DEPARTMENT OF THE NAVY
BUREAU OF MEDICINE AND SURGERY
7700 ARLINGTON BOULEVARD
FALLS CHURCH VA 22042

IN REPLY REFER TO
BUMEDINST 6470.10C
BUMED-M3
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BUMED INSTRUCTION 6470.10C

From: Chief, Bureau of Medicine and Surgery

Subj: MANAGEMENT OF IRRADIATED OR RADIOACTIVELY CONTAMINATED PERSONNEL

Ref: See enclosure (1)

Encl: (1) References
(2) Definitions
(3) Planning Guidance for a Radiological Casualty Response
(4) External Irradiation
(5) Determination of Dose from External Irradiation
(6) Deterministic Effects of Exposure to Ionizing Radiation and Acute Radiation Syndromes
(7) Radiological Surveys of Personnel and Areas
(8) External Contamination and Decontamination
(9) Internal Contamination and Decontamination
(10) Wound Contamination and Decontamination
(11) Collection and Processing of Bioassay and Bio-dosimetry Samples
(12) Information on Select Radionuclides
(13) Supplies for Personnel Decontamination
(14) Contact List

1. Purpose. References (a) through (v) listed in enclosure (1), provide guidance to applicable Navy and Marine Corps commands and Navy-sponsored operations for the assessment, management, and treatment of personnel who are externally irradiated, externally contaminated with radioactive material, or internally contaminated with radioactive material, with or without compounding physical injury, due to an unplanned exposure from a radiological event or emergency. Enclosure (1) contains the references used within this instruction. Enclosures (2) through (12) are provided to assist in managing the medical and radiological controls aspects pertaining to irradiated or contaminated persons who may also be injured. Memorization of the specifics (e.g., instrument reading to dose conversion factors) is neither necessary nor intended. Enclosure (13) provides guidance to commands on supplies for personnel decontamination. This instruction is a complete revision and should be read in its entirety. The changes in subparagraphs 1a through 1g have been implemented.

a. Implemented new planning guidance for a radiological casualty response, dose estimation methods for external irradiation, deterministic effects, and acute radiation syndromes.

b. Implemented new guidance on conducting radiological surveys of personnel.

c. Implemented new guidance on collecting and processing of bioassay and bio-dosimetry samples.

d. Updated and expanded information in enclosures pertaining to external irradiation, external contamination, wound contamination, internal contamination, and decontamination methods.

e. Updated information on select radionuclides and consolidated into one enclosure. Added a summary data table of the select radionuclides that are associated with the Navy Radiation Health Program.

f. Included diagrams for documenting radiation survey data acquired during decontamination evolutions.

g. Implemented required information based on current Bureau of Medicine and Surgery (BUMED) standards for directives to include records management and review and effective date.

2. Cancellation. BUMEDINST 6470.10B.

3. Scope and Applicability

a. This instruction applies to Navy and Marine Corps commands and Navy sponsored operations, which have personnel that could potentially be externally or internally contaminated with radioactive material or irradiated while conducting their duties. It also applies to Navy medical treatment facilities (MTF) or medical departments located within Navy sea- and shore-based commands that have medical and radiological personnel that could respond to a radiological casualty and provide medical treatment and decontamination support. In the absence of Defense Health Agency (DHA) guidance, this instruction may be used to assist DHA-affiliated MTF response personnel in the medical management of irradiated or radioactively contaminated personnel.

b. This instruction primarily applies to the period from actual irradiation or contamination of an individual, with or without physical injury, to the time when the individual is medically stabilized and fully decontaminated if applicable. This includes the transfer of a seriously injured individual to a designated MTF with definitive care capability and the individual's stay at the MTF including decontamination support, if applicable. It also provides directives, information, and guidance on possible follow-up actions or care (e.g., bioassay and bio-dosimetry analysis and internal dose mitigation therapy) that may be required after the initial medical and radiological response.

Note: Definitive care is defined as the complete medical, surgical, and health physics support necessary to provide a comprehensive evaluation and treatment of seriously irradiated, contaminated, or injured personnel, or any combination of the three.

c. Although applicable to the irradiation or contamination of individuals following emergency exposure situations that are unexpected, such as an act of terrorism or an act of war, the procedures outlined in this instruction are intended primarily for use in occupational or accidental exposure environments.

4. Background

a. The use of radiation sources within Navy and Marine Corps commands and Navy-sponsored operations continues to expand, which increases the risk for personnel to be accidentally irradiated or contaminated. Sources of radiation include radioactive material, machine- or power-generated x-ray machines, and linear accelerators. The sources encountered, including radionuclides of interest, can vary depending on the area of operations, to include nuclear propulsion, medicine, nuclear weapons, industry, and research.

b. The procedures and guidelines involving medical and radiological control response, general information, and physical data contained in enclosures (2) through (12) were compiled from references (a) through (v). It is highly recommended that commands retain electronic copies of these references.

c. The values found in this instruction are sufficiently accurate to predict the dose and clinical response. However, prior to assigning a dose of record, a health physicist, medical physicist, or other qualified radiation health personnel should verify these values, along with the validity of the dose methodology, with the values stated in the most recent scientific literature and applicable reports. Recognized authorities on radiation protection standards include the international commission on radiological protection (ICRP) and the national council on radiation protection and measurements (NCRP). The assignment of a dose of record will normally be in consultation with the BUMED Radiation Effects Advisory Board (REAB).

5. Action. Local procedures or guidelines for the management of irradiated or contaminated individuals, with or without injuries, due to a radiological casualty, must be developed by applicable commands defined in paragraph 3. See enclosure (14) for contact information for guidance and support, if required, and enclosure (3) for planning considerations to support the development of command procedures or guidelines.

6. Medical Care

a. The treatment of life-, limb-, or vision-threatening injuries always takes precedence over radiological controls. During emergency treatment of a contaminated-injured person, it is acceptable to spread contamination and not consider decontamination efforts until the attending

physician deems the patient is medically stable. After this point, radiological controls should be implemented to minimize or prevent internal and wound contamination, spreading of contamination in general, and skin dose.

Notes: 1. The possible contamination, or efforts to minimize the spread of contamination of medical personnel, should only be considered after the injured person has been medically stabilized. However, standard precautions taken by medical personnel for bloodborne pathogens always apply, and the use of these precautions in most situations is effective at controlling contamination during medical emergencies.

2. In general, medical personnel should avoid wearing unnecessary personal protective equipment, which would impose undue stress, reduce their manual dexterity, and cause anxiety in the patient. Respirators are likely unnecessary unless the individual is highly contaminated. Another consideration is to avoid securing ventilation unless required by an applicable command radiological control manual.

b. Under no circumstances will any person be denied access to necessary medical treatment or MTFs because the person is contaminated, externally or internally, by radioactive material.

Note: A key principle during casualty response is to ensure emergency medical personnel rendering emergent care are not impeded. The radiation exposure hazard to medical personnel from treating contaminated injured persons will likely be minimal. Therefore, necessary medical or surgical treatment must not be delayed. It is instructive to note that no health care worker in the United States has ever suffered a radiation injury secondary to rendering emergency care to a contaminated-injured person.

c. An individual's survival from radiation exposure or radioactive contamination should not be in question unless one or more of the listed events occurred:

(1) Dose to the entire body exceeds 200 rad (2 Gy).

