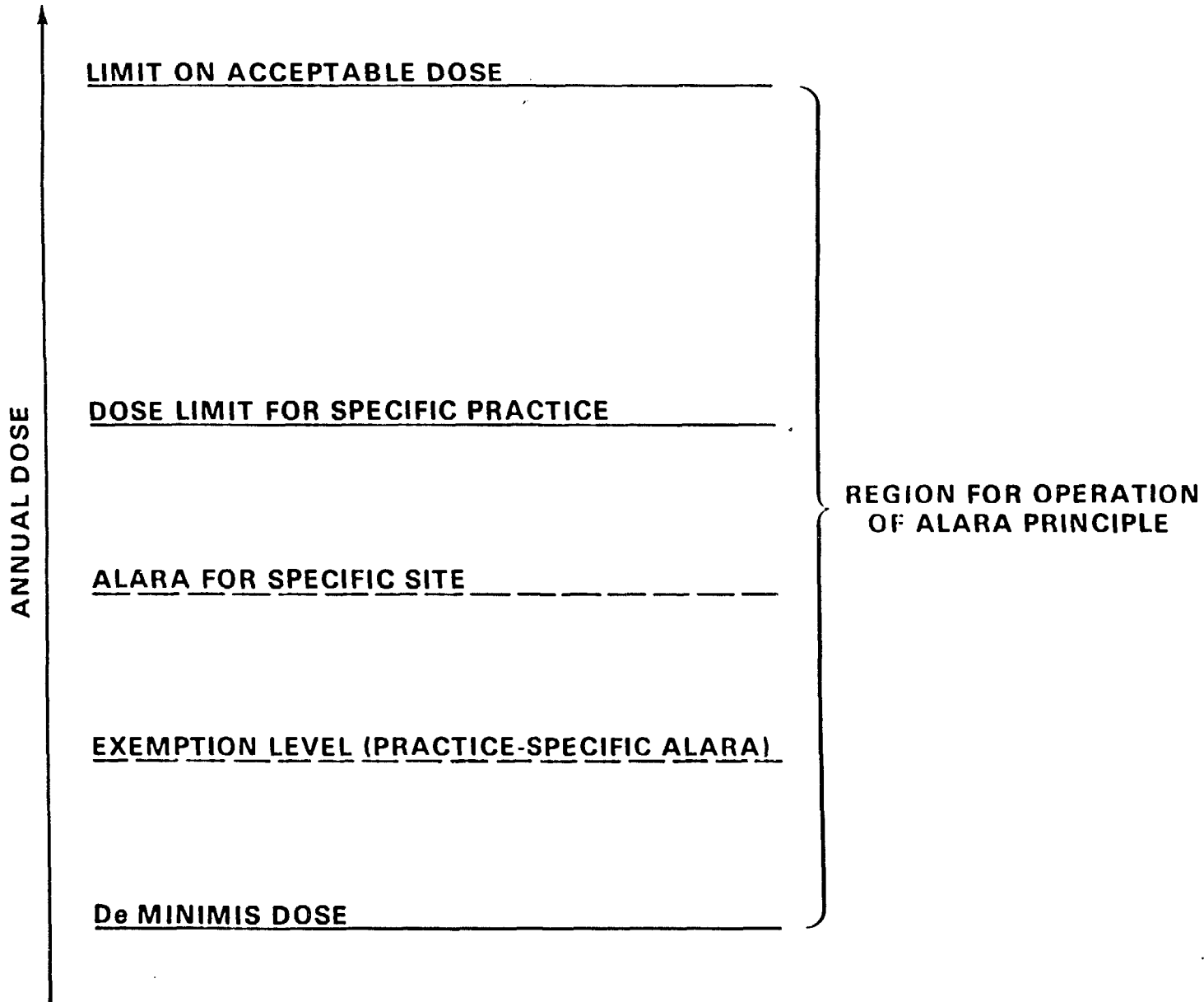
DE MINIMIS DOSE -

GENERALLY APPLICABLE DOSE BELOW WHICH CONTROL OF EXPOSURES BY REGULATORY AUTHORITIES WOULD BE DELIBERATELY AND SPECIFICALLY CURTAILED; I.E., LIMIT BELOW WHICH NO FURTHER REDUCTION IN DOSE SHOULD BE ATTEMPTED USING ALARA PRINCIPLE  
LEVEL IS BASED ONLY ON CONSIDERATION OF NEGLIGIBLE RISK

RELATIONSHIP BETWEEN DOSE LIMITS,  
ALARA, AND DE MINIMIS DOSE

FOLLOWING FIGURE SHOWS RELATIONSHIP BETWEEN -

- LIMIT ON ACCEPTABLE DOSE IN GENERALLY APPLICABLE RADIATION PROTECTION STANDARD
- DOSE LIMIT IN ENVIRONMENTAL RADIATION STANDARD FOR SPECIFIC PRACTICE
- DOSE FROM SITE-SPECIFIC APPLICATION OF ALARA PRINCIPLE FOR PARTICULAR PRACTICE
- EXEMPT DOSE FOR ANY SITE FROM PRACTICE-SPECIFIC APPLICATION OF ALARA PRINCIPLE
- GENERALLY APPLICABLE DE MINIMIS DOSE



## RECOMMENDATIONS FOR A DE MINIMIS DOSE

### DRAFT REVISIONS OF NCRP RECOMMENDATIONS -

ANNUAL EFFECTIVE DOSE EQUIVALENT OF  $0.01$  MSV (1 MREM), BASED ON ASSUMED NEGLIGIBLE RISK OF  $10^{-7}$  PER YEAR

POPULATION DOSE ASSESSMENTS SHOULD EXCLUDE ANNUAL EFFECTIVE DOSE EQUIVALENTS FOR INDIVIDUALS LESS THAN  $0.01$  MSV (1 MREM)

### PROPOSED REVISIONS OF NRC RADIATION PROTECTION STANDARDS (10 CFR PART 20) -

SUGGESTION OF ANNUAL DOSE EQUIVALENT OF  $0.1$  MREM ( $1 \mu$ SV), BASED ON ASSUMED NEGLIGIBLE LIFETIME RISK OF  $10^{-6}$

