U.S. Department of Energy

Washington, D.C.

ORDER

DOE 5400.5

2-8-90

Change 2: 1-7-93

SUBJECT: RADIATION PROTECTION OF THE PUBLIC AND THE ENVIRONMENT

1. PURPOSE. To establish standards and requirements for operations of the Department of Energy (DOE) and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.

2. SUPERSESSION. DOE 5480.1A, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROGRAM FOR DOE OPERATIONS, of 8-13-81, Chapter XI that addressed public and environmental radiation protection standards and control practices.

3. SCOPE. The provisions of this Order apply to all Departmental Elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer.

4. IMPLEMENTING PROCEDURES AND REQUIREMENTS. This Order becomes effective 5-8-90. Within 2 months from the date of issuance of the Order (2-8-90), the DOE Field Office Manager shall provide to the appropriate Program Office, with a copy to EH-1 for review and comment: a. a certification for those areas covered by the Order for which field elements are in compliance; and/or b. a request for exemption for areas not yet in compliance that includes a Plan for achieving compliance. Within 3 months of issuance, the appropriate Program Office will submit to EH-1 the certification and/or the request for exemption(s). The compliance plan accompanying the request for exemption shall include schedules of activities which will lead to compliance with the requirements of this Order.

5. POLICY. It is the policy of DOE to implement legally applicable radiation protection standards and to consider and adopt, as appropriate, recommendations by authoritative organizations, e.g., the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP). It is also the policy of DOE to adopt and implement standards generally consistent with those of the Nuclear Regulatory Commission (NRC) for DOE facilities and activities not subject to licensing authority.

6. OBJECTIVES.

   a. Protecting the Public. It is DOE's objective to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established in this Order and to control radioactive contamination through the management of real and personal property. It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases and to assess doses to members of the public.

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INITIATED BY: Office of Environment, Safety and Health

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b. Protecting the Environment. In addition to providing protection to members of the public, it is DOE'S objective to protect the environment from radioactive contamination to the extent practical.

7. LEGISLATIVE AUTHORITY. The Atomic Energy Act of 1954, as amended, authorizes the Department to protect the health and safety of the public against radiation in conducting the Department's programs.

8. REFERENCES.

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k. DOE 5480.11, RADIATION protection FOR OCCUPATIONAL WORKERS, of 12-21-88, which establishes radiation protection standards and program requirements for workers.

l. DOE 5480.23, NUCLEAR SAFETY ANALYSIS REPORTS, of 4-10-92, which establishes requirements for contractors to develop safety analyses that establish and evaluate the adequacy of the safety bases of nuclear facilities.

m. DOE 5482.16, ENVIRONMENT, SAFETY, AND HEALTH APPRAISAL PROGRAM, of 9-23-86, which establishes the DOE environment, safety, and health appraisal program.

n. DOE 5483.1A, Occupational SAFETY AND HEALTH PROGRAM FOR DOE EMPLOYEES AT GOVERNMENT-OWNED, CONTRACTOR-OPERATED FACILITIES, of 6-22-83, which establishes requirements for the protection of the health and safety of employees at DOE contractor-operated facilities.

o. DOE 5484.1, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION INFORMATION REPORTING REQUIREMENTS, of 2-24-81, which establishes procedures for the reporting of information having environmental protection, safety, or health protection significance.

p. DOE Orders in the 5500 series that outline responsibilities for emergency preparedness and response.

q. DOE 5820.2A, RADIOACTIVE WASTE MANAGEMENT, of 9-26-88, which establishes policies and guidelines for the management of radioactive waste and contaminated facilities.

r. DOE 6430.1A, GENERAL DESIGN CRITERIA, of 4-6-89, which provides general design criteria for use in the acquisition of the Department's facilities and establishes responsibilities and authorities for the development and maintenance of those criteria.

s. DOE publication DOE/EH-0070, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public," of 7-88, which provides conversion factors for use in calculating dose from radionuclides external to the body.

t. DOE publication DOE/EH-0071, "Internal Dose Conversion Factors for Calculation of Dose to the Public," of 7-88, which provides conversion factors for use in calculating dose from radionuclides in the body.

u. DOE Publication DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance," of 1-91, which-establishes elements of a radiological monitoring program in support of DOE 5400.1 and 5400.5.

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v. DOE publication DOE/EV/1830-T5, “A Guide to Reducing Radiation Exposure to as Low as Reasonably Achievable,” of 4-80, which provides contractor personnel with general guidance regarding programs and techniques to reduce radiation exposure to levels as low as is reasonably achievable.

w. DOE publication, “Formerly Utilized Sites Remedial Action Program; Summary Protocol: Identification - Characterization - Designation - Remedial Action - Certification, ” of 1-86, which provides procedures for conducting remedial actions at formerly utilized sites.

x. DOE/CH-8901, “A Manual for Implementing Residual Radioactive Material Guidelines; A Supplement to U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites,” of 6-89, which provides guidance on the implementation of DOE residual radioactive material limits.

y. EPA Publication EPA-520/l-88-020, Federal Guidance Report No. 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, ” of 1988, which provides preferred dose conversion factors for use by Federal agencies.

z. Title 10 CFR Part 60, “Disposal of High-Level Wastes in Geologic Repositories,” which prescribes rules governing the licensing of DOE to receive and possess source, special nuclear, and byproduct material at a geologic repository operations area.

aa. Title 10 CFR Part 72, “Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI),” which establishes requirements, procedures, and criteria for licensing ISFSI.

bb. Title 40 CFR Part 61, Subpart H, "National Emission Standard for Radionuclide Emissions from Department of Energy (DOE) Facilities,” which regulates radionuclide air emissions from DOE facilities.

cc. Title 40 CFR Part 141, “National Interim Primary Drinking Water Regulations (Safe Drinking Water Act),” which prescribes radionuclide concentration limits for public drinking water.

dd. Title 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations, ” which contains the radiation dose limits for members of the public in the general environment and curie release limits for radioactive materials released into the general environment from operations within the nuclear fuel cycle operations that are associated with the production of electrical power.

ee. Title 40 CFR Part 191, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes," which establishes requirements for the management and disposal of spent nuclear fuel, high-level, and transuranic wastes.

ff. Title 40 CFR Part 192, "Standards for Remedial Actions at Inactive Uranium Processing Sites," of 1-5-83, which concerns the control of residual radioactive material at designated processing or disposal sites.

gg. Title 42 U.S.C. 300, et seq., Safe Drinking Water Act, as amended, which authorizes EPA to promulgate regulations under two specific programs: the first protects the Nation's public drinking water supplies; the second protects subsurface waters by regulating underground injection of materials.

hh. Title 42 U.S.C. 2011, et seq., Atomic Energy Act of 1954, as amended, which authorizes the conduct of atomic energy activities and establishes authority for protecting the health and safety of the public.

ii.

qq. ICRP Publication 45, "Quantitative Bases for Developing a Unified Index of Harm," Pergamon Press, Oxford, England.

rr. ICRP Publication 48, "The Metabolism of Plutonium and Related Elements," Pergamon Press, Oxford, England.

ss. National Council on Radiation Protection and Measurements (NCRP) Report No. 91, "Recommendations on Limits for Exposure to Ionizing Radiation," NCRP, Bethesda, MD 20814.

tt. Nuclear Regulatory Commission, Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," of 6-74, which establishes limits for surface contamination on materials and equipment.

uu. Nuclear Regulatory Commission publication, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source or Special Nuclear Material," of 7-82.

vv. Oak Ridge National Laboratory (ORNL), Publication CCC - 475, 11-86, "CAAC - Code System for Implementation of Atmospheric Dispersion Assessment Required by the Clean Air Act." RSIC Computer Code Collection.

9. RESPONSIBILITIES AND AUTHORITIES.

a. The Secretary. Many provisions in this order permit and/or necessitate the exercise of discretion and/or judgment in carrying out the requirements of the Order. In those instances, the determination of whether, in the exercise of such discretion and/or judgment, the requirements of this Order were complied with rests initially with the relevant Department authority and, ultimately, with the Secretary. The Secretary retains the sole and final authority to determine what acts are necessary to comply with this Order. Further, the Secretary retains the authority to suspend any and all requirements under this Order whenever the Secretary deems it necessary. This authority may be delegated by the Secretary as appropriate.

b. In addition to those responsibilities and authorities contained in DOE 5480.1B and DOE 5400.1, the following responsibilities and authorities are assigned:

(1) Assistant Secretary for Environment, Safety and Health (EH-1)

(a) Develop DOE public and environmental radiation protection policy and requirements; and

(b) Approve, if warranted, specific exceptions to this Order, pursuant to provisions in DOE 5400.1 and DOE 5820.2A.

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(2) Program Secretarial Officers.

(a) Implement DOE public and environmental radiation protection policy and requirements in their respective programs; and

(b) Implement, if warranted, interim control strategies proposed by field organizations pursuant to this Order and DOE 5820.2A.

(3) Heads of Field Elements.

(a) Implement provisions of this Order for their respective activities;

(b) Maintain appropriate capabilities at each operating site for monitoring and assessing routine and unplanned releases of radioactive materials, with respect to the characteristics of radioactive material released and the release modes, consistent with the types of operations conducted;

(c) Process specific requests for exceptions to this Order, pursuant to paragraph II.la(4); and

(d) Temporarily suspend the requirements of this Order when doing so is in their judgement necessary to minimize damage to life or property or to protect public health or safety. Whenever this provision is invoked, such suspension and the reason therefore are to be reported to EH-1 at the earliest practicable time.

(4) Director, Naval Nuclear Propulsion Program: Executive Order 12344, statutorily prescribed by PL 98-525 (42 USC 7158 note) establishes the responsibilities and authority of the Director, Naval Nuclear Propulsion Program (who is also the Deputy Assistant Secretary for Naval Reactors within the Department) over all facilities and activities which comprise the Program, a joint Navy-DOE organization. The policy principle promoted by these executive and legislative actions is cited in the Executive Order as "... preserving the basic structure, policies, and practices developed for this Program in the past...". Accordingly, The Naval Nuclear Propulsion program is exempt from the provisions of this Order. The Director shall maintain an environmental protection program to ensure compliance with applicable environmental statues and regulations. The Director and EH-1 shall cooperatively develop information exchange and other mutually beneficial programs as appropriate, consistent with PL 98-525.

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10. DEFINITIONS.

a. As Low As Reasonably Achievable (ALARA) is a phrase (acronym) used to describe an approach to radiation Protection to control or manage exposures (both individual and collective to the work force and the general public) and releases of radioactive material to the environment as low as social, technical, economic, practical, and public policy considerations permit. As used in this Order, ALARA is not a dose limit, but rather it is a process that has as its objective the attainment of dose levels as far below the applicable limits of the Order as practicable.

b. Best Available Technology (BAT) means the preferred technology for treating a particular process liquid waste, selected from among others after taking into account factors related to technology, economics, public policy, and other parameters. As used in this Order, BAT is not a specific level of treatment, but the conclusion of a selection process that includes several treatment alternatives.

c. Derived Concentration Guide (DCG) is the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in an effective dose equivalent of 100 mrem 0.1 rem (1 mSv). DCGs do not consider decay products when the parent radionuclide is the cause of the exposure (DCG values are presented in Chapter III) (1 rem = 0.01 sievert).

d. Dose Terms.

(1) Absorbed Dose is the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad (or gray). (1 rad = 0.01 gray.)

(2) Collective Dose Equivalent and Collective Effective Dose Equivalent are the sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within an 80-km radius, for the purposes of this Order, and they are

expressed in units of person-rem (or person-sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-sievert). For purposes of this Order, the 80-km distance shall be measured from a point located centrally with respect to major facilities or DOE program activities.

(3) Committed Dose Equivalent is the predicted total dose equivalent to a tissue or organ over a 50-year period after a known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or sievert).

(4) Committed Effective Dose Equivalent is the sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or sievert).

(5) Deep Dose Equivalent, as used in this Order, means the dose equivalent in tissue at a depth of 1 cm deriving from external (penetrating) radiation.

(6) Dose Equivalent is the product of absorbed dose in rad (or gray) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert).

(7) Effective Dose Equivalent is the summation of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health-effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent due to penetrating radiation from sources external to the body. Effective dose equivalent is expressed in units of rem (or sievert).

(8) Public Dose means the dose received by member(s) of the public from exposure to radiation and to radioactive material released by a DOE facility or operation, whether the exposure is within a DOE site boundary or off- site. It does not include dose received from occupational exposures, doses received from naturally occurring “background” radiation, doses received as a patient from medical practices, or doses received from consumer products.

(9) Weighting Factor is tissue-specific and represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue. The weighting factors recommended by the ICRP (Publication 26) and used here are

Organ or Tissue	Weighting Factor
Gonads	0.25
Breasts	0.15
Red Bone Marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder	0.30

[1] "Remainder means the five other organs with the highest dose (e.g., liver, kidney, spleen, thymus, adrenal, pancreas, stomach, small intestine, or upper and lower large intestine, but excluding skin, lens of the eye, and extremities). The weighting factor for each of these organs is 0.06.

(10) Quality Factor is the principal modifying factor used to ulate the dose equivalent from the absorbed dose. For the purposes of this Order, the following quality factors, which are taken from DOE 5480.11, are to be used.

Radiation Type	Quality Factor
X-rays, gamma rays, positrons, and electrons (including tritium)	1
Neutrons, <10 keV	3
Neutrons, >10 keV	10
Protons and single charged particles of unknown energy with rest mass > one atomic mass unit	
Alpha particles	20
Multiple-charged particles (and particles of unknown charge) of unknown energy	

For neutrons of known energies, the more detailed quality factors given in DOE 5480.11 may be used.

e. Members of the Public means persons who are not occupationally

f. Monitoring Terms.

(1) Effluent Monitoring is the collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying contaminants, assessing radiation exposures of members of the public, and demonstrating compliance with applicable standards.

(2) Environmental Surveillance is the collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media from DOE sites and their environs and the measurement of external radiation for purposes of demonstrating compliance with applicable standards, assessing radiation exposures of members of the public, and assessing effects, if any, on the local environment.

g. Protective Action Guides (PAG) are projected numerical dose values established by EPA, DOE, or States for individuals in the population. These values may trigger protective actions that would reduce or avoid the projected dose.

h. Radioactivity means the property or characteristic of radioactive material to spontaneously "disintegrate" with the emission of energy in the form of radiation. The unit of radioactivity is the curie (or becquerel).

i. Reference Man means a hypothetical aggregation of human (male and female) physical and physiological characteristics arrived at by international consensus (ICRP Publication 23). These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult from ionizing radiation to a common base. The "reference man" is assumed to inhale 8400 cubic meters of air in a year and to ingest 730 liters of water in a year.

j. Release of Property, as used in this Order, means the exercising of DOE's authority to release property from its control after confirming that residual radioactive material (over which DOE has authority) on the property has been determined to meet the guidelines for residual radioactive material in Chapter IV or any other applicable radiological requirements. There may be instances in which DOE or other authority will impose restrictions on the management and/or use of the property if the residual radioactive material guidelines of Chapter IV are not met or if other applicable Federal, State, or local requirements cause the imposition of such restrictions.

k. Remedial Action means those actions consistent with permanent remedy taken instead of, or in addition to, removal action in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment.

l. Residual Radioactive Material means any radioactive material which is in or on soil, air, equipment, or structures as a consequence of past operations or activities.

m. Settleable Solids

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CHAPTER I

GENERAL

1. BACKGROUND. This Order has been developed to integrate, consolidate, and update the portions of DOE 5480.1B that addressed public and environmental radiation protection standards and control practices. Specifically, this Order replaces requirements of DOE 5480.1B, Chapter XI; adopts current guidance and standards issued by national and international authoritative bodies on radiation protection; incorporates current regulatory requirements applicable to DOE operations; and consolidates and upgrades DOE guidance for contaminated property. The following paragraphs provide a summary of the topics considered in this Order.

2. DOSE STANDARDS AND TERMINOLOGY.

   a. International Commission on Radiological Protection (ICRP). This Order adopts and implements radiation protection dose standards consistent with the recommendations of the ICRP. In 1977, the ICRP recommended a system of dose limitations that has been adopted and implemented by essentially all countries with nuclear programs. The ICRP system of dose limitations provides a scientific basis for health protection and selection of dose limits. The system also reflects current information on health risks, dosimetry, and radiation practices, and promotes a more uniform and consistent application of radiation protection among diverse activities than had previously been possible. The ICRP system is based on sophisticated analytical models and requires computer capabilities for making evaluations or using the dose conversion tables produced from such evaluations.

   b. Other Sources of Regulations and Guidance. DOE is required to comply with legally applicable rules and regulations of other Federal, State, and local agencies, some of which have not adopted the ICRP system. The result is a mixture of dose standards, terminology, and units. Therefore, some dose limits in this Order are expressed in terms of effective dose equivalent, consistent with current ICRP recommendations, while others are expressed in terms of dose equivalent to the whole body or to specific organs, consistent with pre-1977 recommendations of ICRP. The presentation of this Order includes both the more traditional dose terms and units and the new dose terms and concepts introduced by the ICRP for their system of dose limitations. Definitions presented in this Order are consistent with the definitions presented in related Orders, such as DOE 5480.11.

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3. DOSE LIMIT SELECTION. The DOE primary standard of 100 mrem (1 mSv) effective dose equivalent to members of the public in a year is lower than the previous primary limit of 500 mrem (5 mSv). The lower value was selected in recognition of the ICRP recommendation to limit the long-term average effective dose equivalent to 100 mrem (1 mSv) per year, or less. Experience suggests that the lower dose is readily achievable for normal operations of DOE facilities. A higher dose limit, not to exceed the 500-mrem effective dose equivalent recommended by ICRP as an occasional annual limit, may be authorized for a limited period if it is justified by unusual operating conditions.

4. AS LOW AS REASONABLY ACHIEVABLE (ALARA). The DOE primary public dose limit is based on consideration of the potential risk of radiation-induced fatal cancers and serious genetic defects (i.e., the ICRP risk-based system). The ICRP recommends that doses to individuals be within the appropriate dose limit for the individuals and that all exposures be ALARA. Accordingly, this Order adopts the ALARA process in planning and carrying out all DOE activities.

5. LIQUID WASTES AND EFFLUENTS.

   a. Protection of Resources. In addition to limiting dose to members of the public (onsite or offsite) to the primary radiation protection standards established in this Order and to the applicable limits of EPA and State regulations, additional controls on the release of liquid wastes are adopted to reduce the potential for radiological contamination of natural resources such as land, ground and surface water, and ecosystems.

   b. Treatment of Liquid Radioactive Waste Streams. Standards for liquid effluent discharges are driven by the DOE ALARA policy and objective to minimize contamination in the environment to the extent practicable. The Order adopts the “best available technology” (BAT) as the appropriate level of treatment for liquid wastes containing radioactive material and provides that the BAT be phased in at the earliest practicable time. Technical and economic considerations are included in determining the BAT. Based on cost and benefit considerations, radioactive waste streams that contain radionuclide concentrations of not more than the derived concentration guide (DCG) reference values at the point of discharge to a surface waterway normally will not require treatment to further reduce the concentration. BAT treatment is provided to protect ground water and to prevent radionuclide buildup in soil.

6. ENVIRONMENTAL PROTECTION. The phasing out of the use of soil columns and the additional requirements associated with the burial of low-level radioactive wastes (discussed in Chapter II) address concerns with potential long-term contamination of the environment on and near DOE activities and

sites. These requirements are intended to prevent the buildup of contamination in soils and ground water and to protect the environment from the spread of contamination from burial trenches and pits.