(2) Dose to a major segment of the body, e.g., head or thoracic region, is approximately several hundred to thousands of rad.

(3) There is a combination of serious physical injury and dose, termed combination injury.

d. Proper medical treatment of an individual involved in a radiological casualty is based upon the severity of the physical injury and an understanding of the estimated dose received from the particular isotope. Table 1 provides the proper priorities when processing irradiated or radioactively contaminated persons, whether they are injured or not. The use of Table 1 is required to ensure a person irradiated or radioactively contaminated is properly treated.

e. In all instances of irradiation or contamination, treat the exposed person symptomatically until the appropriate medical and health physics evaluations have been performed. If a person receives an exposure, which is not expected to produce clinical symptoms, care should be taken not to frighten the person or to give the perception a significant exposure has occurred. Alleviation of fears will reduce psychosomatic symptoms, which can be misinterpreted to be symptoms of high radiation exposure.

Notes: During a casualty response, it is important to ensure medical responders are not impeded when rendering emergent care for reasons such as issuing dosimeters or controlling access to restricted areas. To stop emergency personnel in such situations displays a lack of understanding and good judgment. Though medical treatment of life-, limb-, or vision-threatening injuries takes priority over radiological controls, radiological control actions may be carried out simultaneously as long as the actions do not impede medical treatment. Examples include pre-staging of radiological control response items to establish a potentially contaminated area or personnel processing area or the partial establishment of a potentially contaminated area, as long as the medical response (e.g., including arrival of an ambulance, treatment by emergency responders, and the egress route) is not impaired.

| Priority | Description | Action |
|---|---|---|
| 1 | Life-, limb-, or vision-threatening injuries (survival questionable) with external irradiation, external, internal or wound contamination. | Manage airway, breathing, and circulation. Transport to MTF for treatment before decontamination efforts. Perform external decontamination, in vitro bioassay, in vivo bioassay (internal monitoring) analysis, internal decontamination, or a combination of these activities as required, once the treating provider declares the person medically stable. Contacting the BUMED REAB is required. See enclosures (4) through (12) for guidance, as applicable. |
| 2 | High external radiation doses (> 400 rad (4 Gy)) to whole body, hundreds of rad to the head or thoracic region), combination of serious physical injury and high dose. Survival questionable. May or may not have external, internal, wound contamination, or a combination of these. | Manage airway, breathing, and circulation. Transport to MTF before decontamination and treat for acute radiation syndrome (ARS). Perform external decontamination, in vitro bioassay, in vivo bioassay (internal monitoring) analysis, internal decontamination, or a combination of these activities as required, once the treating provider declares the person medically stable. Contacting the BUMED REAB is required. See enclosures (4) through (12) for guidance, as applicable. |
| 3 | Physical injuries (not life-threatening, but requiring medical attention) with an external radiation dose less than 400 rad (4 Gy), but greater than the occupational dose limits in reference (b), chapter 4 regarding external, internal, wound contamination, or a combination of these. | Decontaminate on-scene or at the command or installation's decontamination facility, if possible, then admit to MTF. If not, admit to an MTF for medical treatment and decontamination. Contact the BUMED REAB if the exposure limits of reference (b), chapter 4 are exceeded. Refer to enclosures (4) through (12) for guidance, as applicable. |
| 4 | Internal contamination (non-physical injury). | Conduct in vitro bioassay, in vivo bioassay (internal monitoring) analysis, or both as applicable. If possible and indicated, intervene to enhance the total-body natural elimination rate of the compound (i.e., perform internal decontamination), or block the uptake of radioactive material by the site(s) or organ(s) in which high uptake may occur. Contact the BUMED REAB if deemed necessary. Refer to enclosures (9), (11), and (12) for guidance. |
| 5 | External contamination (non-physical injury). | Decontaminate eyes, skin, or both, and admit to MTF if radiation burns are expected. Contact BUMED REAB if deemed necessary. Refer to enclosures (7), (8), and (12) for guidance. |

Table 1. Priorities in Processing Irradiated or Contaminated Persons

7. Specialist Assistance

a. For assistance, if desired, in planning for the medical treatment or decontamination of an individual, along with subsequent actions such as obtaining dose reconstruction support or in vivo bioassay, in vitro bioassay, or bio-dosimetry analysis services, contact the BUMED REAB. If required, the BUMED REAB can also assist in obtaining additional consultation services involving radiation specialists (such as medical providers and health physicists) to support medical treatment and decontamination of an individual. Enclosure (14) is a listing of contact information for the BUMED REAB.

b. Funding, if required, for consultation services will be arranged by the command or higher authority, i.e., immediate superior in command, or type commander. Funding guidance can be obtained from the BUMED REAB.

8. Radiation Dose Units. The definitions of radiation dose units and units of ionizing radiation in this instruction have not changed from those of traditional usage in the Navy. These definitions have been replaced in scientific literature and in most other countries with the system international (SI). Equivalent units taken from enclosure (1), reference (d) (available at: https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/) are provided in Table 2 and used throughout this instruction.

| **Traditional units** | **SI units** | **SI or other units** |
|---|---|---|
| One rad | $1 \times 10^{-2}$ gray (Gy) | One centigray (cGy) |
| One rem | $1 \times 10^{-2}$ sievert (Sv) | One centisievert (cSv) |
| One curie (Ci) | $3.7 \times 10^{10}$ becquerel (Bq) | $3.7 \times 10^{10}$ disintegrations/second |
| **SI units** | **Traditional units** | **Other units** |
| One gray (Gy) | 100 rad | |
| One sievert (Sv) | 100 rem | |
| One becquerel (Bq) | $2.7 \times 10^{-11}$ curie (Ci) | 1 disintegration/second |

Table 2. Equivalent traditional, SI, and other units

9. Reporting and Record Procedures. Medical reporting and documentation requirements for radiation exposure and radioactive contamination are provided in enclosure (1), reference (b), Radiation Health Protection Manual, chapter 4. Enclosure (1), reference (b) is available at https://www.med.navy.mil/directives/Pages/Publications.aspx.

10. Records Management

a. Records created as a result of this instruction, regardless of format or media, must be maintained and dispositioned per the records disposition schedules located on the Department of the Navy (DON) Directorate for Administration, Logistics, and Operations, Directives and

Records. Management Division portal page at https://portal.secnav.navy.mil/orgs/DUSNM/DONAA/DRM/Records-and-Information-Management/Approved%20Record%20Schedules/Forms/AllItems.aspx.

b. For questions concerning the management of records related to this instruction or the records disposition schedules, please contact the local records manager or the DON Directorate for Administration, Logistics, and Operations, Directives and Records Management Division program office.