POPULATION DOSE ASSESSMENTS SHOULD EXCLUDE ANNUAL DOSE EQUIVALENTS FOR INDIVIDUALS LESS THAN 1 MREM ( $0.01$  MSV)

### PROPOSAL OF NATIONAL RADIOLOGICAL PROTECTION BOARD (U.K.) -

ANNUAL EFFECTIVE DOSE EQUIVALENT OF  $0.05$  MSV (5 MREM), I.E., 1% OF DOSE LIMIT FOR ANY YEAR RECOMMENDED BY ICRP

REDUCTION BY A FACTOR OF 10 FOR ANY PRACTICE WHEN EXPOSURE TO SEVERAL DE MINIMIS SOURCES COULD OCCUR



RECOMMENDATIONS FOR A DE MINIMIS DOSE

(CONTINUED)

ADVISORY GROUP OF INTERNATIONAL ATOMIC ENERGY AGENCY -

ANNUAL EFFECTIVE DOSE EQUIVALENT OF  $0.01$  MSV (1 MREM), BASED ON ASSUMED NEGLIGIBLE RISK OF  $10^{-7}$  PER YEAR

FOR EXPOSURE TO SEVERAL DE MINIMIS SOURCES, ANNUAL EFFECTIVE DOSE EQUIVALENT SHOULD BE LESS THAN  $0.1$  MSV (10 MREM)

PRACTICE MAY BE LEFT UNREGULATED IF POPULATION DOSE COMMITMENT IS LESS THAN 1 PERSON-SV (100 PERSON-REM)

DE MINIMIS DOSE APPLIES ONLY TO MAN-MADE RADIONUCLIDES, BECAUSE NATURALLY OCCURRING RADIONUCLIDES IN THEIR UNDISTURBED STATE LEAD TO DOSES HIGHER THAN DE MINIMIS LEVEL

SUMMARY - RECOMMENDATIONS BY REGULATORY AUTHORITIES ARE IN THE RANGE  $0.001$ - $0.1$  MSV ( $0.1$ -10 MREM).

PROPOSALS FOR DETERMINING EXEMPT QUANTITIES  
OF RADIOACTIVITY FOR WASTE DISPOSAL

DOE THRESHOLD GUIDANCE (SEPTEMBER 1986) -

ANNUAL EFFECTIVE DOSE EQUIVALENT OF 1-10 MREM (0.01-0.1 MSV)

NRC POLICY STATEMENT ON RADIOACTIVE WASTE BELOW REGULATORY  
CONCERN (AUGUST 29, 1986) -

MAXIMUM EXPECTED ANNUAL EFFECTIVE DOSE EQUIVALENT OF A FEW  
MREM FOR OFF-SITE INDIVIDUALS FROM NORMAL OPERATIONS AND  
ANTICIPATED EVENTS

COLLECTIVE DOSES TO CRITICAL POPULATION GROUPS AND GENERAL  
POPULATION ARE SMALL

POTENTIAL DOSES FROM ACCIDENTS AND INTRUSION INTO DISPOSAL  
SITE AFTER LOSS OF INSTITUTIONAL CONTROLS ARE NOT  
SIGNIFICANT

NRC IS DEVELOPING GENERIC RULEMAKING (10 CFR PARTS 2 AND  
20) TO REPLACE POLICY STATEMENT

ATOMIC ENERGY CONTROL BOARD OF CANADA -

ANNUAL EFFECTIVE DOSE EQUIVALENT OF 0.05 MSV (5 MREM)

POTENTIAL FOR EXPOSURE OF LARGE POPULATIONS TO EXEMPT DOSE  
SHOULD BE SMALL; I.E., DOSE FROM DISPOSAL OF EXEMPT  
MATERIALS SHOULD BE LOCALIZED

RULEMAKINGS AND GUIDANCES ON EXEMPT QUANTITIES  
OF RADIOACTIVE MATERIALS

NRC STANDARDS -

10 CFR PART 20 -

- DISPOSAL OF SCINTILLATION MATERIALS AND ANIMAL CARCASSES CONTAINING LESS THAN 0.05  $\mu\text{Ci/g}$  OF H-3 AND C-14

10 CFR PART 30 -

- EXEMPT QUANTITIES OF BY-PRODUCT MATERIALS, CONTAMINATED RESINS, SELF-LUMINOUS PRODUCTS, AND GAS AND AEROSOL DETECTORS

10 CFR PART 40 -

- UNIMPORTANT QUANTITIES OF SOURCE MATERIALS

10 CFR PART 71 -

- PACKAGING AND TRANSPORTATION OF MATERIALS CONTAINING LESS THAN 0.002  $\mu\text{Ci/g}$

EXEMPT QUANTITIES OF RADIOACTIVITY IN NRC STANDARDS ARE NOT EASILY RELATED TO SPECIFIC DOSE LIMITS, AND DOSES MAY BE WELL ABOVE DE MINIMIS LEVEL

RULEMAKINGS AND GUIDANCES ON EXEMPT QUANTITIES  
OF RADIOACTIVE MATERIALS  
(CONTINUED)

NRC BRANCH TECHNICAL POSITION ON DISPOSAL OF RESIDUAL THORIUM  
OR URANIUM (OCTOBER 5, 1981) -

CONCENTRATION LIMITS FOR DISPOSAL WITH NO RESTRICTION ON  
BURIAL METHOD OF (1) 10 PCI/G FOR NATURAL THORIUM OR URANIUM  
WITH DAUGHTERS PRESENT AND IN EQUILIBRIUM, (2) 35 PCI/G FOR  
DEPLETED URANIUM, AND (3) 30 PCI/G FOR ENRICHED URANIUM

LIMITS ARE BASED ON EPA CLEANUP STANDARDS FOR RA-226 IN  
SOIL (40 CFR PART 192), AND RESULTING ANNUAL DOSE MAY BE  
WELL ABOVE DE MINIMIS LEVEL