7. DISCHARGES TO SANITARY SEWERAGE. The control of releases of liquid wastes to community sanitary sewer systems is designed to be generally consistent with requirements imposed by NRC on its licensees. As discussed in Chapter II, the "best available technology" (BAT) selection process is to be applied to the treatment of liquid wastes released to sanitary sewerage when concentrations of radionuclides would otherwise exceed five times the DCG reference values given in Chapter III. Operators should ensure that the total annual discharge of radioactive material to the sanitary sewer system will not cause exposures to members of the general public that will result in doses exceeding a small fraction of the basic annual dose limit.

8. EFFLUENT MONITORING AND ENVIRONMENTAL SURVEILLANCE.

a. Demonstration of Compliance. Demonstrations of compliance with requirements of this Order generally will be based upon calculations that make use of information obtained from monitoring and surveillance programs. The abilities to detect, quantify, and adequately respond to unplanned releases of radioactive material to the environment also rely on in-place effluent monitoring, monitoring of environmental transport and diffusion conditions, and assessment capabilities. This will enable DOE to develop useful data and to collect and analyze pertinent information on unplanned releases in a timely manner. It is the intent of DOE that the monitoring and surveillance programs for the DOE activities, facilities, and locations be of high quality. Although some differences result from specific site or specific activity conditions, uniformity in the methods and performance criteria used in obtaining the information is desirable.

b. Monitoring and Surveillance Requirements. To ensure that the effluent monitoring and environmental surveillance programs are of good quality at all DOE facilities and sites, certain requirements and recommendations are provided in DOE publication DOE/EH-0173T which deals with radiological effluent monitoring and environmental surveillance.

9. RESIDUAL RADIOACTIVE MATERIAL. DOE practices and requirements for residual radioactive material are presented in Chapter IV, including limits of potential dose, authorized contamination limits for the release of property, and ALARA considerations.

10. DOSE EVALUATIONS

a. Standard Methods. Data developed by the Department to demonstrate that DOE operations comply with applicable standards and requirements should be correct and representative. Accordingly, this Order requires that calculations of dose to the public from exposures resulting from both

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routine and unplanned activities be performed using standard EPA or DOE dose conversion factors or analytical models prescribed in regulations applicable to DOE operations.

b. Supplemental Documents. The dose conversion factors and derived concentrations needed to make dose evaluations to meet DOE requirements are provided in Chapter III and three supplemental documents: EPA-520/1-88-020, Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration Factors for Inhalation, Submersion, and Ingestion;" DOE/EH-0071, "Internal Dose Conversion Factors for Calculation of Dose to the Public," and DOE/EH-0070, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public." The dose conversion factors in these documents provide the primary basis for determining compliance with this Order. The table of DCGs (Chapter III) has been expanded considerably to present all classes of uptake and retention.

c. EPA Models. The use of AIRDOS/RADRISK, CAP-88, or AIRDOS-PC models is prescribed by EPA in 40 CFR Part 61, Subpart H, to evaluate potential doses from airborne releases. Thus, two evaluations of doses from airborne pathways could be required: one to satisfy 40 CFR Part 61 requirements and one for DOE purposes using contemporary dosimetry. [Caution: Unless modified, AIRDOS/RADRISK (also known as CAP-88 or AIRDOS-PC) is not suitable for calculating doses from accidents.]

11. REPORTING. The Order addresses the notification of headquarters personnel when DOE activities might have caused, or might cause, a noncompliance with requirements of this Order. These requirements are in addition to the general requirements for reporting, specified in DOE 5484.1. "Federally permitted" designation of releases, for purposes of EPA reporting requirements, are addressed in section 11.7.

CHAPTER II

REQUIREMENTS FOR RADIATION PROTECTION OF THE PUBLIC AND THE ENVIRONMENT

1. PUBLIC DOSE LIMITS. Dose limits for members of the public are presented in this chapter. The primary public dose limits include consideration of all exposure modes from-all DOE-activities (including remedial actions). The primary dose limit is expressed as an effective dose equivalent, a term developed by the ICRP for their risk-based system, which requires the weighted summation of doses to various organs of the body. Additional public dose limits are established by EPA regulations for exposures to several selected sources or exposure modes (pathways or conditions). Public dose limits promulgated by EPA for selected exposure modes are sometimes expressed as dose equivalents, which do not include risk-based weighting or summation of doses to various organs, and sometimes expressed as effective dose equivalent. DOE must also comply with legally applicable requirements (e.g., 40 CFR Parts 61, 191, and 192 and 10 CFR Parts 60 and 72), including administrative and procedural requirements. Except for those provided in paragraph II.1a(4), administrative and procedural requirements of legally applicable regulations are not addressed in this Order. Such legally applicable regulations must be consulted for provisions not addressed in this Order.

   a. DOE Public Dose Limit--All Exposure Modes, All DOE Sources of Radiation. Except as provided by 11.1a(4), the exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem (1 mSv). Dose evaluations should reflect realistic exposure conditions (see II.6b).

      (1) Dose Components. The limit of 100 mrem (1 mSv) effective dose equivalent in a year specified in paragraph II.1a is the sum of the effective dose equivalent (or deep dose equivalent, if dosimeter data are used) from exposures to radiation sources external to the body during the year plus the committed effective dose equivalent from radionuclides taken into the body during the year.

      (2) Exposure Modes. Other than for sources specifically excepted, doses to members of the public from all exposure modes that could contribute significantly to the total dose shall be considered for evaluation. Requirements and methods for performing the evaluations are discussed in paragraph II.6.

(3) Application. The public dose limits in paragraph II.1a apply to doses from exposures to radiation sources from routine activities, including remedial actions and naturally occurring radionuclides released by DOE processes and operations. The dose limits also apply to the doses to individuals who are exposed to radiation or contamination by radionuclides at properties subsequent to remedial action and release of the property. Limits for radon and its decay products in air are provided in terms of Working Levels and concentrations in air and are addressed independently (Chapter IV and Figure III-l). In addition, DOE operators are required to report DOE-related effective dose equivalent contributions of 10 mrem (0.10 mSv) or more in a year (see paragraph II.7).

(a) Doses from Sources Other than DOE Man-Made or Enhanced Natural Radionuclides.

(b)

(4) Exceptions. Unusual circumstances could affect a DOE activity in such a manner that the potential public dose could exceed an effective dose equivalent of 100 mrem (1 mSv) in a year.

(a) Temporary Increases of Dose Limit. If avoidance of the higher exposures is impracticable, the Manager of the DOE Field Office, in coordination with their Program Office, may request from EH-1 specific authorization for a temporary public dose limit higher than 100 mrem (1 mSv), but not to exceed 500 mrem (5 mSv), for the year. The temporary higher dose limit derives from ICRP recommendations (ICRP Publication 45) for a principal stochastic dose limit of 100 mrem (1 mSv) effective dose equivalent in a year for exposures to the public, and a subsidiary dose limit of 500 mrem (5 mSv) effective dose equivalent in a year, for some years, if the dose averaged over a lifetime does not exceed the principal limit of 100 mrem (1 mSv) effective dose equivalent per year. The specific sources excepted in paragraph II.1a(3)(b) are also excepted for II.1a(4)(a).

(b) Justification for Increase of Public Dose Limit. A request to EH-1 for a dose limit higher than 100 mrem (1 mSv) shall be accompanied by documentation that discusses the need for the increase, the alternatives considered, and the application of the ALARA process. EH-1 may approve such a request, or a lesser increase in the public dose limit, as appropriate.

b. Airborne Emissions Only, All DOE Sources of Radionuclides. To the extent required by the Clean Air Act, the exposure of members of the public to radioactive materials released to the atmosphere as a consequence of routine DOE activities shall not cause members of the public to receive, in a year, an effective dose equivalent greater than 10 mrem (0.1 mSv). Exposures to, and releases of, radon-220, radon-222, and their respective decay products are subject to DOE limits (See Figure III-3 and paragraphs IV.4b and IV.6).

(1) Title 40 CFR Part 61. The public dose limits as outlined in paragraph II.1b are established by EPA regulation 40 CFR Part 61, Subpart H, under the authority of the Clean Air Act. These limits apply offsite where the members of the public reside or abide. Subparts Q and T provide radon flux limits for DOE radium storage and disposal facilities (Chapter IV) and DOE inactive uranium mill tailings sites regulated under 40 CFR Part 192.

(2) AIRDOS/RADRISK Codes. To demonstrate compliance analytically with air emissions for the Clean Air Act Standards, doses to the individuals shall be evaluated using the version of AIRDOS/RADRISK known as CAP-88 or, when available and approved, AIRDOS-PC. Other computer codes or models, such as “Comply Code,” which are specifically approved in accordance with 40 CFR Part 61, may also be used.

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(3) Environmental Measurements. Compliance may also be demonstrated through environmental or effluent measurements using EPA-approved techniques. In this case, the doses estimated are to individuals in areas offsite, where they are assumed to reside at the point of maximum annual air concentration.

c. All Exposure Modes, Sources from Management and Storage of Spent Nuclear Fuel, High-Level, and Transuranic Wastes at Disposal Facilities. To the extent required by 40 CFR Part 191, the exposure of members of the public to direct radiation or radioactive material released from DOE management and storage activities at a disposal facility for spent nuclear material or for high-level or transuranic radioactive wastes that are not regulated by the NRC shall not cause members of the public to receive, in a year, a dose equivalent greater than 25 mrem (0.25 mSv) to the whole body or a committed dose equivalent greater than 75 mrem (0.75 mSv) to any organ.

(1) 40 CFR Part 191. The dose limits as outlined in paragraph II.lc, are established by Section 191.03(b) of EPA regulation 40 CFR Part 191, Subpart A, "Environmental Standards for Management and Storage." The implementation of the requirements of Subpart B, "Environmental Standards for Disposal," is beyond the scope of this Order. DOE waste management and storage activities at facilities other than disposal facilities are subject to the dose limits outlined in paragraph II.lc. The Waste Isolation Pilot Plant, for purposes of this Order, is considered to be a disposal facility subject to this Order and 40 CFR Part 191. Other requirements and guidelines for the management and storage of spent nuclear fuel and high-level and transuranic waste at DOE facilities that are not licensed by the NRC are given in DOE 5820.2A.

(2) Regulatory Requirements. DOE facilities and operations, in some instances, are subject to the regulatory requirements of the NRC and the EPA, e.g., 10 CFR Parts 60 and 72 and 40 CFR Parts 61, 191, and 192. It is Departmental policy that DOE facilities and operations will comply fully with the requirements of those and other applicable regulatory requirements. In addition, these same DOE facilities and operations shall comply with all applicable requirements in this Order unless they are duplicative or conflict with any of the other Federal regulatory requirements. The resolution of issues concerning duplicative or conflicting requirements will be conducted pursuant to the issue coordination provisions of DOE 5400.2A.

(3) Evaluation of Exposure Modes. Dose conversion factors that provide dose estimates for exposure to concentrations of specific radionuclides in air and water and selected exposure modes are

provided in the documents Federal Guidance Report No. 11 (EPA-520/l-88-020), DOE/EH-0070 and DOE/EH-0071. Use of these factors is discussed in paragraph 11.6b.

d. Drinking Water Pathway Only, All DOE Sources of Radionuclides. It is the policy of DOE to provide a level of Protection for persons consuming water from a public drinking water supply operated by the DOE, either directly or through a DOE contractor, that is equivalent to that provided to the public by the public community drinking water standards of 40 CFR Part 141. These systems shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) in a year. Combined radium-226 and radium-228 shall not exceed 5×10^{-9} μCi/ml and gross alpha activity (including radium-226 but excluding radon and uranium) shall not exceed 1.5×10^{-8} μCi/ml.

(1) DOE Drinking Water Systems. The dose limit is consistent with the drinking water criteria in 40 CFR Part 141, "National Interim Primary Drinking Water Regulations (Safe Drinking Water Act)."

(2) Dose Components. The dose limit is the effective dose equivalent to individuals whose exclusive source of drinking water contains a radionuclide, or a mixture of radionuclides, at a monthly average level of four percent of the appropriate DCG value. For simplicity, it is assumed that site workers are also exposed to four percent of DCG values or the radium and gross alpha levels in II.1d for drinking water while away from the DOE site.

(3) Impact on Other Systems. The liquid effluents from DOE activities shall not cause private or public drinking water systems downstream of the facility discharge to exceed the drinking water radiological limits in 40 CFR Part 141.

2. THE ALARA PROCESS. Field Elements shall develop a program and shall require contractors to implement the ALARA Process for all DOE activities and facilities that cause public doses.

a. Considerations. ALARA requires judgment with respect to what is reasonably achievable. Factors that relate to societal, technological, economic, and other public policy considerations shall be evaluated to the extent practicable in making such judgments. Factors to be considered, at a minimum, shall include:

(1) The maximum dose to members of the public;

(2) The collective dose to the population;

(3) Alternative processes, such as alternative treatments of discharge streams, operating methods, or controls;

(4) Doses for each process alternative;

(5) Costs for each of the technological alternatives;

(6) Examination of the changes in-cost among alternatives;

(7) Changes in societal impact associated with process alternatives, e.g., differential doses from various pathways.

b. Evaluations. A quantitative cost-benefit analysis (e.g., optimization) could be performed, given the results of the considerations noted in paragraph 11.2a, above. However, the parameters needed to evaluate the cost-benefit analyses are difficult to quantify, and evaluations themselves can be expensive. Furthermore, the evaluations include many additional assumptions, judgments, and limitations that are often difficult to reflect as uncertainties in the analyses. Therefore, except for meeting requirements of the National Environmental Policy Act, qualitative analyses are acceptable, in most instances, for ALARA judgments, especially where potential doses are well below the dose limit. The bases for such judgments should be documented. More detailed analyses should be considered if the decisions might result in doses that approach the limit.

3. MANAGEMENT AND CONTROL OF RADIOACTIVE MATERIALS IN LIQUID DISCHARGES AND PHASEOUT OF SOIL COLUMNS. In addition to the requirement to limit dose to members of the public (onsite or offsite) in accordance with the standards established in paragraphs II.1a and II.1d, further controls are imposed on liquid releases to protect resources such as land, surface water, ground water, and the related ecosystems from undue contamination. DCGs are not release limits, but rather are screening values for considering BAT for these discharges and for making dose estimates. The following requirements apply at the point of discharge from the conduit to the environment.

a. Discharges of Liquid Waste to Surface Waters.

(1) Discharge at Greater Than DCG Level. For liquid wastes containing radionuclides from DOE activities which are discharged to surface water, the best available technology (BAT) is the prescribed level of treatment if the surface waters otherwise would contain, at the point of discharge and prior to dilution, radioactive material at annual average concentrations greater than the DCG values in liquids given in Chapter III. The BAT selection process shall be

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implemented in accordance with II.3a(1)(a) and (b), below. Although there is no known practicable method for removing tritium from liquid waste streams, facilities and operations are to be designed and operated so that tritium sources and releases are considered in the ALARA process.

(a) BAT Selection. Selection of the best available technology for a specific application will be made from among candidate alternative treatment technologies which are identified by an evaluation process that includes factors related to technology, economics, and public policy considerations. Factors that are to be considered in selecting BAT, at a minimum, shall include:

1 the age of equipment and facilities involved;

2 the process employed;

3 the engineering aspects of the application of various types of control techniques;

4 process changes;

5 the cost of achieving such effluent reduction;

6 non-water quality environmental impact (including energy requirements);

7 safety considerations; and

8 public policy considerations.

BAT analyses are difficult to express quantitatively because the factors do not have a common denominator. However, consideration of the factors will permit qualitative evaluations which will support judgments.

(b) Plan and Schedule for Implementation. A plan and schedule to install waste treatment systems in existing facilities, if justified by a BAT analysis, shall be developed within 6 months of the issuance date of this Order, to permit compliance with paragraph II.3a(1) at the earliest practicable time. The plan shall include an ALARA section on tritium, where applicable. General design criteria are presented in DOE 6430.1A.

(c) Approval. The plan shall be submitted for approval to the responsible DOE Field Office Manager and updated annually, consistent with the provisions of DOE 5820.2A for preparing and updating Waste Management Plans.

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(2) Discharge at Less Than DCG Level. Implementation of the BAT process for liquid radioactive wastes is not required where radionuclides are already at a low level, i.e., the annual average concentration is less than DCG level. In that case, the cost consideration component of BAT analysis precludes the need for additional treatment, since any additional treatment would be unjustifiable on a cost-benefit basis. Therefore, additional treatment will not be required for waste streams that contain radionuclide concentrations of not more than the DCG values in Chapter III at the point of discharge to a surface waterway. However, the ALARA provisions are applicable.

(3) Multiple Radionuclides. For purposes of II.3a(1), above, the DCG for liquid waste streams containing more than one type of radionuclide shall be the sum of the fractional DCG values.

(4) Sedimentation. To prevent the buildup of radionuclide concentrations in sediments, liquid process waste streams containing radioactive material in the form of settleable solids may be released to natural waterways if the concentration of radioactive material in the solids present in the waste stream does not exceed 5 pCi (O.2 Bq) per gram above background level, of settleable solids for alpha-emitting radionuclides or 50 pCi (2 Bq) per gram above background level, of settleable solids for beta-gamma-emitting radionuclides.

(5) Interim Dose Limit for Native Aquatic Animal Organisms. To protect native animal aquatic organisms, the absorbed dose to these organisms shall not exceed 1 rad per day from exposure to the radioactive material in liquid wastes discharged to natural waterways. DOE publication DOE/EH-0173T provides guidance on monitoring and calculating dose for aquatic organisms.

(6) New Facilities. New facilities shall be designed and constructed to meet the discharge requirements shown in paragraph II.3a.

b. Discharges of Liquid Waste to Aquifers and Phaseout of Soil Columns.

(1) Phasing Out the Use of Soil Columns. The use of soil columns (i.e., trenches, cribs, ponds, and drain fields) to retain, by sorption or ion exchange, suspended or dissolved radionuclides from liquid waste streams shall be discontinued at the earliest practicable time in favor of an acceptable alternative disposal means. DOE activities that currently discharge liquids containing radioactive materials not first treated by BAT to soil columns, shall develop, within 6 months of the issuance date of this Order, a plan and schedule for implementing alternate acceptable disposal at the earliest practicable time. The BAT selection process shall be applied to those liquid waste streams that will continue to be discharged to soil columns for indefinite periods and which contain process-derived radionuclides. The plan shall be submitted for approval

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to the respective DOE Field Office Manager and updated annually, consistent with the provisions of DOE 5820.2A for preparing and updating Waste Management Plans.

(2) Prohibition of New or Increased Discharge Quantities and New Soil Columns. Except as permitted by the provisions in paragraph 11.3e(l), new or increased discharges of radionuclides in liquid waste to active soil columns and virgin soil columns shall be prohibited after the effective date of this Order.

c. Management of Soil Columns, Natural Drainage Systems, and Ground Water at active Sites Previously Contaminated with Radioactive Material.

(1) Inactive Receptors. Contaminated soil columns, drainage systems, and groundwater to which contaminated liquid discharges have been discontinued shall be managed or decontaminated pursuant to the procedures and requirements of DOE 5480.4 and in the 5400 series.

