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## **Radiation Protection**

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*This course was adapted from the United States Army Corps of Engineers (USACE), Publication No. EM 385-1-80, "Radiation Protection", which is in the public domain.*

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## CHAPTER 1

### Organization of USACE Radiation Protection Program

1-1. Purpose. This guidance manual prescribes the requirements of the Radiation Protection Program of the U.S. Army Corps of Engineers contained in Engineer Regulation (ER) 385-1-80, Ionizing Radiation Protection, and Engineer Manual (EM) 385-1-1, Safety and Health Requirements Manual. It is to be used when activities utilize or handle radioactive material (which includes radioactive wastes) or a radiation generating device. Radiation generating devices include X-ray equipment, accelerators, lasers, radio-frequency and electro-magnetic field generators. Authoritative guidance and regulations are contained in 10 CFR (Energy) and the (NRC) NUREGS/Regulatory Guides, 29 CFR (Labor) in general and 29 CFR 1910 and 1926 (OSHA) regulations specifically, and 40 CFR (Protection of the Environment). This manual is intended to assist USACE Commands in integrating essential requirements contained in Federal, DOD, DA and USACE radiation protection regulations to ensure that the safety and health requirements of all agencies are met.

1-2. Applicability. This manual is applicable to U.S. Army Corps of Engineers (USACE) personnel and visitors to a worksite under the jurisdiction of USACE where radioactive material or a radiation generating device may be present. It shall be used in conjunction with ER 385-1-80 and EM 385-1-1. Contractor requirements concerning ionizing and non-ionizing radiation protection issues are contained in EM 385-1-1.

1-3. Distribution Statement. Approved for public release; distribution is unlimited.

1-4. References. Appendix A contains a list of references used in this manual.

1-5. Policy.

a. USACE will work to ensure that all personnel radiation exposure is kept as low as is reasonably achievable (ALARA) taking technological, social, and economic factors into account. Radiation exposure to USACE personnel, visitors and contractors, as well as to the general public, will be controlled so that exposures are held below regulatory limits.

b. Personnel involved with ionizing radiation work of any kind will be knowledgeable of the programs, policies, and procedures contained in ER 385-1-80 and this manual. Personnel working with non-ionizing radiation should be knowledgeable of the specific information concerning these topics presented in this manual. They should demonstrate responsibility and accountability through an informed, disciplined, and cautious attitude toward radiation and radioactivity.

c. Continuing improvement in radiation (ionizing and non-ionizing) protection is

essential to USACE operations involving radiation. Personnel working with radiation are expected to look for ways to improve radiation protection and make USACE projects more efficient.

1-6. Management Commitment, Involvement, and Leadership. Superior, consistent performance is achieved when qualified personnel use approved procedures and when management actively monitors the work place and assesses ongoing activities. All levels of management must emphasize the need for high standards of radiation safety through direct communication, clear instruction, and frequent inspections of the work area.

1-7. Scope.

a. This manual fully describes policies and procedures for the safe use of radioactive material and radiation generating devices at all USACE sites. It should be used to evaluate the acceptability of health and safety practices by USACE personnel and contractors on USACE controlled sites.

b. The manual is intended to be consistent with all Federal (NRC, OSHA, EPA, DOE, and DOT), DA, USACE, State, and local statutes and regulations (that is, “applicable regulations”), and integrate the various regulations into one coherent publication for USACE operations. It will be revised whenever necessary to achieve consistency with statutes and regulations.

c. For all contracts and activities that require Federal, State, or local licensure or permitting, such licenses or permits shall be secured, and all license or permit conditions shall be adhered to. If the stated license or permit conditions vary from applicable sections of this manual, such license or permit conditions prevail. Contractors will be required to secure proper licensure or permitting (for activities that require it) within specified time frames and before the date that they are scheduled to begin the work. All USACE Commands and contractors using Army radioactive materials will meet requirements of Nuclear Regulatory Commission (NRC) licenses and Army Radiation Authorizations (ARAs) issued to USACE and the U.S. Army Materiel Command (which possesses NRC licenses for depleted uranium ammunition items at various installations) and of applicable Army technical publications.

d. Alternatives to procedures addressed in this manual may be acceptable provided the alternatives achieve the same, or higher, level of radiation protection. Alternative procedures must be approved by the Radiation Safety Officer, Laser Safety Officer or Radio Frequency Safety Officer, as appropriate, and for specific conditions, higher level authorities prior to implementation.

1-8. Overview of this Manual. This manual is designed to address all health and safety aspects of work with radiation within USACE. Most personnel within USACE will not need the entire manual but will need to select the chapters and sections applicable



to their work requirements. Some generic classifications of radiation work are listed in Table 1-1 with reference to the applicable chapters of this manual. It is recommended that all personnel working with radioactive material and radiation generating devices read Chapters 1, 2 and 3 of this manual. Depending on the type of work being performed, portions of other chapters may be applicable.

Table 1-1. Personnel Positions in Relation to Applicable Chapters

Applicable Section of EM 385-1-80	Personnel Positions						
	AUA	AU	RSO	LSO	RFSO	Supervisor Originator Reviewer CQA	SOHO RSC RSSO HPs
Chapter 1-Radiation Protection Program	X	X	X	X	X	X	X
Chapter 2- Personnel Responsibilities	X	X	X	X	X	X	X
Chapter 3- Introduction to Radioactive Material Ion to Radiation	X	X	X			X	X
Chapter 4- Licensing and Permitting		X	X			X	X
Chapter 5- Dose Limits and ALARA	X	X	X			X	X
Chapter 6- Working with Radiation	X	X	X			X	X
Chapter 7- Personnel Monitoring			X			X	X
Chapter 8- Transportation of Radioactive Material			X			X	X
Chapter 9- Waste Management			X			X	X
Chapter 10- Lasers				X		X	X
Chapter 11- Radio Frequency and EMF			X		X	X	X

AU Authorized User  
 AUA Authorized User Assistant  
 RSO Radiation Safety Officer  
 LSO Laser Safety Officer  
 RFSO Radio Frequency Safety Officer  
 Supervisor Supervisor of activities involving radioactive material  
 Originator Originator of projects/plans/procedures using radioactive material  
 Reviewer Reviewer of projects/plans/procedures using radioactive material  
 CQA USACE Construction Quality Assurance personnel  
 SOHO Safety and Occupational Health Office  
 RSC Radiation Safety Committee  
 RSSO Radiation Safety Staff Officer  
 HPs Health Physics personnel

## CHAPTER 2

### USACE Personnel Responsibilities and Qualifications

2-1. The Chief, Safety and Occupational Health Office (CESO), HQUSACE. The Chief, Safety and Occupational Health Office, HQUSACE, is responsible for program management and oversight for licensing, accountability, possession, use, storage, transfer and disposal of all radioactive material and radiation generating devices within USACE. This responsibility shall be discharged by:

- a. Appointing, in writing, and maintaining on staff a qualified Radiation Safety Staff Officer (RSSO).
- b. Assuring USACE Direct Reporting Unit implementation of Department of Army and USACE radiation protection policy.
- c. Ensuring that each USACE Command possessing an NRC radioactive material license or ARA is audited at least triennially for compliance with the USACE Radiation Protection Program.

2-2. Radiation Safety Staff Officer (RSSO).

a. The RSSO is the senior health physicist at the Environmental and Munitions Center of Expertise. The RSSO will have the following necessary training, experience, and education:

(1) meet the qualification and classification standards for the Office of Personnel Management (OPM) job series for a GS-1306, Health Physicist; or GS-690, Industrial Hygienist; with three years of experience in the occupational health/radiation protection field.

(2) formal training covering:

(a) the physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(b) the biological effects of radiation including effects to an embryo fetus;

(c) the instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation;

(d) radiation safety techniques and procedures. This training shall include the use of time, distance, shielding, engineering controls, and personnel protective equipment (PPE) to reduce exposure to radiation; and

(e) employees rights and responsibilities.

(3) practical, hands-on experience using radiation instrumentation, procedures, and theory.

(4) knowledge of the USACE Radiation Protection Program, the record keeping requirements for work with radioactive material and radiation generating devices, and applicable NRC, EPA, DOE, DOT, OSHA, and DA regulations pertaining to radioactive material and radiation generating devices.

b. Duties of the RSSO are as follows:

(1) Serve as a primary focal point for coordination with other Federal agencies, Department of Defense and DA officials concerning radiation safety issues and providing radiation safety consultation in coordination with the EM CX, to USACE Divisions, Districts, Labs, and Centers.

(2) Provide coordination, administration and technical review of all USACE applications, renewals, amendments and terminations of all NRC licenses and ARAs for the possession, use, transportation, transfer or disposal of radioactive material and radiation generating devices, and maintaining liaison with the NRC.

(3) Provide recordkeeping for all paperwork and correspondence regarding applications, renewals, amendments and terminations of authorization for the possession, use, transportation, transfer or disposal of licensed and or permitted radioactive material and radiation generating devices.

(4) Provide (may be through a designee) Radiation Protection Audits to all locations possessing an NRC license or ARA for radioactive material or radiation generating devices, at least on a triennial basis.

2-3. USACE Commanders. The Commander of any USACE District, Lab or Center shall:

a. Ensure that a Radiation Safety Committee (RSC) is formed when the Command possesses an NRC license with a condition stating that the licensee shall have an RSC in the absence of a license requirement, or if the Commander considers an RSC necessary. The RSC will consist of personnel and duties described in paragraph 2-11.

b. Designate, in writing, a qualified person to serve as USACE Command Radiation Safety Officer (RSO) when any of the following is true:

- (1) an NRC License, Army Reactor Permit, ARA or applicable technical publication requires it,
- (2) radioactive materials are possessed by the Command,
- (3) personnel are required to wear dosimetry, and/or
- (4) personnel are required to participate in a radiological bioassay program.

c. Fund, maintain and support the RSO and the Radiation Protection Program. The RSO shall meet the qualifications and provide the services described in paragraph 2-4.

d. Fund, maintain and support the Laser Safety Officer (LSO) and the Laser Safety Program when a USACE Command operates, maintains or services a non-type-classified Class IIIb or Class IV laser system as defined in section 1.3, ANSI Z136.1. The RSO may be designated as the LSO. The LSO shall meet the qualifications and provide the services described in paragraph 2-5.

#### 2-4. Radiation Safety Officer (RSO).

a. The RSO (also known as a Radiation Protection Officer (RPO) in other documents) is a person designated by the USACE Command and tasked with the supervision of the USACE Radiation Protection Program for that command. The RSO shall have direct access to the Commander for radiation protection purposes. The RSO ensures compliance with current legal requirements (AR's, ER 385-1-80, EM 385-1-1, etc.) for radiation protection and with this manual. The RSO may limit or cease operations within their Command where there is an imminent and legitimate radiation safety issue.

b. The RSO shall be responsible for:

(1) Establishing written policies and procedures to assure compliance with applicable Federal, DoD, and Army radiation protection regulations and directives. These documents will include emergency response plans as necessary and procedures for investigating and reporting radiation accidents, incidents, and overexposures.

(2) Assuring that all personnel occupationally exposed to radiation receive appropriate radiation protection training commensurate with potential hazards from radiation sources they may encounter.

(3) Maintaining an inventory of radiation sources as higher headquarters directs and IAW with requirements of NRC licenses, Army reactor permits, ARAs, and technical publications.

(4) Approving and filing records noting all Authorized Users, Authorized Users' Assistants and site supervisors working with radioactive materials or radiation generating devices within the Command.

(5) Providing or securing an acceptable source for all required initial and annual refresher training for all individuals within the Command.

c. The RSO will review the USACE Radiation Protection Program for their Command annually for content and implementation. The RSO will assure that the quality and timeliness of the program meet the radiation safety standards outlined in this manual. The RSO will review work with radiation within the Command. The RSO will write and/or review Standing Operating Procedures to ensure the safety, timeliness, and compatibility with existing radiation regulations.

d. The RSO shall be trained to a level commensurate with the duties and responsibilities of the Radiation Protection Program for which they are responsible and in accordance with applicable NRC regulations and license conditions, ARAs, and other program documents. The RSO shall be technically qualified, meeting the experience, training, and education requirements listed below:

(1) A working knowledge of applicable NRC, EPA, DOE, DOT, OSHA and U.S. Army regulations pertaining to radioactive material, radiation generating devices, radioactive and mixed waste used within their Command.

(2) Formal training covering:

(a) The physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(b) The biological effects of radiation and effects to an embryo fetus;

(c) The instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(d) Radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

(3) Practical, hands-on experience using radiation instrumentation, procedures, and theory.

(4) A working knowledge of the Army Radiation Protection Program and the USACE Radiation Protection Program, and the record keeping requirements for work with radioactive material and radiation generating devices used within their Command.

e. Refresher training should occur annually and retraining should occur after a significant regulatory change or every five years.

f. An individual with any responsibility for preparing radioactive material for shipment must complete training required by 49 CFR 173.1(b).

#### 2-5. Laser Safety Officer (LSO).

a. The LSO is a person designated by the USACE Command tasked with the supervision of the Laser Sections of the USACE Radiation Protection Program for that command. The LSO ensures compliance with current directives for laser safety (EM 385-1-1, TB MED 524, ANSI Z136.1, etc.) and with this manual.

b. The LSO shall be trained to a level commensurate with the duties and responsibilities of the radiation program for which they are responsible and in accordance with applicable regulations. The LSO shall complete a formal course of instruction addressing such topics as laser fundamentals, terminology, biological effects, hazard analysis, protective and control measures. Refresher training and retraining should occur as required.

c. The LSO will review the USACE Laser Safety Program for their Command annually for content and implementation. The LSO will assure that the quality and timeliness of the program meet the laser safety standards outlined in this manual. The LSO will write and review Standing Operating Procedures that describe the execution of the Laser Safety Program. The LSO will restrict the use of lasers to individuals that are technically qualified and meet the experience, training, and education requirements listed below:

(1) a working knowledge of applicable regulations pertaining to lasers used within their Command,

(2) practical, hands-on experience using lasers, laser procedures, and laser theory, and

(3) a working knowledge of the Army Radiation Protection Program and the USACE Radiation Protection Program, and the record keeping requirements for work with lasers within their Command.

2-6. Qualified Health Physics Personnel. A qualified Health Physicist (HP) is responsible for assisting the RSO, LSO, and/or RFSO with their USACE Command Radiation Protection Program, and reviewing Scopes of Work, Work Plans, and/or Site Safety and Health Plans for all work involving radiation. Qualified HPs are personnel:

- a. Meeting the Office of Personnel Management Standards for the HP Series, GS-1306, and having three years experience in work with radiation; or
- b. Certified as a Health Physicist by the American Board of Health Physics, or certified by the American Board of Industrial Hygiene (Certified Industrial Hygienist) and one year experience working with radiation; or
- c. Identified as being a qualified HP by the Director of Army Radiation Protection, Army Safety Office, or the Army Surgeon General, and having three years experience in work with radiation.
- d. USACE HPs are all members of the USACE Radiation Safety Support Team.