PROPOSED EPA RULEMAKING ON REPORTABLE QUANTITIES OF  
RADIONUCLIDES UNDER CERCLA (40 CFR PART 302) -

CURRENT REPORTABLE QUANTITY OF RADIONUCLIDES (AND OTHER  
HAZARDOUS SUBSTANCES) RELEASED TO ENVIRONMENT IS ONE POUND

PROPOSED RULEMAKING GIVES REVISED REPORTABLE QUANTITIES OF  
RADIONUCLIDES RELEASED TO ENVIRONMENT BASED ON (1) LIMIT ON  
DOSE EQUIVALENT OF 0.5 REM (5 MSV), (2) ANNUAL LIMITS ON  
INTAKE BY INHALATION AND INGESTION IN ICRP PUBLICATION 30,  
AND (3) ASSUMPTION THAT EXPOSURES OCCUR 30 M FROM SOURCE

CONSIDERATION OF  
AGE DEPENDENCE OF DOSE

TREATMENT OF AGE DEPENDENCE OF DOSE  
FOR EXPOSURES OF THE PUBLIC

RADIATION PROTECTION STANDARDS, ENVIRONMENTAL RADIATION STANDARDS, AND DOSE ASSESSMENTS FOR THE PUBLIC USUALLY ASSUME EXPOSURES OF YOUNG ADULTS.

COMMON EXCEPTION IS DOSE TO CHILD'S THYROID FROM INGESTION OF I-131 IN MILK

PROPER CALCULATIONS OF EXTERNAL AND INTERNAL DOSE FOR PUBLIC EXPOSURES WOULD TAKE INTO ACCOUNT AGE DEPENDENCE OF -

- ORGAN MASSES, SHAPES, AND LOCATIONS IN THE BODY
- RADIONUCLIDE ABSORPTION IN GI TRACT
- DEPOSITION AND RETENTION OF INHALED RADIONUCLIDES IN LUNGS
- DISTRIBUTION AND RETENTION OF ABSORBED ACTIVITY IN ORGANS

PROPER CALCULATIONS ARE BECOMING AVAILABLE FOR MANY RADIONUCLIDES; MOST EARLIER CALCULATIONS CONSIDER ONLY AGE DEPENDENCE OF ORGAN MASSES AND POSSIBLY GI-TRACT UPTAKE, BUT NOT OTHER FACTORS, AND IN SOME CASES ARE BASED ON OUTDATED DOSIMETRY MODELS IN ICRP PUBLICATION 2.

## EXAMPLES OF AGE-DEPENDENT DOSE CALCULATIONS

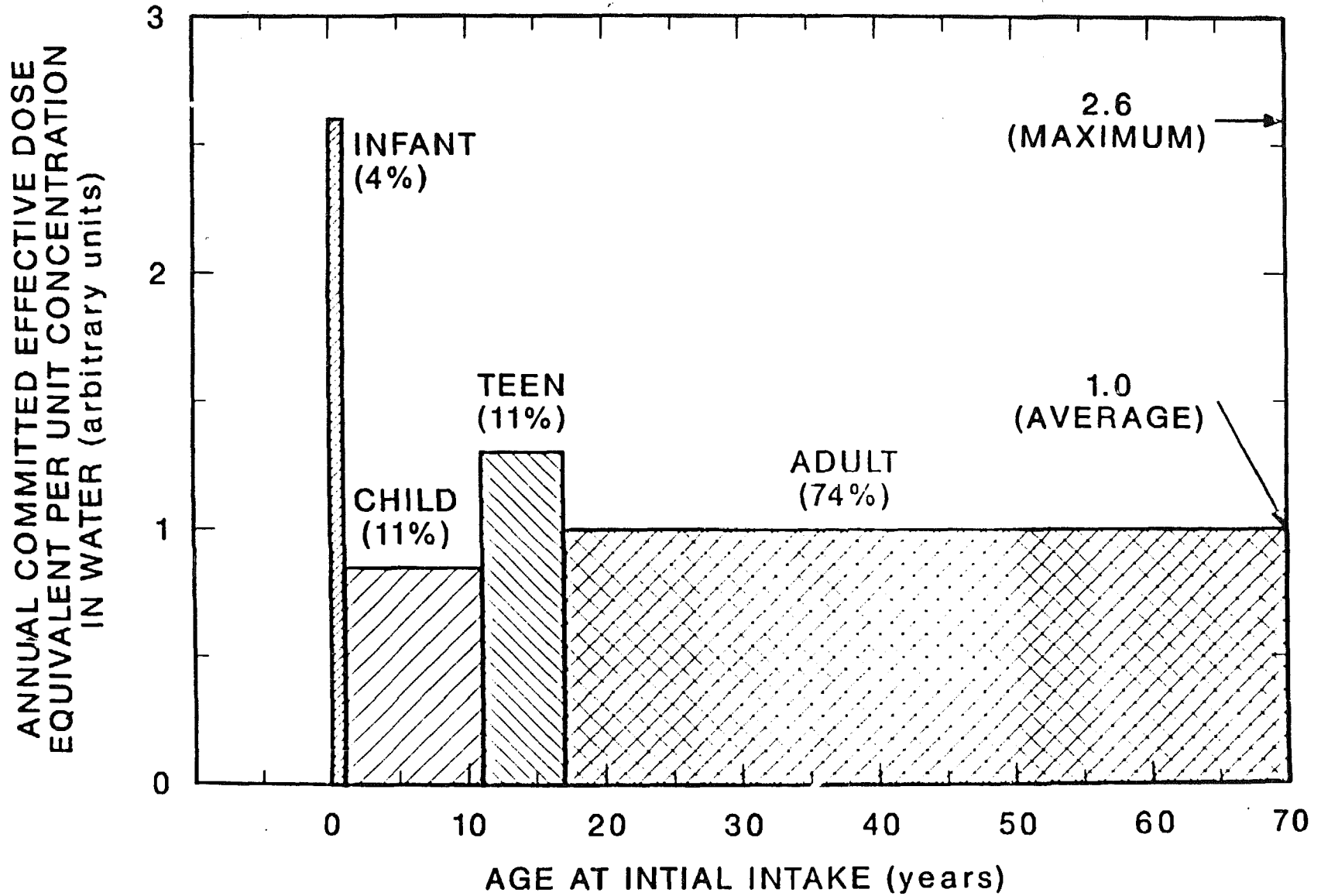
FOLLOWING TWO FIGURES SHOW EXAMPLES OF PROPER AGE-DEPENDENT CALCULATIONS OF ANNUAL COMMITTED EFFECTIVE DOSE EQUIVALENTS FROM INGESTION OF SR-90 AND NATURAL URANIUM IN DRINKING WATER, NORMALIZED TO VALUE FOR ADULTS.