(2) Discharge of Other Liquids. Liquid discharges, even though uncontaminated, are prohibited in inactive release areas to prevent the further spread of radionuclides previously deposited.

d. Discharges of Liquid Waste to Sanitary Sewerage. The BAT selection process shall be implemented if liquid wastes discharged from DOE activities into sanitary sewerage contain radionuclides at concentrations, averaged monthly, would otherwise be greater than five times the DCG values for liquids given in Chapter III at the point of discharge. That is, the BAT selection process shall be implemented if the total of the fractions of the average concentrations for each radionuclide to its respective DCG value would otherwise exceed 5.

(1) Discharges to public sewers should be coordinated with the operators of the waste water treatment works.

(2) Concentrations shall be controlled so that long-term buildup of radionuclides in solids will not present a handling and disposal problem at sewage disposal plants.

(3) Liquid wastes containing concentrations or quantities of radioactive materials that, when averaged monthly, are greater than those specified in paragraph II.3d may be discharged into a chemical or sanitary sewerage system (e.g., systems with drain fields excepted) if the system is owned by the Federal Government. However, ALARA process considerations are required. Such a sewerage system will provide liquid waste treatment prior to discharge to surface waters in accordance with the requirements of paragraph 11.3a(1).

(4) Operators should ensure that the total annual discharge of radioactive material to the sanitary sewer system will not cause

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exposures to members of the general public that will result in doses exceeding a small fraction of the basic annual dose limit.

e. Exceptions for Liquid Waste Control Requirements.

(1) Interim Control Strategies. DOE Field Office Managers responsible for DOE activities that cannot comply, when this Order is issued, with requirements shown in paragraph II.3, shall develop an interim control strategy with adequate documentation identifying the alternatives considered and evaluation thereof. Such interim control strategies shall be adopted and implemented under the provisions of DOE 5820.2A, Chapter III, paragraph 3a(2), within 6 months of the issuance of this Order, and shall be reevaluated every 2 years thereafter.

(2) Tritium Control. There is no practicable technology available for removing tritium from dilute liquid waste streams. Therefore, process alternatives that reduce the amount of tritium entering the liquid waste streams shall be identified and evaluated in accordance with the DOE ALARA policy. Tritium decay in transit in confined ground water may be an acceptable alternative to direct release to the atmosphere or to surface waters. A description and summary of the alternatives considered in the control of tritium releases shall be incorporated into the site Waste Management Plan required by DOE 5820.2A.

4. MANAGEMENT OF LOW-LEVEL RADIOACTIVE SOLID WASTE. The requirements for the management of low-level wastes are presented in DOE 5400.1 and DOE 5820.2A. Design, operational, and monitoring requirements for disposal of solid low-level waste containing no constituents regulated by The Resource Conservation and Recovery Act (RCRA) are addressed in DOE 5820.2A.

5. RELEASE OF PROPERTY HAVING RESIDUAL RADIOACTIVE MATERIAL.

a. Release of Real Property. Release of real property (land and structures) shall be in accordance with the guidelines and requirements for residual radioactive material presented in Chapter IV. These guidelines and requirements apply to both DOE-owned facilities and to private properties that are being prepared by DOE for release. Real properties owned by DOE that are being sold to the public are subject to the requirements of

survey with appropriate instruments indicate that the property is less than the contamination limits presented in Figure IV-1.

c. Release of Materials and Equipment.

(1) Surface Contamination Levels. Prior to being released, property shall be surveyed to determine whether both removable and total surface contamination (Including contamination present on and under any coating) are in compliance with the levels given in Figure IV-1 and that the contamination has been subjected to the ALARA process.

(2) Potential for Contamination. Property shall be considered to be potentially contaminated if it has been used or stored in radiation areas that could contain unconfined radioactive material or that are exposed to beams of particles capable of causing activation (neutrons, protons, etc.).

(3) Surveys. Surfaces of potentially contaminated property shall be surveyed using instruments and techniques appropriate for detecting the limits stated in Figure IV-1.

(4) Inaccessible Areas. Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property may be released after case-by-case evaluation and documentation based on both the history of its use and available measurements demonstrate that the unsurveyable surfaces are likely to be within the limits given in Figure IV-1.

(5) Records. The records of released property shall include:

(a) A description or identification of the property;

(b) The date of the last radiation survey;

(c) The identity of the organization and the individual who performed the monitoring operation;

(d) The type and identification number of monitoring instruments;

(e) The results of the monitoring operation; and

(f) The identity of the recipient of the released material.

(6) Volume Contamination. No guidance is currently available for release of material that has been contaminated in depth, such as activated material or smelted contaminated metals (e.g., radioactivity per unit volume or per unit mass). Such materials may be released if criteria and survey techniques are approved by EH-1.

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6. DEMONSTRATION OF COMPLIANCE WITH THE DOSE LIMITS. Compliance with the dose limits of this Order shall be demonstrated by documentation of an appropriate combination of measurements and calculations to evaluate potential doses and the results of the evaluations.

a. Monitoring and Surveillance. General requirements for routine effluent monitoring are part of the environmental monitoring plan prescribed in DOE 5400.1. Specific requirements for radiological effluent monitoring and environmental surveillance and their schedule of implementation are prescribed in DOE publication DOE\EH-0173T which deals with radiological effluent monitoring and environmental surveillance. The monitoring requirements are applicable to all DOE and DOE contractor operations that are subject to the standards and requirements of this Order.

b. Dose Evaluations. Doses to members of the public in the vicinity of DOE activities shall be evaluated and documented to demonstrate compliance with the dose limits of this Order and to assess exposures of the public from unplanned events. Collective doses to the public within 80 km of the site shall also be evaluated and documented at least annually.

(1) Modeling. Analytical models used for dose evaluations shall be appropriate for characteristics of emissions (e.g., gas, liquid, or particle; depositing or non-depositing; buoyant or non-buoyant); mode of release (e.g., stack or vent; crib or pond; surface water or sewer; continuous or intermittent); environmental transport medium (e.g., air or water); and exposure pathway (e.g., inhalation; ingestion of food, water, or milk; direct radiation). Information on dispersion (transport and diffusion) in the environment, demography, land use (including the location and number of dairy and slaughter animals), food supplies, and exposure pathways used in the dose calculations shall be appropriate to evaluate actual and potential doses in the environs of DOE facilities. Such information shall be updated as necessary to document significant changes that could affect dose evaluations. Dose evaluation models that are codified, approved, or accepted by regulatory or other authorities shall be used where appropriate, such as the AIRDOS/RADRISK codes for demonstrating compliance with 40 CFR Part 61, Subpart H.

(2) Dose Conversion Factors. Except as provided in paragraph II.6b(2)(d), tables of approved dose conversion factors in paragraphs II.6b(2)(a), (b), and (c), below, shall be used to evaluate doses unless otherwise legally required, e.g., use of AIRDOS/RADRISK codes pursuant to 40 CFR Part 61, Subpart H.

(a) Committed Dose Conversion Factors. Radionuclides taken into the body, generally by exposure modes whereby the radionuclide is ingested or inhaled, will continue to irradiate the body as long as they exist and are retained by the body. The dose delivered to a body over the lifetime of the individual from a single

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committed dose conversion factors shall be used, as appropriate, and are presented in EPA-520/1-88-020, Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," and in DOE/EH-0071, "Internal Dose Conversion Factors for Calculation of Dose to the Public." These conversion factors are based upon the ICRP reference man model, and the committed dose is the dose integrated over an interval of 50 years.

(b) External Dose Conversion Factors. The doses from exposure to external radiation from radionuclide concentrations in air and in water that result from submersion or from exposure to contaminated plane surfaces shall be estimated, as appropriate, using the external dose conversion factors presented in EPA-520/1-88-020, Federal Guidance Report No. 11, "Limiting Values of Radionuclides Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion" and in DOE/EH-0070, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public."

(c) Derived Concentration Guides (DCG). DCG values are presented as reference values in Chapter III for each of three exposure modes: inhalation of air containing the radionuclide; submersion in a semi-infinite cloud of air containing the radionuclide; and ingestion of water containing the radionuclide. The DCG tables may be used to evaluate only the three exposure modes upon which they are based.

(d) Other Methods and Alternatives. Methods and alternatives other than those discussed above and as prescribed in applicable regulations shall be submitted to EH-1 for approval. EH-1 may approve the alternative method, if appropriate.

(3) Parametric Considerations.

(a) Dose limits for members of the general public, from routine operation of a DOE activity, shall be expressed as a dose received by the individuals during the year (if, for example, the exposure is external to the body) or the committed dose received by the individual over a period of 50 years from radionuclides taken into the body during the year. The limits should not be interpreted as dose rates per se, especially not in the sense of instantaneous dose rates.

(b) Doses calculated should be as realistic as practicable. Consequently, the individuals subject to the greatest exposure shall be identified, to the extent practicable, so that the highest dose might be determined.

(c) Dose limits apply to actual or committed doses to real individuals. Consequently, all factors germane to dose determination should be applied. Alternatively, if available data are not sufficient to evaluate these factors or if they are too costly to determine, the assumed parametric values shall be sufficiently conservative so that it is unlikely that individuals would actually receive a dose that would exceed the dose calculated using the values assumed.

(d) Parametric values used in performing dose calculations shall be recorded.

(e) Collective public dose in the environs of a site with multiple emission points may be estimated using the assumption that all emissions occur from a single point centrally located on the site. Guidance on combining emission points is provided in EPA-450/477-001, "Guidelines for Air Quality Maintenance Planning and Analysis," Vol. 10, Revised: Procedures for Evaluating Air Quality Impact of New Stationary Sources.

(f) The assumption of a single point of emission, as discussed in II.6b(3)(e), may be used to calculate public dose for the maximally exposed individuals if the emission points are close to one another relative to the distance to the site boundary. Otherwise, the public dose to the maximally exposed individuals should be determined taking into consideration the actual locations of emissions on the site with respect to the offsite locations.

7. REPORTING REQUIREMENTS. In addition to the reporting requirements of DOE 5400.1 and DOE 5484.1, the responsible DOE Field Office Manager shall notify, in a timely manner, the relevant Program Office(s) and the Deputy Assistant Secretary for Environment (EH-20) of actual or potential exposures of members of the public that could result in either an effective dose equivalent from DOE sources exceeding 10 mrem (0.1 mSv) in a year; or exceeding any limit or not meeting any other requirement specified in this Order or any other legally applicable limits, or a combined dose equal to or greater than 100 mrem (1 mSv) effective dose equivalent in a year due to DOE and other man-made sources of radiation (medical, consumer products, and natural sources excepted). For purposes of determining compliance with the reporting requirements of 40 CFR Parts 302 and 355, releases of source, by-product, and special nuclear material that occur from DOE activities are considered to be "Federally permitted" releases if they do not exceed the limits specified in this Order and the operations and releases are in compliance with DOE policies, and guidelines, and requirements specified in DOE Orders, including DOE 5820.2A.

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8. RECORDS.

a. Content. Records developed shall include information and data necessary to identify and characterize releases of radioactive material to the environment, their fate in the environment, and their probable impact on radiation doses to the public. Basic information used assess compliance with the requirements of this Order pursuant to paragraph II.6, and the results of such assessments, shall be incorporated as part of the record.

b. Retention. Information and data developed pursuant to this Order shall be retained consistent with the requirements of DOE 1324.2A and other legally applicable requirements.

9. UNITS. All reports, notifications, and records developed pursuant to DOE Order requirements shall present data in the units used in the applicable regulation or DOE Order.

CHAPTER III

DERIVED CONCENTRATION GUIDES FOR AIR AND WATER

1. PURPOSE. The Derived Concentration Guide (DCG) values listed in this chapter are provided as reference values for conducting radiological environmental protection programs at operational DOE facilities and sites. Derived Air Concentrations (DAC) guides for controlling occupational intake of radionuclides through inhalation are listed in DOE 5480.11.

2. BASIS. The DCG values are presented for each of three exposure modes: 1) ingestion of water; 2) inhalation of air; and 3) immersion in a gaseous cloud. The DCG values for internal exposure shown in Figure III-1 are based on a committed effective dose equivalent of 100 mrem for the radionuclide taken into the body by ingestion or inhalation during one year. To use the DCGs for comparison with the DOE drinking water systems criterion of 4 mrem/yr (0.04 mSv/yr), use 4 percent of the DCG values for ingestion. Compliance with the 40 CFR Part 61, Subpart H, criterion of 10 mrem/yr (0.10 mSv/yr) effective dose equivalent is demonstrated using the AIRDOS/RADRISK models prescribed by the EPA. Alternative gastrointestinal-tract (GI-tract) absorption factors (f_1) and lung retention classes (noted as D, W, or Y in the Task Group Lung Model used to produce the inhalation dose factors reported in ICRP Publication 30) are listed for specific compounds, by element, in Figure III-2 for cross-referencing with the internal DCGS in Figure III-1. The data in Figure III-2 are listed in alphabetical order, by element name. Removal half-times assigned to the compounds with lung retention classes D, W, and Y are 0.5, 50, and 500 days, respectively. The air immersion DCG values shown in Figure III-3 are based on an effective dose equivalent of 100 mrem from exposure during one year. Figure III-1 contains six columns of information: Radionuclide/Chemical Form/Isomer Half-Life; f_1 Value (GI-tract absorption); Ingested Water DCG (μCi/mL); Inhaled Air DCG for Lung Retention Class D (μCi/mL); and Inhaled Air DCG for Lung Retention Class W (μCi/mL); and Inhaled Air DCG for Lung Retention Class Y (μCi/mL). Figure III-2 contains five columns of information: Element/Symbol; Atomic Number; compound; f_1 value; and Lung Retention Class. Figure III-3 contains three columns of information: Radionuclide; Half-life in units of seconds (s), minutes (min), hours (h), days (d), or years (yr); and Air Immersion DCG (μCi;mL).

   a. Exposure Conditions for Ingestion of Water and Inhalation. Under conditions of continuous exposure, members of the public are assumed to ingest 730 liters of drinking water or to inhale 8,400 cubic meters of air (for exposure of 24 hours per day, 365 days per year), as given for the "reference man" in ICRP Publication 23. Only single modes of exposure were considered in the calculation of the DCGs - that is, they apply to either inhalation or ingestion, not to

a combination of both. The dose factors used to calculate the DCG values for internal exposure were taken from the report "Internal Dose Conversion Factors for Calculation of Dose to the Public" (DOE/EH-0071). For ingestion, DCG values are tabulated for all values of f_1 for each radionuclide given in ICRP Publication 30, as modified for several transuranic elements by ICRP Publication 48. For inhalation, DCG values are given for all combinations of f_1 and lung retention class (D, W, or Y) given by the ICRP, as tabulated in Figure III-2. For radionuclides with multiple f_1 listings, where specific data for an airborne or liquid release are lacking, the f_1 value that results in the most restrictive DCG for ingested water or inhaled air should be used.

b. Exposure Conditions for Air Immersion. The air immersion DCGs were calculated for a continuous, nonshielded exposure via immersion in a semi-infinite atmospheric cloud. The dose conversion factors used to calculate the DCG values for air immersion were taken from the report "External Dose-Rate Conversion Factors for Calculation of Dose to the Public" (DOE/EH-0070). The DCG value for air immersion listed in Figure III-3 for a given radionuclide is determined either by a limit on annual effective dose equivalent, which provides a limit on stochastic radiation effects, or by a limit on annual dose equivalent to any organ, which provides a limit on nonstochastic radiation effects. For most of the radionuclides listed in Figure III-3, the DCG value is determined by the limit on annual effective dose equivalent. Thus, the few cases where the DCG value is determined by the limit on annual dose equivalent to skin are indicated in the figure by an appropriate footnote. Again, the DCGs listed in Figure III-3 account only for immersion in a semi-infinite cloud and do not account for inhalation or ingestion exposures. Three classes of radionuclides are included in the air immersion DCGs given in Figure III-3, as described below.

(1) Class 1. The first class of radionuclides includes selected noble gases and short-lived activation products that occur in gaseous form. For these radionuclides, inhalation doses are negligible compared to the external dose from immersion in an atmospheric cloud.

(2) Class 2. The second class of radionuclides includes those for which a DCG value for inhalation has been calculated (using the ICRP inhalation dose equivalent factors), but for which the DCG value for external exposure to a contaminated atmospheric cloud is more restrictive (i.e., results in a lower DCG value). These radionuclides generally have half-lives of a few hours or

less, or are eliminated from the body following inhalation sufficiently rapidly to limit the inhalation dose.

(3) Class 3. The third class of radionuclides includes selected isotopes with relatively short half-lives that were not considered in ICRP Publication 30. These radionuclides typically have half-lives that are less than 10 minutes, they do not occur as a decay product of a longer-lived radionuclide, or they lack sufficient decay data to permit internal dose calculations. These radionuclides are also typified by a radioactive emission of highly intense, high-energy photons and rapid removal from the body following inhalation.

c. Application to Mixtures of Radionuclides. The DCG values are given for individual radionuclides. For known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding DCG must not exceed 1.0.

3. LIMITATIONS. The values given in Figures III-1 and III-3 account for only three exposure pathways (ingested water or inhaled air or air immersion) and do not include other potentially significant pathways. When more complex environmental pathways are involved, a more complete pathway analysis is required for calculating public radiation doses resulting from the operation of DOE facilities.