2-7. Authorized Users (AUs). AUs are individuals who, by their training and experience, are allowed to work, unsupervised, with radioactive material or radiation generating devices. AUs may also directly supervise Authorized Users Assistants working with radioactive material. All AUs must be approved by the facility RSC, if one exists. If the facility does not have an RSC, the AUs must be approved by the RSO. All AUs must meet the following training and experience requirements:

- a. A working knowledge of applicable regulations and guidance pertaining to radioactive material, radiation generating devices, and radioactive and mixed waste with which they may be working;
- b. Unless different requirements are stated in the license, authorization or permit conditions, formal training covering:
  - (1) the physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;
  - (2) the biological effects of radiation and effects to an embryo fetus;
  - (3) the instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and
  - (4) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.
- c. Practical, hands-on experience using radiation instrumentation and procedures. The level of training will be commensurate with the hazard presented by the radioactive material or radiation generating device; and

d. A working knowledge of the USACE and his or her Command Radiation Protection Program, and the record keeping requirements for the radioactive material and radiation generating devices used in their work.

e. instruction as to their responsibilities under the Command NRC license, or Army Radiation Authorization (ARA). This includes:

(1) the employer's duty to provide safe working conditions;

(2) a report of all radiation exposure to the individual;

(3) the individual's responsibility to adhere to the NRC's regulations and the Command's radioactive material license, or ARA; and

(4) the individual's responsibility to report any violation or other occurrence to the RSO.

f. Authorized users of portable gauges must complete eight hours of training in the safety and use of the gauge from the manufacturer or similar provider.

2-8. Authorized Users' Assistants (AUAs). AUAs are individuals allowed to work with radioactive material only under the supervision of an AU (that is, in the physical presence of the AU) and have the training and experience described below:

a. Formal instruction in the following:

(1) the health effects, including effects to an embryo fetus, associated with exposure to the radioactive material or radiation they work with;

(2) ways to minimize exposure;

(3) the purpose and use of protective equipment used in their work; and

(4) the applicable regulations to their work.

b. Practical, hands-on experience using radiation instrumentation and procedures.

c. Instruction as to their responsibilities under the USACE Command NRC license, or ARA. This includes:

(1) the employer's duty to provide safe working conditions;

(2) a report of all radiation exposure to the individual;



(3) the individual's responsibility to adhere to the NRC's regulations and the Command's radioactive material license, or ARA; and

(4) the individual's responsibility to report any violation or other occurrence to the RSO.

#### 2-9. Site Supervisors/Construction Quality Assurance Personnel.

a. Individuals working as site supervisors or construction quality assurance representatives on projects involving radioactive material or radiation generating devices must be knowledgeable of: the principles of radiation protection; applicable regulations pertaining to radioactive material and radiation generating devices, and the application of these principles and regulations to worker and public health and safety at project sites.

b. Individuals who supervise work or act as construction quality assurance representatives at sites involving radioactive material or radiation generating devices should have radiation safety training covering the following:

(1) physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(2) biological effects of radiation and effects to an embryo fetus;

(3) instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(4) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

#### 2-10. Project/Plan/Procedure Originators and Reviewers.

a. Individuals who originate or review projects, plans, or procedures involving radioactive material or radiation generating devices must be knowledgeable of the principles of radiation protection, the applicable regulations pertaining to radioactive material and radiation generating devices, and the application of these principles and regulations to worker and public health and safety.

b. Originators and reviewers of plans, projects or procedures for work at sites using radioactive material or radiation generating devices should have radiation safety training covering the following:

(1) physics of radiation, radiation's interaction with matter, and the mathematics necessary to understand the above subjects;

(2) biological effects of radiation;

(3) instrumentation necessary to detect, monitor, and survey radiation, and the use of such instrumentation; and

(4) radiation safety techniques and procedures. This training will include the use of time, distance, shielding, engineering controls, and PPE to reduce exposure to radiation.

#### 2-11. Radiation Safety Committee (RSC)

a. Each Command possessing an NRC license and/or an ARA with a condition stating that the licensee or ARA shall have an RSC, or where the Commander deems necessary, shall form an RSC. At a minimum, the RSC will consist of:

(1) the Commanding Officer (CO) or deputy;

(2) the RSO, who will act as recorder for all meetings;

(3) the Chief, Safety and Occupational Health Office; and

(4) A representative Authorized User from each group using radioactive material or radiation generating devices in the Command.

b. The RSC is accountable to its USACE Commander. The CO or his/her deputy chairs the RSC. The RSC will meet at least once each six-month period and at the call of the chair. The RSC will continually evaluate radiological work activities, and make recommendations to the RSO and management. In addition to its responsibilities established in the Army Radiation Protection Program, the RSC responsibilities include:

(1) annual review of USACE Command personnel exposure records;

(2) establishing criteria for determining the appropriate level of review and authorization for work involving radiation exposure; and,

(3) evaluating health and safety aspects of the construction and design of facilities and systems and planned major modifications or work activities involving radioactive material or radiation generating devices.

2-12. Additional Training Special Applications. Additional training may be required for work involving special applications (for example, plutonium, fissile uranium, tritium, and accelerator facilities). Personnel working with special applications should consult with the EM CX for additional training requirements.

2-13. All Personnel Including Visitors at a Radiation Site.

a. Regulations require that all individuals who are likely to receive 100 mrem above background in one year shall be kept informed of the presence of radioactive material or radiation in the area and shall be instructed annually in the following:

- (1) the health effects associated with exposure to the radioactive material or radiation;
- (2) ways to minimize exposure;
- (3) the purpose and use of protective equipment and survey instruments used in the area;
- (4) the regulations applicable to the area.

b. The extent of instruction shall be commensurate with the extent of the hazard in the area.

## CHAPTER 3

### Introduction to Radiation

#### 3-1. Atomic Structure.

a. The atom, which has been referred to as the "fundamental building block of matter," is itself composed of three primary particles: the proton, the neutron, and the electron. Protons and neutrons are relatively massive compared to electrons and occupy the dense core of the atom known as the nucleus. Protons are positively charged while neutrons are neutral. The negatively charged electrons are found in a cloud surrounding the nucleus.

b. The number of protons within the nucleus defines the atomic number, designated by the symbol  $Z$ . In an electrically neutral atom (that is, one with equal numbers of protons and electrons),  $Z$  also indicates the number of electrons within the atom. The number of protons plus neutrons in the nucleus is termed the atomic mass, symbol  $A$ .

c. The atomic number of an atom designates its specific elemental identity. For example, an atom with a  $Z=1$  is hydrogen, an atom with  $Z=2$  is helium, and  $Z=3$  identifies an atom of lithium. Atoms characterized by a particular atomic number and atomic mass are called nuclides. A specific nuclide is represented by its chemical symbol with the atomic mass in a superscript (for example,  $^3\text{H}$ ,  $^{14}\text{C}$ ,  $^{238}\text{U}$ ) or by spelling out the chemical symbol and using a dash to indicate the atomic mass (for example radium-222, uranium-238). Nuclides with the same number of protons (that is, same  $Z$ ) but different number of neutrons (that is, different  $A$ ) are called isotopes. Isotopes of a particular element have nearly identical chemical properties, but may have vastly different radiological properties.

#### 3-2. Radioactive Decay.

a. Depending upon the ratio of neutrons to protons within its nucleus, an isotope of a particular element may be stable or unstable. Over time, the nuclei of unstable isotopes spontaneously disintegrate or transform in a process known as radioactive decay or radioactivity. As part of this process, various types of ionizing radiation may be emitted from the nucleus. Nuclides which undergo radioactive decay are called radionuclides. This is a general term as opposed to the term radioisotope which is used to describe an isotopic relationship. For example,  $^3\text{H}$ ,  $^{14}\text{C}$ , and  $^{125}\text{I}$  are radionuclides. Tritium ( $^3\text{H}$ ), on the other hand, is a radioisotope of hydrogen.

b. Many radionuclides such as radium-226, potassium-40, thorium-232, and uranium-238 occur naturally in the environment while others such as phosphorus-32 or sodium-22 are primarily produced in nuclear reactors or particle accelerators. Any material which contains measurable amounts of one or more radionuclides is referred to as a radioactive material. As any handful of soil or plant material will contain some

measurable amount of radionuclides, we must distinguish between background radioactive materials and manmade or enhanced concentrations of radioactive materials.

c. Uranium, thorium and their progeny, including radium and radon are Naturally Occurring Radioactive Materials (NORM). Along with an isotope of potassium (K-40) they make up the majority of NORM materials and are found in most soil and water, and are even found in significant quantities within the human body.

d. Another group of radionuclides are referred to as transuranics. These are merely elements with Z numbers greater than that of uranium (92). All transuranics are radioactive. Transuranics are typically produced in spent fuel reprocessing facilities and nuclear weapons detonations.

### 3-3. Activity.

a. The quantity which expresses the degree of radioactivity or radiation producing potential of a given amount of radioactive material is activity. The activity may be considered the rate at which a number of atoms of a material disintegrate, or transform from one isotope to another which is accompanied by the emission of radiation. The most commonly used unit of activity is the curie (Ci) which was originally defined as that amount of any radioactive material which disintegrates at the same rate as one gram of pure radium. That is,  $3.7 \times 10^{10}$  disintegrations per second (dps). A millicurie (mCi) =  $3.7 \times 10^7$  dps. A microcurie ( $\mu$ Ci) =  $3.7 \times 10^4$  dps. A picocurie (pCi) =  $3.7 \times 10^{-2}$  dps.

b. The Systeme Internationale (SI) unit of activity is the Becquerel (Bq) which equals 1 dps. Systeme Internationale units, such as meters and grams, are in use throughout the rest of the world. Only the United States still uses units of curies for activity.

c. The activity of a given amount of radioactive material is not directly related to the mass of the material. For example, two one-curie sources containing cesium-137 might have very different masses, depending upon the relative proportion of non-radioactive atoms present in each source. For example, 1 curie of pure cesium-137 would weigh 87 grams, and 50 billion kilograms (100 million tons) of seawater would contain about 1 curie of Cs-137 from fallout.

3-4. Half-life. When half of the radioactive atoms in a given quantity of radioactive material have decayed, the activity is also decreased by half. The time required for the activity of a quantity of a particular radionuclide to decrease to half its original value is called the half-life ( $T_{1/2}$ ) for the radionuclide.

3-5. Types of Ionizing Radiation. Ionizing radiation may be electromagnetic or may consist of high speed subatomic particles of various masses and charges.

a. Alpha Particles. Certain radionuclides of high atomic mass (for example, Ra-226, U-238, Pu-239) decay by the emission of alpha particles. These are tightly bound units of

two neutrons and two protons each (a helium nucleus). Emission of an alpha particle results in a decrease of two units of atomic number (Z) and four units of atomic mass (A). Alpha particles are emitted with discrete energies characteristic of the particular transformation from which they originate.

b. Beta Particles. A nucleus with a slightly unstable ratio of neutrons to protons may decay by changing a neutron into a proton, or a proton into a neutron through the emission of either a high speed electron or positron called a beta particle. This results in a net change of one unit of atomic number (Z), up one for a beta minus and down one for a beta plus. The beta particles emitted by a specific radionuclide range in energy from near zero to up to a maximum value characteristic of the particular transformation.

c. Gamma-rays.

(1) A nucleus which has disintegrated is left in an excited state with more energy than it can contain. This excited nucleus may emit one or more photons (that is, particles of electromagnetic radiation) of discrete energies to rid itself of this energy. The emission of these gamma-rays does not alter the number of protons or neutrons in the nucleus but instead has the effect of moving the nucleus from a higher to a lower energy state. Gamma-ray emission frequently follows beta decay, alpha decay, and other nuclear decay processes.

(2) X-rays and gamma-rays are electromagnetic radiation, as is visible light. The frequencies of X- and gamma rays are much higher than that of visible light and so each carries much more energy. Gamma- and X-rays cannot be completely shielded. They can be attenuated by shielding but not stopped completely. A gamma emitting nuclide may yield multiple gamma- and X-rays, each with its own discrete energy. It is possible to identify a gamma emitting nuclide by its spectrum of emitted energies of photons.

d. X-rays. X-rays are also part of the electromagnetic spectrum and are indistinguishable from gamma-rays. The only difference is their source (that is, orbital electrons rather than the nucleus). X- Rays are emitted with discrete energies by electrons as they shift orbits and lose energy following certain types of nuclear excitement or decay processes.

e. Neutrons. Neutrons are uncharged particles released during fission of heavy atoms (uranium) or released from some non-radioactive material after bombardment by alpha particles (americium-beryllium [Am-Be] sources). Because neutrons are uncharged particles, they travel further in matter. When neutrons are sufficiently slowed down in matter (thermalized) they are absorbed by matter with an accompanying burst of gamma radiation. Other transformations can occur once an atom absorbs a neutron and the nucleus can become unstable. The nature of production of the neutron determines whether it is emitted in a spectrum (as in fission) or at a discrete energy (as from Am-Be sources).

### 3-6. Characteristics of Different Types of Ionizing Radiation.

a. Alpha particles have a high specific ionization and a relatively short range. Alpha particles are massive and carry a double positive charge. This combination allows alpha particles to carry a large amount of energy but to easily transfer that energy and be stopped. In air, alpha particles travel only a few centimeters, while in tissue, only fractions of a millimeter. For example, an alpha particle cannot penetrate the dead cell layer of human skin.

b. Beta particles have a much lower specific ionization than alpha particles and a considerably longer range. The relatively energetic betas from P-32 have a range of 6 meters in air or 8 millimeters in tissue. The low-energy betas from H-3, on the other hand, are stopped by only 6 millimeters of air or 5 micrometers of tissue.

c. Gamma- and X-rays are referred to as indirectly ionizing radiation since, having no charge, they do not directly apply impulses to orbital electrons as do alpha and beta particles. A gamma- ray or X-ray instead proceeds through matter until it undergoes a chance interaction with a particle. If the particle is an electron, it may receive enough energy to be ionized whereupon it causes further ionization by direct interactions with other electrons. The net result is that indirectly ionizing particles liberate directly ionizing particles deep inside a medium, much deeper than the directly ionizing particles could reach from the outside. Because gamma rays and X-rays undergo only chance encounters with matter, they do not have a finite range. In other words, a given gamma ray has a definite probability of passing through any medium of any depth.

d. Neutrons are also indirectly ionizing. When striking massive particles such as the nuclei of atoms, the neutron undergoes elastic scattering losing very little energy to the target nucleus. But when a neutron strikes a hydrogen nuclei (a single proton, about the same mass as a neutron) the energy is shared nearly equally between the neutron and the proton resulting in a loss of about half of the neutron's energy before the interaction. The proton now is a charged, directly ionizing particle moving through matter until all of its energy is transferred to the matter.

3-7. Human Health Effects. The effects of ionizing radiation described at the level of the human organism can be divided broadly into two categories: stochastic (effects that occur by chance) or deterministic (non-stochastic) effects (characterized by a threshold dose below which effects do not occur).

a. Stochastic Effects. Stochastic effects are those that occur by chance. Stochastic effects caused by ionizing radiation consist primarily of genetic effects and cancer. As the dose to an individual increases, the probability that cancer or a genetic effect will occur also increases. However, at no time, even for high doses, is it certain that cancer or genetic damage will result. Similarly, for stochastic effects, there is no threshold dose below which it is relatively certain that an adverse effect cannot occur. In addition, because stochastic effects can occur in unexposed individuals, one can never



be certain that the occurrence of cancer or genetic damage in an exposed individual is due to radiation.

b. Deterministic (Non-Stochastic) Effects.