11. Review and Effective Date. Per OPNAVINST 5215.17A, Healthcare Operations (BUMED-M3) will review this instruction annually around the anniversary of its issuance date to ensure applicability, currency, and consistency with Federal, Department of Defense, Secretary of the Navy, and Navy policy and statutory authority using OPNAV 5215/40 Review of Instruction. This instruction will be in effect for 10 years, unless revised or cancelled in the interim, and will be reissued by the 10-year anniversary date if it is still required, unless it meets one of the exceptions in OPNAVINST 5215.17A, paragraph 9. Otherwise, if the instruction is no longer required, it will be processed for cancellation as soon as the need for cancellation is known following the guidance in OPNAV Manual 5215.1 of May 2016.

12. Forms and Information Management Control. The NAVMED forms subparagraphs are available at http://www.med.navy.mil/directives/Pages/NAVMEDForms.aspx.

a. NAVMED 6470/1 (series) Exposure to Ionizing Radiation.

b. NAVMED 6470/13 (series) Ionizing Radiation Medical Examination.

c. NAVMED 6470/18 Personnel Monitoring and Decontamination.

d. NAVMED 6470/19 Detailed Personnel Monitoring Survey.

e. NAVMED 6470/20 Detailed Face Monitoring Survey.

f. NAVMED 6470/21 Detailed Hand Monitoring Survey.

g. NAVMED 6470/22 General Contamination, Radiation, and Airborne Survey.

B. L. GILLINGHAM

Releasability and distribution:
This instruction is cleared for public release and is available electronically only via the Navy Medicine Web site, https://www.med.navy.mil/directives/Pages/BUMEDInstructions.aspx

REFERENCES

(a) NAVMED P-117
(b) NAVMED P-5055
(c) National Council on Radiation Protection and Measurements Report 161, 2008. Management of Persons Contaminated with Radionuclides: Handbook (NOTAL)
(d) Title 10, Code of Federal Regulations, Part 20
(e) BUMEDINST 3440.10A
(f) Medical Management of Radiological Casualties (Armed Forces Radiobiology Research Institute)
(g) The Medical Aspects of Radiation Incidents, 2017, 4th Ed. Radiation Emergency Assistance Center/Training Site (REAC/TS)
(h) Federal Guidance Report 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion
(i) ICRP, 1988. Limits for Intakes of Radionuclides by Workers: An Addendum. ICRP Publication 30 (Part 4). Ann. ICRP 19 (4)
(j) Nuclear Regulatory Commission Regulatory Guide 8.36, 1992. Radiation Dose to the Embryo/Fetus
(k) Nuclear Regulatory Commission Regulatory Guide 8.9, 1993. Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program
(l) ICRP, 1979. Limits for Intakes of Radionuclides by Workers. ICRP Publication 30 (Part 1). Ann. ICRP 2 (3-4)(m) ICRP, 1980
(m) Limits for Intakes of Radionuclides by Workers. ICRP Publication 30 (Part 2). Ann. ICRP 4 (3-4)
(n) ICRP, 1980. Limits for Intakes of Radionuclides by Workers. ICRP Publication 30 (Part 3). Ann. ICRP 6 (3-4)
(o) Nuclear Regulatory Commission Regulatory Guide 8.34, 1992. Monitoring Criteria and Methods to Calculate Occupational Radiation Doses
(p) ICRP, 1991. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Ann. ICRP 21 (1-3) Annex A
(q) ICRP, 1994. Human Respiratory Tract Model for Radiological Protection. ICRP Publication 66. Ann. ICRP 24 (1-3)
(r) ICRP, 2012. Compendium of Dose Coefficients based on ICRP Publication 60. ICRP Publication 119. Ann. ICRP 41 (Suppl.)
(s) Intake Retention Fractions Developed from Models Used in the Determination of Dose Coefficients Developed for ICRP Publication 68 - Particulate Inhalation, Charles A. Potter, Health Physics Society, pp. 594-789
(t) ICRP, 1994. Dose Coefficients for Intakes of Radionuclides by Workers. ICRP Publication 68. Ann. ICRP 24 (4)
(u) National Council on Radiation Protection and Measurements Report 156, 2006. Development of a Biokinetic Model for Radionuclide-contaminated Wounds and Procedures for their Assessment, Dosimetry and Treatment: Handbook
(v) BUMEDINST 6710.71A

# DEFINITIONS

1. Absorbed Dose. The energy imparted by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad or Gray.

2. Absorption. Movement of material to blood regardless of mechanism. Generally applies to the uptake into blood of soluble substances and material dissociated from particles.

3. Activity. The rate of disintegration (transformation) or decay of radioactive material. The unit of activity is the curie or becquerel.

4. Adult. A person 18 years of age or older.

5. Annual Limit on Intake (ALI). The ALI for radioactive materials is the smaller amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year (40 hours per week for 50 weeks) that would result in either a committed effective dose equivalent or committed effective dose of 5 rem (50 milli-seivert (mSv)) or a committed dose equivalent or committed equivalent dose of 50 rem (500 mSv) to any individual organ or tissue. The ALI values are based on the intake rate and standards for "reference man" as defined in International Commission on Radiological Protection Report No. 23, 1975.

6. Background Radiation. Radiation from cosmic sources, naturally occurring radioactive materials on the earth's surface including radon in concentrations or levels commonly found in structures or the environment, and global fallout as it commonly exists in the environment from the testing of nuclear explosive devices. Background radiation does not include radiation from source, byproduct, or special nuclear materials regulated by the U. S. Nuclear Regulatory Commission.

7. Bioassay Analysis. The measurement of amount or concentration of radioactive material in the body or in biological material excreted or removed from the body and analyzed for purposes of estimating the quantity of radioactive material in the body.

8. Biodosimetry. The use of physiological, chemical or biological markers of exposure of human tissues to ionizing radiation for reconstructing doses to individuals or populations.

9. Biological Half-life. The time interval required for the body to eliminate 50 percent of any substance by normal routes of elimination: metabolic turnover and excretion.

10. Bureau of Medicine and Surgery Radiation Effects Advisory Board (BUMED REAB). Composed of Navy medical and health physics experts with extensive scientific and medical knowledge on the effects of ionizing radiation and is BUMED's authority on determining a person's fitness for work involving exposure to ionizing radiation.

11. Clearance. The action that results in the movement of radioactive material from the site of deposition in tissues and organs. This action can be natural or induced by therapeutic means.

12. Committed Dose Equivalent ($H_{T,50}$) and Committed Equivalent Dose (CEqD) ($H_T,50$). The equivalent dose calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body (i.e., total organ dose for 50 years from internal contamination). It does not include contributions from radiation sources external to the body. Committed dose equivalent and committed equivalent dose is expressed in units of rem.

13. Committed Effective Dose Equivalent ($H_E$,50) and Committed Effective Dose (E(t)). The sum of the products of the committed dose equivalent or committed equivalent dose to each affected organ or tissue and the appropriate tissue weighting factor ($W_T$) for each affected organ or tissue. The commitment period is taken to be 50 years for adults. E(t) and $H_E$,50 both equal $\Sigma W_T H_E$,50; t is the integration time in years following the intake; see the tissue weighting factor table under the tissue weighting factor definition for $W_T$ values. For committed effective dose, the committed period is also taken to age 70 years for children.

14. Contamination. Radioactive material present in any substance, in any area, or on any surface where its presence is unwanted or unexpected.