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
H-3 (Water)	-	2.E-03	-[1]	1.E-07[2]	-
H-3 (Elemental)	-	-	-	2.E-02[2]	-
Be-7	5.E-03	1.E-03	-	5.E-08	4.E-08
Be-10	5.E-03	3.E-05	-	4.E-10	3.E-11
C-11 (Org)	-	1.E-02	-	1.E-06	-
C-11 (CO)	-	-	3.E-06	-	-
C-11 (CO_2)	-	-	1.E-06	-	-
C-14 (Org)	-	7.E-05	-	6.E-09	-
C-14 (CO)	-	-	4.E-06	-	-
C-14 (CO_2)	-	-	5.E-07	-	-
F-18[3]	1.E+00	1.E-03	2.E-07	2.E-07	2.E-07
Na-22	1.E+00	1.E-05	1.E-09	-	-
Na-24[3]	1.E+00	1.E-04	1.E-08	-	-
Mg-28	5.E-01	2.E-05	4.E-09	3.E-09	-
Al-26	1.E-02	1.E-05	1.E-10	2.E-10	-
Si-31	1.E-02	3.E-04	6.E-08	7.E-08	6.E-08
Si-32	1.E-02	8.E-05	6.E-10	3.E-10	1.E-11
P-32	8.E-01	2.E-05	2.E-09	9.E-10	-
P-33	8.E-01	2.E-04	2.E-08	6.E-09	-
S-35	8.E-01	3.E-04	4.E-08	5.E-09	-
	1.E-01	2.E-04	-	-	-
S-35 (Gas)	-	-	3.E-08	-	-
Cl-36[3]	1.E+00	5.E-05	6.E-09	6.E-10	-
Cl-38	1.E+00	7.E-04	1.E-07	1.E-07	-
Cl-39	1.E+00	1.E-03	1.E-07	1.E-07	-
K-40	1.E+00	7.E-06	9.E-10	-	-
K-42	1.E+00	1.E-04	1.E-08	-	-
K-43[3]	1.E+00	2.E-04	2.E-08	-	-
K-44	1.E+00	9.E-04	2.E-07	-	-

Figure III-1
Derived Concentration Guides (DCGs) for Members of the Public from Ingested Water and Inhalation Resulting in 100 mrem/yr

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
K-45	1.E+00	1.E-03	3.E-07	-	-
Ca-45	3.E-01	5.E-05	-	2.E-09	-
Ca-47	3.E-01	2.E-05	-	2.E-09	-
Sc-43	1.E-04	2.E-04	-	-	5.E-08
Sc-44m	1.E-04	1.E-05	-	-	2.E-09
Sc-44 3/	1.E-04	1.E-04	-	-	3.E-08
Sc-46	1.E-04	2.E-05	-	-	6.E-10
Sc-47	1.E-04	7.E-05	-	-	7.E-09
Sc-48	1.E-04	2.E-05	-	-	3.E-09
Sc-49	1.E-04	6.E-04	-	-	1.E-07
Ti-44	1.E-02	7.E-06	3.E-11	7.E-11	1.E-11
Ti-45 3/	1.E-02	2.E-04	6.E-08	8.E-08	7.E-08
V-47	1.E-02	9.E-04	2.E-07	2.E-07	-
V-48	1.E-02	2.E-05	3.E-09	2.E-09	-
V-49	1.E-02	3.E-03	8.E-08	4.E-08	-
Cr-48	1.E-01	2.E-04	3.E-08	2.E-08	2.E-08
	1.E-02	2.E-04	-	-	-
Cr-49 3/	1.E-01	8.E-04	2.E-07	2.E-07	2.E-07
	1.E-02	8.E-04	-	-	-
Cr-51	1.E-01	1.E-03	1.E-07	6.E-08	5.E-08
	1.E-02	1.E-03	-	-	-
Mn-51	1.E-01	6.E-04	1.E-07	1.E-07	-
Mn-52m 3/	1.E-01	9.E-04	2.E-07	2.E-07	-
Mn-52	1.E-01	2.E-05	3.E-09	2.E-09	-
Mn-53	1.E-01	1.E-03	6.E-08	3.E-08	-
Mn-54	1.E-01	5.E-05	2.E-09	2.E-09	-
Mn-56 3/	1.E-01	1.E-04	4.E-08	5.E-08	-
Fe-52	1.E-01	3.E-05	7.E-09	6.E-09	-
Fe-55	1.E-01	2.E-04	5.E-09	1.E-08	-
Fe-59	1.E-01	2.E-05	8.E-10	1.E-09	-
Fe-60	1.E-01	9.E-07	2.E-11	4.E-11	-
Co-55	5.E-02	3.E-05	-	7.E-09	6.E-09
	3.E-01	4.E-05	-	-	-
Co-56	5.E-02	1.E-05	-	7.E-10	5.E-10

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Co-56	3.E-01	1.E-05	-	-	-
Co-57	5.E-02	2.E-04	-	7.E-09	2.E-09
	3.E-01	1.E-04	-	-	-
Co-58m	5.E-02	2.E-03	-	2.E-07	2.E-07
	3.E-01	2.E-03	-	-	-
Co-58	5.E-02	5.E-05	-	3.E-09	2.E-09
	3.E-01	4.E-05	-	-	-
Co-60m[3]	5.E-02	4.E-02	-	9.E-06	6.E-06
	3.E-01	4.E-02	-	-	-
Co-60	5.E-02	1.E-05	-	4.E-10	8.E-11
	3.E-01	5.E-06	-	-	-
Co-61	5.E-02	5.E-04	-	1.E-07	1.E-07
	3.E-01	6.E-04	-	-	-
Co-62m	5.E-02	1.E-03	-	4.E-07	4.E-07
	3.E-01	1.E-03	-	-	-
Ni-56	5.E-02	4.E-05	5.E-09	3.E-09	-
Ni-56 (Vapor)	-	-	3.E-09	-	-
Ni-57[3]	5.E-02	4.E-05	1.E-08	7.E-09	-
Ni-57 (Vapor)	-	-	1.E-08	-	-
Ni-59	5.E-02	7.E-04	9.E-09	2.E-08	-
Ni-59 (Vapor)	-	-	4.E-09	-	-
Ni-63	5.E-02	3.E-04	4.E-09	6.E-09	-
Ni-63 (Vapor)	-	-	2.E-09	-	-
Ni-65[3]	5.E-02	2.E-04	6.E-08	7.E-08	-
Ni-65 (Vapor)	-	-	4.E-08	-	-
Ni-66	5.E-02	1.E-05	4.E-09	1.E-09	-
Ni-66 (Vapor)	-	-	7.E-09	-	-
Cu-60[3]	5.E-01	8.E-04	2.E-07	3.E-07	2.E-07
Cu-61	5.E-01	3.E-04	7.E-08	1.E-07	8.E-08
Cu-64	5.E-01	3.E-04	7.E-08	5.E-08	5.E-08
Cu-67	5.E-01	1.E-04	2.E-08	1.E-08	1.E-08
Zn-62	5.E-01	4.E-05	-	-	7.E-09
Zn-63	5.E-01	7.E-04	-	-	2.E-07
Zn-65	5.E-01	9.E-06	-	-	6.E-10
Zn-69m	5.E-01	1.E-04	-	-	2.E-08
Zn-69	5.E-01	2.E-03	-	-	3.E-07
Zn-71m	5.E-01	2.E-04	-	-	4.E-08
Zn-72	5.E-01	3.E-05	-	-	3.E-09
Ga-65[3]	1.E-03	2.E-03	4.E-07	5.E-07	-
Ga-66	1.E-03	3.E-05	8.E-09	-	7.E-09

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Ga-67	1.E-03	2.E-04	3.E-08	2.E-08	-
Ga-68 3/	1.E-03	4.E-04	1.E-07	1.E-07	-
Ga-70	1.E-03	2.E-03	4.E-07	5.E-07	-
Ga-72 3/	1.E-03	3.E-05	8.E-09	7.E-09	-
Ga-73	1.E-03	1.E-04	4.E-08	4.E-08	-
Ge-66	1.E+00	7.E-04	6.E-08	5.E-08	-
Ge-67	1.E+00	1.E-03	2.E-07	2.E-07	-
Ge-68	1.E+00	1.E-04	9.E-09	2.E-10	-
Ge-69	1.E+00	4.E-04	4.E-08	2.E-08	-
Ge-71	1.E+00	1.E-02	1.E-06	1.E-07	-
Ge-75	1.E+00	2.E-03	2.E-07	2.E-07	-
Ge-77	1.E+00	2.E-04	2.E-08	1.E-08	-
Ge-78	1.E+00	7.E-04	5.E-08	5.E-08	-
As-69	5.E-01	1.E-03	-	3.E-07	-
As-70	5.E-01	4.E-04	-	1.E-07	-
As-71	5.E-01	1.E-04	-	1.E-08	-
As-72	5.E-01	2.E-05	-	3.E-09	-
As-73	5.E-01	2.E-04	-	4.E-09	-
As-74	5.E-01	4.E-05	-	2.E-09	-
As-76	5.E-01	3.E-05	-	4.E-09	-
As-77	5.E-01	1.E-04	-	1.E-08	-
As-78	5.E-01	2.E-04	-	5.E-08	-
Se-70	8.E-01	5.E-04	9.E-08	1.E-07	-
	5.E-02	3.E-04	-	-	-
Se-73m	8.E-01	2.E-03	4.E-07	3.E-07	-
	5.E-02	9.E-04	-	-	-
Se-73 3/	8.E-01	2.E-04	3.E-08	4.E-08	-
	5.E-02	9.E-05	-	-	-
Se-75	8.E-01	2.E-05	2.E-09	1.E-09	-
	5.E-02	8.E-05	-	-	-
Se-79	8.E-01	2.E-05	2.E-09	1.E-09	-
	5.E-02	1.E-04	-	-	-
Se-81m	8.E-01	1.E-03	2.E-07	2.E-07	-
	5.E-02	7.E-04	-	-	-
Se-81	8.E-01	2.E-03	5.E-07	6.E-07	-
	5.E-02	2.E-03	-	-	-
Se-83	8.E-01	1.E-03	3.E-07	3.E-07	-
	5.E-02	9.E-04	-	-	-
Br-74m	1.E+00	6.E-04	9.E-08	1.E-07	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Br-74	1.E+00	1.E-03	2.E-07	2.E-07	-
Br-75	1.E+00	1.E-03	1.E-07	1.E-07	-
Br-76	1.E+00	1.E-04	1.E-08	1.E-08	-
Br-77[3/]	1.E+00	4.E-04	6.E-08	5.E-08	-
Br-80m[3/]	1.E+00	6.E-04	4.E-08	3.E-08	-
Br-80[3/]	1.E+00	2.E-03	4.E-07	5.E-07	-
Br-82[3/]	1.E+00	8.E-05	1.E-08	9.E-09	-
Br-83	1.E+00	2.E-03	2.E-07	1.E-07	-
Br-84[3/]	1.E+00	9.E-04	1.E-07	2.E-07	-
Rb-79	1.E+00	2.E-03	3.E-07	-	-
Rb-81m[3/]	1.E+00	7.E-03	8.E-07	-	-
Rb-81[3/]	1.E+00	1.E-03	1.E-07	-	-
Rb-82m	1.E+00	3.E-04	4.E-08	-	-
Rb-83	1.E+00	2.E-05	2.E-09	-	-
Rb-84	1.E+00	1.E-05	2.E-09	-	-
Rb-86	1.E+00	1.E-05	2.E-09	-	-
Rb-87	1.E+00	3.E-05	4.E-09	-	-
Rb-88[3/]	1.E+00	8.E-04	1.E-07	-	-
Rb-89[3/]	1.E+00	2.E-03	3.E-07	-	-
Sr-80	3.E-01	3.E-02	5.E-06	-	-
	1.E-02	3.E-02	-	-	6.E-06
Sr-81	3.E-01	7.E-04	2.E-07	-	-
	1.E-02	6.E-04	-	-	2.E-07
Sr-83	3.E-01	8.E-05	2.E-08	-	-
	1.E-02	6.E-05	-	-	8.E-09
Sr-85m[3/]	3.E-01	6.E-03	1.E-06	-	-
	1.E-02	6.E-03	-	-	2.E-06
Sr-85	3.E-01	7.E-05	6.E-09	-	-
	1.E-02	1.E-04	-	-	4.E-09
Sr-87m[3/]	3.E-01	1.E-03	3.E-07	-	-
	1.E-02	1.E-03	-	-	4.E-07
Sr-89	3.E-01	2.E-05	2.E-09	-	-
	1.E-02	2.E-05	-	-	3.E-10
Sr-90	3.E-01	1.E-06	5.E-11	-	-
	1.E-02	1.E-05	-	-	9.E-12
Sr-91	3.E-01	6.E-05	1.E-08	-	-
	1.E-02	5.E-05	-	-	8.E-09
Sr-92[3/]	3.E-01	9.E-05	2.E-08	-	-
	1.E-02	7.E-05	-	-	2.E-08
Y-86m	1.E-04	6.E-04	-	1.E-07	1.E-07

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Y-86 3/	1.E-04	3.E-05	-	8.E-09	7.E-09
Y-87	1.E-04	6.E-05	-	8.E-09	7.E-09
Y-88	1.E-04	3.E-05	-	6.E-10	6.E-10
Y-90m 3/	1.E-04	2.E-04	-	3.E-08	3.E-08
Y-90	1.E-04	1.E-05	-	2.E-09	1.E-09
Y-91m 3/	1.E-04	4.E-03	-	6.E-07	4.E-07
Y-91	1.E-04	2.E-05	-	4.E-10	3.E-10
Y-92	1.E-04	7.E-05	-	2.E-08	2.E-08
Y-93	1.E-04	3.E-05	-	7.E-09	6.E-09
Y-94	1.E-04	8.E-04	-	2.E-07	2.E-07
Y-95	1.E-04	1.E-03	-	4.E-07	3.E-07
Zr-86	2.E-03	4.E-05	9.E-09	6.E-09	6.E-09
Zr-88	2.E-03	1.E-04	5.E-10	1.E-09	7.E-10
Zr-89	2.E-03	4.E-05	8.E-09	6.E-09	6.E-09
Zr-93	2.E-03	9.E-05	4.E-11	1.E-10	2.E-10
Zr-95	2.E-03	4.E-05	6.E-10	9.E-10	7.E-10
Zr-97	2.E-03	2.E-05	5.E-09	3.E-09	3.E-09
Nb-88	1.E-02	2.E-03	-	5.E-07	5.E-07
Nb-89 (66 min)	1.E-02	3.E-04	-	1.E-07	9.E-08
Nb-89 (122 min)	1.E-02	1.E-04	-	4.E-08	4.E-08
Nb-90	1.E-02	3.E-05	-	6.E-09	6.E-09
Nb-93m	1.E-02	3.E-04	-	3.E-09	4.E-10
Nb-94	1.E-02	3.E-05	-	5.E-10	4.E-11
Nb-95m	1.E-02	7.E-05	-	6.E-09	5.E-09
Nb-95	1.E-02	6.E-05	-	3.E-09	3.E-09
Nb-96	1.E-02	3.E-05	-	6.E-09	6.E-09
Nb-97 3/	1.E-02	6.E-04	-	2.E-07	2.E-07
Nb-98	1.E-02	4.E-04	-	1.E-07	1.E-07
Mo-90	8.E-01	1.E-04	2.E-08	-	-
	5.E-02	6.E-05	-	-	1.E-08
Mo-93m	8.E-01	3.E-04	4.E-08	-	-
	5.E-02	1.E-04	-	-	3.E-08
Mo-93	8.E-01	1.E-04	1.E-08	-	-
	5.E-02	6.E-04	-	-	4.E-10
Mo-99	8.E-01	5.E-05	6.E-09	-	-
	5.E-02	3.E-05	-	-	3.E-09
Mo-101 3/	8.E-01	2.E-03	3.E-07	-	-
	5.E-02	1.E-03	-	-	4.E-07
Tc-93m	8.E-01	2.E-03	4.E-07	7.E-07	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Tc-93	8.E-01	8.E-04	2.E-07	2.E-07	-
Tc-94m	8.E-01	5.E-04	1.E-07	1.E-07	-
Tc-94	8.E-01	2.E-04	4.E-08	6.E-08	-
Tc-96m[3/]	8.E-01	4.E-03	7.E-07	6.E-07	-
Tc-96	8.E-01	5.E-05	7.E-09	5.E-09	-
Tc-97m	8.E-01	1.E-04	2.E-08	3.E-09	-
Tc-97	8.E-01	9.E-04	1.E-07	1.E-08	-
Tc-98	8.E-01	3.E-05	4.E-09	7.E-10	-
Tc-99m[3/]	8.E-01	2.E-03	4.E-07	6.E-07	-
Tc-99	8.E-01	1.E-04	1.E-08	2.E-09	-
Tc-101[3/]	8.E-01	4.E-03	8.E-07	9.E-07	-
Tc-104	8.E-01	8.E-04	2.E-07	2.E-07	-
Ru-94	5.E-02	4.E-04	1.E-07	1.E-07	1.E-07
Ru-97	5.E-02	2.E-04	4.E-08	3.E-08	3.E-08
Ru-103	5.E-02	5.E-05	4.E-09	2.E-09	2.E-09
Ru-105[3/]	5.E-02	1.E-04	3.E-08	3.E-08	3.E-08
Ru-106	5.E-02	6.E-06	2.E-10	1.E-10	3.E-11
Rh-99m	5.E-02	5.E-04	1.E-07	2.E-07	2.E-07
Rh-99	5.E-02	7.E-05	7.E-09	5.E-09	5.E-09
Rh-100	5.E-02	4.E-05	1.E-08	9.E-09	9.E-09
Rh-101m	5.E-02	2.E-04	3.E-08	2.E-08	2.E-08
Rh-101	5.E-02	6.E-05	1.E-09	2.E-09	4.E-10
Rh-102m	5.E-02	4.E-05	1.E-09	9.E-10	3.E-10
Rh-102	5.E-02	2.E-05	2.E-10	4.E-10	1.E-10
Rh-103m	5.E-02	1.E-02	3.E-06	3.E-06	3.E-06
Rh-105	5.E-02	1.E-04	3.E-08	1.E-08	1.E-08
Rh-106m	5.E-02	2.E-04	6.E-08	9.E-08	8.E-08
Rh-107	5.E-02	3.E-03	6.E-07	6.E-07	6.E-07
Pd-100	5.E-03	4.E-05	3.E-09	3.E-09	3.E-09
Pd-101	5.E-03	4.E-04	7.E-08	8.E-08	7.E-08
Pd-103	5.E-03	2.E-04	1.E-08	1.E-08	8.E-09
Pd-107	5.E-03	1.E-03	5.E-08	2.E-08	9.E-10
Pd-109	5.E-03	6.E-05	1.E-08	1.E-08	1.E-08
Ag-102	5.E-02	2.E-03	4.E-07	5.E-07	5.E-07
Ag-103	5.E-02	1.E-03	2.E-07	3.E-07	3.E-07
Ag-104m	5.E-02	9.E-04	2.E-07	3.E-07	3.E-07
Ag-104	5.E-02	6.E-04	2.E-07	4.E-07	4.E-07
Ag-105	5.E-02	7.E-05	3.E-09	4.E-09	4.E-09
Ag-106m	5.E-02	2.E-05	2.E-09	2.E-09	2.E-09