(1) Unlike stochastic effects, deterministic effects are characterized by a threshold dose below which they do not occur. In addition, the magnitude of the effect is directly proportional to the size of the dose. Furthermore, for deterministic effects, there is a clear causal relationship between radiation exposure and the effect. Examples of deterministic effects include sterility, erythema (skin reddening), and cataract formation. Each of these effects differs from the other in both its threshold dose and in the time over which this dose must be received to cause the effect (that is acute vs. chronic exposure).

(2) The range of deterministic effects resulting from an acute exposure to radiation is collectively termed "radiation syndrome." This syndrome may be subdivided as follows:

(a) Hemopoietic syndrome - characterized by depression or destruction of bone marrow activity with resultant anemia and susceptibility to infection (whole body dose of about 200 rads);

(b) Gastrointestinal syndrome - characterized by destruction of the intestinal epithelium with resultant nausea, vomiting, and diarrhea (whole body dose of about 1000 rads); and

(c) Central nervous system syndrome - direct damage to nervous system with loss of consciousness within minutes (whole body doses in excess of 2000 rads).

3-8. Determinants of Dose. The effect of ionizing radiation upon humans or other organisms is directly dependent upon the size of the dose received and the rate at which the dose is received (for example, 100 mrem in an hour versus 100 mrem in a year). The dose, in turn, is dependent upon a number of factors including the strength of the source, the distance from the source to the affected tissue, and the time over which the tissue is irradiated. The manner in which these factors operate to determine the dose from a given exposure differs significantly for exposures which are "external" (that is, resulting from a radiation source located outside the body) and those which are "internal" (that is, resulting from a radiation source located within the body).

a. External Exposures.

(1) Exposure to sources of radiation located outside the body are of concern primarily for sources emitting gamma- rays, X-rays, or high energy beta particles. External exposures from radioactive sources which emit alpha or beta particles with energies less than 70 keV are not significant since these radiations do not penetrate the dead outer cell layer of the skin.



(2) As with all radiation exposures, the size of the dose resulting from an external exposure is a function of:

- (a) The strength of the source;
- (b) The distance from the source to the tissue being irradiated; and
- (c) The duration of the exposure.

In contrast to the situation for internal exposures, however, these factors can be altered (either intentionally or inadvertently) for a particular external exposure situation, changing the dose received.

(3) The effectiveness of a given dose of external radiation in causing biological damage is dependent upon the portion of the body irradiated. For example because of differences in the radiosensitivity of constituent tissues, the hand is far less likely to suffer biological damage from a given dose of radiation than are the gonads. Similarly, a given dose to the whole body has a greater potential for causing adverse health effects than does the same dose to only a portion of the body.

#### b. Internal Exposures.

(1) Exposure to ionizing radiation from sources located within the body is of concern for sources emitting any and all types of ionizing radiation. Of particular concern are internally emitted alpha particles which cause significant damage to tissue when depositing their energy along highly localized paths.

(2) In contrast to the situation for external exposures, the source-to-tissue distance, exposure duration, and source strength cannot be altered for internal radiation sources. Instead, once a quantity of radioactive material is taken up by the body (for example, by inhalation, ingestion, or absorption) an individual is "committed" to the dose which will result from the quantities of the particular radionuclide(s) involved. Some medical treatments are available to increase excretion rates of certain radionuclides in some circumstances and thereby reduce the committed effective dose equivalent.

(3) In general, radionuclides taken up by the body do not distribute equally throughout the body's tissues. Often a radionuclide concentrates in an organ. For example, I-131 and I-125, both isotopes of iodine, concentrate in the thyroid, radium and plutonium in the bone, and uranium in the kidney.

(4) The dose committed to a particular organ or portion of the body depends, in part, upon the time over which these areas of the body are irradiated by the radionuclide. This,

in turn, is determined by the radionuclide's physical and biological half-lives (that is, the effective half-life). The biological half-life of a radionuclide is defined as the time required for one half of a given amount of radionuclide to be removed from the body by normal biological turnover (in urine, feces, sweat).

### 3-9. Background Radiation.

a. All individuals are continuously exposed to ionizing radiation from various natural sources. These sources include cosmic radiation and naturally occurring radionuclides within the environment and within the human body. The radiation levels resulting from natural sources are collectively referred to as "natural background". Naturally occurring radioactive material (NORM) can be detected in virtually everything. Natural potassium contains about 0.01% potassium-40, a powerful beta emitter with an associated gamma ray. Uranium, thorium and their associated decay products, which are also radioactive, are common trace elements found in soils throughout the world. Natural background and the associated dose it imparts vary considerably from one location to another in the U.S. and ranges from 5 to 80 microroentgens per hour. It is estimated that the cumulative individual dose in the United States from all sources is 620 mrem per year (NCRP, 2009).

b. Approximately 50% of the background dose is from natural sources such as radon gas and cosmic/terrestrial sources. The primary source of man-made non-occupational exposures is medical irradiation, particularly diagnostic procedures (for example, X-ray, computed tomography scans, and nuclear medicine examinations). Such procedures, on average, represent 48% of the background dose. All sources of man-made, non-occupational exposures such as nuclear weapons fallout, nuclear power plant operations, and the use of radiation sources in industry and universities contribute an average of less than one mrem/person/year in the U.S .

### 3-10. Radiation Quantities.

a. Exposure (roentgen). Exposure is a measure of the strength of a radiation field at some point. It is usually defined as the amount of charge (that is, sum of all ions of one sign) produced in a unit mass of air when the interacting photons are completely absorbed in that mass. The most commonly used unit of exposure is the roentgen (R) which is defined as that amount of X or gamma radiation which produces  $2.58 \times 10^{-4}$  coulombs per kilogram (C/kg) of dry air. In cases where exposure is to be expressed as a rate, the unit would be roentgens per hour (R/hr) or more commonly, milliroentgen per hour (mR/hr). The roentgen applies only to photons and only in air. Because of their limited use, no new unit in the SI system has been chosen to replace it.

b. Absorbed Dose (rad). Whereas exposure is defined for air, the absorbed dose is the amount of energy imparted by radiation to a given mass of any material. The most common unit of absorbed dose is the rad (Radiation Absorbed Dose) which is defined as a dose of 0.01 joule per kilogram of the material in question. One common conversion factor is from roentgens (in air) to rads in tissue. An exposure of 1 R typically gives an

absorbed dose of 0.97 rad to tissue. Absorbed dose may also be expressed as a rate with units of rad/hr or millirad/hr. The SI unit of absorbed dose is the gray (Gy) which is equal to 1 joule/kg which is equal to 100 rads.

c. Dose Equivalent (rem). Although the biological effects of radiation are dependent upon the absorbed dose, some types of particles produce greater effects than others for the same amount of energy imparted. For example, for equal absorbed doses, alpha particles may be 20 times as damaging as beta particles. In order to account for these variations when describing human health risk from radiation exposure, the quantity, dose equivalent, is used. This is the absorbed dose multiplied by certain "quality" and "modifying" factors (Q) indicative of the relative biological-damage potential of the particular type of radiation. The unit of dose equivalent is the rem (Radiation Equivalent in Man) or, more commonly, millirem. For beta, gamma- or X-ray exposures, the numerical value of the rem is essentially equal to that of the rad. The SI Unit of dose equivalent is the sievert (Sv) which is equal to 100 rem.

d. Deep Dose Equivalent (DDE). The DDE is the dose to the whole body tissue at 1 centimeter (cm) beneath the skin surface from external radiation. The DDE can be considered to be the contribution to the total effective dose equivalent (TEDE) from external radiation.

e. Effective Dose Equivalent (EDE). Multiplying the dose equivalent by a weighting factor that relates to the radiosensitivity of each organ and summing these weighted dose equivalents produces the effective dose equivalent. The EDE is used in dosimetry to account for different organs having different sensitivities to radiation.

f. Committed Dose Equivalent (CDE). The CDE is the dose equivalent to organs from the intake of a radionuclide over the 50-year period following the intake. Radioactive material inside the body will act according to its chemical form and be deposited in the body, emitting radiation over the entire time they are in the body. For purposes of dose recording, the entire dose equivalent organs will receive over the 50-years following the intake of the radionuclides is assigned to the individual during the year that the radionuclide intake took place. The CDE is usually derived from a table or computer program, as the value is dependent upon the radionuclide, its chemical form, the distribution of that chemical within the body, the mass of the organs and the biological clearance time for the chemical. The CDE can be calculated from the data in 10 CFR 20 Appendix B, or from the EPA Federal Guidance Report #11 if there is only one target organ, otherwise the dose must be calculated from the contribution of the radionuclide in every organ to the organ of interest.

g. Committed Effective Dose Equivalent (CEDE). Multiplying the committed dose equivalent by a weighting factor that relates to the radiosensitivity of each organ and summing these weighted dose equivalents produces the committed effective dose equivalent. The CEDE can be considered to be the contribution from internal radionuclides to the TEDE.

h. Total Effective Dose Equivalent (TEDE). The sum of the DDE and the CEDE. Regulations are designed to limit occupational exposures to a TEDE to the

whole body of 5 rem per year, and to limit the sum of the DDE and the CDE to any one organ to 50 rem per year.

3-11. Biological Effects of Ionizing Radiation. Biological effects of radiation have been studied at different levels; the effects on cells, the effects on tissues (groups of cells), the effects on organisms, and the effects on humans. Some of the major points are reviewed below.

a. The energy deposited by ionizing radiation as it interacts with matter may result in the breaking of chemical bonds. If the irradiated matter is living tissue, such chemical changes may result in altered structure or function of constituent cells.

b. The cell nucleus is the major site of radiation damage leading to cell death. This is due to the importance of the DNA within the nucleus in controlling all cellular function. Damage to the DNA molecule may prevent it from providing the proper template for the production of additional DNA or Ribonucleic Acid (RNA). In general, it has been found that cell radiosensitivity is directly proportional to reproductive capacity and inversely proportional to the degree of cell differentiation.

c. The considerable variation in the radiosensitivities of various tissues is due, in part, to the differences in the sensitivities of the cells that compose the tissues. Also important in determining tissue sensitivity are such factors as the state of nourishment of the cells, interactions between various cell types within the tissue, and the ability of the tissue to repair itself.

d. The relatively high radiosensitivity of tissues consisting of undifferentiated, rapidly dividing cells suggest that, at the level of the human organism, a greater potential exists for damage to the fetus or young child than to an adult for a given dose. This has, in fact, been observed in the form of increased birth defects following irradiation of the fetus and an increased incidence of certain cancers in individuals who were irradiated as children.

3-12. Ways to Minimize Exposure.

a. There are four factors used to minimize external exposure to radiation; time, distance, shielding, and engineering controls. Projects involving the use of radioactive material or radiation generating devices need to be designed so as to minimize exposure to external radiation, and accomplish the project. A proper balance of ways to minimize exposure and the needs of the project need to be considered from the earliest design stages. For example, if a lead apron protects a worker from the radiation, but slows him or her down so that it requires three times as many hours to complete the job, the exposure is not minimized. Additionally, placing a worker in full protective equipment and subjecting the worker to the accompanying physical stresses to prevent a total exposure of a few millirem does not serve the needs of the project or of the worker.

(1) Time. Dose is directly proportional to the time an individual is exposed to the radiation. Less time of exposure means less dose. Time spent around a source of radiation can be minimized by good design, planning the operation, performing dry-runs to practice the operation, and conscientious work practices.

(2) Distance. Dose is inversely proportional to the square of the distance from the radiation source. For example, doubling the distance from a source will quarter the dose. Distance from a radiation source can be maximized by good design, planning the operation, using extended handling tools or remote handling tools as necessary and by conscientious work practices.

(3) Shielding.

(a) Dose can be reduced by the use of shielding. Virtually any material will shield against radiation but its shielding effectiveness depends on many factors. These factors include material density, material thickness and type, the radiation energy, and the geometry of the radiation being shielded. Consult a qualified expert (such as a member of the Corps' Radiation Safety Support Team) to determine shielding requirements. Cost considerations often come into play. The shielding provided by a few centimeters of lead may be equaled by the shielding provided by a few inches of concrete, and the price may be lower for the concrete.

(b) Shielding can be used to reduce dose by placing radiation sources in shields when not in use, placing shielding between the source and yourself, good design of the operation, and conscientious work practices.

(4) Engineering Controls. Engineering Controls are defined as devices, systems, and/or controls that will preclude the release of radiation or radioactive material to the workplace or environment, thereby protecting the worker and the population in general from a hazardous exposure. Examples of engineering controls include ventilation systems and custom enclosures.

b. Personnel Protective Equipment (PPE). PPE is a last resort method for radiation exposure control. When engineering controls using time, distance, shielding, dust suppression, or contamination control cannot adequately lower the exposure to ionizing radiation or radioactive material, PPE may be used. PPE may include such items as:

- (1) Full-face, air- purifying respirators (APRs) with appropriate cartridges;
- (2) Self-contained breathing apparatus (SCBA);
- (3) Supplied air; and
- (4) Shielded gloves, aprons, and other clothing.

c. Selection of PPE is based on unique conditions at each job site. The PPE may be required in the following circumstances:

- (1) When handling contaminated materials with removable contamination;
- (2) When working in contamination, high contamination, and Airborne Radioactivity Areas; or
- (3) When required by an NRC license or ARA.

d. Specific PPE requirements for each job site should be obtained from USACE or a USACE contractor HP or industrial hygienist. Respirator use must meet the requirements of 29 CFR 1910 or 1926 and USACE respiratory protection requirements of EM 385-1-1. The respiratory protection factors for different types of respirators are listed in 10 CFR 20, Appendix A.

e. Any PPE will slow down the working speed of personnel, and extend the time needed for entry and exit. The increase in dose due to the increased time in the radiation field must be weighed against the radiation dose reduction caused by the use of PPE. The use of whole body personal protective equipment, particularly the impermeable type can cause heat stress problems. A heat stress monitoring program shall be considered, based on ambient conditions, to evaluate and control heat stress hazards whenever PPE is used.

### 3-13. Monitoring and Surveying Equipment.

a. Radiation monitoring equipment needs to be selected that can detect the radiation or radiations in question. Some radiations are extremely difficult to detect in the field. Weak beta emitters such as tritium (maximum beta energy of 18.6 kilo-electron volts (keV) and weak gamma emitters, such as iodine-125, present monitoring problems. Prior to work involving radioactive materials, consult the RSO, project HP, or a member of the RSST to select appropriate instruments and procedures for the detection and quantification of the specific radiation in question.

b. An adequate number and type of radiation survey meters and monitoring devices shall be available to support the Radiation Protection Program. The RSO must maintain at least two survey instruments to accommodate maintenance and calibration downtime. Calibrate radiation survey instruments used for health or safety purposes at least annually (or as specified in TB 43–0180) using National Institute of Standards and Technology traceable radiation sources (see TB 750–25). Some instruments may require more frequent calibration. Consult applicable technical publications for appropriate calibration intervals as necessary.

c. Calibration sources will be of a type and activity appropriate for the intended use of the instrument.

d. Radiation survey instruments should be response checked with an appropriate check source before and after use. Fixed, walk-through, portal, or step-in contamination monitors shall be response checked on a routine basis sufficient to ensure satisfactory operation, in accordance with the manufacturer's instructions. A log should be maintained to document these checks.

e. Appendix H to the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides information on various field and laboratory equipment used to measure radiation levels and radioactive material concentrations. The equipment is divided into two broad groupings of field survey and laboratory instruments and each group is subdivided into equipment that measures alpha, beta, gamma, x-rays, and radon. A single sheet for each gives type of use, primary and secondary radiation detected, applicability to site surveys, operation, specificity/sensitivity, and cost of the equipment and surveys performed.