ALL ASPECTS OF CALCULATION ARE AGE-DEPENDENT, INCLUDING DRINKING WATER INTAKES, EXCEPT ORGAN-SPECIFIC WEIGHTING FACTORS IN EFFECTIVE DOSE EQUIVALENT

PERCENTAGES GIVE PORTION OF COMMITTED DOSE FROM A LIFETIME'S INTAKES ATTRIBUTABLE TO EACH AGE GROUP

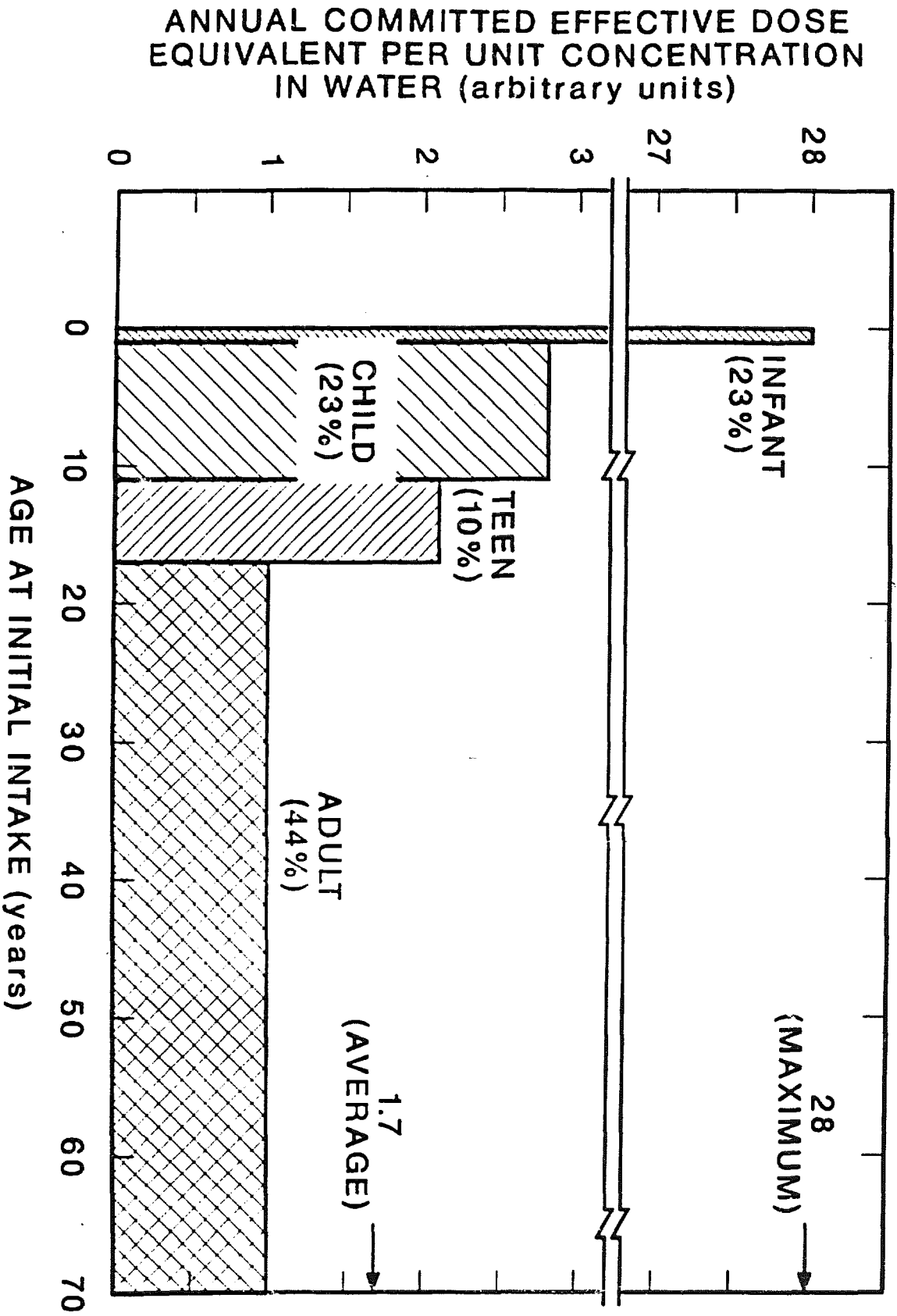
NUMBERS ON RIGHT-HAND SIDE GIVE MAXIMUM ANNUAL DOSE FOR ANY AGE GROUP AND ANNUAL DOSE AVERAGED OVER A LIFETIME'S INTAKES

# DOSE FROM <sup>90</sup>Sr IN DRINKING WATER





# DOSE FROM NATURAL URANIUM IN DRINKING WATER



## IMPLICATIONS OF AGE-DEPENDENT DOSE CALCULATIONS

FUNDAMENTAL PREMISE - GOAL OF RADIATION STANDARDS IS  
LIMITATION OF LIFETIME RISK

EXAMPLE AGE-DEPENDENT DOSE CALCULATIONS SHOW THAT USUAL  
PRACTICE OF LIMITING DOSE TO THE PUBLIC FOR EACH YEAR OF  
EXPOSURE -

- COULD LEAD TO ANNUAL DOSES FOR YOUNGER AGE GROUPS IN  
EXCESS OF LIMIT IN RADIATION PROTECTION STANDARDS (I.E.,  
0.5 REM) IF DOSE IS CALCULATED ONLY FOR ADULTS, EVEN IN  
CASE OF LIMIT ON ANNUAL DOSE FOR SPECIFIC PRACTICES OF  
25 MREM

- COULD PROVIDE POOR CORRESPONDENCE WITH LIMIT ON LIFETIME  
RISK FROM CHRONIC EXPOSURES IF LIMIT ON ANNUAL DOSE IS  
APPLIED TO YOUNGER AGE GROUPS

CALCULATIONS SHOW THAT CLOSER CORRESPONDENCE WITH LIMIT ON  
LIFETIME RISK IS OBTAINED IF RADIATION STANDARDS FOR THE  
PUBLIC ARE EXPRESSED AS (1) A PRINCIPAL LIMIT ON ANNUAL DOSE  
AVERAGED OVER A LIFETIME AND (2) A SUBSIDIARY LIMIT ON DOSE IN  
ANY YEAR IN ACCORDANCE WITH RADIATION PROTECTION STANDARDS.