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Ag-106	5.E-02	2.E-03	4.E-07	5.E-07	5.E-07
Ag-108m	5.E-02	2.E-05	4.E-10	6.E-10	6.E-11
Ag-110m	5.E-02	1.E-05	3.E-10	4.E-10	2.E-10
Ag-111	5.E-02	3.E-05	4.E-09	2.E-09	2.E-09
Ag-112	5.E-02	9.E-05	2.E-08	2.E-08	2.E-08
Ag-115	5.E-02	9.E-04	2.E-07	2.E-07	2.E-07
Cd-104	5.E-02	6.E-04	2.E-07	3.E-07	3.E-07
Cd-107	5.E-02	6.E-04	1.E-07	1.E-07	1.E-07
Cd-109	5.E-02	1.E-05	1.E-10	3.E-10	3.E-10
Cd-113m	5.E-02	9.E-07	8.E-12	3.E-11	3.E-11
Cd-113	5.E-02	8.E-07	8.E-12	3.E-11	3.E-11
Cd-115m	5.E-02	9.E-06	2.E-10	3.E-10	3.E-10
Cd-115	5.E-02	3.E-05	3.E-09	3.E-09	3.E-09
Cd-117m[3/]	5.E-02	1.E-04	3.E-08	4.E-08	3.E-08
Cd-117[3/]	5.E-02	1.E-04	3.E-08	4.E-08	3.E-08
In-109	2.E-02	5.E-04	1.E-07	2.E-07	-
In-110 (69 min)	2.E-02	4.E-04	1.E-07	1.E-07	-
In-110 (5 h)	2.E-02	1.E-04	4.E-08	5.E-08	-
In-111	2.E-02	1.E-04	2.E-08	2.E-08	-
In-112	2.E-02	6.E-03	1.E-06	2.E-06	-
In-113m[3/]	2.E-02	1.E-03	3.E-07	5.E-07	-
In-114m	2.E-02	9.E-06	2.E-10	2.E-10	-
In-115m	2.E-02	4.E-04	1.E-07	1.E-07	-
In-115	2.E-02	1.E-06	3.E-12	1.E-11	-
In-116m[3/]	2.E-02	7.E-04	2.E-07	3.E-07	-
In-117m	2.E-02	3.E-04	8.E-08	1.E-07	-
In-117[3/]	2.E-02	2.E-03	4.E-07	5.E-07	-
In-119m	2.E-02	1.E-03	3.E-07	3.E-07	-
Sn-110	2.E-02	9.E-05	3.E-08	3.E-08	-
Sn-111	2.E-02	2.E-03	5.E-07	6.E-07	-
Sn-113	2.E-02	5.E-05	3.E-09	1.E-09	-
Sn-117m	2.E-02	5.E-05	5.E-09	3.E-09	-
Sn-119m	2.E-02	1.E-04	6.E-09	2.E-09	-
Sn-121m	2.E-02	1.E-04	2.E-09	1.E-09	-
Sn-121	2.E-02	2.E-04	4.E-08	3.E-08	-
Sn-123m	2.E-02	1.E-03	3.E-07	3.E-07	-
Sn-123	2.E-02	2.E-05	1.E-09	4.E-10	-
Sn-125	2.E-02	1.E-05	2.E-09	8.E-10	-
Sn-126	2.E-02	8.E-06	1.E-10	2.E-10	-
Sn-127	2.E-02	2.E-04	5.E-08	4.E-08	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Sn-128	2.E-02	3.E-04	6.E-08	9.E-08	-
Sb-115	1.E-01	2.E-03	6.E-07	-	-
	1.E-02	2.E-03	-	7.E-07	-
Sb-116m	1.E-01	6.E-04	2.E-07	-	-
	1.E-02	6.E-04	-	3.E-07	-
Sb-116	1.E-01	2.E-03	7.E-07	-	-
	1.E-02	2.E-03	-	8.E-07	-
Sb-117 3/	1.E-01	2.E-03	5.E-07	-	-
	1.E-02	2.E-03	-	7.E-07	-
Sb-118m	1.E-01	2.E-04	5.E-08	-	-
	1.E-02	1.E-04	-	5.E-08	-
Sb-119	1.E-01	4.E-04	1.E-07	-	-
	1.E-02	4.E-04	-	6.E-08	-
Sb-120 (16 min)	1.E-01	5.E-03	1.E-06	-	-
	1.E-02	5.E-03	-	1.E-06	-
Sb-120 (6 d)	1.E-01	3.E-05	5.E-09	-	-
	1.E-02	3.E-05	-	3.E-09	-
Sb-122	1.E-01	2.E-05	5.E-09	-	-
	1.E-02	2.E-05	-	3.E-09	-
Sb-124m	1.E-01	7.E-03	2.E-06	-	-
	1.E-02	7.E-03	-	1.E-06	-
Sb-124	1.E-01	2.E-05	2.E-09	-	-
	1.E-02	1.E-05	-	6.E-10	-
Sb-125	1.E-01	6.E-05	6.E-09	-	-
	1.E-02	5.E-05	-	1.E-09	-
Sb-126m 3/	1.E-01	2.E-03	4.E-07	-	-
	1.E-02	2.E-03	-	5.E-07	-
Sb-126	1.E-01	2.E-05	3.E-09	-	-
	1.E-02	1.E-05	-	1.E-09	-
Sb-127	1.E-01	2.E-05	5.E-09	-	-
	1.E-02	2.E-05	-	2.E-09	-
Sb-128 (9 h)	1.E-01	3.E-05	1.E-08	-	-
	1.E-02	3.E-05	-	8.E-09	-
Sb-128 (10 min)	1.E-01	3.E-03	9.E-07	-	-
	1.E-02	3.E-03	-	1.E-06	-
Sb-129 3/	1.E-01	8.E-05	2.E-08	-	-
	1.E-02	8.E-05	-	2.E-08	-
Sb-130	1.E-01	5.E-04	1.E-07	-	-
	1.E-02	5.E-04	-	2.E-07	-
Sb-131	1.E-01	5.E-04	9.E-08	-	-
	1.E-02	5.E-04	-	1.E-07	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Te-116	2.E-01	2.E-04	5.E-08	7.E-08	-
Te-121m	2.E-01	2.E-05	9.E-10	1.E-09	-
Te-121	2.E-01	9.E-05	1.E-08	7.E-09	-
Te-123m	2.E-01	3.E-05	1.E-09	1.E-09	-
Te-123	2.E-01	3.E-05	1.E-09	3.E-09	-
Te-125m	2.E-01	4.E-05	2.E-09	2.E-09	-
Te-127m	2.E-01	2.E-05	1.E-09	6.E-10	-
Te-127	2.E-01	2.E-04	5.E-08	4.E-08	-
Te-129m	2.E-01	1.E-05	1.E-09	6.E-10	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Te-131m	2.E-01	9.E-06	3.E-09	2.E-09	-
Te-131	2.E-01	7.E-04	1.E-07	1.E-07	-
Te-132	2.E-01	2.E-05	2.E-09	2.E-09	-
Te-133m 3/	2.E-01	2.E-04	3.E-08	3.E-08	-
Te-133 3/	2.E-01	9.E-04	1.E-07	1.E-07	-
Te-134 3/	2.E-01	7.E-04	1.E-07	1.E-07	-
I-120m	1.E+00	4.E-04	5.E-08	-	-
I-120	1.E+00	2.E-04	3.E-08	-	-
I-121	1.E+00	8.E-04	1.E-07	-	-
I-123	1.E+00	3.E-04	4.E-08	-	-
I-124	1.E+00	4.E-06	6.E-10	-	-
I-125	1.E+00	4.E-06	5.E-10		
[illegible]	[illegible]	[illegible]	[illegible]		
I-128 3/	1.E+00	2.E-03	3.E-07	-	-
I-129	1.E+00	5.E-07	7.E-11	-	-
I-130	1.E+00	3.E-05	5.E-09	-	-
I-131	1.E+00	3.E-06	4.E-10	-	-
I-132m	1.E+00	3.E-04	5.E-08	-	-
I-132 3/	1.E+00	2.E-04	4.E-08	-	-
I-133	1.E+00	1.E-05	2.E-09	-	-
I-134 3/	1.E+00	7.E-04	1.E-07	-	-
I-135 3/	1.E+00	7.E-05	1.E-08	-	-
Cs-125	1.E+00	2.E-03	3.E-07	-	-
Cs-127	1.E+00	2.E-03	2.E-07	-	-
Cs-129 3/	1.E+00	6.E-04	8.E-08	-	-
Cs-130	1.E+00	3.E-03	4.E-07	-	-
Cs-131	1.E+00	6.E-04	7.E-08	-	-
Cs-132	1.E+00	7.E-05	1.E-08	-	-
Cs-134m	1.E+00	3.E-03	3.E-07	-	-
CS-134	1.E+00	2.E-06	2.E-10	-	-
Cs-135m	1.E+00	3.E-03	5.E-07	-	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Cs-135	1.E+00	2.E-05	3.E-09	-	-
Cs-136	1.E+00	1.E-05	2.E-09	-	-
Cs-137	1.E+00	3.E-06	4.E-10	-	-
Cs-138[3/]	1.E+00	9.E-04	1.E-07	-	-
Ba-126	1.E-01	2.E-04	4.E-08	-	-
Ba-128	1.E-01	1.E-05	4.E-09	-	-
Ba-131m	1.E-01	1.E-02	3.E-06	-	-
Ba-131	1.E-01	8.E-05	2.E-08	-	-
Ba-133m	1.E-01	7.E-05	2.E-08	-	-
Ba-133	1.E-01	4.E-05	2.E-09	-	-
Ba-135m	1.E-01	9.E-05	3.E-08	-	-
Ba-139	1.E-01	3.E-04	7.E-08	-	-
Ba-140	1.E-01	2.E-05	3.E-09	-	-
Ba-141[3/]	1.E-01	7.E-04	2.E-07	-	-
Ba-142[3/]	1.E-01	1.E-03	3.E-07	-	-
La-131	1.E-03	1.E-03	3.E-07	4.E-07	-
La-132	1.E-03	9.E-05	2.E-08	3.E-08	-
La-135	1.E-03	1.E-03	3.E-07	2.E-07	-
La-137	1.E-03	3.E-04	2.E-10	6.E-10	-
La-138	1.E-03	2.E-05	8.E-12	3.E-11	-
La-140	1.E-03	2.E-05	3.E-09	3.E-09	-
La-141	1.E-03	1.E-04	2.E-08	3.E-08	-
La-142	1.E-03	2.E-04	5.E-08	8.E-08	-
La-143	1.E-03	1.E-03	2.E-07	2.E-07	-
Ce-134	3.E-04	2.E-05	-	2.E-09	2.E-09
Ce-135	3.E-04	4.E-05	-	9.E-09	8.E-09
Ce-137m	3.E-04	7.E-05	-	1.E-08	9.E-09
Ce-137	3.E-04	1.E-03	-	3.E-07	3.E-07
Ce-139	3.E-04	1.E-04	-	2.E-09	2.E-09
Ce-141	3.E-04	5.E-05	-	2.E-09	1.E-09
Ce-143	3.E-04	3.E-05	-	4.E-09	4.E-09
Ce-144	3.E-04	7.E-06	-	6.E-11	3.E-11
Pr-136	3.E-04	2.E-03	-	6.E-07	5.E-07
Pr-137	3.E-04	1.E-03	-	4.E-07	3.E-07
Pr-138m	3.E-04	3.E-04	-	1.E-07	1.E-07
Pr-139	3.E-04	1.E-03	-	3.E-07	3.E-07
Pr-142m	3.E-04	2.E-03	-	4.E-07	3.E-07
Pr-142	3.E-04	3.E-05	-	5.E-09	4.E-09
Pr-143	3.E-04	3.E-05	-	2.E-09	2.E-09

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Pr-144	3.E-04	1.E-03	-	3.E-07	3.E-07
Pr-145	3.E-04	9.E-05	-	2.E-08	2.E-08
Pr-147	3.E-04	2.E-03	-	5.E-07	4.E-07
Nd-136	3.E-04	4.E-04	-	1.E-07	1.E-07
Nd-138	3.E-04	5.E-05	-	2.E-08	1.E-08
Nd-139m	3.E-04	1.E-04	-	4.E-08	3.E-08
Nd-139	3.E-04	2.E-03	-	8.E-07	7.E-07
Nd-141	3.E-04	4.E-03	-	2.E-06	1.E-06
Nd-147	3.E-04	4.E-05	-	2.E-09	2.E-09
Nd-149 3/	3.E-04	3.E-04	-	6.E-08	6.E-08
Nd-151	3.E-04	2.E-03	-	5.E-07	4.E-07
Pm-141	3.E-04	2.E-03	-	4.E-07	4.E-07
Pm-143	3.E-04	1.E-04	-	1.E-09	2.E-09
Pm-144	3.E-04	3.E-05	-	3.E-10	3.E-10
Pm-145	3.E-04	3.E-04	-	5.E-10	4.E-10
Pm-146	3.E-04	4.E-05	-	1.E-10	1.E-10
Pm-147	3.E-04	1.E-04	-	5.E-10	3.E-10
Pm-148m	3.E-04	2.E-05	-	7.E-10	7.E-10
Pm-148	3.E-04	1.E-05	-	1.E-09	1.E-09
Pm-149	3.E-04	4.E-05	-	5.E-09	4.E-09
Pm-150	3.E-04	1.E-04	-	4.E-08	4.E-08
Pm-151	3.E-04	5.E-05	-	8.E-09	7.E-09
Sm-141m	3.E-04	8.E-04	-	2.E-07	-
Sm-141	3.E-04	2.E-03	-	4.E-07	-
Sm-142	3.E-04	2.E-04	-	6.E-08	-
Sm-145	3.E-04	2.E-04	-	1.E-09	-
Sm-146	3.E-04	7.E-07	-	2.E-13	-
Sm-147	3.E-04	8.E-07	-	2.E-13	-
Sm-151	3.E-04	4.E-04	-	4.E-10	-
Sm-153	3.E-04	5.E-05	-	7.E-09	-
Sm-155	3.E-04	2.E-03	-	5.E-07	-
Sm-156	3.E-04	1.E-04	-	2.E-08	-
Eu-145	1.E-03	4.E-05	-	5.E-09	-
Eu-146	1.E-03	3.E-05	-	3.E-09	-
Eu-147	1.E-03	8.E-05	-	4.E-09	-
Eu-148	1.E-03	3.E-05	-	8.E-10	-
Eu-149	1.E-03	3.E-04	-	7.E-09	-
Eu-150 (12 h)	1.E-03	9.E-05	-	2.E-08	-
Eu-150 (34 yr)	1.E-03	2.E-05	-	4.E-11	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Eu-152m	1.E-03	7.E-05	-	2.E-08	-
Eu-152	1.E-03	2.E-05	-	5.E-11	-
Eu-154	1.E-03	2.E-05	-	5.E-11	-
Eu-155	1.E-03	1.E-04	-	3.E-10	-
Eu-156	1.E-03	2.E-05	-	1.E-09	-
Eu-157	1.E-03	6.E-05	-	1.E-08	-
Eu-158	1.E-03	5.E-04	-	1.E-07	-
Gd-145	3.E-04	1.E-03	4.E-07	4.E-07	-
Gd-146	3.E-04	4.E-05	3.E-10	7.E-10	-
Gd-147	3.E-04	5.E-05	1.E-08	8.E-09	-
Gd-148	3.E-04	7.E-07	4.E-14	1.E-13	-
Gd-149	3.E-04	8.E-05	5.E-09	6.E-09	-
Gd-151	3.E-04	2.E-04	1.E-09	3.E-09	-
Gd-152	3.E-04	9.E-07	5.E-14	2.E-13	-
Gd-153	3.E-04	1.E-04	6.E-10	1.E-09	-
Gd-159	3.E-04	7.E-05	2.E-08	1.E-08	-
Tb-147	3.E-04	2.E-04	-	7.E-08	-
Tb-149	3.E-04	1.E-04	-	2.E-09	-
Tb-150	3.E-04	1.E-04	-	5.E-08	-
Tb-151	3.E-04	1.E-04	-	2.E-08	-
Tb-153	3.E-04	1.E-04	-	2.E-08	-
Tb-154	3.E-04	5.E-05	-	1.E-08	-
Tb-155	3.E-04	2.E-04	-	2.E-08	-
Tb-156m (24 h)	3.E-04	2.E-04	-	2.E-08	-
Tb-156m (5 h)	3.E-04	4.E-04	-	6.E-08	-
Tb-156	3.E-04	3.E-05	-	3.E-09	-
Tb-157	3.E-04	1.E-03	-	1.E-09	-
Tb-158	3.E-04	3.E-05	-	5.E-11	-
Tb-160	3.E-04	2.E-05	-	5.E-10	-
Tb-161	3.E-04	5.E-05	-	4.E-09	-
Dy-155	3.E-04	2.E-04	-	6.E-08	-
Dy-157[3/]	3.E-04	5.E-04	-	2.E-07	-
Dy-159	3.E-04	3.E-04	-	6.E-09	-
Dy-165	3.E-04	4.E-04	-	1.E-07	-
Dy-166	3.E-04	2.E-05	-	2.E-09	-
Ho-155	3.E-04	1.E-03	-	4.E-07	-
Ho-157	3.E-04	7.E-03	-	3.E-06	-
Ho-159	3.E-04	6.E-03	-	2.E-06	-
Ho-161	3.E-04	3.E-03	-	1.E-06	-

Figure III-1 (contd)

Ho-164	3.E-04	6.E-03	-	1.E-06	-
Ho-166m	3.E-04	2.E-05	-	2.E-11	-
Ho-166	3.E-04	2.E-05	-	4.E-09	-
Ho-167	3.E-04	4.E-04	-	1.E-07	-
Er-161	3.E-04	4.E-04	-	2.E-07	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Er-169	3.E-04	1.E-04	-	6.E-09	-
Er-171	3.E-04	1.E-04	-	2.E-08	-
Er-172	3.E-04	4.E-05	-	3.E-09	-
Tm-162	3.E-04	2.E-03	-	7.E-07	-
Tm-166	3.E-04	1.E-04	-	3.E-08	-
Tm-167	3.E-04	7.E-05	-	5.E-09	-
Tm-170	3.E-04	3.E-05	-	5.E-10	-
Tm-171	3.E-04	4.E-04	-	1.E-09	-
Tm-172	3.E-04	2.E-05	-	3.E-09	-
Tm-173	3.E-04	1.E-04	-	3.E-08	-
Tm-175	3.E-04	3.E-03	-	6.E-07	-
Yb-162	3.E-04	2.E-03	-	7.E-07	7.E-07
Yb-166	3.E-04	4.E-05	-	5.E-09	4.E-09
Yb-167	3.E-04	8.E-03	-	2.E-06	2.E-06
Yb-169	3.E-04	5.E-05	-	2.E-09	2.E-09
Yb-175	3.E-04	9.E-05	-	8.E-09	8.E-09
Yb-177	3.E-04	4.E-04	-	1.E-07	1.E-07
Yb-178	3.E-04	4.E-04	-	1.E-07	9.E-08
Lu-169	3.E-04	7.E-05	-	1.E-08	1.E-08
Lu-170	3.E-04	3.E-05	-	5.E-09	5.E-09
Lu-171	3.E-04	5.E-05	-	4.E-09	5.E-09
Lu-172	3.E-04	3.E-05	-	3.E-09	3.E-09
Lu-173	3.E-04	1.E-04	-	1.E-09	6.E-10
Lu-174m	3.E-04	8.E-05	-	8.E-10	5.E-10
Lu-174	3.E-04	1.E-04	-	6.E-10	4.E-10
Lu-176m	3.E-04	2.E-04	-	6.E-08	5.E-08
Lu-176	3.E-04	2.E-05	-	3.E-11	2.E-11
Lu-177m	3.E-04	2.E-05	-	3.E-10	2.E-10
Lu-177	3.E-04	7.E-05	-	5.E-09	5.E-09
Lu-178m	3.E-04	2.E-03	-	4.E-07	4.E-07