## CHAPTER 4

### Dose Limits and ALARA

4-1. Occupational Dose Limit Structure. To ensure compliance with all regulatory agencies, USACE has established a three tiered approach to worker dose limits. Tier 1 is the NRC regulatory dose limits which are never to be exceeded. Tier 2 is the USACE dose limits which are effectively 10% of the NRC limits. The USACE limits will ensure that USACE workers will be in compliance with applicable regulations and they cannot be exceeded without the written approval of the RSSO. Tier 3 are project specific dose goals which will be set below the USACE dose limits. Project specific dose goals are used to promote the concept of ALARA; keeping the dose as low as is reasonably achievable, taking social, technical and financial considerations into account. Army and NRC regulations require a radiation protection program that promotes ALARA. Table 4-1 highlights the dose limits put forth in the three-tiered approach.

#### 4-2. USACE Dose Limits.

a. Tier 1 Annual Limits with RSSO Approval. With the written approval of the RSSO, the annual occupational dose shall not exceed the more limiting of:

- (1) 5 rem (5000 millirem (mrem))(0.05 sieverts (Sv)) whole body (TEDE),
- (2) The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue of 50 rem (50000 mrem)(0.5 Sv),
- (3) 15 rem (15000 mrem)(0.15 Sv) to the lens of the eye, or
- (4) 50 rem (50000 mrem)(0.5 Sv) shallow dose equivalent to the skin or any extremity.

b. Tier 2 Annual Limits Without RSSO Approval. Without the written approval of the RSSO, the annual occupational dose shall not exceed the more limiting of:

- (1) 0.5 rems (500 mrem) (0.005 sieverts (Sv)) TEDE,
- (2) The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue of 5 rems (5000 mrem)(0.05 Sv),
- (3) 1.5 rems (1500 mrem)(0.015 Sv) to the lens of the eye,
- (4) 5 rems (5000 mrem) (0.05 Sv) shallow dose equivalent to the skin, or any extremity, or



c. Tier 3 Suggested ALARA Limits. To keep doses ALARA, the user shall set administrative action levels below the Tier 2 dose limits. The ALARA limits shall be realistic and attainable. ALARA limits can be set at any level, but need to take the particulars of each project into account. Example annual ALARA limits for a small project involving little radioactive material could be:

(1) 0.1 rems (0.001 sieverts (Sv)) TEDE,

(2) The sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue of 0.5 rems (0.005 Sv),

(3) 0.15 rems (0.0015 Sv) to the lens of the eye, or

(4) 0.5 rems (0.005 Sv) shallow dose equivalent to the skin, or any extremity.

d. Any exposure in excess of an ALARA limit requires investigation by the RSO.

Table 4-1. Occupational Dose Limits

Body part	Annual limits with RSSO approval (Tier 1)	Annual limits without RSSO approval (Tier 2)	Suggested ALARA limits (Tier 3)
Whole body	5 rem (0.05 Sv)	0.5 rem (0.005 Sv)	0.1 rem (0.001 Sv)
Individual organ	50 rem (0.5 Sv)	5 rem (0.05 Sv)	0.5 rem (0.005 Sv)
Lens of eye	15 rem (0.15 Sv)	1.5 rem (0.015 Sv)	0.15 rem (0.15 Sv)
Skin or extremity	50 rem (0.5 Sv)	5 rem (0.05 Sv)	0.5 rem (0.005 Sv)

e. Planned special exposures (see definitions) shall not be performed.

f. Because the embryo/fetus is very radiosensitive, the NRC has set lower dose limits. To accomplish this, and to ensure privacy and working rights, the NRC has defined regulations for the control of doses to a Declared Pregnant Woman (DPW). A declared pregnant woman means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. Declarations shall be in accordance with 10 CFR 20. Occupational exposure of a declared pregnant woman shall be reported to the RSO. The dose limit to a DPW is 500 mrem over the entire gestation period. This limit includes both internal and external doses received due to occupational exposure.

g. Agreement States have the same dose limits as the NRC, but some include regulation of NORM and NARM materials and radiation generating devices.

h. Note that compliance with the USACE dose limits will ensure compliance with the NRC and Agreement State dose limits.

4-3. OSHA Dose Limits. OSHA adopted the NRC dose limits as they were written in 1969. According to the OSHA standards, no employer shall use radioactive materials or radiation generating devices in a manner which would cause any individual to receive a dose during one calendar quarter in excess of:

a. 1.25 rem to the whole body; head and trunk; active blood forming organs; lens of eyes or gonads.

b. 18.75 rem to the hands and forearms; feet and ankles.

c. 7.5 rem to the skin of the whole body.

Compliance with the USACE dose limits ensures compliance with OSHA dose limits. OSHA's regulations, 29 CFR 1910.1096(p)(2), state that NRC licensees complying with the Commission's radiation protection standards shall be deemed to be in compliance with the with OSHA's ionizing radiation protection standards.

4-4. Monitoring Requirements. Both OSHA and NRC have requirements to monitor internal and external doses to individuals who can reasonably be expected to receive a dose greater than 10% of the maximum permissible dose. Compliance with USACE Tier 2 dose limits will keep workers at doses below 10% of the maximum permissible doses. The RSO will issue dosimetry to occupationally exposed individuals as deemed necessary to demonstrate compliance with Federal, Army and USACE regulations, and to ensure that doses are kept ALARA. See Chapter 7, Personnel Monitoring.

4-5. Doses to the Public.

a. NRC and Agreement States presently require that a licensee restrict doses to the public to 100 mrem/year TEDE from licensed activities. The EDE in any unrestricted area may not exceed 2 mrem in any one hour. The maximum allowable dose to the public from effluents from a licensed facility is 50 mrem/year. Listed in Appendix B of 10 CFR 20 is a calculated concentration for each specific radionuclide yielding 50 mrem/year.

b. At 10 CFR 20.1101(d) the NRC requires that licensees using unsealed sources of radioactive material demonstrate that air emissions do not result in doses greater than the constraint limit of 0.1mSv (10 mrem) TEDE. Keep in mind that the dose limit to members of the public in 4-5.a. (100 mrem per year or 1 mSv per year) includes doses

from all pathways, including direct radiation, liquid effluents, and airborne effluents. The constraint, in this case, may be interpreted as that fraction of the public dose limit allocated to airborne emissions to ensure that doses are ALARA through this particular release pathway.

c. For decontaminated and decommissioned facilities to be released without restrictions, the dose to the average member of the critical group from residual contamination must be below 25 mrem/year above background and ALARA.

## CHAPTER 5

### Licensing and Permitting

#### 5-1. Overview of Regulatory Agencies.

##### a. U.S: Nuclear Regulatory Commission (NRC).

(1) The Atomic Energy Act of 1954 charges the NRC with the responsibility of writing and enforcing regulations for possession of source, byproduct or special nuclear material. The NRC does that by issuing licenses that contain conditions that licensees must meet. License holders are inspected by NRC to determine if regulations are being followed by the licensee. At NRC discretion, violations may lead to enforcement action and serious or repeated violations in the opinion of NRC may lead to revocation of a license and confiscation of radioactive material. NRC regional contact information is located at [www.nrc.gov](http://www.nrc.gov).

(2) Although the NRC is the federal agency responsible for adopting and enforcing rules and regulations that apply to users of radioactive material, broad administrative responsibilities have been transferred to some state governments. In 1959 the Atomic Energy Commission (predecessor agency to the NRC) was permitted to make agreements with those states that could operate a suitable radiological health program for the radioactive material users in their states. States that have such agreements with the NRC are called Agreement States. A list of Agreement States is located at [www.nrc.gov](http://www.nrc.gov).

b. Agreement States. Agreement States have their own state regulations and they provide personnel to license and inspect users of radioactive material. Agreement State regulations must be as stringent as NRC regulations and, usually, are more stringent. Agreement states do not issue licenses to Federal agencies, including the U.S. Army; only the NRC may do so.

c. U.S. Environmental Protection Agency (EPA). The Atomic Energy Act of 1954 and Reorganization Plan No. 3 authorized the EPA to establish standards to protect human health and the environment from the effects of radiation. The EPA does not license radioactive materials, but regulates their release to the environment and the exposure of the public to radiation.

d. Occupational Safety and Health Administration (OSHA). OSHA is authorized to protect worker health and safety. OSHA does not license radioactive materials however, radiation exposures not regulated by the NRC are regulated by OSHA. OSHA's standards for occupational exposure to all non-licensed ionizing radiation sources are in 29 CFR 1910.1096 and 1926.53. See OSHA Directive, CPL 02-00-086 - CPL 2.86 - Memorandum of Understanding between the OSHA and the NRC, 22 December 1989, for a delineation of radiation sources regulated by each agency.

5-2. Types of NRC Radioactive Material Licenses. Nuclear Regulatory Commission licenses for radioactive material are of two types: general and specific.

a. General Licenses. NRC general licenses are provided in 10 CFR 31 and are effective without submitting an application and without receiving a licensing document. Generally licensed devices usually contain little activity and pose minimal risk to the user. Devices which may be generally licensed include: static eliminators, some calibration sources, some measuring, gauging and controlling devices and self-luminous exit signs. Generally licensed material still requires compliance with 10 CFR 19 and 10 CFR 20 requirements for worker instructions and notices, and radiation protection standards. Additionally, for many generally licensed items, there are requirements for leak testing and inventories, as well as prohibitions on transfer or disposal except for return to the manufacturer or transfer to the holder of a specific license for that radioactive item. Appendix K to NRC's NUREG-1556, Vol. 16, is entitled "Guidance for 10 CFR 31.5 General Licensees (Q&As)". It contains useful information for general licensees. USACE requires that generally licensed items have an ARA (see paragraph 5-5).

b. Specific Licenses. Specific licenses require the submission of an application (either to the NRC or an Agreement State depending upon who has jurisdiction) and the issuance of licensing documents from the regulatory agency. It is illegal to transfer (sell or give) licensed radioactive material to another person or institution unless the recipient has a license to possess the material. Consequently, radionuclide supply companies require information about a customer's license before they will fill an order. Devices which may be specifically licensed include moisture/density gauges and industrial radiography cameras. NRC's NUREG-1556, "Consolidated Guidance About Materials Licenses" should be reviewed by specific licensees for information specific to their program.

c. Exempt Quantities.

(1) A list of exempt quantities, that is, the amount of a particular radionuclide that can be obtained without a general or specific license can be found in 10 CFR 30.71, Schedule B. These NRC regulations also list exempt concentrations, that is, the concentration of a particular radionuclide in a product that can be obtained without a general or specific license (10 CFR 30.70, Schedule A). Additionally, NRC and Agreement State regulations contain a listing of exempt items, that is, items containing radioactive material that can be obtained without a general or specific license. If you are unsure of the licensing requirements for a device you wish to use, contact the Command RSO.

(2) \*NOTE\* As previously mentioned, there is some radioactive material that is not regulated by the NRC, but is regulated by Agreement States. Most Department of

Defense sites are exclusive Federal jurisdiction and so are regulated by the NRC, but some bases and some portions of bases may be state property and may be regulated by the state. Always check to determine whether or not the site you are on is exclusive federal jurisdiction. This is normally done through the Command Real Estate function and the Office of Counsel.

5-3. Radiation Generating Devices. The NRC does not license radiation generating (X-ray) devices since they do not contain radioactive material. Most states, however, require registration and/or licensing of radiation generating devices. States do not have authority to regulate devices used only at exclusive Federal jurisdiction facilities, but many states request that they be notified of all radioactive materials and devices located within their boundary. Facilities located on nonexclusive federal jurisdiction facilities, may be subject to state regulation. Some uses may be regulated by the Food and Drug Administration under Title 21.

5-4. Reciprocity Requirements.

a. The NRC and Agreement States recognize each other's radioactive material licenses. That is, an Agreement State licensed company can perform work in an NRC jurisdiction under the company's Agreement State license. Likewise, an NRC licensed company can perform work in an Agreement State's jurisdiction under the company's NRC license.

b. When a state-licensed contractor desires to perform work in an "NRC-state," the contractor must first be granted reciprocity by the NRC. The contractor must provide the NRC with a copy of its state radioactive material license and inform the NRC of its work intentions using NRC Form 241. There is a fee for filing NRC Form 241 which depends on the type of license and work to be performed.

c. When a state-licensed contractor desires to work in another Agreement State, the contractor must notify the Agreement State using the appropriate state form.

d. An NRC licensed contractor performing work on a site under an Agreement State's jurisdiction must notify the Agreement State using the appropriate state form. Some Agreement States also charge a fee for reciprocity.

e. Federal agencies licensed by the NRC are not subject to Agreement State radiation control regulations. Thus, federal licensees who are authorized to work at temporary job sites under their NRC licenses may do so anywhere in the United States and its territories.

5-5. Army Radiation Authorization (ARA). An ARA is required for a USACE Command to receive, possess, use, or transfer radioactive material that is not specifically licensed by the NRC or an ionizing radiation generating device. An ARA is not required for radioactive material that is covered by another MACOM's similar authorization.

a. An ARA is required for all radioactive material, including generally licensed material, except:

(1) Byproduct, source, or special material which the NRC has declared to be license-exempt (10 CFR 30, sections 30.14 through 30.20; 10 CFR 40, sections 40.13 and 40.14; and 10 CFR 70, section 70.14).

(2) Material less than 0.1 microcurie ( $\mu\text{Ci}$ ) [3.7 kilobecquerels (kBq)] of radium.

(3) Material less than 1  $\mu\text{Ci}$  (37 kBq) of any naturally occurring or accelerator produced radioactive material (NARM) other than radium.

(4) Electron tubes containing less than 10  $\mu\text{Ci}$  (370 kBq) of any NARM radioisotope.

(5) Machine-produced ionizing radiation sources not capable of producing a high radiation area or very high radiation area. (For example medical and dental diagnostic X-ray systems do not require an ARA.)

(6) Army nuclear reactors and Army reactor-produced radioactive material that remain at the reactor site. The Army Reactor Office issues Army reactor permits for these sources per AR 50-7, Army Reactor Program.

b. All ARA applications, amendments, termination requests, and correspondence will be forwarded to the RSSO. The RSSO will review these documents, and when they are in compliance, issue on behalf of the Commanding General, USACE, the ARA and any required conditions via CESO.

c. Application for an ARA, amendment to an ARA, or termination of an ARA including all enclosures, will be submitted using DA Form 3337, to the RSSO not later than 30 days prior to the date the action is needed.

d. ARA conditions will specify the time period for which the ARA is valid, and any special procedures applicable to the possession and use of the radioactive materials or radiation generating devices.

e. Radioactive materials and radiation generating devices will not be procured until the required ARAs have been received.