PRACTICE OF LIMITING DOSE FOR EACH YEAR OF EXPOSURE IS BASED  
ON ACCEPTED PRACTICE FOR OCCUPATIONAL EXPOSURES BUT IS  
ARBITRARY FOR PUBLIC EXPOSURES

RADIATION STANDARDS FOR THE PUBLIC  
EXPRESSED DIRECTLY AS LIMITS ON RISK

POSSIBLE RADIATION STANDARDS FOR THE PUBLIC  
EXPRESSED AS LIMITS ON RISK

(1) RADIATION PROTECTION STANDARD

LIMIT ON LIFETIME RISK FOR INDIVIDUALS FROM ALL SOURCES,  
EXCLUDING NATURAL BACKGROUND AND MEDICAL PRACTICES, OF  
 $10^{-3}$

LIMIT CORRESPONDS TO VALUE IMPLICIT IN DOSE LIMIT FOR  
CHRONIC EXPOSURES CURRENTLY RECOMMENDED BY ICRP AND NCRP

(2) CONSIDERATION OF MULTIPLE SOURCES OF EXPOSURE FOR  
INDIVIDUALS IN CRITICAL GROUPS

LIMIT ON LIFETIME RISK OF  $(1/N) \times 10^{-3}$  PER SOURCE

VALUE OF N TO BE DETERMINED BY REGULATORY AUTHORITIES  
BUT NOT LIKELY TO EXCEED 3 OR 4

(3) ENVIRONMENTAL RADIATION STANDARDS FOR SPECIFIC PRACTICES

QUESTION NECESSITY OF APPORTIONING ACCEPTABLE RISK AMONG  
SPECIFIC PRACTICES; CURRENT STANDARDS ARE NOT BASED ON  
RISK LIMITATION

GOAL OF RISK REDUCTION FOR SPECIFIC PRACTICES COULD BE  
EXPRESSED BY MEANS OF ALARA PRINCIPLE, GUIDANCES, OR  
DESIGN OBJECTIVES

## DATA NEEDED FOR ESTIMATING LIFETIME RISK

### (1) DEMOGRAPHICS

SPECIFICATION OF CRITICAL GROUP AND LIVING HABITS OVER TIME

CONSIDERATION OF AGE DEPENDENCE OF COMPETING RISKS

### (2) BIOKINETICS

AGE DEPENDENCE OF UPTAKE, DISTRIBUTION, AND RETENTION OF RADIONUCLIDES IN THE BODY

### (3) ACTIVITY-DOSE RELATIONS

AGE DEPENDENCE OF DOSE RATE IN TISSUES AT RISK PER UNIT CONCENTRATION OF RADIONUCLIDES IN BODY ORGANS OR ENVIRONMENT

### (4) DOSE-RESPONSE RELATIONS

INCIDENCE OF HEALTH EFFECTS OR FATALITIES VS AGE AT EXPOSURE AND TIME AFTER EXPOSURE

ESTIMATES OF RISK FOR MOST RADIONUCLIDES MUST BE BASED ON ASSUMED ACTIVITY-DOSE AND DOSE-RESPONSE RELATIONS, BECAUSE THERE ARE FEW DATA IN HUMANS ON EXPOSURE-RESPONSE RELATIONS.

## EXPOSURE-RISK RELATION

FOLLOWING EQUATIONS GIVE GENERAL EXPRESSION FOR PROBABILITY OF HEALTH EFFECT FROM A LIFETIME'S RADIATION EXPOSURE AND SIMPLIFICATION RESULTING FROM USUAL ASSUMPTION FOR RADIATION STANDARDS OF LINEAR DOSE-RESPONSE RELATION.

## PROBABILITY OF HEALTH EFFECT FROM RADIATION EXPOSURE

$D(j)$  = dose at age  $j$

$R[j,k,D(j)]$  = probability of health effect at age  $k$  from dose at age  $j$ ,  
assuming no competing risk

$S(k)$  = probability of living to age  $k$  from all competing risks

Probability of health effect from radiation exposure —

$$P \approx \sum_{110}^{k=1} S(k) \sum_k^{j=0} R[j,k,D(j)]$$

For linear dose-response model —

$$R[j,k,D(j)] = R_1(j,k) \times D(j)$$

EXAMPLES OF LIFETIME RISKS FROM  
CHRONIC AND ACUTE EXPOSURES

FOLLOWING FOUR FIGURES SHOW EXAMPLES OF CALCULATED LIFETIME RISKS FROM CHRONIC AND ACUTE INTAKES WITH DIFFERENT ASSUMED AGE-DEPENDENT FACTORS, NORMALIZED TO RISK BASED ON USUAL ASSUMPTION THAT EXPOSED INDIVIDUAL IS ADULT LIVING TO AGE 70 WITH NO CONSIDERATION OF COMPETING RISKS.