15. Curie (Ci). The unit of radioactivity. One curie equals $3.7 \times 10^{10}$ nuclear disintegrations per second (1 Ci = $3.7 \times 10^{10}$ Bq).

16. Decontamination. Action taken to remove radioactive material from clothing and the external surfaces of the body, from rooms, building surfaces, equipment, or other items.

17. Deep Dose Equivalent ($H_d$). Applies to external whole-body exposure; the dose equivalent at a tissue depth of 1 cm (1,000 mg/cm$^2$) and establishes a standard depth for specifying the dose from whole-body external exposure.

18. Definitive Care. The complete medical, surgical, and health physics support necessary to provide a comprehensive evaluation and treatment of seriously irradiated, contaminated, or injured personnel, or any combination of the three.

19. Deposition. Any action resulting in the occurrence of radioactive material on or in external surfaces of the body or in internal tissues and organs.

20. Derived Air Concentration (DAC). The concentration of a given radionuclide in air which, if breathed for a working year (40 hours per week for 50 weeks) under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one annual limit of intake.

21. Deterministic Effects. Harmful tissue reactions that occur in personnel who receive greater than a threshold dose; the severity of the effect varies with the dose. Examples are radiation-induced cataracts (lens of the eye), radiation induced erythema (skin), radiation-induced pneumonitis (lungs), hematopoietic failure (bone marrow), hypothyroidism (thyroid), and gastrointestinal (GI) failure (GI tract).

22. Dose. A general term denoting the quantity of energy from ionizing radiation absorbed in a tissue or organ either from an external source or from radioactive material in the body. When unspecified, dose refers to quantity of absorbed dose, measured in gray (1 Gy = 1 J $kg^{-1}$) or rad (1 rad = 100 ergs $g^{-1}$).

23. Dose Coefficient. Radiation dose per unit of activity intake.

24. Dose Equivalent ($H_T$). The product of the absorbed dose (D) and the radiation weighting factor ($w_R$), where $H_T = D \times w_R$. Its purpose is to have a single unit, regardless of the type of radiation, describing the radiation effect on humans. The dose equivalent has the unit "rem." The dose equivalent for each type and energy of ionizing radiation must be determined by using the radiation weighting factors or neutron fluences listed under the radiation weighting factor definition unless otherwise approved by BUMED.

25. Dosimeter. A device used to measure an absorbed dose of external ionizing radiation.

26. Effective Dose. The calculated radiation dose to the entire body, accounting for the distribution of the dose among the organs and tissues of the body, the relative biological effectiveness of the different types of radiations and for the radiation sensitivities of the various organs and tissues that might be irradiated. The term effective dose, as used in this instruction for internally-deposited radionuclides, always means committed effective dose calculated over a 50-year period following the radionuclide intake for adults and from intake to age 70 for intakes by children.

27. Effective Dose Equivalent ($H_E$). The probability of a stochastic effect, e.g., cancer induction or heritable effect, in any tissue is proportional to the dose equivalent to that tissue. The value for the proportionality factors differs among the various tissues because of the differences in tissue radio-sensitivity. If radiation dose is uniform throughout the body then the total risk factor is one. For non-uniform radiation, such as partial body exposure to an external radiation field, or from internal exposure where the isotope concentrates to different degrees in the various organs or tissues, tissue weighting factors, which are based on their relative susceptibility to stochastic effects, may be used to calculate an effective dose equivalent. The effective dose equivalent is the sum of the products of the tissue weighting factors applicable to each of the body organs or tissues that are irradiated and the dose equivalent to these organs or tissues. ($H_E = \Sigma w_T H_T$); see the tissue weighting factor table under the tissue weighting factor definition for $W_T$ values.

28. Effective Half-life. The time interval required for the radioactivity of a certain amount of radioactive substance distributed in tissues and organs to decrease to half its original value due to radioactive decay and biological elimination.

29. Exposure. Receipt of ionizing radiation, either by proximity to external sources of ionizing radiation or through intake of radioactive material into the body.

30. External Contamination. Unwanted radioactive material deposited on the outside of the body on the clothing, skin, hair, or body cavities such as the outer ear and eye. An area of the body is considered to be externally contaminated if detectable counts on the skin are greater than two-times background based on reference (c). Program-specific radiological control manuals or standard operating procedures may institute different limits to define the contamination action level.

31. Extremities. Extremities include the arm below the elbow and leg below the knee.

32. Ingestion. The process in which radioactive material is taken into the digestive system. Amounts ingested are equivalent to an intake, although only a fraction may be absorbed into the blood system and deposited in tissues and organs and eventually excreted in urine. The ingested activity that is not absorbed to blood is excreted in feces.

33. Inhalation. The process in which air and substances, such as radioactive materials, entrained in the air are taken into the respiratory tract through the nose or mouth. The activity of a radionuclide inhaled may differ from the activity deposited in the respiratory tract since some fraction, depending upon its physical and chemical properties and the physiological state of the person, may be promptly exhaled.

34. Intake. The amount of radioactive material taken into the body by inhalation, absorption through the skin, ingestion or through wounds. It is distinguished from uptake, which is the amount of material that eventually enters the systemic circulation, or deposition, which is the amount of the substance that is deposited in organs and tissues.

35. Internal Contamination. Unwanted radioactive material deposited within the body following an intake of the material by absorption through skin, ingestion, inhalation, or through wounds or breaks in the skin.

36. In vitro Bioassay Analysis. The measurement of radioactive material in the human body utilizing instrumentation that detects radiation emitted from biological material excreted from the body (see also bioassay analysis).

37. In vivo Bioassay (Internal Monitoring) Analysis. The measurement of radioactive material in the human body (such as lung or whole-body counts) utilizing instrumentation (e.g., whole-body counting or internal monitoring equipment) that detects radiation emitted from the radioactive material in the body (see also bioassay analysis).

38. Ionizing Radiation. Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter. Ionizing radiation includes: gamma rays, x-rays, alpha particles, beta particles, neutrons, protons, and other particles and electromagnetic waves capable of producing ions.

39. Ionizing Radiation Sources. Any material, equipment, or device, which emits or is capable of generating ionizing radiation. This includes naturally occurring and artificially induced radioactive material, special nuclear material, nuclear reactors, particle generators and accelerators, medical or dental x-ray or fluoroscopic equipment, industrial radiographic equipment, certain electromagnetic wave generators, and certain analytical instruments such as x-ray diffraction spectrometers, electron microscopes, nuclear moisture density meters, etc.

40. Irradiation. The action of incurring radiation by a body, tissue, or organ from either external or internal radiation sources.

41. Neutron Activation. The formation of a new isotope through the absorption of neutrons by the nucleus of a given nuclide. Often, a process causing the formation of certain radionuclides near a nuclear fission reaction.

42. Occupationally Exposed Personnel. People who receive exposure to ionizing radiation in the course of their employment or duties, includes radiation workers, limited radiation workers, and non-radiation workers.

43. Pathways. Routes by which material deposited in organ systems can be transported away from the affected organs. For example, materials deposited in the respiratory tract can move out of the respiratory tract by absorption into blood, to the GI tract via the pharynx, and to regional lymph nodes via lymphatic channels (ICRP, 1994a).