#### 5-6. Army Radiation Permits (ARP) and Other Service Installation Permits.

a. Non-Army agencies (including USACE contractors) wishing to use, store, or possess radioactive materials or radiation generating devices on any DA installation



must obtain an Army Radiation Permit (ARP). The non-Army applicant will apply by letter with supporting documentation to the District/Lab/Center Commander.

b. The ARP application will specify start and stop dates for the ARP and describe for what uses the applicant needs the ARP. The District/Lab/Center Commander will approve the application only if the applicant provides evidence to show that one of the following is true:

(1) The applicant possesses a valid NRC license or Department of Energy (DOE) radiological work permit that allows the applicant to use the source as specified in the ARP application.

(2) The applicant possesses a valid Agreement State license that allows the applicant to use radioactive material as specified in the ARP application, and the applicant has filed NRC Form-241, Report of Proposed Activities in Non-Agreement States, Areas of Exclusive Federal Jurisdiction, or Offshore Waters with the NRC in accordance with 10 CFR 150.20. An ARP issued under these circumstances will be valid for no more than 180 days in any calendar year.

(3) For machine-produced ionizing radiation sources (e.g., an x-ray machine), the applicant has an appropriate State authorization that allows the applicant to use the source as specified in the ARP application or has in place a radiation protection program that complies with Army regulations.

(4) For overseas installations, the applicant has an appropriate host-nation authorization as necessary that allows the applicant to use the source as specified in the ARP application or has in place a radiation protection program that complies with Army regulations.

c. All ARPs will require applicants to remove all permitted sources from Army property by the end of the permitted time.

d. Disposal of radioactive material by non-Army agencies on Army property is prohibited. However, the installation Commander may authorize radioactive releases to the atmosphere or to the sanitary sewage system that are in compliance with all applicable Federal, DoD, and Army regulations.

e. USACE personnel and USACE contractors wishing to use radioactive materials or radiation generating devices on any Air Force installation must obtain permission from the installation. On Air Force property, contact the installation Environmental Health Section for instructions. The USACE RSSO can provide assistance with obtaining the required permission.

f. USACE personnel and USACE contractors wishing to use radioactive materials or radiation generating devices on any Navy installation must obtain permission from



the installation. On Navy property, contact the installation Safety Office for instructions. The USACE RSSO can provide assistance with obtaining the required permission.

5-7. Applying for an NRC Specific License. If it is determined that a Command needs to possess radioactive material, the following steps should be followed:

- a. Check with the CO to ensure that the Command will support the license and all the accompanying costs and responsibilities.
- b. Find the source of funding for paying licensing, maintenance and training costs.
- c. Contact the RSSO and coordinate the licensing.
- d. Obtain a copy of the NRC Form 313 “Application for Byproduct Material Usage”. Consult NRC’s “Consolidated Guidance About Materials Licenses” (NUREG-1556). This NUREG contains program specific guidance intended to facilitate the license application process.
- e. Note that the application and all accompanying documentation will become a part of the license. Everything an applicant commits to in the application and subsequent correspondence will be binding in the license.
- f. Photocopy and keep a copy of the application and all submittals as these documents will probably be “tied down” on the license. When a document is “tied down,” it is specifically identified on the license and the regulatory agency can inspect against it, that is, the applicant must abide by all commitments made in those documents.
- g. All NRC license or ARA applications, amendment requests, renewals, and terminations requests must be routed to the HQUSACE RSSO. For example, a request to obtain an NRC license amendment would be coordinated with the Chief, SOHO. Following coordination, it would flow from the local RSO, to the HQUSACE RSSO for review and approval followed by CESO action.
- h. Failure to follow the information flow process is a violation of the USACE delegation requirements specified by DA. Technical consultations between NRC offices and license holders at USACE Commands may take place, though notification of the RSSO of such communications is recommended.
- i. Under CERCLA, the Federal lead agency is exempt from licensing and permitting requirements for work done on site, but not from the substantive requirements of such regulations (42 USC 9621(e)). Corps personnel should work with all applicable Federal regulatory agencies including EPA and NRC to ensure that the intent of all applicable regulations are fully met. For FUSRAP cleanups, see the Director’s Decision DD-99-7 (March, 26, 1999) for specific information.

5-8. Applying for an ARA.

a. If it is determined that an activity needs NORM, NARM or an ionizing radiation generating device, the following steps should be followed:

(1) Check with the CO to ensure that the unit will support the permit and all the accompanying costs and responsibilities.

(2) Find the source of funding for paying maintenance and training costs. All users of the radioactive material will require initial and likely annual refresher training.

(3) Contact the RSSO and coordinate the permitting.

(4) Obtain DA Form 3337 "Application for Army Radiation Authorization" and "Instructions for preparing DA Form 3337" from the Army Publishing Directorate website at <http://www.apd.army.mil>. The instructions are self-explanatory.

b. The application for an ARA is made by submitting DA Form 3337 to the USACE RSSO. The Form does not get sent to the address listed in the "Instructions for preparing DA Form 3337". The application will include a list of all NRC licenses and other ARAs held by the Command. Renewals or amendments will be submitted in the same manner as an original application. Renewal requests should be submitted at least 30 days prior to expiration date.

5-9. Amendment Requests.

a. An amendment to an NRC or Agreement State radioactive material license or an ARA is necessary anytime:

(1) additional radionuclides or radioactive material of another chemical or physical form is desired;

(2) the use of radioactive material changes from the currently authorized use;

(3) the Radiation Protection Program or waste disposal method will change substantially; or

(4) the RSO is listed on the license by name, and a new RSO is then appointed.

b. Amendment requests are submitted in the same way as new licenses or permits. Licensees may not procure requested radionuclides or quantities until the amendment has been approved.

#### 5-10. Renewing Licenses or ARAs.

a. Radioactive material licenses are issued for five years and must be renewed to stay in effect. The NRC will send a Notice of License Expiration Letter 120 days before the license expires. A sample of this letter is in NUREG-1556. It will also send the necessary forms to renew the license. License renewal requests must be submitted to the RSSO for review and forwarding at least 60 days prior to the expiration date. If sufficient time is not available to prepare the renewal request, the applicant may ask the NRC (in writing) to extend the expiration date for up to 90 days.

b. License renewal requests that are received by the NRC thirty days prior to the expiration date will be deemed “timely filed.” The NRC will send a “timely filed letter” (or postcard). With this letter, the licensee may continue operating under the old license until the NRC issues the renewed license. If material is needed, the supplier may ask to see this “timely filed letter.”

c. If a license is not renewed in a timely manner, all radionuclide use must cease on the date of expiration. At this point, the NRC will require submission of a new license application. The NRC will take appropriate action on expired licenses which could include a visit to the facility. The RSO should contact the RSSO for assistance with an expired license.

d. ARAs also must be renewed by submitting DA Form 3337 to the RSSO not later than 30 days prior to the date the action is needed.

#### 5-11. Transfer of Radioactive Material.

a. Should a Command wish to transfer radioactive material to another Command, a Request for Authorization to Transfer Radioactive Materials (ENG Form 4790-R) must be completed and submitted to the RSSO through command channels.

b. The RSSO will review the request, and the receiving Command’s radioactive license or ARA to ensure that all regulations, license or ARA conditions are met, then approve the transfer if appropriate.

c. When the Command receives authorization to transfer the materials, the RSO shall ensure that the radioactive materials are packaged and shipped according to DOT and NRC regulations (see Chapter 8).

#### 5-12. Terminating a Radioactive Material License or ARA.

a. When a Command no longer wishes to possess or use licensed or permitted radioactive material, the license or ARA must be terminated. License or ARA termination involves disposal of all radioactive material, a survey of the premises for radioactive material contamination (a “close-out survey”) if applicable, submission of

disposal documentation and the close-out survey results, and a written request for termination of the license or ARA submitted to the RSSO. The RSSO will review the request and submit it to the proper regulatory agency or DA official for acceptance. The close-out survey must be performed in all areas that may possibly be contaminated with radioactive material. Sealed sources, that have passed required wipe tests, pose little hazard of contamination. Where unsealed forms of radionuclides have been used, the survey should be conducted in accordance with MARSSIM. MARSSIM refers to the close-out survey as a “final status survey”.

b. The Multi-Agency Radiation Survey and Assessment of Materials and Equipment manual (MARSAME) is a supplement to MARSSIM. MARSAME provides technical information on approaches for planning, implementing, assessing, and documenting surveys to determine proper disposition of materials and equipment (M&E). The scope of MARSAME is M&E potentially affected by radioactivity, including metals, concrete, tools, equipment, piping, conduit, furniture and dispersible bulk materials such as trash, rubble, roofing materials, and sludge. The wide variety of M&E requires additional flexibility in the survey process, and this flexibility is incorporated into MARSAME. MARSAME should be used for release of M&E.

c. The NRC’s Timeliness Rule establishes criteria for timely decommissioning upon termination of operations. The Timeliness Rule applies to situations when the licensee has decided to permanently cease principle activities at the entire site or at any separate building or outdoor area; or no principle activities have been conducted in such areas for a period of 24 months even if no decision has been made to permanently cease principle activities.

d. The Timeliness Rule establishes requirements for notifying the NRC of pending decommissioning actions, establishes requirements for when decommissioning plans need to be submitted, and establishes requirements for completing decommissioning activities. NUREG-1757, Vol. 3, Rev. 1 should be consulted for additional information.

e. The license is considered formally terminated only upon receipt of the letter of termination from the NRC.

## CHAPTER 6

## Working with Radiation

6-1. Caution Signs and Labels.

a. Appropriate warnings are required in all areas, rooms, and on all containers in which significant amounts of radiation or radioactive material may be found. Warnings consist of postings and labeling. In general, areas or rooms are “posted” with signs whereas containers, devices, equipment, etc., are “labeled.” The specific warning to be used depends on the type and degree of hazard present. The RSO will post rooms, hoods, work areas, etc. The AU is responsible for appropriate labeling.

(1) Posting Caution Signs. A room or area in which radioactive material is used or stored may require posting if the dose rate in the room or area is likely to exceed 5 mrem in any one hour at 30 cm from the source or source container. Table 6-1 specifies when a room or area must be posted as a Radiation Area, a High Radiation Area, or a Very High Radiation Area.

Table 6-1. Caution Sign Posting Requirements

Dose Rate	Distance From Source	Posting Required
5 mrem in any one hour.	30 cm	“Caution, Radiation Area”
100 mrem in any one hour.	30 cm	“Caution, High Radiation Area”
500 rad in any one hour.	1 m	“Grave Danger, Very High Radiation Area”

## (2) NRC Required Labeling.

(a) When a container has a quantity of radioactive material equal to or greater than that listed in 10 CFR 20 Appendix C, a “Caution, Radioactive Material” label will be affixed to the outside of the container. Most gauges and instruments containing radioactive material such as a soil density gauges, electron capture sections of gas chromatographs, or sediment density probes will require this label. The label should be large enough to be conspicuous. Standard labels are roughly 4 in (10.2 cm.) x 3.5 in (8.9 cm).

(b) Each AU shall, prior to disposal of any uncontaminated empty container to an unrestricted area, remove or deface the radiation label or otherwise clearly indicate that the container no longer contains radioactive material.

(c) Be advised that this labeling requirement is separate from the labeling requirements of DOT. A package or radioactive material prepared for transportation may also need DOT labels as describe in Chapter 8, Transportation of Radioactive Material.

(d) An AU is not required to label containers when they are attended by an individual who takes the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits labeled in accordance with DOT regulations, or containers which are accessible only to individuals authorized to handle or use them or to work in the vicinity thereof, provided that the contents are indentified to such individuals by a readily available written record.

### (3) Restricted Area verses Control Area

(a) The NRC defines a restricted area as an area, access to which is limited by the licensee for the purpose of protecting individuals from exposure to radiation and radioactive materials. Any dose received by any individual in a "restricted area" is an "occupational dose." No one in a restricted area is a "member of the public." Access to restricted areas must be controlled, e.g., by barriers, signs, or guards. Posting of a restricted area as a restricted area is not required although other posting may be required within the area.

(b) The NRC defines a controlled area as an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason. Outside "restricted areas", whether the dose to an individual is an "occupational dose" or a "public dose" depends on what the individual is doing and not on what area (controlled or unrestricted area) the individual is in when the dose is received. Signs and labels shall have a yellow background with a magenta or black standard radiation symbol. Lettering shall be magenta or black, but magenta is preferred color.

### 6-2. Airborne Radioactivity.

a. If the activities you are engaged in are suspected to create airborne radioactivity (for example, vapors or aerosols), the RSO or HP can conduct the appropriate surveys and calculations to determine if posting the area is required. If necessary, these area will be posted with a "Caution, Airborne Radioactivity Area".

b. The RSO will arrange a time to conduct the posting of each authorized use location prior to approving that location for radioactive material use. A facility posting checklist is utilized to document postings.

6-3. Rooms/Areas in Which Radioactive Material is No Longer Used or Stored. The AU is responsible for notifying the RSO when radioactive material usage in a room or area has ceased. The RSO will perform a close-out survey of the area to ensure no residual contamination, remove all signs and postings, document the survey and, if necessary, apply to amend or terminate all applicable NRC Licenses and/or ARAs.

6-4. Receiving Radioactive Material. NRC regulations require that written instructions for receiving and opening packages be maintained and followed by all personnel receiving radioactive material. Refer to 10 CFR 20.1906 and NUREG-1556 for complete guidance. NUREG-1556 also contains model procedures for safely opening packages containing licensed materials.

6-5. Radioactive Material and Radiation Generating Device Inventory.

a. The RSO for each USACE Command is responsible for all radioactive material and radiation generating devices owned or possessed by the Command, regardless of whether the material and radiation generating device is authorized under a specific license or ARA. In order to ensure control of all radioactive material and radiation generating devices, the RSO shall maintain a written inventory of all radioactive material and radiation generating devices within the Command.

b. The RSO for each Command owning or possessing radioactive material or radiation generating devices shall physically inventory each item at least semi-annually, and more often if their license requires it. This will usually be accomplished along with the semi-annual wipe test. For remote sources, such as those assigned to dredges, the RSO may have an AU perform the physical inventory of the item(s).

6-6. Storing Radioactive Material. The AU is responsible for assuring that all radioactive material is stored in a secure manner when not in use. Sealed sources used in the field may be locked in their storage containers. Sealed sources stored in a building may be locked in a storage room or storage cabinet. Unsealed sources may be locked in a storage container, cabinet, drawer, refrigerator, or freezer. Labs where unsealed sources are used shall be locked whenever the lab is unattended. Sealed sources in fixed use locations may be secured in their work position. The AU must ensure that where ever radioactive sources are stored, proper labeling and posting is used.