FIRST RESULTS FOR INGESTION OF I-131 IN MILK SHOW THAT INCLUSION OF ALL AGE-DEPENDENT FACTORS CAN INCREASE LIFETIME RISK BY MORE THAN AN ORDER OF MAGNITUDE EVEN FOR CHRONIC LIFETIME INTAKES

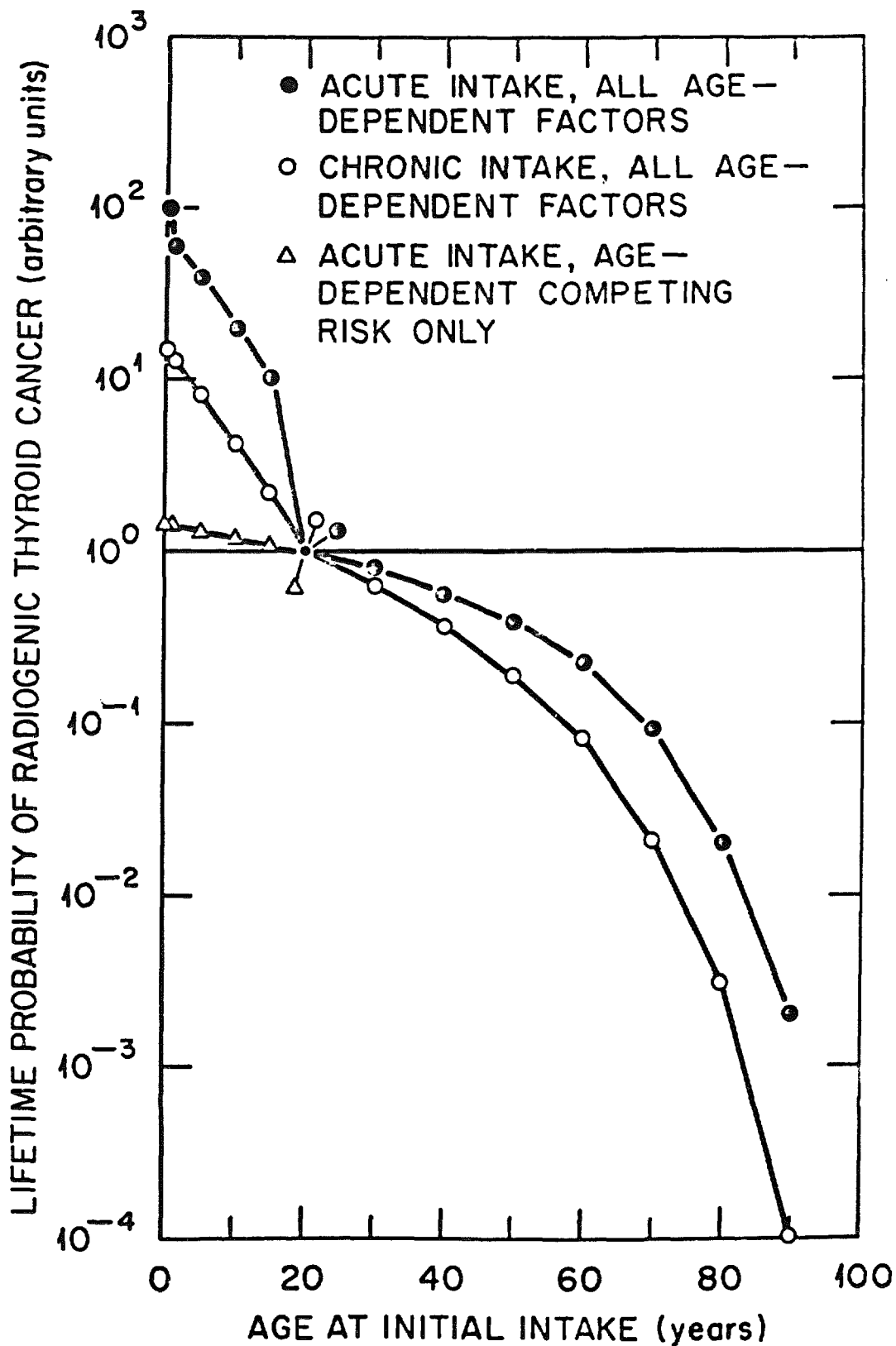
RESULTS FOR INGESTION OF U-238 IN DRINKING WATER SHOW PRONOUNCED AGE DEPENDENCE OF LIFETIME RISK FOR ACUTE INTAKES BUT LESS SO FOR CHRONIC LIFETIME INTAKES

RESULTS FOR INGESTION OF SR-90 IN DRINKING WATER SHOW LESS PRONOUNCED AGE DEPENDENCE OF LIFETIME RISK FOR ACUTE OR CHRONIC LIFETIME INTAKES