44. Personnel Processing Area. An area, either within or adjacent to a potentially contaminated area, in which decontamination of a contaminated person or contaminated-injured person is performed.

45. Physical Half-life. The time interval required for an amount of certain radioactive nuclei to decay to half of its original value.

46. Potentially Contaminated Area. Any area that may potentially contain radioactive surface contamination and involve the medical and radiological response to a contaminated person or contaminated-injured person including medical evaluation and treatment and personnel processing and decontamination.

47. Rad. The unit of absorbed dose (D) which is equal to the absorption of 100 ergs per gram.

48. Radiation Detection, Indication and Computation (RADIAC). Instruments used for the detection and measurement of type, intensity, and exposure rate or dose of radiation.

49. Radiation Weighting Factor ($w_R$). That factor which is multiplied by the absorbed dose (D) to obtain a quantity which equates to a common scale, the dose equivalent ($H_T$), of any type of ionizing radiation to which a person is exposed ($H_T = D \times w_R$).

a. For ionizing particles heavier than protons and with sufficient energy to reach the lens of the eye, the $w_R$ equals 20.

b. For neutron fluency with known energy distributions, the dose equivalent will be determined using the table of neutron fluence per unit dose equivalents in enclosure (1), reference (d).

c. For neutrons of unknown energy and for protons, $w_R$ equals 10.

d. For x-ray, gamma or beta radiation, $w_R$ equals 1.

50. Radioactive Material. A pure or mixed substance (gas, liquid, or solid) that contains unstable radioactive atoms that emit radiation as they decay.

51. Radionuclide. Naturally occurring or artificially produced unstable atom that transforms to a stable or unstable atom and releases radiation in the process.

52. Relative Biological Effectiveness (RBE). The ratio of the doses from a reference radiation to cause the same level of effect as a non-reference radiation. Reference radiation normally is gamma or x-rays with a mean linear energy transfer of 3.5 keV $\mu m^{-1}$ or less. RBE generally depends on dose, dose per fraction if the dose is fractionated, dose rate, and biological endpoint. When calculating RBE-weighted absorbed doses for deterministic effects in this instruction, RBE values of two and seven were used for alpha-particle irradiation of the bone marrow and lungs, respectively.

53. Retention. Describes the propensity for radioactive materials to remain at the site of deposition. Retention is frequently described by a rate function.

54. Roentgen (R). A unit of exposure to ionizing radiation. It is that amount of x-ray or gamma radiation $\leq$ 3 MeV that will produce in air $2.58 \times 10^{-4}$ coulombs of charge per kilogram of air at standard temperature and pressure.

55. Roentgen Equivalent Man (Rem). The unit of dose equivalent ($H_T$) which is equal to the absorbed dose in rad multiplied by the radiation weighting factor. The rem must be the unit of dose equivalent for record purposes unless otherwise specified by BUMED.

56. Stochastic Effects. Health effects that occur randomly and for which the probability of the effect increases with increased absorbed dose without threshold. For example, cancer and hereditary effects are regarded as being stochastic.

57. The System International (SI) of Units. Units established by the international commission on radiation units and measurements (ICRU) and are used by many countries. As such, they may be encountered in the scientific literature. These units equate to the rem, rad and curie, referred to as traditional units:

a. One gray (Gy) = 100 rad

b. One sievert (Sv) = 100 rem

c. One becquerel (Bq) = 2.7 x $10^{-11}$ curie (Ci) = One disintegration/sec

d. One rad = One centigray (cGy) = 1 x $10^{-2}$ gray (Gy)

e. One rem = One centisievert (cSv) = 1 x $10^{-2}$ sievert (Sv)

f. One curie = 3.7 x $10^{10}$ becquerel (Bq)

58. Total Effective Dose Equivalent. The sum of the deep dose equivalent (external dose) and the committed effective dose equivalent or committed effective dose (internal dose).

59. Uptake. Quantity of a radionuclide taken up by the systemic circulation (e.g., by injection into the blood, by absorption from compartments in the respiratory or GI tracts, or by absorption through the skin or through wounds in the skin) (NCRP, 1987).

60. Tissue Weighting Factors ($w_T$). The tissue weighting factor for an organ or tissue is the proportion of the risk of stochastic effects (random probability effects, e.g., cancer) resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. For calculating the effective dose equivalent, the listed values are prescribed by enclosure (1), reference (p). Reference (p) is available at https://journals.sagepub.com/doi/pdf/10.1177/ANIB_19_4.

| Organ or Tissue | Tissue Weighting Factor, $w_T$ |
|---|---|
| Gonads | 0.20 |
| Red Bone Marrow | 0.12 |
| Colon | 0.12 |
| Lung | 0.12 |
| Stomach | 0,12 |
| Bladder | 0.05 |
| Breast | 0.05 |
| Liver | 0.05 |
| Oesophagus | 0.05 |
| Thyroid | 0.05 |
| Skin | 0.01 |
| Bone surface | 0.01 |
| Remainder[1] | 0.05 |
| Whole Body | 1.00 |

Note: The remainder, with a tissue weighting factor of 0.05, is composed of the following additional tissues and organs: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus, and uterus. Consult reference (p) for further explanation and additional information regarding the remainder of tissues and organs, and how to apply their waiting factors to determine dose.

61. Whole Body. For purposes of external exposure; head, trunk (including male gonads), arms above the elbow, and legs above the knee.

# PLANNING GUIDANCE FOR A RADIOLOGICAL CASUALTY RESPONSE

1. Background

a. An effective medical and radiological response to a radiological casualty that involves irradiated personnel, externally contaminated personnel, internally contaminated personnel, or a combination of these, with or without physical injury, is critical to ensure that personnel are adequately treated in a timely manner. For a mass-radiological casualty that overwhelms the command's response assets, such as emergency response personnel, equipment, and supplies, the command or base-installation's emergency response plan should be activated to effectively respond to the casualty. Larger Navy MTFs have a mass-casualty decontamination team capability, which could be utilized if necessary under the Navy Medicine emergency management program per enclosure (1), reference (e). Reference (e) is available at https://www.med.navy.mil/directives/Pages/BUMEDInstructions.aspx.

b. A medical and radiological response to a radiological casualty may include, but is not limited to, initial shipboard medical or Federal fire and emergency services on-scene response, patient transport to a MTF or decontamination facility, treatment of an overexposure or physical injury at an MTF, and detecting radiation or radioactive contamination hazards. The response may also include establishing a potentially contaminated area and personnel processing area with decontamination capabilities (on-scene or at a MTF), external contamination detection or personnel surveys (i.e., frisking) using RADIAC instruments, decontamination, external and internal dose estimation, supportive medical care, and therapy for internal dose mitigation.

2. Planning Guidance for a Medical and Radiological Response Involving an Irradiated- or Contaminated-injured Person. When planning for a response to a radiological casualty involving personnel, the command should consider the actions listed in subparagraphs 2a through 3g.

a. Number of personnel who are occupationally exposed to radioactive material or radiation sources while performing their duties.

b. Radioactive material or radiation sources including sealed and unsealed sources and machine- or power-generated sources in the workplace.