6-7. Accident/Incident Response.

a. There is always a possibility of an accident involving radiation or radioactive material. USACE will strive for a zero accident tolerance level. This can be accomplished using Standing Operating Procedures, conscientious work practices, and having and practicing an Accident / Emergency Response Plan.

b. The plan, required for all HTRW sites, must provide guidance for response to



fire, natural disasters, radioactive material spill, and inadvertent radiation exposure. The plan will address the following procedures:

- (1) Evacuation of the building/area;
- (2) Treatment of injured personnel;
- (3) Firefighting;
- (4) Spill response;
- (5) Personnel decontamination; and
- (6) Any additional site specific requirements.

c. Holders of NRC licenses, ARPs, and ARAs will ensure that all emergency responders (e.g., the installation fire chief) that may encounter radiation, are aware of applicable regulations and conditions as appropriate.

#### 6-8. Accident/Incident Reporting.

a. The RSO will report the loss or theft of NRC licensed radioactive materials to the RSSO and the NRC within the time frames listed in 10 CFR 20.

b. Theft or loss of material or devices listed on an ARA shall be reported to the RSSO as soon as practicable.

c. The RSO will notify the RSSO of any exposure exceeding Tier 2 USACE Dose Limits and any release of radioactive materials that could potentially cause a dose to an individual to exceed the Tier 2 USACE dose limits, or an event that could lead to a member of the public receiving a significant portion of the 100 millirem/yr dose limit. The RSO will notify the RSSO and the NRC of overexposures and releases as defined by the NRC in 10 CFR 20.

d. Additional reporting requirements which may or may not be applicable can be found in DA PAM 385-24, Chapter 6, Special Reporting Requirements.

#### 6.9 Audits and Reviews.

a. The RSSO, or their designee (typically a member of the RSST), will audit each Command that possesses a radioactive material license or ARA tri-annually. The audit is to ensure personnel safety and compliance with regulatory requirements. The audit may consist of a records review, facility inspection, interviews with the RSO and AUs,

and an exit interview with the RSC or the Commander, depending on the activity at the



Command. The audit will be documented and a copy furnished to the RSO.

b. The RSO will review their Radiation Protection Program annually for content and implementation. The RSO will ensure that the quality and timeliness of their program meet the radiation safety guidelines outlined in this manual. The RSO will review all work with radiation within his/her Command. The RSO will perform the annual review with the purpose of anticipating the needs of the program in the coming year. The review will be documented.

c. Additional audits and reviews may be performed as deemed beneficial to the Command by the RSSO, the RSO, or the Commander.

## CHAPTER 7

### Personnel Monitoring

#### 7-1. External Monitoring.

a. To indicate the amount of radiation to which a person has been externally exposed, an individual monitoring device may be used. NRC regulations define an “individual monitoring device” as a device designed to be worn by a single individual for the assessment of dose equivalent. Examples of dosimeters include film badges, thermoluminescent dosimeters (TLDs), optically stimulated luminescence (OSL) dosimeters, pocket ionization chambers (“pencils”), alarm rate meters, track etch dosimeters, and neutron sensitive film. Occupational exposure to radiation shall be monitored by:

(1) Adults likely to receive in one year, from sources external to the body, a dose in excess of the Tier 2 limits specified in Chapter 5;

(2) A declared pregnant woman likely to receive during the pregnancy, from sources external to the body, a dose in excess of 10 per cent of the Tier 2 limits in Chapter 5; and

(3) An individual entering a high or very high radiation area.

b. Most individuals who work in radiation areas never approach values which require personnel monitoring. Statistical evaluations of monitoring results have shown that 70% of all monitored Authorized Users’ Assistants receive no measurable exposure and another 20% receive less than 100 mrem per year. Exposure histories have documented the fact that usually only those individuals who work in radiology, radiography, and other fields using high activity sources are required to be monitored.

c. Within USACE, the RSO will determine which USACE personnel should wear dosimeters. Dosimetry is issued, in most cases, to document low exposures.

d. The RSO will instruct personnel in the proper use of dosimeters, will issue dosimeters, will collect dosimeters and submit them for analysis, and will review the analysis results. Dosimeters (except direct and indirect reading pocket ionization chambers) will be processed by a laboratory which holds a current accreditation from the National Voluntary Laboratory Accreditation Program (NVALP) of the National Institute of Standards and Technology (NIST).

e. Most contractors use vendor supplied services. USACE personnel will use the Army Dosimetry Center (USADC) for dosimetry services. Exposures shall be reported

and recorded. Exposures shall be recorded using the computer generated printout generated by USADC or NRC Form 5.

f. Personnel should not expose their dosimeter to security X-ray devices, excessive heat, or medical sources of radiation. Should job conditions dictate, dosimeters may be removed from a job site as part of an employee's routine travel to and from work. At sites where dosimeter use is routine, and there is a responsible individual to manage the dosimeters, the personal dosimeters should be stored at site and not taken home each night. A dosimeter shall be returned to the RSO if an employee will not be physically present at the job site for a period of one month or greater.

g. A person whose dosimeter is lost, damaged, or contaminated while working will immediately exit the radiation control area and report the occurrence to the RSO. Reentry of the person into the radiation control area will not be permitted without RSO approval. Dosimeters will not be used by USACE personnel for operations at locations other than USACE sites.

#### 7-2. Internal Monitoring.

a. NRC regulations also require that each licensee monitor the occupational intake of radioactive material by and assess the committed effective dose equivalent to:

(1) Adults likely to receive in one year an intake in excess of 10 percent of the applicable ALI; and

(2) A declared pregnant woman likely to receive during the pregnancy, a committed effective dose equivalent in excess of 50 mrem.

b. If a licensee is required to monitor both external and internal exposures, then the external and internal doses must be totaled to demonstrate compliance with the dose limits specified in Chapter 5.

c. Internal monitoring can be achieved via bioassay. A bioassay is a determination of the kind, quantity, or concentration and location of radioactive material in the body. A direct (in vivo) bioassay measurement may be made by whole body counting (that is, counting the gamma-rays emanating from a radionuclide in a given organ). An indirect (in vitro) bioassay measurement may be made by assessing the quantity of a specific radionuclide in samples that are excreted (for example, urine, feces, or blood). There are four types of bioassays:

(1) Baseline: Prior to potential exposure;

(2) Routine: At a specified frequency (for example, quarterly);

(3) Postoperational: Within two weeks of the last possible exposure when operations are being discontinued or when the worker is terminating duties with exposure to radioisotopes; and

(4) Diagnostic: Follow-up bioassay performed within two weeks of any measurement exceeding the action level. This will confirm the preceding measurement and allow an estimate of effective half-life.

d. Within USACE, personnel shall participate in a bioassay program when they are likely to receive an intake that may result in a committed effective dose equivalent of 100 mrem or more, or, when an intake of radiation is suspected for any reason. Specific bioassay requirements will be determined by the RSO for each job site. Bioassay procedures, supplies, lab analysis and dose assessment may be obtained on a cost reimbursable basis from the U.S. Army Public Health Command.

e. Personnel shall be notified promptly of positive bioassay results, as well as the results of dose assessments and subsequent refinements. Dose assessment results shall be provided in terms of mrem to the organ(s) and whole body.

f. Management shall require a post-operational bioassay when a person who participated in the bioassay program terminates employment or concludes work involving the potential for internal exposure.

### 7-3. Advanced Monitoring.

a. Multiple dosimeters may be issued to personnel to assess whole-body exposure in non-uniform radiation fields or as required in radiation work plans. Non-uniform radiation fields exist when the dose to a portion of the whole body will exceed the dose to the primary dosimeter by more than 50 percent, and, the anticipated whole-body dose is greater than 100 mrem.

b. The use of an alarm rate meter is encouraged for entry into a high radiation area or when a planned dose of greater than 100 mrem in one week is expected. An alarm rate meter provides an early warning of elevated exposure through the use of a preset dose rate or an integrated dose. A direct reading (pencil) dosimeter may be used in place of an alarm rate meter. A pencil dosimeter with the lowest range applicable (typically 0-200 mR) should be selected. The alarm rate meter or the pencil dosimeter should be worn simultaneously with the primary dosimeter. The alarm rate meter or pencil dosimeter should not be allowed to exceed 75 percent of full scale.

c. The establishment and maintenance of a comprehensive area monitoring program may minimize the number of areas requiring the issuance of personnel dosimeters and demonstrate that doses outside radiation work areas are negligible. Minimizing the number of personnel dosimeters issued lowers the costs of operating the dosimetry program and reduces costs associated with maintaining personnel with enhanced training and qualifications.

d. Area-monitoring dosimeters should be used in controlled areas to supplement existing monitoring programs, and to provide data in the event of an emergency. Area-

monitoring dosimeters should be used to record and document radiation levels in routinely occupied areas that are adjacent to areas where radiation, or operations with radiation exist. Area-monitoring dosimeter results could be used to support dosimetry investigation if personnel express concerns about their work environments and possible exposure to ionizing radiation.

e. Any pregnant worker who wishes to voluntarily enroll in the fetal monitoring program needs to contact the RSO. Declared pregnant workers may be assigned a dosimeter to wear at waist level to measure fetal exposure.

f. The RSO will furnish each worker annually with a written report of the worker' dose.

## CHAPTER 8

### Transportation of Radioactive Material

8-1. Purpose. This chapter is intended to introduce containment, control, and communication requirements when transporting radioactive material. This chapter is not an exhaustive review of all regulatory requirements which pertain to shipping radioactive material.

8-2. Applicability. This chapter applies to all personnel who ship or transport radioactive material and all personnel who supervise operations which involve shipments or transportation of radioactive material.

8-3. Regulations.

a. The transportation of radioactive material is regulated jointly at the Federal level by the DOT and the NRC. The division of responsibilities between DOT and NRC is specified in a memorandum of understanding. DOT regulates shippers, carriers, Type A packages and LOW SPECIFIC ACTIVITY (LSA) packages, and it issues Certificates of Competent Authority for International Shipments. Relevant DOT regulations may be found in 49 CFR 170-189.

b. NRC regulates Type B and fissile packages; it is responsible for transportation safeguards; it investigates accidents/incidents, and it is a technical advisor to DOT. Relevant NRC regulations may be found in 10 CFR 71. It is worth noting that 10 CFR 71.5 requires NRC licensees to comply with 49 CFR 170-189.

c. DOE controls and regulates shipments of U.S. Government program related nuclear materials. DOE requires shippers and carriers of non-weapons under their authority to conform to DOT and NRC regulations.

d. U.S. Postal Service (USPS) guidance for mailable radioactive material may be found in USPS Publication 52, "Hazardous, Restricted, and Perishable Mail".

e. For purposes of transportation, radioactive material is defined in 49 CFR 173.403 as any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in the table in 49 CFR 173.436 or values derived according to the instructions in 49 CFR 173.433.

f. Hazardous material is defined by DOT as any substance, including mixtures and solutions of substances, which the Secretary of Transportation has determined to be capable of posing an unreasonable risk to health, safety and property when transported in commerce (49 CFR 171.8). Radioactive material is considered hazardous material by DOT's definition.

#### 8-4. Procedures.

a. Nuclear transportation regulations ensure safety by effective containment of the material; effective control of the radiation emitted from the package; preventing criticality for fissile radioactive material; and adequate dissipation of any heat generated in a package. Primarily, safety in transport is accomplished by proper packaging of the radioactive material and by accurately communicating any associated hazards.

b. Hazard communication is achieved through correct marking, labeling, placarding, manifesting, and emergency response information.

c. International shipments of RAM shall be in accordance with the requirements of the International Air Transport Association (IATA Section 10), and the International Maritime Organization/International Maritime Dangerous Goods regulations.

d. Do not transfer radium and items containing radium to non-DoD agencies or activities (except for disposal as radioactive waste).

#### 8-5. Hazmat Employee Training.

a. A hazmat employer is defined by DOT as a person who uses one or more of its employees in connection with, among other things, transporting hazardous materials in commerce. It is a hazmat employer's responsibility to ensure that each of its hazmat employees receives training such that hazmat employees can recognize and identify hazardous materials, know how to respond in an emergency situation, know self-protection measures, and know accident prevention methods (49 CFR 172.700).

b. Hazmat employees shall receive the training at least once every two years. Training provided by employers to comply with OSHA regulations (29 CFR 1910.120) or EPA regulations (40 CFR 311.1) may be used to satisfy DOT's hazmat employee training requirements if the topics specified in the preceding paragraph are covered.

c. EM 1110-35-1. Chapter 11 of EM 1110-35-1, Management Guidelines for Working with Radioactive and Mixed Waste further explains the procedures and issues involved in transportation of radioactive materials and should be consulted.

## CHAPTER 9

### Waste Management

9-1. Introduction. Radioactive waste management is an important part of a Radiation Protection Program. There are few options for disposal of radioactive waste and all are costly. A well thought out waste management program will make radiation protection simpler and less expensive. Given that the rules and regulations governing radioactive waste disposal are complex and very dynamic, it is recommended that licensees and ARA holders consult with the RSSO for waste management support.

9-2. Elements of a Waste Management Program. There are five elements of a radioactive waste management program. These elements are:

- a. Material tracking;
- b. Waste minimization;
- c. Waste recycling;
- d. Waste storage; and
- e. Waste disposal.

9-3. Material Tracking. Any project involving radioactive material will have a radioactive material tracking program in effect. This program will document the arrival on site of the radioactive material, the package receipt procedures, an active inventory of all materials and their locations at all times, all radioactive waste generated, and the final disposal of the radioactive material. On HTRW sites where there is radioactive contamination, the radioactive material will be entered into the tracking program as the contamination is containerized, or remediated. Each container will be labeled and tracked from inception until final disposal at the disposal site.

9-4. Waste Minimization. The most effective method of dealing with radioactive waste is to not generate it. This is often the case when using sealed sources. When working with unsealed sources or on HTRW sites this is usually not possible. Radioactive waste disposal costs are based on the volume of waste disposed, so there is a financial incentive to minimize the amount of waste produced. Where radioactive waste is generated or packaged, waste minimization techniques should be used. These techniques include avoiding equipment contamination, limiting the spread of contamination, decontamination of items where it is cost effective, efficient packing of bulky items and compaction or supercompaction where possible.



9-5. Waste Recycling. A number of companies will recycle certain radioactive and mixed wastes. Sealed sources are often in demand by companies and universities. Radioactively contaminated metals can be smelted and cast as parts for disposal containers for other radioactive wastes. If a project involves recyclable radioactive wastes, contact the EM CX for a POC at the recycling facility.

9-6. Waste Storage. There may be no disposal option for some radioactive wastes. Storage on site in most cases requires NRC or Agreement State licensing of the site and is generally not recommended. If the waste is a mixed waste, the RCRA time limit for storage on-site without a Part B permit may be in effect. If long term storage is needed, contact the EM CX for assistance.

9-7. Department of the Army.

a. The U.S. Army Joint Munitions Command (JMC), AMSIO-DMW, Rock Island, IL 61299-6000, has been appointed as the executing agent for disposal of DoD radioactive waste. As per DoD 4715.6-R, Low-Level Radioactive Waste Disposal Program, the executing agent is responsible for inventorying and reporting all DoD waste disposal. The executing agent also serves as the POC for the disposal compacts and operates two DoD storage facilities for radioactive waste that cannot be disposed due to compact status.

b. All DoD low level radioactive waste (LLRW) not associated with environmental remediation will be disposed through the DoD Executive Agent for low-level radioactive waste disposal. USACE disposal of DoD LLRW waste must be coordinated through the EM CX. The EM CX will then coordinate the action with the DoD executing agent for low-level radioactive waste disposal

c. A DoD Component that generates LLRW from an environmental restoration site will coordinate its disposal plans with the Executive Agent prior to taking LLRW disposal actions. This will allow the Executive Agent the opportunity to review the plans for safety and compliance.