Figure III-1 (contd)

	f_1	Ingested Water DCG	Inhaled Air DCG (μCi/mL)		
Lu-178	3.E-04	1.E-03	-	3.E-07	3.E-07
Lu-179	3.E-04	2.E-04	-	4.E-08	4.E-08
Hf-170	2.E-03	7.E-05	1.E-08	1.E-08	-
Hf-172	2.E-03	3.E-05	4.E-11	1.E-10	-
Hf-173	2.E-03	1.E-04	3.E-08	3.E-08	-
Hf-175	2.E-03	8.E-05	2.E-09	3.E-09	-
Hf-177m	2.E-03	5.E-04	1.E-07	2.E-07	-
Hf-178m	2.E-03	7.E-06	6.E-12	2.E-11	-
Hf-179m	2.E-03	3.E-05	1.E-09	1.E-09	-
Hf-180m	2.E-03	2.E-04	5.E-08	6.E-08	-
Hf-181	2.E-03	3.E-05	9.E-10	1.E-09	-
Hf-182m	2.E-03	1.E-03	2.E-07	3.E-07	-
Hf-182	2.E-03	1.E-05	4.E-12	2.E-11	-
Hf-183	2.E-03	6.E-04	1.E-07	1.E-07	-
Hf-184	2.E-03	7.E-05	2.E-08	2.E-08	-
Ta-173	1.E-03	2.E-04	-	5.E-08	4.E-08
Ta-174	1.E-03	7.E-04	-	2.E-07	2.E-07
Ta-175	1.E-03	2.E-04	-	4.E-08	3.E-08
Ta-176	1.E-03	1.E-04	-	3.E-08	3.E-08
Ta-177	1.E-03	3.E-04	-	5.E-08	4.E-08
Ta-178	1.E-03	5.E-04	-	2.E-07	2.E-07
Ta-179	1.E-03	6.E-04	-	1.E-08	2.E-09
Ta-180m	1.E-03	6.E-04	-	2.E-07	1.E-07
Ta-180	1.E-03	4.E-05	-	1.E-09	6.E-11
Ta-182m	1.E-03	6.E-03	-	1.E-06	1.E-06
Ta-182	1.E-03	2.E-05	-	7.E-10	3.E-10
Ta-183	1.E-03	3.E-05	-	3.E-09	2.E-09
Ta-184	1.E-03	5.E-05	-	1.E-08	1.E-08
Ta-185	1.E-03	7.E-04	-	2.E-07	2.E-07
Ta-186	1.E-03	2.E-03	-	5.E-07	5.E-07
W-176	1.E-02	3.E-04	-	-	-
	3.E-01	4.E-04	1.E-07	-	-
W-177	1.E-02	6.E-04	-	-	-
	3.E-01	7.E-04	2.E-07	-	-
W-178	1.E-02	1.E-04	-	-	-
	3.E-01	2.E-04	5.E-08	-	-
W-179	1.E-02	2.E-02	-	-	-
	3.E-01	2.E-02	4.E-06	-	-
W-181	1.E-02	4.E-04	-	-	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
W-181	3.E-01	5.E-04	8.E-08	-	-
W-185	1.E-02	7.E-05	-	-	-
	3.E-01	1.E-04	2.E-08	-	-
W-187	1.E-02	5.E-05	-	-	-
	3.E-01	7.E-05	2.E-08	-	-
W-188	1.E-02	2.E-05	-	-	-
	3.E-01	2.E-05	3.E-09	-	-
Re-177	8.E-01	3.E-03	6.E-07	8.E-07	-
Re-178	8.E-01	3.E-03	6.E-07	7.E-07	-
Re-181	8.E-01	1.E-04	2.E-08	2.E-08	-
Re-182 (64 h)	8.E-01	4.E-05	6.E-09	5.E-09	-
Re-182 (12 h)3/	8.E-01	2.E-04	3.E-08	4.E-08	-
Re-184m	8.E-01	6.E-05	7.E-09	1.E-09	-
Re-184	8.E-01	6.E-05	8.E-09	3.E-09	-
Re-186m	8.E-01	4.E-05	5.E-09	4.E-10	-
Re-186	8.E-01	5.E-05	7.E-09	4.E-09	-
Re-187	8.E-01	2.E-02	2.E-06	2.E-07	-
Re-188m	8.E-01	2.E-03	3.E-07	3.E-07	-
Re-188	8.E-01	5.E-05	7.E-09	6.E-09	-
Re-189	8.E-01	9.E-05	1.E-08	1.E-08	-
Os-180	1.E-02	3.E-03	9.E-07	1.E-06	1.E-06
Os-181	1.E-02	4.E-04	1.E-07	1.E-07	1.E-07
Os-182	1.E-02	6.E-05	1.E-08	1.E-08	9.E-09
Os-185	1.E-02	7.E-05	1.E-09	2.E-09	2.E-09
Os-189m	1.E-02	2.E-03	5.E-07	5.E-07	4.E-07
Os-191m	1.E-02	4.E-04	7.E-08	5.E-08	4.E-08
Os-191	1.E-02	7.E-05	5.E-09	4.E-09	3.E-09
Os-193	1.E-02	4.E-05	1.E-08	7.E-09	6.E-09
Os-194	1.E-02	2.E-05	1.E-10	1.E-10	2.E-11
Ir-182	1.E-02	1.E-03	3.E-07	4.E-07	3.E-07
Ir-184	1.E-02	2.E-04	6.E-08	7.E-08	6.E-08
Ir-185	1.E-02	1.E-04	3.E-08	3.E-08	2.E-08
Ir-186	1.E-02	6.E-05	2.E-08	1.E-08	1.E-08
Ir-187	1.E-02	3.E-04	7.E-08	7.E-08	6.E-08
Ir-188	1.E-02	5.E-05	1.E-08	8.E-09	8.E-09
Ir-189	1.E-02	1.E-04	1.E-08	9.E-09	9.E-09
Ir-190m3/	1.E-02	5.E-03	5.E-07	5.E-07	5.E-07
Ir-190	1.E-02	3.E-05	2.E-09	2.E-09	2.E-09
Ir-192m	1.E-02	9.E-05	2.E-10	5.E-10	4.E-11
Ir-192	1.E-02	3.E-05	6.E-10	9.E-10	5.E-10

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Ir-194m	1.E-02	2.E-05	2.E-10	4.E-10	2.E-10
Ir-194	1.E-02	3.E-05	7.E-09	5.E-09	4.E-09
Ir-195m	1.E-02	2.E-04	6.E-08	7.E-08	5.E-08
Ir-195	1.E-02	4.E-04	1.E-07	1.E-07	1.E-07
Pt-186	1.E-02	4.E-04	9.E-08	-	-
Pt-188	1.E-02	4.E-05	4.E-09	-	-
Pt-189	1.E-02	3.E-04	7.E-08	-	-
Pt-191	1.E-02	1.E-04	2.E-08	-	-
Pt-193m	1.E-02	8.E-05	1.E-08	-	-
Pt-193	1.E-02	1.E-03	6.E-08	-	-
Pt-195m	1.E-02	6.E-05	1.E-08	-	-
Pt-197m	1.E-02	4.E-04	1.E-07	-	-
Pt-197	1.E-02	9.E-05	2.E-08	-	-
Pt-199	1.E-02	1.E-03	3.E-07	-	-
Pt-200	1.E-02	3.E-05	8.E-09	-	-
Au-193	1.E-01	2.E-04	3.E-08	4.E-08	4.E-08
Au-194	1.E-01	7.E-05	9.E-09	3.E-09	1.E-08
Au-195	1.E-01	1.E-04	1.E-08	3.E-09	1.E-09
Au-198m	1.E-01	2.E-05	3.E-09	2.E-09	2.E-09
Au-198	1.E-01	6.E-05	4.E-09	6.E-09	7.E-09
Au-199	1.E-01	8.E-05	8.E-09	8.E-09	8.E-09
Au-200m	1.E-01	3.E-05	4.E-09	5.E-09	6.E-09
Au-200	1.E-01	7.E-04	9.E-08	1.E-07	2.E-07
Au-201	1.E-01	2.E-03	3.E-07	5.E-07	5.E-07
Hg-193m (Org)	1.E+00	3.E-04	3.E-08	-	-
	4.E-01	1.E-04	-	-	-
Hg-193m	2.E-02	9.E-05	2.E-08	2.E-08	-
Hg-193m (Vapor)	-	-	2.E-08	-	-
Hg-193 (Org)	1.E+00	1.E-03	2.E-07	-	-
	4.E-01	5.E-04	-	-	-
Hg-193	2.E-02	4.E-04	1.E-07	1.E-07	-
Hg-193 (Vapor)	-	-	7.E-08	-	-
Hg-194 (Org)	1.E+00	5.E-07	7.E-11	-	-
	4.E-01	1.E-06	-	-	-
Hg-194	2.E-02	2.E-05	1.E-10	3.E-10	-
Hg-194 (Vapor)	-	-	7.E-11	-	-
Hg-195m (Org)	1.E+00	1.E-04	1.E-08	-	-
	4.E-01	8.E-05	-	-	-
Hg-195m	2.E-02	6.E-05	1.E-08	9.E-09	-
Hg-195m (Vapor)	-	-	9.E-09	-	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Hg-195 (Org)	1.E+00	1.E-03	1.E-07	-	-
	4.E-01	5.E-04	-	-	-
Hg-195	2.E-02	4.E-04	8.E-08	8.E-08	-
Hg-195 (Vapor)	-	-	7.E-08	-	-
Hg-197m (Org)	1.E+00	2.E-04	2.E-08	-	-
	4.E-01	1.E-04	-	-	-
Hg-197m	2.E-02	8.E-05	2.E-08	1.E-08	-
Hg-197m (Vapor)	-	-	1.E-08	-	-
Hg-197 (Org)	1.E+00	3.E-04	3.E-08	-	-
	4.E-01	2.E-04	-	-	-
Hg-197	2.E-02	1.E-04	3.E-08	2.E-08	-
Hg-197 (Vapor)	-	-	2.E-07	-	-
Hg-199m (Org)	1.E+00	3.E-03	4.E-07	-	-
	4.E-01	2.E-03	-	-	-
Hg-199m	2.E-02	2.E-03	4.E-07	4.E-07	-
Hg-199m (Vapor)	-	-	2.E-07	-	-
Hg-203 (Org)	1.E+00	1.E-05	2.E-09	-	-
	4.E-01	2.E-05	-	-	-
Hg-203	2.E-02	7.E-05	3.E-09	3.E-09	-
Hg-203 (Vapor)	-	-	2.E-09	-	-
Tl-194m	1.E+00	2.E-03	4.E-07	-	-
Tl-194	1.E+00	7.E-03	1.E-06	-	-
Tl-195	1.E+00	2.E-03	3.E-07	-	-
Tl-197	1.E+00	2.E-03	3.E-07	-	-
Tl-198m	1.E+00	8.E-04	1.E-07	-	-
Tl-198	1.E+00	5.E-04	7.E-08	-	-
Tl-199	1.E+00	2.E-03	2.E-07	-	-
Tl-200 3/	1.E+00	2.E-04	3.E-08	-	-
Tl-201	1.E+00	5.E-04	5.E-08	-	-
Tl-202	1.E+00	9.E-05	1.E-08	-	-
Tl-204	1.E+00	4.E-05	5.E-09	-	-
Pb-195m	2.E-01	2.E-03	5.E-07	-	-
Pb-198	2.E-01	9.E-04	2.E-07	-	-
Pb-199	2.E-01	6.E-04	2.E-07	-	-
Pb-200	2.E-01	9.E-05	1.E-08	-	-
Pb-201	2.E-01	2.E-04	5.E-08	-	-
Pb-202m	2.E-01	2.E-04	7.E-08	-	-
Pb-202	2.E-01	4.E-06	1.E-10	-	-
Pb-203	2.E-01	1.E-04	2.E-08	-	-
Pb-205	2.E-01	9.E-05	3.E-09	-	-
Pb-209	2.E-01	7.E-04	1.E-07	-	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Pb-210	2.E-01	3.E-08	9.E-13	-	-
Pb-211	2.E-01	3.E-04	1.E-09	-	-
Pb-212	2.E-01	3.E-06	8.E-11	-	-
Pb-214	2.E-01	2.E-04	2.E-09	-	-
Bi-200	5.E-02	8.E-04	2.E-07	2.E-07	-
Bi-201	5.E-02	3.E-04	7.E-08	9.E-08	-
Bi-202	5.E-02	4.E-04	1.E-07	2.E-07	-
Bi-203	5.E-02	7.E-05	2.E-08	1.E-08	-
Bi-205	5.E-02	4.E-05	6.E-09	3.E-09	-
Bi-206	5.E-02	2.E-05	3.E-09	2.E-09	-
Bi-207	5.E-02	3.E-05	4.E-09	8.E-10	-
Bi-210m	5.E-02	2.E-06	1.E-11	2.E-12	-
Bi-210	5.E-02	2.E-05	9.E-10	6.E-11	-
Bi-212	5.E-02	1.E-04	6.E-10	7.E-10	-
Bi-213	5.E-02	2.E-04	7.E-10	8.E-10	-
Bi-214	5.E-02	6.E-04	2.E-09	2.E-09	-
Po-203	1.E-01	7.E-04	2.E-07	2.E-07	-
Po-205	1.E-01	6.E-04	9.E-08	2.E-07	-
Po-207	1.E-01	2.E-04	6.E-08	7.E-08	-
Po-210	1.E-01	8.E-08	1.E-12	1.E-12	-
At-207	1.E+00	2.E-04	6.E-09	5.E-09	-
At-211	1.E+00	3.E-06	2.E-10	1.E-10	-
Rn-220	-	-4/	-4/	-4/	-4/
Rn-222	-	-5/	-5/	-5/	-5/
Fr-222	1.E+00	6.E-05	1.E-09	-	-
Fr-223	1.E+00	2.E-05	2.E-09	-	-
Ra-223	2.E-01	3.E-07	-	2.E-12	-
Ra-224	2.E-01	4.E-07	-	4.E-12	-
Ra-225	2.E-01	4.E-07	-	2.E-12	-
Ra-226	2.E-01	1.E-07	-	1.E-12	-
Ra-227	2.E-01	6.E-04	-	4.E-08	-
Ra-228	2.E-01	1.E-07	-	3.E-12	-
Ac-224	1.E-03	5.E-05	9.E-11	1.E-10	1.E-10
Ac-225	1.E-03	1.E-06	1.E-12	2.E-12	1.E-12
Ac-226	1.E-03	3.E-06	9.E-12	1.E-11	1.E-11
Ac-227	1.E-03	1.E-08	2.E-15	7.E-15	1.E-14
Ac-228	1.E-03	6.E-05	4.E-11	1.E-10	1.E-10

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Th-226	2.E-04	1.E-04	-	4.E-10	3.E-10
Th-227	2.E-04	4.E-06	-	8.E-13	7.E-13
Th-228	2.E-04	4.E-07	-	5.E-14	4.E-14
Th-229	2.E-04	4.E-08	-	6.E-15	7.E-15
Th-230	2.E-04	3.E-07	-	4.E-14	5.E-14
Th-231	2.E-04	1.E-04	-	1.E-08	2.E-08
Th-232	2.E-04	5.E-08	-	7.E-15	1.E-14
Th-234	2.E-04	1.E-05	-	5.E-10	4.E-10
Th-Natural	2.E-04	5.E-08	-	7.E-15	1.E-14
Pa-227	1.E-03	1.E-04	-	3.E-10	2.E-10
Pa-228	1.E-03	3.E-05	-	5.E-11	3.E-11
Pa-230	1.E-03	2.E-05	-	1.E-11	8.E-12
Pa-231	1.E-03	1.E-08	-	9.E-15	1.E-14
Pa-232	1.E-03	4.E-05	-	1.E-10	2.E-10
Pa-233	1.E-03	4.E-05	-	2.E-09	1.E-09
Pa-234[3/]	1.E-03	7.E-05	-	2.E-08	2.E-08
U-230	5.E-02	2.E-07	1.E-12	8.E-13	-
	2.E-03	1.E-06	-	-	6.E-13
U-231	5.E-02	1.E-04	2.E-08	1.E-08	-
	2.E-03	1.E-04	-	-	1.E-08
U-232	5.E-02	1.E-07	1.E-12	9.E-13	-
	2.E-03	2.E-06	-	-	2.E-14
U-233	5.E-02	5.E-07	4.E-12	2.E-12	-
	2.E-03	5.E-06	-	-	9.E-14
U-234	5.E-02	5.E-07	4.E-12	2.E-12	-
	2.E-03	5.E-06	-	-	9.E-14
U-235	5.E-02	6.E-07	5.E-12	2.E-12	-
	2.E-03	5.E-06	-	-	1.E-13
U-236	5.E-02	5.E-07	5.E-12	2.E-12	-
	2.E-03	6.E-06	-	-	1.E-13
U-237	5.E-02	5.E-05	6.E-09	4.E-09	-
	2.E-03	5.E-05	-	-	4.E-09
U-238	5.E-02	6.E-07	5.E-12	2.E-12	-
	2.E-03	6.E-06	-	-	1.E-13
U-239[3/]	5.E-02	2.E-03	4.E-07	4.E-07	-
	2.E-03	2.E-03	-	-	4.E-07
U-240	5.E-02	3.E-05	9.E-09	7.E-09	-
	2.E-03	3.E-05	-	-	6.E-09
U-Natural	5.E-02	6.E-07	5.E-12	2.E-12	-
	2.E-03	6.E-06	-	-	1.E-13
Np-232	1.E-03[6/]	6.E-03[7/]	-	1.E-08[8/]	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Np-233	1.E-03[6]	2.E-02[7]	-	8.E-06[8]	-
Np-234	1.E-03[6]	8.E-05[7]	-	6.E-09[8]	-
Np-235	1.E-03[6]	6.E-04[7]	-	3.E-09[8]	-
Np-236 (1.E+05 yr)	1.E-03[6]	2.E-07[7]	-	1.E-13[8]	-
Np-236 (22 h)	1.E-03[6]	1.E-04[7]	-	2.E-10[8]	-
Np-237	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
Np-238	1.E-03[6]	4.E-05[7]	-	4.E-10[8]	-
Np-239	1.E-03[6]	5.E-05[7]	-	5.E-09[8]	-
Np-240[3]	1.E-03[6]	7.E-04[7]	-	2.E-07[8]	-
Pu-234	1.E-03[6]	1.E-04[7]	-	5.E-10[8]	-
	1.E-05[6]	2.E-04[7]	-	-	4.E-10[8]
Pu-235	1.E-03[6]	1.E-02[7]	-	7.E-06[8]	-
	1.E-05[6]	2.E-02[7]	-	-	6.E-06[8]
Pu-236	1.E-03[6]	1.E-07[7]	-	8.E-14[8]	-
	1.E-05[6]	5.E-06[7]	-	-	9.E-14[8]
Pu-237	1.E-03[6]	1.E-04[7]	-	8.E-09[8]	-
	1.E-05[6]	3.E-04[7]	-	-	7.E-09[8]
Pu-238	1.E-03[6]	4.E-08[7]	-	3.E-14[8]	-
	1.E-05[6]	3.E-06[7]	-	-	4.E-14[8]
Pu-239	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
	1.E-05[6]	2.E-06[7]	-	-	4.E-14[8]
Pu-240	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
	1.E-05[6]	2.E-06[7]	-	-	4.E-14[8]
Pu-241	1.E-03[6]	2.E-06[7]	-	1.E-12[8]	-
	1.E-05[6]	1.E-04[7]	-	-	2.E-12[8]
Pu-242	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
	1.E-05[6]	2.E-06[7]	-	-	4.E-14[8]
Pu-243	1.E-03[6]	4.E-04[7]	-	8.E-08[8]	-
	1.E-05[6]	4.E-04[7]	-	-	9.E-08[8]
Pu-244	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
	1.E-05[6]	2.E-06[7]	-	-	4.E-14[8]
Pu-245	1.E-03[6]	6.E-05[7]	-	1.E-08[8]	-
	1.E-05[6]	6.E-05[7]	-	-	1.E-08[8]
Am-237	1.E-03[6]	2.E-03[7]	-	7.E-07[8]	-
Am-238	1.E-03[6]	8.E-04[7]	-	1.E-08[8]	-
Am-239	1.E-03[6]	1.E-04[7]	-	3.E-08[8]	-
Am-240	1.E-03[6]	5.E-05[7]	-	6.E-09[8]	-
Am-241	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
Am-242m	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-
Am-242	1.E-03[6]	1.E-04[7]	-	2.E-10[8]	-
Am-243	1.E-03[6]	3.E-08[7]	-	2.E-14[8]	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Am-244m	1.E-03 6/	2.E-03 7/	-	1.E-08 8/	-
Am-244	1.E-03 6/	7.E-05 7/	-	7.E-10 8/	-
Am-245	1.E-03 6/	8.E-04 7/	-	2.E-07 8/	-
Am-246m	1.E-03 6/	2.E-03 7/	-	4.E-07 8/	-
Am-246 3/	1.E-03 6/	9.E-04 7/	-	2.E-07 8/	-
Cm-238	1.E-03 6/	4.E-04 7/	-	3.E-09 8/	-
Cm-240	1.E-03 6/	2.E-06 7/	-	1.E-12 8/	-
Cm-241	1.E-03 6/	3.E-05 7/	-	7.E-11 8/	-
Cm-242	1.E-03 6/	1.E-06 7/	-	7.E-13 8/	-
Cm-243	1.E-03 6/	5.E-08 7/	-	3.E-14 8/	-
Cm-244	1.E-03 6/	6.E-08 7/	-	4.E-14 8/	-
Cm-245	1.E-03 6/	3.E-08 7/	-	2.E-14 8/	-
Cm-246	1.E-03 6/	3.E-08 7/	-	2.E-14 8/	-
Cm-247	1.E-03 6/	3.E-08 7/	-	2.E-14 8/	-
Cm-248	1.E-03 6/	8.E-09 7/	-	6.E-15 8/	-
Cm-249	1.E-03 6/	1.E-03 7/	-	5.E-08 8/	-
Bk-245	5.E-04	6.E-05	-	3.E-09	-
Bk-246	5.E-04	7.E-05	-	7.E-09	-
Bk-247	5.E-04	6.E-08	-	2.E-14	-
Bk-249	5.E-04	2.E-05	-	9.E-12	-
Bk-250	5.E-04	3.E-04	-	2.E-09	-
Cf-244	1.E-03 6/	9.E-04 7/	-	1.E-09 8/	1.E-09 8/
Cf-246	1.E-03 6/	1.E-05 7/	-	2.E-11 8/	2.E-11 8/
Cf-248	1.E-03 6/	5.E-07 7/	-	3.E-13 8/	3.E-13 8/
Cf-249	1.E-03 6/	3.E-08 7/	-	2.E-14 8/	3.E-14 8/
Cf-250	1.E-03 6/	7.E-08 7/	-	5.E-14 8/	6.E-14 8/
Cf-251	1.E-03 6/	3.E-08 7/	-	2.E-14 8/	3.E-14 8/
Cf-252	1.E-03 6/	1.E-07 7/	-	1.E-13 8/	9.E-14 8/
Cf-253	1.E-03 6/	1.E-05 7/	-	5.E-12 8/	4.E-12 8/
Cf-254	5.E-04 6/	5.E-08 7/	-	5.E-14 8/	4.E-14 8/
Es-250	5.E-04	1.E-03	-	3.E-09	-
Es-251	5.E-04	2.E-04	-	3.E-09	-
Es-253	5.E-04	6.E-06	-	4.E-12	-
Es-254m	5.E-04	9.E-06	-	3.E-11	-
Es-254	5.E-04	9.E-07	-	3.E-13	-
Fm-252	5.E-04	1.E-05	-	3.E-11	-
Fm-253	5.E-04	4.E-05	-	2.E-11	-
Fm-254	5.E-04	8.E-05	-	2.E-10	-