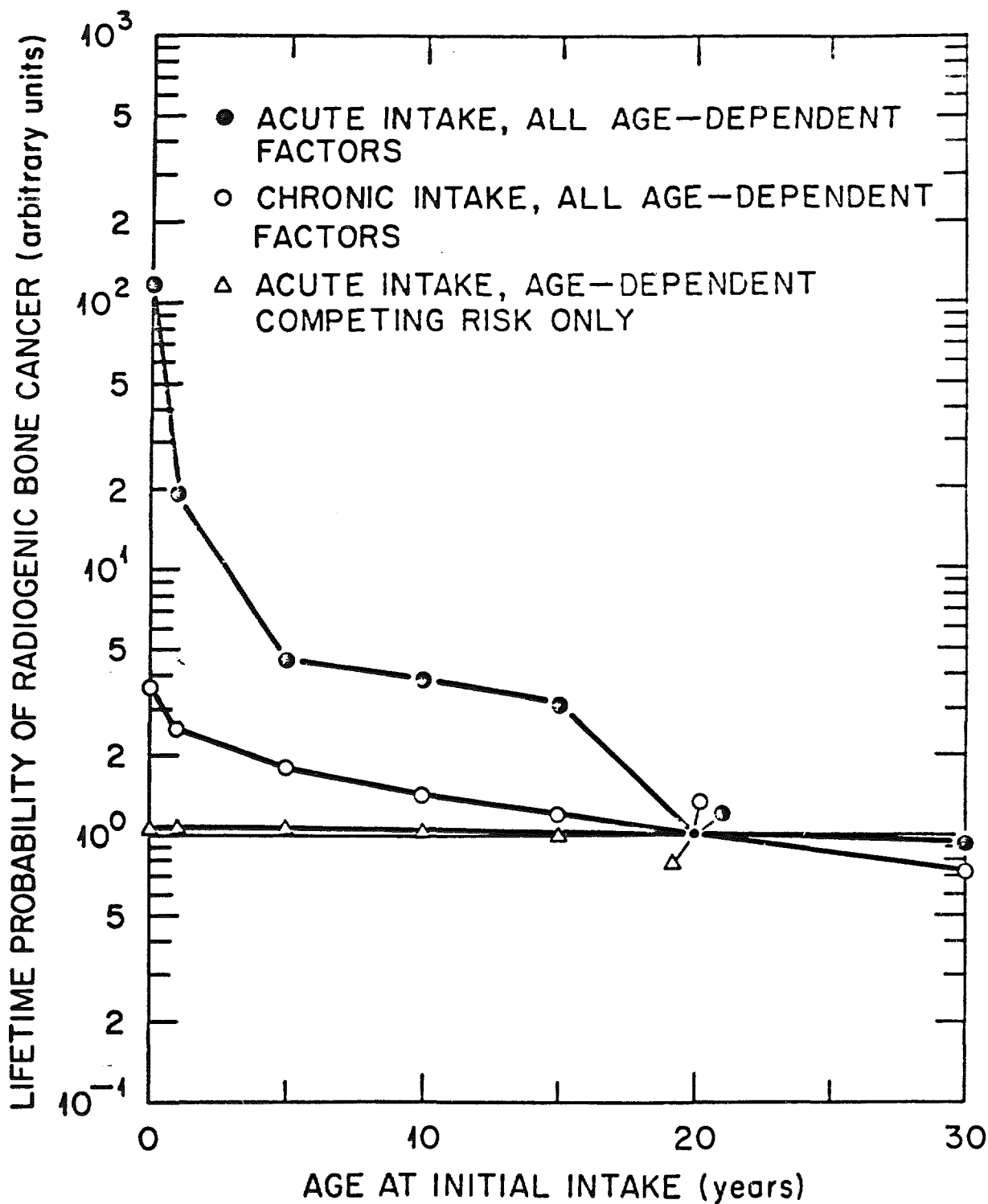
SECOND RESULTS FOR INGESTION OF I-131 IN MILK SHOW DIFFERENCE BETWEEN RISK FROM CHRONIC LIFETIME INTAKES EXPRESSED AS PROBABILITY OF PREMATURE DEATH OR NUMBER OF YEARS OF LIFE LOST