9-8. Management Guidelines for Working With Radioactive and Mixed Waste.

EM 1110-35-1 should be consulted when radioactive waste is generated and requires management. Following is a description of the contents of EM 1110-35-1.

a. Chapter 1 explains the purpose, scope and intended audience of this guidance document. It lists some important units, quantities and conversions that are necessary to fully understand and work on remediation of radioactively contaminated sites.

b. Chapter 2 explains how the presence of radioactive waste affects the necessary actions and associated management of a project.

- c. Chapter 3 explains the TPP approach to managing remediation at sites contaminated with radioactive materials.
- d. Chapter 4 discusses health and safety concerns relative to a radioactive site.
- e. Chapter 5 describes the conceptual site model and risk assessment.
- f. Chapter 6 describes sampling of radioactive materials.
- g. Chapter 7 describes characterization of sites.
- h. Chapter 8 describes characterizing radioactive waste.
- i. Chapter 9 addresses the primary regulatory processes involved at radioactive remediation sites.
- j. Chapter 10 addresses remedies and innovative technologies that may be used at radioactive remediation sites.
- k. Chapter 11 explains the procedures and issues involved in transportation of radioactive materials.
- l. Chapter 12 discusses options and methods of disposal of radioactive materials.
- m. Chapter 13 discusses the Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM) Final Status Survey (FSS).
- n. Appendix A provides references and bibliography of regulatory documents, regulations and laws.
- o. Appendix B provides contact information for Federal and state radiation control agencies.
- p. Appendix C includes technical information on radioactive materials, decay, measuring techniques, and instrumentation.
- q. Appendix D lists some typical remediation site characteristics.

## CHAPTER 10

### Laser Safety

10-1. Introduction. As stated in Chapter 2, any Command whose personnel are occupationally exposed to class IIIb or class IV lasers shall have a Laser Safety Officer (LSO). The LSO shall ensure that personnel exposure to laser radiation is kept within guidelines listed in ANSI Z136.1 and ANSI Z136.3, and that work with lasers is accomplished in accordance with OSHA regulations as stated in 29 CFR 1926.54, and USACE guidance in EM 385-1-1. This shall be accomplished by establishing and ensuring compliance with a Laser Protection Program.

10-2. Classifications of Lasers. Lasers are classified by their hazard capabilities. There are two classification systems, the "old system" used before 2002, and the "revised system" being phased in since 2002. The ANSI Z136.1 standard accurately defines the classifications of lasers depending on the power output and light wavelength, but in general the "old" and "revised" classifications are as shown in the following tables:

Table 10-1 Old System Classification

Class I	Cannot produce hazardous radiation. These devices may contain an embedded class IIIb or class IV laser.
Class II	Continuous intrabeam exposure may damage the eye. Momentary intrabeam exposure (<0.25 second) is not damaging to the eye.
Class III	Can damage the eye during momentary intrabeam exposure.
Class IIIa	Intermediate power lasers (1-5mW) – Only hazardous for intrabeam viewing.
Class IIIb	Moderate power lasers (5-500mW) – In general Class IIIb lasers will not be a fire hazard, nor are they generally capable of producing a hazardous diffuse reflection.
Class IV	May damage the skin as well as the eye during momentary intrabeam exposure or exposure to diffuse reflection. These lasers may be fire hazards and may produce laser generated air contaminants (ozone) and plasma radiation.

Table 10-2 Revised System Classifications

Class 1	Safe under all conditions of normal use. This means the maximum permissible exposure (MPE) cannot be exceeded when viewing a laser with the naked eye or with the aid of typical magnifying optics (e.g. telescope or microscope).
Class 1M	Safe for all conditions of use except when passed through magnifying optics such as microscopes and telescopes. The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam.
Class 2	Safe because the blink reflex will limit the exposure to no more than 0.25 seconds. Many laser pointers and measuring instruments are class 2.
Class 2M	Safe because of the blink reflex if not viewed through optical instruments.
Class 3R	Safe if handled carefully, with restricted beam viewing. With a class 3R laser, the MPE can be exceeded, but with a low risk of injury
Class 3B	Hazardous if the eye is exposed directly, but diffuse reflections such as those from paper or other matte surfaces are not harmful. Protective eyewear is typically required where direct viewing of a class 3B laser beam may occur.
Class 4	The highest and most dangerous class of laser. By definition, a class 4 laser can burn the skin, or cause devastating and permanent eye damage as a result of direct, diffuse or indirect beam viewing. Most industrial, scientific, military, and medical lasers are in this category.

10-3. Laser Protection Program. A Laser Protection Program, is required for Commands where personnel may be exposed to class IIIa, class IIIb or class IV laser radiation, should consist of the following:

- a. List of personnel responsibilities and qualifications,
- b. List of training requirements for operators and bystanders,
- c. Description of the types and hazard potentials for the types of lasers used in the Command,
- d. Description of laser safety measures used in the Command,
- e. Compendium of Standing Operating Procedures for the lasers used within the Command, and

f. Emergency response plan.

10-4. OSHA Standards. OSHA 29 CFR 1926.54 addresses worker exposure to non-ionizing radiation. OSHA requires that:

- a. Only qualified and trained personnel work with laser equipment,
- b. Proof of qualification shall be carried by the operator,
- c. If the potential for exposure to direct or reflected laser light above the exposure limit exists, then workers will be furnished with acceptable eye protection,
- d. Laser work areas must be properly posted,
- e. Beam shutters and caps must be utilized,
- f. Unattended lasers shall be shut off,
- g. Only mechanical or electrical means will be used for beam alignment; beam alignment will not be made by eye,
- h. The beam shall not be directed at employees,
- i. Lasers shall not be used in the rain or in foggy conditions if possible,
- j. Each laser shall be labeled to indicate its maximum output,
- k. Lasers shall be used above the heads of personnel when possible, and
- l. Employees shall not be exposed to light intensities above the exposure limits.

10-5. USACE Standards. Refer to the following indicated references for personnel radiation exposure standards for laser radiation: ANSI Z136.1, ANSI Z136.3, and ANSI Z136.6, 21 CFR 1040, DoDI 6055.15, and TB Med 524.

10-6. DOD Program.

(a) The US Army Public Health Command (PHC) Laser/Optical Radiation Program has served as the Army's laser safety consultant for over 30 years. The Laser/Optical Radiation Program is the Department of Defense's leader in laser hazard analysis providing support to all the Uniformed Services as well as many other Federal agencies. PHC has extensive laboratory, field service and data collection capabilities and should be contacted for laser safety support.

(b) PHC serves as the Army's functional area expert for laser radiation. PHC should be contacted to obtain the Maximum Permissible Exposure (MPE) which is the level of laser radiation to which a person may be exposed without known hazardous effects or adverse biological changes in the eye or skin per American National Standards Institute (ANSI) Standard Z136.1 (Reference (e)).

10-7. Suspected Laser Eye Injuries.

a. Immediately evacuate personnel suspected of experiencing potentially damaging eye exposure from laser radiation to the nearest medical facility for an eye examination. Laser eye injuries require immediate specialized ophthalmologic care to minimize long-term visual acuity loss. Medical personnel should obtain medical guidance for laser injuries from the Tri-Service Laser Incident Hotline, (800) 473-3549 or 1-888-232-3764, DSN 798-3764, commercial (937) 938-3764, or e-mail [ESOH.Service.center@wpafb.af.mil](mailto:ESOH.Service.center@wpafb.af.mil).

b. Report all nonionizing incidents or accidents to:

(1) Commander, Public Health Command, 5158 Blackhawk Road, Aberdeen Proving Ground, MD 21010-5403, (800) 222-9698 (24 hour phone line).

(2) Public Health Command Laser/Optical Radiation Program (DSN 584-3932/ 2331 or commercial (410) 436-3932/2331 or (800) 222-9698 after duty hours) (e-mail [laserincident@amedd.army.mil](mailto:laserincident@amedd.army.mil)).

## CHAPTER 11

### Radio Frequency and Microwave Safety

#### 11-1. General.

a. A Radio Frequency Safety Officer (RFSO) will be designated whenever there are RF sources that exceed the permissible exposure limits (PEL) of DoDI 6055.11. An RFSO with responsibility for a nonionizing Radiation Safety Program (other than a laser program) shall complete a formal course of instruction addressing such topics as RF radiation, terminology, biological effects, and exposure control measures. An acceptable course is offered by the Army Public Health Command.

b. The duties of an RFSO are listed in section 4.1.2.1, Institute of Electrical and Electronics Engineers (IEEE) C95.7

c. USACE will comply with RF Radiation Safety Program elements in DoDI 6055.11. Type-classified RF electromagnetic radiation (EMR) emitting system users will comply with radiation safety requirements in applicable technical publications.

d. Users will adopt no practice and conduct no operation involving planned exposure of personnel to RF levels in excess of the applicable maximum permissible exposures in DoDI 6055.11.

e. Routine use of RF protective clothing to protect personnel is prohibited. Protective equipment, such as electrically insulated gloves and shoes for protection against RF shock and burn, or for insulation from the ground plane, is permissible when engineering controls or procedures cannot eliminate exposure hazards and ensure compliance with induced current limits in DoDI 6055.11. Users will identify, attenuate, or control potentially hazardous RF electromagnetic fields and other radiation hazards associated with Army electronic equipment by engineering design, administrative actions, or protective equipment (in that order), or a combination thereof. Use process and engineering controls before personal protective equipment to protect workers.

f. Proponents of RF EMR-emitting systems will include radiation safety requirements in technical publications about siting, operation, and maintenance of these systems.

#### 11-2. Measurement and Evaluation of Radio Frequency Fields.

a. Use measurement procedures and techniques recommended in IEEE C95.3 as basic guidance for evaluating RF hazards.

b. Records of surveys, reports, calculations, and control measures for each type-classified RF EMR emitter will be maintained by the RFSO.

c. Where multiple RF EMR emitters are located in fixed arrangements, RF evaluation data will include a determination of weighted contributions from expected simultaneously operated emitters.

11-3. Siting Commercial Telecommunications Equipment on Army Installations.

Guidance for siting commercial telecommunications equipment on Army installations is obtained from the Defense Information Systems Agency Joint Spectrum Center (JSC), Defense Switched Network (DSN) 281–2555 or commercial 410–293–2555.

11-4. Warning Signs.

a. RF warning signs are required to be posted at all access points to areas where levels exceed the PELs. Posting should be determined and maintained by the Safety and Occupational Health Office (SOHO).

b. Where 10 times the PELs are exceeded, other warning devices, such as flashing lights, audible signals, barriers or interlocks should be used.

c. RF protective clothing shall not be used as a routine method of protecting personnel from RF levels that exceed the PELs.

11-5. RF Safety Training. USACE personnel routinely working with equipment that emits RF levels that may exceed the PELs shall receive training from the RFSO, addressing:

- a. Potential hazards of RF,
- b. Procedures and restrictions to control RF exposures, and
- c. Their responsibility to limit their RF exposure.

Timely refresher training in RF safety shall be incorporated into other periodic safety training programs.



## APPENDIX A

### References

#### Section I Required Publications

10 CFR Energy, Chapter 1 Nuclear Regulatory Commission

21 CFR Food and Drugs

29 CFR Labor

40 CFR Transportation

NUREG-1566  
Consolidated Guidance About Materials Licenses

NUREG-1757  
Consolidated Decommissioning Guidance

DOD 4715.6-R  
Low-Level Radioactive Waste Disposal Program

DoDI 6055.8  
Occupational Radiation Protection Program

DoDI 6055.11  
Protection of DoD Personnel from Exposure to Radio Frequency Radiation and Military Exempt Lasers

DoDI 6055.15  
DoD Laser Protection Program

AR 11-34  
Respiratory Protection

AR 40-5  
Preventive Medicine

AR 40-13  
Radiological Advisory Medical Teams

AR 50-5  
Nuclear Surety

AR 50-7  
Army Reactor Program

AR 200-1  
Environmental Protection and Enhancement

AR 385-10  
U.S. Army Safety Program

DA PAM 385-24  
The Army Radiation Safety Program

TB 43-0180  
Calibration and Repair Requirements for the Maintenance of Army Materiel

TB 750-25  
Maintenance of Supplies and Equipment, Army TMDE, Calibration and Repair Support Program

TB MED 524  
Control of Hazards to Health From Laser Radiation

TM 38-250  
Packing and Handling: Hazardous Materials

TM 3-261  
Handling and Disposal of Unwanted Radioactive Materials

TM 55-315  
Transportability Guidance for the Safe Transport of Radioactive Materials

EM 385-1-1  
Safety and Health Requirements Manual

EM 1110-35-1  
Management Guidelines for Working With Radioactive and Mixed Waste

ER 385-1-80  
Ionizing Radiation Protection

ER 385-1-92

USACE Safety and Occupational Health Document for Hazardous, Toxic and Radiological Waste Activities

ANSI Z136.1

American National Standard for Safe Use of Lasers'.