Note: It would not be implausible for an event involving radioactive material to be accompanied by a release of toxic industrial chemicals (TIC) or toxic industrial materials (TIM). In such an event, TICs or TIMs may be the predominant hazard and should be considered as a part of the overall response to the accident or incident.

c. Probability of an external or internal contamination event or a high dose exposure event.

d. Number of personnel that may require medical treatment, decontamination, or both, based on realistic casualty scenarios.

e. Availability of medical and radiological control personnel to provide management and care of irradiated or contaminated personnel.

f. Availability of medical assets including MTFs and medical transportation services.

g. The possible number and locations of command decontamination stations or facilities, along with decontamination supplies and facility features (e.g., showers and sinks) required based on realistic casualty scenarios.

h. Radiation detection, indication and computation (RADIAC) or radiation detection instrumentation and personal protective equipment (PPE) requirements.

i. Dosimetry requirements for applicable personnel (e.g., emergency responders, medical staff, and radiological control personnel).

j. Any memoranda of understanding or agreement with outside organizations and commands (e.g., immediate superior in command, Federal fire and emergency services, and civilian and DoD MTFs).

k. Training requirements for personnel providing the medical and radiological control response.

3. Guidance for On-scene Medical and Radiological Response to a Radiological Casualty Involving an Irradiated- or Contaminated-Injured Person (Ambulatory or Non-ambulatory)

a. Planning guidance for on-scene arrival.

(1) Training requirements for emergency responders responsible for evaluating an irradiated- or contaminated-injured person, with the understanding that medical attention to life-, limb-, or vision-threatening injuries always takes precedence over radiological control actions.

(2) Training requirements for using PPE based on personnel rendering medical care or performing radiological control actions. The medical response should not be impeded to don (i.e., put on) PPE. However, standard precautions for medical responders are always acceptable and generally adequate for contamination control.

(3) Personal dosimetry for emergency responders is appropriate unless its acquisition impedes adequate medical care response.

(4) Search and rescue for potentially contaminated and injured persons is performed as soon as possible. If medically safe to do so and circumstances deem it necessary, remove injured personnel from the hazard area to a triage area as soon as possible.

b. There should be a screening or triage process for individuals for life-, limb-, or vision-threatening injuries and for evidence of irradiation or contamination. Actions that provide immediate medical attention to life-, limb-, or vision-threatening injures always take precedence over radiological control actions. See reference (c) for specific items to consider when conducting a medical assessment of a contaminated-injured person.

c. There should be an on-scene potentially contaminated area that encompasses the incident area, along with an adjacent personnel processing area to decontaminate the contaminated-injured person if the individual is not required to be transported to a MTF (i.e., the individual is medically stable and ambulatory) and only minor or spot decontamination is required. For example, the personnel processing area should be used for the decontamination of hands and spot decontamination of the arms and face. Gross or comprehensive decontamination of the body, including the face or any wounds, should be performed at the command or installation's decontamination facility or MTF.

Note: To simplify the decision-making process and better use available resources, it is acceptable to transfer an ambulatory and stable contaminated-injured person to the command or installation's decontamination station or MTF prior to the performance of any decontamination of the individual.

d. The personnel processing area should be composed of the following core components:

(1) Supplies for decontamination. See enclosure (13) for guidance on decontamination supplies.

(2) Trained personnel for performing contamination surveys and decontamination of personnel.

(3) A frisking station at the entry and exit of the personnel processing area to survey any potentially contaminated persons before and after decontamination.

(4) Appropriate, calibrated RADIAC instruments and associated probes.

e. A command or installation decontamination station or facility should be established to perform more complex decontamination evolutions (i.e., beyond decontamination of the hands or spot decontamination of the arms and face).

f. Access to in vivo bioassay (internal monitoring) analysis services may be required. If internal contamination is confirmed following the analysis and the contaminated-injured person did not require transport to a MTF as part of the initial medical response, follow-on actions must be included in the medical and radiological casualty response plan for subsequent actions that

may need to be taken to properly monitor and treat the internally contaminated person. This may include required access to an MTF, in vitro bioassay analysis, and treatment for internal decontamination or dose mitigation. Contact the BUMED REAB if in vivo bioassay analysis services are not readily available.

g. Required reporting to the Navy Automated Radiation Exposure Registry (NARER) of internal and external contamination and external exposure per reference (b) that exceeds the applicable Federal limit per reference (d).

4. Guidance for a MTF (Shipboard, Clinic, or Hospital) Response to a Radiological Casualty Involving an Irradiated- or Contaminated-injured Person

a. Ensure medical personnel are properly trained to evaluate an irradiated-injured person or contaminated-injured person with the understanding that medical attention to life-, limb-, or vision-threatening injuries always takes precedence over radiological control actions.

b. If time permits, ensure the medical staff is wearing appropriate PPE for treating a contaminated-injured person. The medical response should not be impeded to don (i.e., put on) PPE. However, standard precautions for medical responders are always acceptable and generally adequate for contamination control.

c. Personal dosimetry for medical personnel is appropriate unless acquisition impedes adequate medical care response.

d. Establish a potentially contaminated area that contains the contaminated-injured person. In general, a personnel processing area should be established within or nearby the potentially contaminated area to decontaminate the contaminated-injured person once the individual is stabilized, depending on the degree of patient mobility. The core components of a personnel processing area are listed in paragraph 3d of this enclosure. Unlike an on-scene personnel processing area, an MTF personnel processing area should allow for gross or comprehensive decontamination of the body, including the face or any wounds.

e. Depending on the platform and available facilities, the decontamination station may include permanent showers and specially designed patient gurneys, which permit the decontamination of an immobile contaminated-injured person.

f. Ensure applicable follow-up actions are performed, such as medical treatment, in vitro bioassay analysis, in vivo bioassay (internal monitoring) analysis, treatment for internal decontamination or dose mitigation, internal or external dose calculations, and reporting.

# EXTERNAL IRRADIATION

1. Definition. External irradiation is exposure to ionizing radiation that originates from sources external to the body. The source of radiation can originate from machine- or power-generated systems (e.g., x-ray machine and linear accelerator) or radioactive material. Radiation types include x-rays, gamma rays, neutrons, or charged particles. Penetrating radiation has sufficient energy to contribute dose to the skin, to tissues at a depth of 1 centimeter (cm) or greater, and to organs. Non-penetrating radiation contributes dose primarily to the skin.

2. Dose Evaluation. Appropriate medical management of irradiated individuals depends upon proper assessment of the clinical seriousness of an overexposure. The biological response is dependent upon the dose received from penetrating and non-penetrating radiation, time over which the dose was received, area and volume irradiated, energy of the radiation, and type of radiation. General information on deterministic effects and the various levels of ARS is provided in enclosure (6) to assist in evaluating the potential seriousness of human exposure from non-penetrating and penetrating radiation.