Figure III-1 (contd)

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Fm-255	5.E-04	1.E-05	-	5.E-11	-
Fm-257	5.E-04	2.E-06	-	6.E-13	-
Md-257	5.E-04	3.E-04	-	2.E-10	-
Md-258	5.E-04	2.E-06	-	8.E-13	-

1/ A dash indicates no values given for this data category.

2/ The inhalation DCG values allow for an additional 50% absorption through the skin, as described in ICRP Publication No. 30: "Limits for Intakes of Radionuclides by Workers." For elemental tritium, the lung dose equivalent is used as the basis for the DCG value shown.

3/ For the radionuclide shown, the DCG for external exposure from immersion in a contaminated plume (listed in Figure III-2) is more restrictive.

4/ DCGs for Rn-220 are being assessed by DOE. Until the review has been completed and new values issued, the value of 3.E-09 μCi/mL given in Figure III-3 shall be used.

5/ DCGs for Rn-222 are being assessed by DOE. Until the review has been completed and new values issued, the value of 3.E-09 μCi/mL given in Figure III-3 shall be used for Rn-222 releases from DOE facilities. In addition, the requirements of Chapter IV, Sections 4b, 6b, and 6d, shall be used when they are applicable.

6/ ICRP Publication No. 48: "The Metabolism of Plutonium and Related Elements."

7/ Based on the listed f_1 value. It is assumed that individual organ doses, except for the gastrointestinal tract, change in proportion to f_1 for all organs, including the "Remainder." Gastrointestinal doses are unchanged because very little material is absorbed in the upper portions of the tract.

8/ It is assumed that the effective dose equivalents are unchanged even though the f_1 values have changed. This is because the contribution to organ dose from inhalation is dependent mainly on transfer from lung to blood when f_1 values are small. Also the gastrointestinal tract dose would be unchanged because the fraction of activity passing through the tract is (1.0 - f_1).

Figure III-1 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Actinium/ Ac	89	Oxides, hydroxides	1.E-03	Y
		Halides, nitrates	1.E-03	W
		All others	1.E-03	D
Aluminum/ Al	13	Oxides, hydroxides, carbides, halides, nitrates, elemental form	1.E-02	W
		All others	1.E-02	D
Americium/ Am	95	All forms	1.E-03	W
Antimony/ Sb	51	Oxides, hydroxides, halides, sulphides, sulphates, nitrates	1.E-01	D
		All others	1.E-02	W
Arsenic/ As	33	All forms	5.E-01	W
Astatine/ At	85	All (as a halide)	1.E+00	W or D; dependent upon associated element
Barium/ Ba	56	All forms	1.E-01	D
Berkelium/ Bk	97	All forms	5.E-04	W
Beryllium/ Be	4	Oxides, halides, nitrates	5.E-03	Y
		All others	5.E-03	W
Bismuth/ Bi	83	All except nitrates	5.E-02	W
		Nitrates	5.E-02	D
Bromine/ Br	35	Bromides	1.E+00	W or D; dependent upon associated element

Figure III-2
Alternative Absorption Factors and Lung Retention Classes for Specific Compounds

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Cadmium/ Cd	48	Oxides, hydroxides	5.E-02	Y
		Sulphates, halides	5.E-02	W
		All others	5.E-02	D
Calcium/ Ca	20	All forms	3.E-01	W
Californium/ Cf	98	Oxides, hydroxides	1.E-03	Y
		All others	1.E-03	W
Carbon/ C	6	Oxides	1/	D
		Organic (^{11}C)	1.E-02	W
		Organic (^{14}C)	7.E-05	W
Cerium/ Ce	58	Oxides, hydroxides, fluorides	3.E-04	Y
		All others	3.E-04	W
Cesium/ Cs	55	All forms	1.E+00	D
Chlorine/ Cl	17	Chloride	1.E+00	W or D; dependent upon associated element
Chromium/ Cr	24	Oxides, hydroxides	1.E-01	Y
		Halides, nitrates	1.E-01	W
		All others	1.E-01	D
		Ingestion 2/		
		Trivalent	1.E-02	-
		Hexavalent	1.E-01	-
Cobalt/ Co	27	Oxides, hydroxides, halides, nitrates	5.E-02	Y
		All others	5.E-02	W
		Ingestion only	3.E-01	-

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Copper/ Cu	29	Oxides, hydroxides	5.E-01	Y
		Sulphites, halides, nitrates	5.E-01	W
		All others	5.E-01	D
Curium/ Cm	96	All forms	1.E-03	W
Dysprosium/ Dy	66	All forms	3.E-04	W
Einsteinium/ Es	99	All forms	5.E-04	W
Erbium/ Er	68	All forms	3.E-04	W
Europium/ Eu	63	All forms	1.E-03	W
Fermium/ Fm	100	All forms	5.E-04	W
Fluorine/ F	9	Fluoride	1.E+00	Y, W, or D; dependent upon associated element
Francium/ Fr	87	All forms	1.E+00	D
Gadolinium/ Gd	64	Oxides, hydroxides, fluorides	3.E-04	W
		All others	3.E-04	
Gallium/ Ga	31	Oxides, hydroxides, carbides, halides, nitrates,	1.E-03	W
		All others	1.E-03	D
Germanium/ Ge	32	Oxides, sulphides, halides	1.E+00	W
		All others	1.E+00	D

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Gold/ Au	79	Oxides, hydroxides	1.E-01	Y
		Halides, nitrates	1.E-01	W
		All others	1.E-01	D
Hafnium/ Hf	72	Oxides, hydroxides, halides, carbides, nitrates	2.E-03	W
		All others	2.E-03	D
Holmium/ Ho	67	All forms	3.E-04	W
Hydrogen/ H	1	Water (^3H)	1.E+00	-
Indium/ In	49	Oxides, hydroxides, halides	2.E-02	W
		All others	2.E-02	D
Iodine/ I	53	All forms	1.E+00	D
Iridium/ Ir	77	Oxides, hydroxides	1.E-02	Y
		Halides, nitrates, metallic form	1.E-02	W
		All others	1.E-02	D
Iron/ Fe	26	Oxides, hydroxides, halides	1.E-01	W
		All others	1.E-01	D
Lanthanum/ La	57	Oxides, hydroxides	1.E-03	W
		All others	1.E-03	D
Lead/ Pb	82	All forms	2.E-01	D
Lutetium/ Lu	71	Oxides, hydroxides, fluorides	3.E-04	Y
		All others	3.E-04	W

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Magnesium/ Mg	12	Oxides, hydroxides, carbides, halides, nitrates	5.E-01	W
		All others	5.E-01	D
Manganese/ Mn	25	Oxides, hydroxides, halides, nitrates	1.E-01	W
		All others	1.E-01	D
Mendelevium/ Md	101	All forms	5.E-04	W
Mercury/ Hg	80	Oxides, hydroxides, halides, nitrates, sulphites	2.E-02	W
		form		
		Organic forms	1.E+00	D
		Vapor	-	D
Molybdenum/ Mo	42	Oxides, hydroxides, MoS_2	5.E-02	Y
		All others	8.E-01	D
		Ingestion[2/]		
		MoS_2	5.E-02	-
		All others	8.E-01	-
Neodymium/ Nd	60	Oxides, hydroxides, carbides, fluorides	3.E-04	Y
		All others	3.E-04	W
Neptunium/ Np	93	All forms	1.E-03	W
Nickel/ Ni	28	Oxides, hydroxides	5.E-02	W
		All others (vapor)	-	D
Niobium/ Nb	41	Oxides, hydroxides	1.E-02	Y
		All others	1.E-02	W

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Osmium/ Os	76	Oxides, hydroxides	1.E-02	Y
		Halides, nitrates	1.E-02	W
		All others	1.E-02	D
Palladium/ Pd	46	Oxides, hydroxides	5.E-03	Y
		Nitrates	5.E-03	W
		All others	5.E-03	D
Phosphorus/ P	15	Phosphates	8.E-01	W or D; dependent upon associated element
Platinum/ Pt	78	All forms	1.E-02	D
Plutonium/ Pu	94	Oxides, hydroxides	1.E-05	Y
		Nitrates		W
		All others	1.E-04	W
		[Note: Use same values for ingestion]	1.E-03	
Polonium/ Po	84	Oxides, hydroxides, nitrates	1.E-01	W
		All others	1.E-01	D
Potassium/ K	19	All forms	1.E+00	D
[redacted] Pr	[redacted]	[redacted] carbides, fluorides	[redacted]	[redacted]
		All others	3.E-04	W
Promethium/ Pm	61	Oxides, hydroxides, carbides, fluorides	3.E-04	Y
		All others	3.E-04	W
Protactinium/ Pa	91	Oxides, hydroxides	1.E-03	Y
		All others	1.E-03	W
Radium/ Ra	88	All forms	2.E-01	W

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Rhenium/ Re	75	Oxides, hydroxides, halides, nitrates	8.E-01	W
		All others	8.E-01	D
Rhodium/ Rh	45	Oxides, hydroxides	5.E-02	Y
		Halides	5.E-02	W
		All others	5.E-02	D
Rubidium/ Rb	37	All forms	1.E+00	D
Ruthenium/ Ru	44	Oxides, hydroxides	5.E-02	Y
		Halides	5.E-02	W
		All others	5.E-02	D
Samarium/ Sm	62	All forms	3.E-04	W
Scandium/ Sc	21	All forms	1.E-04	Y
Selenium/ Se	34	Oxides, hydroxides, carbides	8.E-01	W
		All others	8.E-01	D
		Ingestion only	5.E-02	-
Silicon/ Si	14	Ceramic forms	1.E-02	Y
		Oxides, hydroxides, carbides, nitrates	1.E-02	W
		All others	1.E-02	D
Silver/ Ag	47	Oxides, hydroxides	5.E-02	Y
		Nitrates, sulphides	5.E-02	W
		All others, elemental form	5.E-02	D
Sodium/ Na	11	All forms	1.E+00	D
Strontium/ Sr	38	$SrTiO_3$	1.E-02	Y
		All others (soluble)	3.E-01	D

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Sulfur/ S	16	Sulphates, sulphides	1.E-01	W or D; dependent upon associated element
		All inorganic	8.E-01	-
		Elemental form	1.E-01	W
		Gases	1.E+00	D
Tantalum/ Ta	73	Oxides, hydroxides, halides, carbides, nitrates, nitrides	1.E-03	Y
		All others	1.E-03	W
Technetium/ Tc	43	Oxides, hydroxides, halides, nitrates	8.E-01	W
		All others	8.E-01	D
Tellurium/ Te	52	Oxides, hydroxides, nitrates	2.E-01	W
		All others	2.E-01	D
Terbium/ Tb	65	All forms	3.E-04	W
Thallium/ Tl	81	All forms	1.E+00	D
Thorium/ Th	90	Oxides, hydroxides	2.E-04	Y
		All others	2.E-04	W
Thulium/ Tm	69	All forms	3.E-04	W
Tin/ Sn	50	Oxides, hydroxides, halides, nitrates, sulphides, $Sn_3(PO_4)_4$	2.E-02	W
		All others	2.E-02	D
Titanium/ Ti	22	$SrTiO_3$	1.E-02	Y
		Oxides, hydroxides, carbides, halides, nitrates	1.E-02	W
		All others	1.E-02	D

Figure III-2 (contd)

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Tungsten/ W	74	Ingestion[2/]		
		Tungstic acid	1.E-02	-
		All others	3.E-01	-
Uranium/ U	92	UO_2, U_3O_8	2.E-03	Y
		UO_3, tetravalent compounds	5.E-02	W
		UF_6, uranyl compounds	5.E-02	D
Vanadium/ V	23	Oxides, hydroxides, carbides, halides	1.E-02	W
		All others	1.E-02	D
Ytterbium/ Yb	70	Oxides, hydroxides, fluorides	3.E-04	Y
		All others	3.E-04	W
Yttrium/ Y	39	Oxides, hydroxides	1.E-04	Y
		All others	1.E-04	W
Zinc/ Zn	30	All forms	5.E-01	Y
Zirconium/ Zr	40	Carbides	2.E-03	Y
		Oxides, hydroxides, halides, nitrates	2.E-03	W
		All others	2.E-03	D

1/ A dash indicates no data for the value shown.
2/ For ingestion, no lung retention classes are listed.

Figure III-2 (contd)

Radionuclide	Half-Life	Air Immersion DCG (μCi/mL)
C-11	20.48 min	2.E-08
N-13	9.97 min	2.E-08
N-16	7.13 s	3.E-09
O-15	122.24 s	2.E-08
F-18[1/]	109.74 min	2.E-08
Na-24[1/]	15.00 h	4.E-09
Mg-27[2/]	9.458 min	2.E-08
Al-28[2/]	2.240 min	1.E-08
Cl-38[1/]	37.21 min	1.E-08
Ar-37	35.02 d	1.E-02
Ar-39	269 yr	4.E-06[3/]
Ar-41	1.827 h	1.E-08
K-43[1/]	22.6 h	2.E-08
Ca-49[2/]	8.719 min	5.E-09
Sc-44[1/]	3.927 h	9.E-09
Sc-46m[2/]	18.72 s	2.E-07
Ti-45[1/]	3.08 h	2.E-08
Ti-51[2/]	5.752 min	5.E-08
V-52[2/]	3.75 min	1.E-08
Cr-49[1/]	42.09 min	2.E-08
Mn-52m[1/]	21.4 min	8.E-09
Mn-56[1/]	2.5785 h	1.E-08
Mn-57[2/]	1.47 min	2.E-07
Co-60m[1/]	10.47 min	4.E-06
Ni-57[1/, 4/]	36.08 h	1.E-08

Figure III-3
Derived Concentration Guides (DCGs) for Members of the Public from External Exposure During Immersion in a Contaminated Atmospheric Cloud

Radionuclide	Half-Life	Air Immersion DCG (μCi/mL)
Ni-65[1/, 5/]	2.520 h	3.E-08
Cu-61[1/]	3.408 h	2.E-08
Cu-62[2/]	9.74 min	2.E-08
Ga-66[1/]	9.40 h	7.E-09
Ga-68[1/]	68.0 min	2.E-08
Ga-72[1/]	14.1 h	7.E-09
Se-73[1/]	7.15 h	2.E-08
Br-77[1/]	57.04 h	6.E-08[6/]
Br-80[1/]	17.4 min	2.E-07
Br-82[1/]	35.30 h	7.E-09
Br-84[1/]	31.80 min	1.E-08
Br-85[2/]	172 s	2.E-07
Kr-79	35.04 h	8.E-08
Kr-81	2.1E+05 yr	2.E-06
Kr-83m	1.83 h	2.E-04
Kr-85	10.72 yr	3.E-06[3/]
Kr-85m	4.48 h	1.E-07
Kr-87	76.3 min	2.E-08
Kr-88	2.84 h	9.E-09
Kr-89	3.16 min	1.E-08
Kr-90	32.32 s	1.E-08
Rb-81[1/]	4.58 h	3.E-08
Rb-82[2/]	1.25 min	2.E-08
Rb-88[1/]	17.8 min	3.E-08
Rb-89[1/]	15.44 min	9.E-09
Rb-90[2/]	157 s	8.E-09
Rb-90m[2/]	258 s	5.E-09
Sr-85m[1/]	67.66 min	9.E-08
Sr-87m[1/]	2.805 h	6.E-08
Sr-92[1/]	2.71 h	1.E-08
Sr-93[2/]	7.3 min	8.E-09
Y-86[1/]	14.74 h	5.E-09
Y-90m[1/]	3.19 h	3.E-08[6/]
Y-91m[1/]	49.71 min	4.E-08
Nb-90[1/]	14.60 h	4.E-09

Figure III-3 (contd)

Radionuclide	Half-Life	Air Immersion DCG (μCi/mL)
Nb-94m[2/]	6.26 min	4.E-06
Nb-97[1/]	72.1 min	3.E-08
Nb-97m[1/]	60 s	3.E-08
Mo-91[2/]	15.49 min	2.E-08
Mo-101[1/]	14.61 min	1.E-08
Tc-95[1/]	20.0 h	2.E-08
Tc-96m[1/]	51.5 min	5.E-07
Tc-99m[1/]	6.02 h	1.E-07
Tc-101[1/]	14.2 min	6.E-08
Ru-105[1/]	4.44 h	2.E-08
Rh-105m[2/]	45 s	7.E-07
Rh-106[2/]	29.92 s	8.E-08
Ag-108[2/]	2.37 min	7.E-07
Ag-109m[2/]	39.6 s	4.E-06
Ag-110[2/]	24.57 s	4.E-07
Cd-111m[2/]	48.7 min	7.E-08
Cd-117[1/]	2.49 h	2.E-08
Cd-117m[1/]	3.36 h	9.E-09
In-113m[1/]	1.658 h	8.E-08
In-114[2/]	71.9 s	5.E-07
In-116m[1/]	54.15 min	8.E-09
In-117[1/]	43.8 min	3.E-08
Sb-117[1/]	2.80 h	1.E-07
Sb-126m[1/]	19.0 min	1.E-08
Sb-129[1/]	4.40 h	1.E-08
Te-133[1/]	12.45 min	2.E-08
Te-133m[1/]	55.4 min	8.E-09
Te-134[1/]	41.8 min	2.E-08
I-122[2/]	3.62 min	2.E-08
I-128[1/]	24.99 min	2.E-07
I-132[1/]	2.30 h	8.E-09
I-134[1/]	52.6 min	7.E-09
I-135[1/]	6.61 h	1.E-08[6/]
I-136[2/]	83 s	7.E-09