ANSI Z136.3

Safe Use of Lasers in Health Care Facilities

ANSI Z136.6

Safe Use of Lasers Outdoors

IEEE C95.1-1991

IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency electromagnetic Fields, 3kHz to 300 Ghz

IEEE C95.3-1991

IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields-RF and Microwave

IEEE C95.7

IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

NCRP 160

Ionizing Radiation Exposure of the Population of the United States

Section II

Related Publications

NUREG 1505, Rev 1

A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys

NUREG 1507

Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminates and Field Conditions

Public Law 93–438

Energy Reorganization Act of 1974

AR 11-34

The Army Respiratory Protection Program

AR 40-13  
Medical Support-Nuclear/Chemical Accidents and Incidents

DA PAM 40-18  
Personnel Dosimetry Guidance & Dose Recording Procedures for Personnel  
Occupationally Exposed to Ionizing Radiation  
FM 8–50  
Prevention and Medical Management of Laser Injuries

TB 43-0116  
Identification of Radioactive Items in the Army

OTSG Policy Memo, dated 11 April 1994  
Subject: Surveillance of Laser and Radio frequency Radiation Personnel

ANSI N13.12  
Surface and Volume Radioactivity Standards for Clearance

ANSI N13.30  
American National Standards Institute, Performance Criteria for Radiobioassay

International Air Transport Association, Section 10  
Dangerous Goods Regulation

## GLOSSARY

### Section I

#### Abbreviations

μCi	microcurie
ALARA	as low as is reasonably achievable
ALI	annual limit of intake
Am-Be	American-beryllium
APR	air-purifying respirator
ARA	Army Radiation Authorization
AS	Agreement State
AU	Authorized User
AUA	Authorized User's Assistant
Bq	becquerel
C/kg	coulombs per kilogram
CDE	committed dose equivalent
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act "Superfund"
CO	Commanding Officer
cpm	counts per minute
DA	U.S. Department of the Army
DDE	deep dose equivalent
DoD	U.S. Department of Defense

DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegrations per second
dps	disintegrations per second
EDE	effective dose equivalent
EPA	Environmental Protection Agency
EMCX	Environmental and Munitions Center of Expertise
EMF	electromagnetic fields
EQ	equation
FOA	field operating activity
FUDS	Formerly Used Defense Site
GM	Geiger-Mueller
Gy	gray
HP	Health Physicist
IATA	International Air Transport Association
ICRU	International Committee for Radiation Units
keV	kilo-electron volts
LLRW	low level radioactive waste
LSA	Low Specific Activity
LSO	Laser Safety Officer
MACOM	Major Army Command
MARLAP	Multi-Agency Radiological Laboratory Analytical Procedures Manual
MARSAME	Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual

MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCA	multi-channel analyzer
mCi	millicurie
MeV	mega-electron-volts
mR/hr	milliroentgen per hour
mR	milliroentgen
MW	mixed waste
NaI	sodium iodide
NARM	Naturally Occurring or Accelerator Produced Radioactive Material
NRC	Nuclear Regulatory Commission
NCRP	National Council on Radiation Protection and Measurements
NIST	National Institute of Standards and Technology
NORM	naturally occurring radioactive material
NRC	U.S. Nuclear Regulatory Commission
NVLAP	National Voluntary Laboratory Accreditation Program
OSHA	Occupational Safety and Health Administration
OSL	Optically Simulated Luminescence
pCi	picocurie
PEL	permissible exposure limit
PPE	personnel protective equipment
PHC	Public Health Command
Q	quality factor
R/hr	roentgens per hour
R	roentgen

Rad	radiation absorbed dose
RAM	radioactive material
RCRA	Resource Conservation and Recovery Act
rem	Roentgen Equivalent Man
RF	radio frequency
RFSO	Radio Frequency Safety Officer
RSC	Radiation Safety Committee
RSO	Radiation Safety Officer
RSSO	Radiation Safety Staff Officer
RSST	Radiation Safety Support Team
SAR	specific absorption rate
SDE	shallow dose equivalent
SOP	standing operating procedure
STC	strong, tight container
Sv	Sievert
$T_{1/2}$	half-life
TEDE	total effective dose equivalent
TI	transport index
USACE	U.S. Army Corps of Engineers
USAIRDC	U.S. Army Ionizing Radiation Dosimetry Center
USAF	U.S. Air Force
USPS	U.S. Postal Service



## GLOSSARY

### Section II

#### Terms

#### ABSORBED DOSE

The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. (See Rad)

#### ABSORPTION

The phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

#### ACTIVITY

The number of nuclear disintegrations occurring in a given quantity of material per unit time. (See curie)

#### ALPHA PARTICLE

A strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

#### ANNUAL LIMIT OF INTAKE (ALI)

The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year.

#### ATOM

Smallest particle of an element which is capable of entering into a chemical reaction.

#### BACKGROUND RADIATION

Ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

#### BETA PARTICLE

Charged particle emitted from the nucleus of an atom, having a mass and charge equal in magnitude to that of the electron.

#### CALIBRATION

Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors.

## BYPRODUCT MATERIAL

There are basically four types of byproduct material:

a. The [Atomic Energy Act](#), as revised in 1978 and in 2005 by the Energy Policy Act (EPAcT), defines byproduct material in Section 11e.(1) as radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or using special nuclear material.

b. The definition in Section 11e.(2) is the tailings or wastes produced by the extraction or concentration of [uranium](#) or thorium from any ore processed primarily for its source material content.

c. The definition in Section 11e.(3) is any discrete source of radium-226 that is produced, extracted, or converted after extraction, before, on, or after the date of enactment of the EPAcT for use for a commercial, medical, or research activity; or any material that has been made radioactive by use of a particle accelerator and is produced, extracted, or converted after extraction, before, on, or after the date of enactment of the EPAcT for use for a commercial, medical, or research activity.

d. The definition in Section 11e.(4) is any discrete source of naturally occurring radioactive material, other than source material, that the Commission, in consultation with the Administrator of the Environmental Protection Agency (EPA), the Secretary of the Department of Energy (DOE), the Secretary of the Department of Homeland Security (DHS), and the head of any other appropriate Federal agency, determines would pose a threat similar to the threat posed by a discrete source of radium-226 to the public health and safety or the common defense and security; and is extracted or converted after extraction before, on, or after the date of enactment of the EPAcT for use in a commercial, medical, or research activity.

## COMMITTED DOSE EQUIVALENT (CDE) - ( $H_{T, 50}$ )

The dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50 year period following the intake.

## COMMITTED EFFECTIVE DOSE EQUIVALENT (CEDE) - ( $H_{g, 50}$ )

The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the Committed Dose Equivalent to these organs or tissues.

## CONTAMINATION, RADIOACTIVE

Deposition of radioactive material in any place where it is not desired, and particularly in any place where the presence may be harmful.

### COUNT (Radiation Measurements)

The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse.

### CRITICAL ORGAN

That organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his or her descendants.

### CURIE

The quantity of any radioactive material in which the number of disintegrations is  $3.700 \times 10^{10}$  per second. Abbreviated Ci. Millicurie - One-thousandth of a curie ( $3.7 \times 10^7$  disintegrations per second). Abbreviated mCi. Microcurie - One-millionth of a curie ( $3.7 \times 10^4$  disintegrations per second). Abbreviated  $\mu$ Ci. Picocurie - One-millionth of a microcurie ( $3.7 \times 10^{-2}$  disintegrations per second or 2.22 disintegrations per minute). Abbreviated pCi.

### DECAY, RADIOACTIVE

Disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

### DECLARED PREGNANT WOMAN

A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

### DEEP DOSE EQUIVALENT (DDE) - ( $H_d$ )

Applies to external whole-body exposure; the dose equivalent at a tissue depth of 1 cm ( $1000 \text{ mg/cm}^2$ ).

### DERIVED AIR CONCENTRATIONS (DAC)

The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate  $1.2 \text{ m}^3/\text{hr}$ ), results in an intake of one ALI.

### DETERMINISTIC (NON-STOCHASTIC EFFECTS)

Health effects, the severity of which varies with dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a deterministic effect (also called a nonstochastic effect).

### DOSE

A general term denoting the quantity of radiation or energy absorbed in a specified mass. For special purposes, it must be appropriately qualified (for example, absorbed dose).

### DOSE, ABSORBED

The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad (or prefixed forms of the unit such as millirad); which is 100 ergs/gram. The SI unit for the rad is the gray. 1 gray = 100 rads.

### DOSE, EQUIVALENT

A quantity used in radiation protection expressing all radiation on a common scale for calculating the effective absorbed dose. The unit of dose equivalent is the rem, which is numerically equal to the absorbed dose in rads multiplied by certain modifying factors such as the quality factor, the distribution factor, etc.

### EFFECTIVE DOSE EQUIVALENT (EDE) - ( $H_E$ )

The sum of the products of the dose equivalent to organ or tissue ( $H_T$ ) and the weighting factors ( $W_T$ ) applicable to each of the body organs or tissues that are irradiated.

### ELECTRON

Negatively charged elementary particle which is a constituent of every neutral atom. Its unit of negative electricity equals  $4.8 \times 10^{-19}$  coulombs. Its mass is 0.00549 atomic mass units.

### ELECTRON VOLT

A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviated eV. Larger multiple units of the electron volt frequently used are: keV for thousand or kiloelectron volts, MeV for million electron volts and BeV for billion electron volts.

### EXPOSURE

A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in volume element of air are completely stopped in air, divided by the mass of air in the volume element. The special unit of exposure is the roentgen.

### EXTREMITY

The hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

### EYE DOSE EQUIVALENT (EDE)

Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter ( $300 \text{ mg/cm}^2$ ).

### FILM BADGE

A packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films

of differing sensitivity, and it may contain filters which shield parts of the film from certain types of radiation.

#### GAMMA RAY

Very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to x-ray.

#### GEIGER-MUELLER (G-M) COUNTER

Highly sensitive gas-filled detector and associated circuitry used for radiation detection and measurement.

#### GENETIC EFFECT OF RADIATION

Inheritable changes, chiefly mutations, produced by the absorption of ionizing radiation. On the basis of present knowledge these effects are purely additive, and there is no recovery.

#### HALF-LIFE, BIOLOGICAL - ( $B_{1/2}$ )

The time required for the body to eliminate one-half of an administered dose of any substance by the regular processes of elimination. This time is approximately the same for both stable and radionuclides of a particular element.

#### HALF-LIFE, EFFECTIVE - ( $E_{1/2}$ )

Time required for a radioactive nuclide in a system to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$E_{1/2} = (B_{1/2} \times T_{1/2}) / (B_{1/2} + T_{1/2})$$

#### HALF-LIFE, RADIOACTIVE - ( $T_{1/2}$ )

Time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

#### HEALTH PHYSICS

The science concerned with recognition, evaluation and control of health hazards from ionizing and non-ionizing radiation.

#### HIGH RADIATION AREA

An area accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

#### ION

Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

### IONIZATION

The process by which a neutral atom or molecule acquires either a positive or a negative charge.

### IONIZATION CHAMBER

An instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

### IONIZATION, SPECIFIC

The number of ion pairs per unit length of path of ionizing radiation in a medium (for example, per centimeter of air or per micron of tissue).

### IONIZING RADIATION

Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

### ISOTOPES

Nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

### MILLIROENTGEN (mR)

A submultiple of the roentgen equal to one one-thousandth (1/1000th) of a roentgen.

### MONITORING, RADIOLOGICAL

Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region as a safety measure for purposes of health protection. For example, Area Monitoring: Routine monitoring of the level of radiation or of radioactive contamination of any particular area, building, room or equipment. Personnel Monitoring: Monitoring any part of an individual, or any part of his clothing (See Radiological Survey).

### NEUTRON

Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

### NUCLIDE

A species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

### OCCUPATIONAL EXPOSURE

The exposure received by an individual in a restricted area or in the course of employment in which the individual's assigned duties involve exposure to ionizing radiation or radioactive material from licensed or unlicensed sources of radiation, whether in the possession of the licensee or another person. Occupational exposure does not include exposure to background radiation, as a patient in medical practices, from voluntary application in medical programs, or as a member of the general public. Workplace exposure to naturally occurring radioactive material, such as radon, is considered background radiation by NRC but may be considered an occupational exposure by OSHA and regulated under 29 CFR 1910.1096

### PLANNED SPECIAL EXPOSURE (PSE)

An infrequent exposure to radiation, separate from and in addition to the annual NRC (Tier 1) dose limit.

### PROTECTIVE BARRIERS

Barriers of radiation absorbing material, such as lead, concrete, plaster, and plastic, that are used to reduce radiation exposure. Protective Barriers, Primary: Barriers sufficient to attenuate the useful beam to the required degree. Protective Barriers, Secondary: Barriers sufficient to attenuate stray or scattered radiation to the required degree.

### RADIATION

1. The emission and propagation of energy through space or through a material medium in the form of waves or particles; for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves.
2. The energy propagated through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term "radiation" or "radiant energy," when unqualified, usually refers to electromagnetic radiation. Such radiation commonly is classified according to frequency as Hertzian, infrared, visible (light), ultraviolet, x-ray, and gamma ray.
3. By extension, corpuscular emissions, such as alpha and beta radiation, or rays of mixed or unknown type, as cosmic radiation.

### RADIATION AREA

An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters.

### RADIATION SAFETY SUPPORT TEAM

A team of USACE Health Physicists capable of providing health physics support to all USACE Divisions, Districts, Centers and Laboratories. The RSST can be accessed via the EM CX at <http://www.environmental.usace.army.mil/>.

#### RADIATION SURVEY

Evaluation of the radiation hazards incident to the production, use or existence of radioactive materials or other sources of radiation under a specific set of conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and a sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

#### RADIONUCLIDE

A nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

#### RADIOTOXICITY

Term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.

#### RELATIVE BIOLOGICAL EFFECTIVENESS (RBE)

For a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

#### REM

The special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors.

#### ROENTGEN (R)

The amount of X or gamma radiation below 3 MeV in energy which produces  $2.58 \times 10^{-4}$  coulombs per kilogram (C/kg) of dry air. The roentgen is the special unit of exposure.

#### SCINTILLATION COUNTER

A counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube.

#### SHALLOW DOSE EQUIVALENT (SDE) - ( $H_s$ )

Applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeters ( $7 \text{ mg/cm}^2$ ) averaged over an area of 1 square centimeter. Shallow Dose Equivalent, Whole Body (WB) means for purposes of external exposure, head, trunk (including male gonads), arms above the elbow or



legs above the knee. Shallow Dose Equivalent, Maximum Extremity (ME) means for purposes of external exposure, arms below the elbow or legs below the knee.

#### SHIELDING MATERIAL

Any material which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in some cases eliminate it. Lead, concrete, aluminum, water, and plastic are examples of commonly used shielding material.

#### SIEVERT

The SI unit of dose equivalent, 1 sievert (Sv) equals 100 rem.

#### SMEAR (Smear or Swipe Test)

A procedure in which a swab, for example, a circle of filter paper, is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose radioactive material.

#### SPECIFIC ACTIVITY

Total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

#### SOURCE MATERIAL

Either the element thorium or the element uranium, provided that the uranium has not been enriched in the isotope uranium-235. Source material also includes any combination of thorium and uranium, in any physical or chemical form, or ores that contain by weight one-twentieth of one percent (0.05 percent) or more of uranium, thorium, or any combination thereof. Depleted uranium (left over from uranium enrichment) is considered source material.

#### SPECIAL NUCLEAR MATERIAL

Defined by Title I of the [Atomic Energy Act of 1954](#) as plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. The definition includes any other material that the Commission determines to be special nuclear material, but does not include source material. The NRC has not declared any other material as SNM.

#### STOCHASTIC EFFECT

Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

#### TOTAL EFFECTIVE DOSE EQUIVALENT (TEDE)

The sum of the Deep Dose Equivalent (for external exposures) and the Committed Effective Dose Equivalent (for internal exposures).

#### TOTAL ORGAN DOSE EQUIVALENT (TODE)

The sum of the Deep Dose Equivalent ( $H_d$ ) and the Committed Dose Equivalent ( $H_{T,50}$ ) to any individual organ or tissue, other than the lens of the eye, being equal to 50 rems (0.5 Sv).

#### THERMOLUMINESCENT DOSIMETER

A dosimeter made of certain crystalline material which is capable of both storing a fraction of absorbed ionizing radiation and releasing this energy in the form of visible photons when heated. The amount of light released can be used as a measure of radiation exposure to these crystals.

#### VERY HIGH RADIATION AREA

An area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at a meter from a radiation source or from any surface that the radiation penetrates.

#### WEIGHTING FACTORS ( $W_T$ )

For an organ or tissue (T) is the proportion or the risk of stochastic effect resulting from irradiation of that organ or tissue of the total risk of stochastic effect when the whole body is irradiated uniformly.

#### X-RAYS

Penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extranuclear part of the atom as x-rays. These rays are sometimes called roentgen rays after their discoverer, W.C. Roentgen.