3. Initial Actions. These initial actions are based on the suspicion of an overexposure from external irradiation. Depending upon the exposed person's physical condition (i.e., a non-life-threatening or life-, limb-, or vision-threatening injury), extent of the acute exposure from external irradiation, and whether radioactive contamination is present internally or externally, the actions listed in subparagraphs 3a through 3c must be taken:

a. Perform medical evaluation. Attend to life-, limb-, or vision-threatening injuries first. Treat the patient symptomatically if the external exposure is expected to be high enough to cause deterministic effects. If injuries are life-, limb-, or vision-threatening or a person is suspected of receiving a high dose that may cause ARS, ensure that the injured person is immediately transported to the nearest MTF capable of providing the appropriate level of care.

b. Obtain and document a history of the exposure. Pay special attention to identify the time and duration of exposure and pertinent questions for dosimetry processing if applicable. Instructions on dosimeter processing for evaluation are outlined in subparagraph 3c of this enclosure.

c. Determine the dose received via dosimeter measurement or estimate, e.g., evaluate personnel dosimetry to include primary and secondary, area monitoring, and accident dosimeters, if applicable, simulate the exposure event, multiply exposure rate by the time, etc. Guidance on determining dose from external exposure to irradiation are provided in enclosure (5). The primary purpose of obtaining the measured or estimated dose is to determine whether clinical symptoms are expected.

Note: Avoid placing undue confidence on an initial rough dose estimate obtained immediately following the accident. These estimates are, at best, a relative measure of exposure and are only useful for screening purposes.

(1) Perform primary dosimetry evaluation. Following medical stabilization, remove the individual's primary dosimeter if worn. Determine which dosimetry-processing center has jurisdiction, the Naval Dosimetry Center (NDC) or one of the Naval Nuclear Propulsion Program (NNPP) shore-processing centers, and then perform the actions listed in subparagraphs 3c(1)(a) through 3c(1)(i) of enclosure (4).

(a) Decontaminate the dosimeter if contaminated. Contact the appropriate dosimetry-processing center for specific instructions regarding the decontamination of the dosimeter.

(b) Submit two control dosimeters (i.e., dosimeter cards) if available.

(c) Provide name and identifier of the person who wore the dosimeter. The identifier could be a DoD identification number or worker (badge) identification number.

(d) Provide date and time of the suspected exposure.

(e) Provide an estimated dose to the individual based on stay time and measured radiation levels if possible.

(f) Provide the type of radiation source or field (e.g., gamma only, beta and gamma, or gamma and neutron) involved in the suspected accident, including a statement regarding any possible shielding.

(g) Provide the approximate position of the dosimeter on the individual's body at the time of the exposure event.

(h) Provide the direction the individual was facing relative to the source, if known.

(i) Ship the dosimeters to the appropriate dosimetry-processing center. Ensure that the dosimeter package is addressed correctly. Shipping containers containing any type of dosimetry should not be placed through a mail or package x-ray scanner because the irradiation of the package will result in inaccurate analysis. Therefore, "DO NOT X-RAY" or similar labels must be placed on the outside of each package.

(2) Perform dose estimate. Per enclosure (1), reference (b), a dose estimate must be conducted at the earliest opportunity. If necessary, contact BUMED REAB for assistance. Guidance on estimating dose from external irradiation is provided in enclosure (5) of this instruction.

4. <u>For measured or estimated doses between 5 rad (5 cGy) and 100 rad (1 Gy) whole body, greater than 5 rad (5 cGy) to the eye, or greater than 50 rad (50 cGy) shallow or extremity dose, perform the actions listed in subparagraphs 4a through 4c of this enclosure</u>

a. Contact the BUMED REAB immediately by telephone or by "IMMEDIATE" message per reference (b).

b. Submit a report that includes the measured or estimated dose to the BUMED REAB within 24 hours of the incident. Per reference (b), perform a NAVMED 6470/13 and related laboratory work. The BUMED REAB will provide guidance on any follow-on care.

c. Document the determined dose on a NAVMED 6470/1 and submit to the NDC and BUMED REAB within 30 days of exposure.

5. For doses greater than 100 rad (1 Gy) whole-body or shallow or extremity doses high enough to cause deterministic effects, perform

a. All actions listed in paragraph 4 of this enclosure.

b. Transfer the individual to a MTF capable of providing definitive care. The individual's transfer should not be delayed to collect information. Make contact with the MTF with the information listed in subparagraphs 5b(1) through 5b(5) of this enclosure.

(1) The parent command's name and contact information.

(2) Name, rank, identification number (e.g., DoD identification number, or worker identification or badge number, or birthdate as appropriate) and age.

(3) Physical injuries and treatment provided.

(4) Dosimetry results.

(5) Suspicion or presence of external or internal contamination.

c. Provide subject matter experts (e.g., Navy military or civilian health physicists) or technical personnel (e.g., radiation health or radiological control technicians) and equipment to the MTF if required to evaluate an individual's dose and maintain radiological controls. Also, ensure a liaison is maintained between the MTF and command.

d. Provide the BUMED REAB with names and telephone numbers of the treating or attending physician and an alternate in charge of the person's medical care at the MTF.

# DETERMINATION OF DOSE FROM EXTERNAL IRRADIATION

1. Introduction. Radiation dose from external irradiation for casualty response triage and determination of the person's expected clinical outcome can be estimated using a variety of methods, depending on the availability of resources including health physics support. Determination of external radiation dose is complex and varies depending on the type of radiation (gamma, x-ray, or neutron), uniformity of the field of exposure, and total time of exposure.

Note: A single estimate may not be sufficient to address all potential radiation exposure scenarios, including management of mass casualties and diagnosis for early medical treatment. Multi-parameter triage (i.e., time to vomiting, lymphocyte count, etc.) is necessary for early response and treatment. Early, approximate assessment of dose is not intended to replace more established, but more time-consuming, techniques of health physics dose reconstruction.

2. Dose Estimate or Evaluation. Methods to estimate an individual's dose are described below. Each applicable method should be evaluated as soon as practicable to help in determining the dose. Each method listed is in no particular order; i.e., each applicable method should be performed in the order most reasonable to the evaluator (e.g., qualified health physicist or medical physicist).

a. Review active dosimeter readings and process passive dosimeters (e.g., primary and secondary personnel dosimetry), if worn and available. If available, area monitoring and accident dosimetry may also be utilized to evaluate dose. Refer to enclosure (4) for processing personnel and area monitor dosimetry.

Note: The Navy's accident dosimetry system is unique to the NNPP. If required, the NNPP will submit accident dosimetry for processing per NDC instruction.

b. If the exposure was accompanied by the release of radioactive material, perform an evaluation of any external contamination. Enclosure (7) of this instruction provides guidance for conducting contamination surveys.