Figure III-3 (contd)

Radionuclide	Half-Life	Air Immersion DCG (μCi/mL)
Xe-122	20.1 h	3.E-07
Xe-123	2.14 h	3.E-08
Xe-125	16.8 h	8.E-08
Xe-127	36.406 d	7.E-08
Xe-129m	8.89 d	8.E-07
Xe-131m	11.84 d	2.E-06
Xe-133	5.245 d	5.E-07
Xe-133m	2.19 d	6.E-07
Xe-135	9.11 h	8.E-08
Xe-135m	15.36 min	5.E-08
Xe-137	3.83 min	9.E-08
Xe-138	14.13 min	2.E-08
Cs-126[2/]	1.64 min	2.E-08
Cs-129[1/]	32.06 h	8.E-08[6/]
Cs-138[1/]	32.2 min	8.E-09
Cs-139[2/]	9.40 min	5.E-08
Ba-137m[2/]	2.552 min	3.E-08
Ba-141[1/]	18.27 min	2.E-08
Ba-142[1/]	10.70 min	2.E-08
La-142[1/]	95.4 min	6.E-09
Pr-144m[2/]	7.2 min	4.E-06
Nd-149[1/]	1.73 h	5.E-08
Gd-162[2/]	9.7 min	5.E-08
Td-162[2/]	7.76 min	2.E-08
Dy-157[1/]	8.06 h	6.E-08
Re-182m[1/]	12.7 h	2.E-08
Os-190m[2/]	9.9 min	1.E-08
Ir-190m[1/]	3.2 h	5.E-07[6/]
Au-195m[2/]	30.6 s	1.E-07

Figure III-3 (contd)

Radionuclide	Half-Life	Air Immersion DCG (μCi/mL)
Tl-200 1/	26.1 h	1.E-08
Tl-207 2/	4.77 min	1.E-06 3/
Tl-208 2/	3.053 min	5.E-09
Tl-209 2/	2.20 min	9.E-09
Tl-210 2/	1.30 min	7.E-09
Pb-204m 2/	66.9 min	9.E-09
Bi-211 2/	2.13 min	4.E-07
Po-211 2/	0.516 s	2.E-06
Rn-220 7/	55.61 s	3.E-09
Rn-222 7/	3.82 d	3.E-09
Th-233 2/	22.3 min	5.E-07
Pa-234 1/	6.70 h	1.E-08
Pa-234m 2/	1.17 min	8.E-07 3/
U-239 1/	23.40 min	4.E-07 6/
Np-240 1/	65 min	2.E-08
Np-240m 2/	7.4 min	6.E-08
Am-246 1/	25.0 min	2.E-08

1/ Committed effective dose equivalent from inhalation is calculated in ICRP Publication 30, but the DCG value for external exposure to a contaminated atmospheric cloud is more restrictive than the DCG value for inhalation.

2/ Committed effective dose equivalent from inhalation is not calculated in ICRP Publication 30, but DCG value for external exposure to contaminated cloud should be more restrictive than DCG value for inhalation due to relatively short half-life of radionuclide.

3/ DCG value is determined by limit on annual dose equivalent to skin, rather than limit on annual effective dose equivalent.

Figure III-3 (contd)

4/ DCG value applies to radionuclide in vapor form only; DCG value for inhalation is more restrictive for radionuclide in inorganic form.

5/ DCG value applies to radionuclide in inorganic or vapor form.

6/ DCG value for exposure to contaminated atmospheric cloud is the same as DCG value for inhalation.

7/ The value shown for radon gas is a result of unit conversion from 3 pCi/L to 3 μCi/mL.

Figure III-3 (contd)

CHAPTER IV

RESIDUAL RADIOACTIVE MATERIAL

1. PURPOSE. This chapter presents radiological protection requirements and guidelines for cleanup of residual radioactive material and management of the resulting wastes and residues and release of property. These requirements and guidelines are applicable at the time the property is released. Property subject to these criteria includes, but is not limited to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and the Surplus Facilities Management Program (SFMP). The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactive material, and control of the radioactive wastes and residues. This chapter does not apply to uranium mill tailings or to properties covered by mandatory legal requirements.

2. IMPLEMENTATION. DOE elements shall develop plans and protocols for the implementation of this guidance. FUSRAP sites shall be identified, characterized, and designated, as such, for remedial action and certified for release. Information on applications of the guidelines and requirements presented herein, including procedures for deriving specific property guidelines for allowable levels of residual radioactive material from basic dose limits, is contained in DOE/CH 8901, "A Manual for Implementing Residual Radioactive Material Guidelines, A Supplement to the U.S. Department of Energy Guidelines for Residual Radioactive Material at FUSRAP and SFMP Sites," June 1989.

   a. Residual Radioactive Material This chapter provides guidance on radiation protection of the public and the environment from:

      (1) Residual concentrations of radionuclides in soil (for these purposes, soil is defined as unconsolidated earth material, including rubble and debris that might be present in earth material);

      (2) Concentrations of airborne radon decay products;

      (3) External gamma radiation,

      (4) Surface contamination; and

      (5) Radionuclide concentrations in air or water resultlng from or associated with any of the above.

b. Basic Dose Limit. The basic dose limit for doses resulting from exposures to residual radioactive material is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined in this Order. The basic dose limits are used for deriving guidelines for residual concentrations of radionuclides in soil. Guidelines for residual concentrations of thorium and radium in soil, concentrations of airborne radon decay products, allowable indoor external gamma radiation levels, and residual surface contamination concentrations are based on existing radiological protection standards (40 CFR Part 192; NRC Regulatory Guide 1.86 and subsequent NRC guidance on residual radioactive material). Derived guidelines or limits based on the basic dose limits for those quantities are used only when the guidelines provided in the existing standards are shown to be inappropriate.

c. Guideline. A guideline for residual radioactive material is a level of radioactive material that is acceptable for use of property without restrictions due to residual radioactive material. Guidelines for residual radioactive material presented herein are of two kinds, generic and specific. The basis for the guidelines is generally a presumed worst-case plausible-use scenario for the property.

(1) Generic guidelines, independent of the property, are taken from existing radiation protection standards. Generic guideline values are presented in this chapter.

(2) Specific property guidelines are derived from basic dose limits using specific property models and data. Procedures and data for deriving specific property guideline values are given by DOE/CH 8901.

d. Authorized Limit. An authorized limit is a level of residual radio active material that shall not be exceeded if the remedial action is to be considered completed and the property is to be released without restrictions on use due to residual radioactive material.

(1) The authorized limits for a property will include:

(a) Limits for each radionuclide or group of radionuclides, as appropriate, associated with residual radioactive material in soil or in surface contaminatlon of structures and equipment .

(b) Limits for each radionuclide or group of radionuclides, as appropriate, in air or water; and

(c) Where appropriate, a limit on external gamma radiation resulting from the residual material.

(2) Under normal circumstances expected at most properties, authorized limits for residual radioactive material are set equal to, or below guideline values. Exceptional conditions for which authorized limits~ might differ from guideline values are specified in paragraphs IV-5 and IV-7.

(3) A property may be released without restrictions if residual radioactive material does not exceed the authorized limits or approved supplemental limits, as defined in paragraph IV.7a, at the time remedial action is completed. DOE actions in regard to restrictions and controls on use of the property shall be governed by

m^2 .

(1) Hot Spots. If the average concentration in any surface or below-surface area less than or equal to 25 , exceeds the limit or guideline by a factor of (lOO/A) , [where A is the area (in square meters) of the region in which concentrations are elevated], limits for "hot-spots" shall also be developed and applied. Procedures for calculating these hot-spot limits, which depend on the extent of the elevated local concentrations, are given in DOE/CH-8901. In addition, reasonable efforts shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

(2) Generic Guidelines. The generic guidelines for residual concentrations of Ra-226, Ra228, Th-230, and Th-232 are:

(a) 5 pCi/g, averaged over the first 15 cm of soil below the surface; and

(b) 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface.

(3) Ingrowth and Mixtures. These guidelines take into account ingrowth of Ra-226 from Th-230 and of Ra-228 from Th-232, and assume secular equilibrium. If both Th-230 and Ra-226 or both Th-232 and Ra-228 are present and not in secular equilibrium, the appropriate guideline is applied as a limit for the radionuclide with the higher concentration. If other mixtures of radionuclide occur, the concentrations of individual radionuclides shall be reduced so that either the dose for the mixtures will not exceed the basic dose limit or the sum of the ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1. Explicit formulas for calculating residual concentration guidelines for mixtures are given in DOE/CH-8901.

b. Airborne Radon Decay Products. Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for release without restriction; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR Part 192) is: In any occupied or habitable building, the objective of remedial action shall be, and a reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. [A working level (WL) is any combination of short lived radon decay products in 1 L of air that will

result in the ultimate emission of 1.3 x 10^5 MeV of potential alpha energy.] In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions by DOE are not required in order to comply with this guideline when there is reason able assurance that residual radioactive material is not the source of the radon concentration.

c. External Gamma Radiation. The average level of gamma radiation inside a building or habitable structure on a site to be released without restrictions shall not exceed the background level by more than 20 μR\h and shall comply with the basic dose limit when an "appropriate-use" scenario is considered. This requirement shall not necessarily apply to structures scheduled for demolition or to buried foundations. External gamma radiation levels or open lands shall also comply with the basic limit and the ALARA process, considering appropriate-use scenarios for the area.

d. Surface Contamination. The generic surface contamination guidelines provided in Figure IV-1 are applicable to existing structures and equipment. These guidelines are generally consistent with standards of the NRC (NRC 1982) and functionally equivalent to Section 4, "Decontamination for Release for Unrestricted Use," of Regulatory Guide 1.86, but apply to nonreactor facilities. These limits apply to both interior equipment and building components that are potentially salvageable or recoverable scrap. If a building is demolished, the guidelines in paragraph IV.6a are applicable to the resulting contamination in the ground,

e. Residual Radionuclides in Air and Water. Residual concentrations of radionuclides in air and water shall be controlled to the required levels shown in paragraph II.1a and as required by other applicable Federal and/or State laws.

AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVE MATERIAL.

a.

Figure IV-1
Surface Contamination Guidelines

Radionuclides[2/]	Allowable Total Residual Surface Contamination (dpm/100 cm²)[1/] Average[3/,4/]	Maximum[4/,5/]	Removable[4/,6/]
Transuranics, I-125, I-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, Pa-231.	RESERVED	RESERVED	RESERVED
Th-Natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232.	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay product, alpha emitters.	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.[7/]	5,000	15,000	1,000

1/ As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

2/ Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

3/ Measurements of average contamination should not be averaged over an area of more than 1 m². For objects of less surface area, the average should be derived for each such object.

4/ The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

5/ The maximum contamination level applies to an area of not more than 100 cm2.

6/ The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

7/ This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

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b. Application of Authorized Limits. Remedial action shall not be considered complete until the residual radioactive material levels comply with the authorized limits, except as authorized pursuant to paragraph IV.7 for special situations where the supplemental limits and exceptions should be considered and it is demonstrated that it is not appropriate to decontaminate the area to the authorized limit or guideline value.

6. CONTROL OF RESIDUAL RADIOACTIVE MATERIAL. Residual radioactive material above the guidelines shall be managed in accordance with Chapter II and the following requirements.

a. Operational and Control Requirements. The operational and control requirements specified in the following Orders shall apply to interim storage, interim management, and long-term management.

(1) DOE 5000.3B, Occurrence Reporting and Processing of Operations Information

(2) DOE 5440.1E, National Environmental Policy Act Compliance Program

(3) DOE 5480.4, Environmental Protection, Safety, and Health Protection Standards

(4) DOE 5482.1B, Environmental, Safety, and Health Appraisal Program

(5) DOE 5483.1A, Occupational Safety and Health Program for DOE Employees at Government-Owned, Contractor-Operated Facilities

(6) DOE 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

(7) DOE 5820.2A, Radioactive Waste Management.

Vertical line denotes change.

b. Interim Storage.

(1) Control and stabilization features shall be designed to provide, to the extent reasonably achievable, an effective life of 50 years with a minimum life of at least 25 years.

(2) Controls shall be designed such that Rn-222 concentrations in the atmosphere above facility surfaces or openings in addition to background levels, will not exceed:

(a) 100 pCi/L at any given point;

(b) An annual average concentration of 30 pCi/L over the facility site; and

(c) An annual average concentration of 3 pCi/L at or above any location outside the facility site.

(d) Flux rates from the storage of radon producing wastes shall not exceed 20 pCi/sq.m-sec , as required by 40 CFR Part 61.

(3) Controls shall be designed such that concentrations of radionuclides in the groundwater and quantities of residual radioactive material will not exceed applicable Federal or State standards.

(4) Access to a property and use of onsite material contaminated by residual radioactive material should be controlled through appropriate administrative and physical controls such as those described in 40 CFR Part 192. These control features should be designed to provide, to the extent reasonable, an effective life of at least 25 years.

c. Interim Management.

(1) A property may be maintained under an interim management arrangement when the residual radioactive material exceeds guideline values if the residual radioactive material is in inaccessible locations and would be unreasonably costly to remove, provided that administrative controls are established by the responsible authority (Federal, State, or local) to protect members of the public and that such controls are approved by the appropriate Program Secretarial Officer.

(2) The administrative controls include but are not limited to periodic monitoring as appropriate; appropriate shielding; physical barriers to prevent access; and appropriate radiological safety measures during maintenance, renovation, demolition, or other activities that might disturb the residual radioactive material or cause it to migrate.

Vertical line denotes change.

(3) The owner of the property should be responsible for implementing the administrative controls and the cognizant Federal, State, or local authorities should be responsible for enforcing them.

d. Long-Term Management.

(1) Uranium, Thorium, and Their Decay Products.

(a) Control and stabilization features shall be designed to provide, to the extent reasonably achievable, an effective life of 1,000 years with a minimum life of at least 200 years.

(b) Control and stabilization features shall be designed to limit Rn-222 emanation to the atmosphere from the wastes to less than an annual average release rate of 20 pCi/m^2/s and prevent increases in the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates shall be in accordance with the requirements of 40 CFR Part 61.

(c) Before any potentially biodegradable contaminated wastes are placed in a long-term management facility, such wastes shall be properly conditioned so that the generation and escape of biogenic gases will not cause the requirement in paragraph IV.6d(1)(b) to be exceeded and that biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph IV.6d(1)(a).

(d) Ground water shall be protected in accordance with legally applicable Federal and State standards.

(e) Access to a property and use of onsite material contaminated by residual radioactive material should be controlled through appropriate administrative and physical controls such as those described in 40 CFR Part 192. These controls should be designed to be effective to the extent reasonable for at least 200 years.

(2) Other Radionuclides. Long-term management of other radionuclides shall be in accordance with Chapters II, III, and IV of DOE 5820.2A, as applicable.

7. SUPPLEMENTAL LIMITS AND EXCEPTIONS. If special specific property circumstances indicate that the guidelines or authorized limits established for a given property are not appropriate for any portion of that property, then the DOE Field Office Manager may request, through the Program Office,

to health and safety, the environment, costs, and public policy considerations. The DOE Field Office Manager shall obtain approval for specific supplemental limits or exceptions from Headquarters as specified in paragraph IV.5, and shall provide to the Headquarters Program Office those materials required by Headquarters for the justification as specified in this paragraph and in the FUSRAP and SFMP protocols and subsequent guidance documents. The DOE Field Office Manager shall also be responsible for coordination with the State and local government regarding the limits or exceptions and associated restrictions as appropriate. In the case of exceptions, the DOE Field Office Manager shall be responsible for coordinating with the State and/or local governments to ensure the adequacy of restrictions or conditions of release and that mechanisms are in place for their enforcement.

a. Supplemental Limits. Any supplemental limits shall achieve the basic dose limits set forth in Chapter II of this Order for both current and potential unrestricted uses of a property. Supplemental limits may be applied to any portion of a property if, on the basis of a specific property analysis, it is demonstrated that

(1) Certain aspects of the property were not considered in the development of the established authorized limits for that property; and

(2) As a result of these certain aspects, the established limits either do not provide adequate protection or are unnecessarily restrictive and costly.

b. Exceptions to the authorized limits defined for a property may be applied to any portion of the property when it is established that the authorized limits cannot reasonably be achieved and that restrictions on use of the property are necessary. It shall be demonstrated that the exception is justified and that the restrictions will protect members of the public within the basic dose limits of this Order and will comply with the requirements for control of residual radioactive material as set forth in paragraph IV.6.

c. Justification for Supplemental Limits and Exceptions. The need for supplemental limits and exceptions shall be documented by the DOE Field Office on a case-by-case basis using specific property data. Every reasonable effort should be made to minimize the use of supplemental limits and exceptions. Examples of specific situations that warrant DOE use of supplemental standards and exceptions are:

(1) Where remedial action would pose a clear and present risk of injury to workers or members of the public, notwithstanding reasonable measures to avoid or reduce risk.

Vertical line denotes change.

(2) Where remedial action, even after all reasonable mitigative measures have been taken, would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected properties, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

(3) Where it is determined that the scenarios or assumptions used to establish the authorized limits do not apply to the property or portion of the property identified, or where more appropriate scenarios or assumptions indicate that other limits are applicable or appropriate for protection of the public and the environment.

(4) Where the cost of remedial action for contaminated soil is unreasonably high relative to long-term benefits and where the residual material does not pose a clear present or future risk after taking necessary control measure. The likelihood that buildings will be erected or that people will spend long periods of time at such a property should be considered in evaluating this risk. Remedial action will generally not be necessary where only minor quantities of residual radioactive material are involved or where residual radioactive material occurs in an inaccessible location at which specific property factors limit its hazard and from which it is difficult or costly to remove. Examples include residual radioactive material under hard-surfaced public roads and sidewalks, around public sewer lines, or in fence-post foundations. A specific property analysis shall be provided to establish that the residual radioactive material would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in paragraph IV.3, and a statement specifying the level of residual radioactive material shall be provided to the appropriate State and/or local agencies for appropriate action, e.g., for inclusion in local land records.

(5) Where there is no feasible remedial action.

8. SOURCES.

a. Basic Dose Limits. Dosimetry model and dose limits are defined in Chapter II of this Order.

b. Generic Guidelines for Residual Radioactive Material. Residual concentrations of radium and thorium in soil are defined in 40 CFR Part 192. Airborne radon decay products are also defined in 40 CFR Part 192, as are guidelines for external gamma radiation. The surface contamination definition is adapted from NRC (1982).

c. Control of Radioactive Wastes and Residues. Interim storage is guided by this Order and DOE 5820.2A. Long-term management is guided by this Order, 40 CFR Part 192, and DOE 5820.2A.