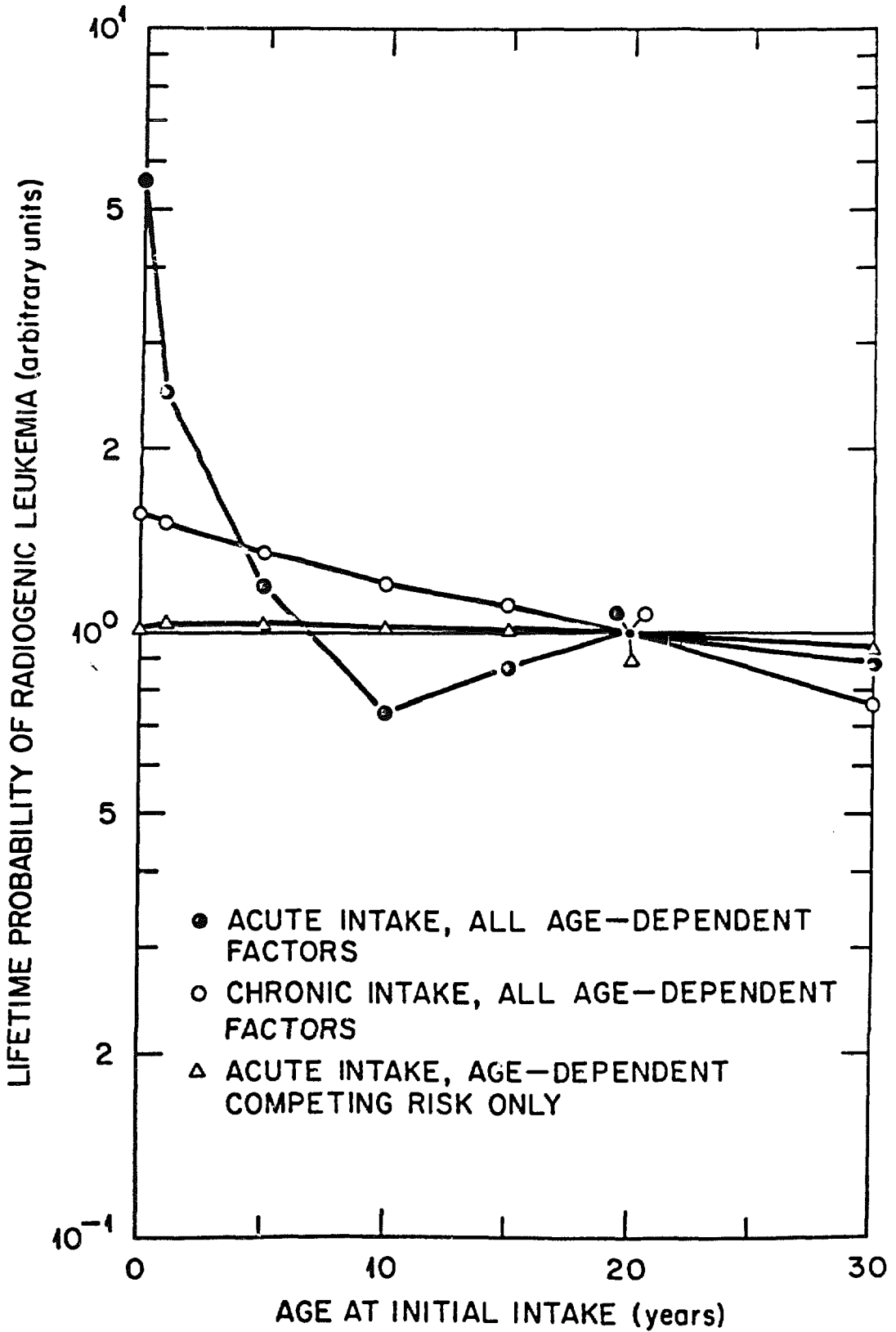
INGESTION OF I-131 IN MILK



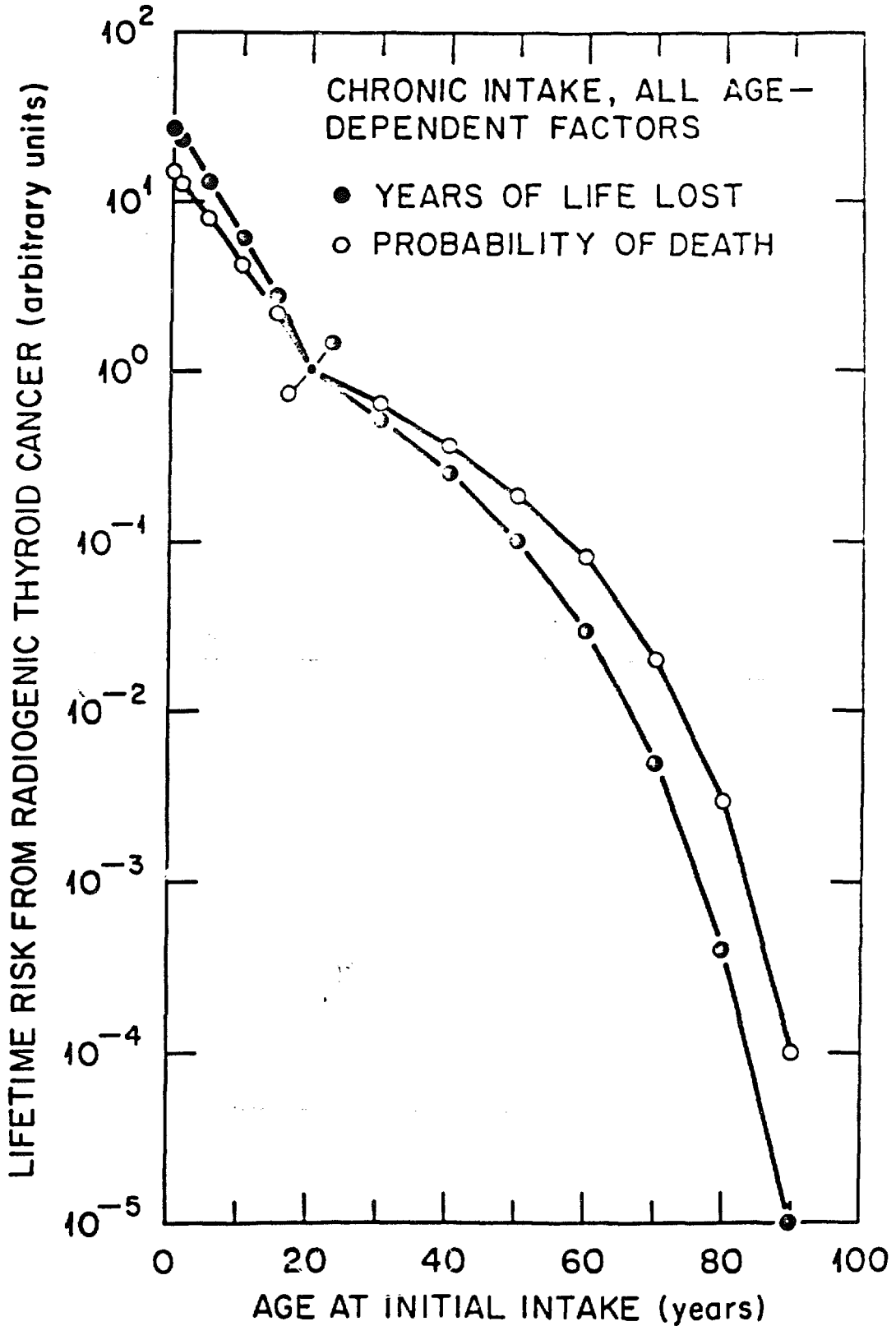
INGESTION OF U-238 IN DRINKING WATER



INGESTION OF SR-90 IN DRINKING WATER



### INGESTION OF I-131 IN MILK



IMPLICATIONS OF RADIATION STANDARDS FOR THE PUBLIC  
EXPRESSED AS LIMITS ON LIFETIME RISK

NECESSARY TO ABANDON LIMIT ON DOSE EQUIVALENT OF 5 MSV  
(0.5 REM) FOR ANY YEAR OF EXPOSURE; APPORTIONMENT OF RISK  
LIMIT INTO ANNUALIZED INCREMENTS IS IRRELEVANT

DOSE COMMITMENT BASED ON FIXED INTEGRATION TIME (50 OR  
70 YEARS) NO LONGER USED; RISK DEPENDS ON DOSE RATE VS AGE

DIFFICULTY IN SPECIFYING ALARA (OPTIMIZATION OF COLLECTIVE  
RISK) IN STANDARDS; RISK LIMIT IS "ACCEPTABLE" FOR NORMAL  
ACTIVITIES AND VALUE OF HUMAN LIFE MUST BE CONSIDERED

NEED TO CONSIDER SIGNIFICANT DIFFERENCES IN ESTIMATED LIFETIME  
RISKS FOR CHRONIC AND ACUTE EXPOSURES

SPECIFICATION OF CRITICAL GROUP MAY DIFFER FOR CHRONIC AND  
ACUTE EXPOSURES AND MAY DEPEND ON RADIONUCLIDE

CALCULATION OF SECONDARY LIMITS ON CONCENTRATIONS OF  
RADIONUCLIDES IN AIR AND WATER IS MORE COMPLICATED THAN WITH  
PRESENT STANDARDS LIMITING ANNUAL DOSE

PROVIDES MAXIMUM FLEXIBILITY IN PLANNING OF RELEASES FROM  
CONTROLLED SOURCES AND DESIGN OF UNCONTROLLED SOURCES

REQUIRES FLEXIBILITY BY REGULATORY AUTHORITIES IN IMPLEMENTING  
STANDARDS AND DETERMINING COMPLIANCE