Note: Refer to references (c) and (f) or applicable command radiation health or radiological control manual or standard operating procedure (SOP) for additional and more specific guidance on conducting contamination surveys if required. Reference (f) is available at: https://www.usuhs.edu/sites/default/files/media/afrri/pdf/4edmmrchandbook.pdf.

c. Evaluate the possibility of internal contamination. See enclosure (9) for guidance on monitoring for internal contamination.

d. Dose calculation based on time in radiation field.

e. Biodosimetry dose calculations for significantly high exposures (>10 rad (10 cGy)) may be determined using a variety of assay methods involving blood samples. The assay method(s) of choice depends on the expected dose based on clinical symptoms or a calculated dose estimate and the area of the body irradiated (i.e., partial or whole-body irradiation). Table 5.1 (derived from references (f), (g), and published and unpublished information from the Armed Forces Radiobiology Research Institute) provides common assay methods based on dose range and expected clinical symptoms. Reference (g) is available at https://orise.orau.gov/reacts/documents/medical-aspects-of-radiation-incidents.pdf. Enclosure (11) of this instruction provides guidance and directions on collecting samples for analysis. If blood analysis is required, contact the BUMED REAB to obtain bio-dosimetry services.

| Dose Range (Rad) | Recommended Dosimetry Method | Clinical Symptoms |
|---|---|---|
| 10-100 | Dicentric assay | None to slight decrease in blood count |
| 100-350 | Lymphocyte depletion kinetics/CBC with differential; serum amylase assay; dicentrics; serial plasma CRP; and Flt-3 ligand | Mild to severe bone marrow damage |
| 350-750 | Lymphocyte depletion kinetics/CBC with differential; serum amylase assay; dicentrics; PCC; serial plasma CRP; and Flt-3 ligand | Pancytopenia, mild to moderate GI damage |
| 750-1000 | Lymphocyte depletion kinetics/CBC with differential; serum amylase assay; dicentrics; PCC serial plasma CRP; and Flt-3 ligand | Bone marrow and GI damage |
| > 1000 | Lymphocyte depletion kinetics/ CBC with differential; serum amylase assay; dicentrics; PCC; serial plasma CRP; and Flt-3 ligand | GI, neurological, and cardiovascular damage |

Table 5.1. Guidance on choice of bio-dosimetry methods

Note: The PCC assay may involve the analysis of dicentrics, excess fragments or rings, or both.

f. Bio-dosimetry dose calculations for significantly high exposures (>10 rad (10 cGy)) may be determined using electron paramagnetic resonance (EPR). This method uses sensitive instrumentation for the analysis of nail and hair clippings to calculate dose. See enclosure (11) for instructions on collecting samples for analysis. Contact the BUMED REAB to obtain bio-dosimetry services involving the EPR methodology if required.

g. Time from exposure to emesis (vomiting). An initial rough estimate for triage purposes can be performed in situations of very high acute doses using time to emesis. If an otherwise healthy adult has a time to emesis within 1 to 2 hours of exposure to the source, it indicates a dose likely in excess of 400 rad (4 Gy) which is potentially fatal if the individual

does not receive medical care. Typically, a faster time to emesis indicates a higher dose although it should be noted psychological impacts might accelerate emesis regardless of dose.

h. Neutron exposure and activation. Neutron exposure is unique because neutrons will activate materials, including elements in the human body, which can confirm that an exposure occurred.

(1) If the history from the individual and witnesses indicates an accidental high neutron exposure may have occurred, the procedures listed in subparagraph 2h(1)(a) through 2h(1)(d) of this enclosure, in addition to the rest of paragraph 2 of this enclosure, should be performed.

(a) Collect approximately 10 ml of blood and 100 ml of urine for activation analysis.

(b) Collect approximately ½ gram of hair for activation analysis.

(c) Collect any metal objects worn by the individual, such as a belt buckle, necklace, or wristwatch, for activation analysis. If metallic objects are removed for activation analysis, carefully document their physical location on the person.

(d) Consult with the BUMED REAB on the proper disposition (i.e., submission) of any samples taken to determine neutron exposure.

(2) Radiation survey reading on body. An initial rough estimate of the dose following a criticality accident may be made using the quick-sort technique based on the measurement of the sodium (Na)-24 activation in the body. Use caution in interpreting the results of the quick-sort method unless it is obvious an exposure has occurred. The quick-sort technique is to be performed in the following manner:

(a) Remove outer clothing and conduct external decontamination if present.

(b) Determine a background dose rate using a Geiger-Muller (GM) survey instrument with a pancake probe (e.g., DT-304 probe or equivalent) or a multi-function RADIAC (MFR) instrument with a gamma probe.

(c) Place the face of the probe of the survey instrument against the abdomen with the person seated and have the person bend forward as far as possible with forearms on thighs. Any increase in count rate is indicative of an exposure.

Note: For an individual who cannot readily bend forward to perform the quick-sort technique (e.g., due to an injury), the probe can be placed against the armpit instead.

(3) Neutron dose determination. Two different dose calculation methods for criticality or high exposure incidents are provided and may be performed using the quick-sort technique.

(a) To calculate neutron dose (in rad), based on the weight of the individual and the RADIAC instrument reading in corrected counts per minute (ccpm) using a GM survey instrument with a pancake probe (e.g., DT-304 or equivalent probe), the Drad equation and information provided in Table 5.2 may be used.

$$D_{\text{rad}} = 2.2 \frac{\text{GM Reading (ccpm)}}{\text{Body Weight (lbs)}}$$

| Weight of subject (lbs) | GM net reading (ccpm) for a 10 rad neutron dose (based on time following exposure (hr)) | | |
|---|---|---|---|
| | 0 | 4 | 15 |
| 125 | 570 | 470 | 280 |
| 150 | 680 | 570 | 340 |
| 175 | 800 | 660 | 400 |
| 200 | 910 | 760 | 450 |
| 225 | 1,000 | 850 | 510 |
| 250 | 1,100 | 940 | 570 |

Table 5.2. Ten (10) rad neutron dose based on the individual's weight and time following exposure.

(b) To calculate neutron dose (in rad), based on the weight of the individual and the RADIAC instrument dose rate reading in mrad $h^{-1}$ using an air-filled ion chamber, the following equation and information provided in Table 5.3 may be used:

$$D_{\text{rad}} = 8{,}000 \frac{\dot{D}\ (\text{mrad h}^{-1})}{\text{Body Weight (lbs)}}$$

| Weight of subject (lbs) | Dose-rate reading (mrad $h^{-1}$) for a 100 rad neutron dose (based on time following exposure (hr)) | | |
|---|---|---|---|
| | 0 | 4 | 15 |
| 125 | 1.6 | 1.3 | 0.8 |
| 150 | 1.9 | 1.6 | 0.9 |
| 175 | 2.2 | 1.8 | 1.1 |
| 200 | 2.5 | 2.1 | 1.2 |
| 225 | 2.8 | 2.3 | 1.4 |
| 250 | 3.1 | 2.6 | 1.6 |

Table 5.3. One hundred (100) rad neutron dose based on the individual's weight and time following exposure.

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# DETERMINISTIC EFFECTS OF EXPOSURE TO IONIZING RADIATION AND ACUTE RADIATION SYNDROMES

1. Background. Deterministic effects from either internal or external exposure to ionizing radiation are those that occur at a threshold dose and for which severity increases with increasing dose. The result is the death of cells and corresponding deleterious effect to the organ and organism. This is in contrast to stochastic effects from exposure to ionizing radiation where the probability of mutation of the cell is a function of increasing dose. Cancer is the primary stochastic health effect of ionizing radiation exposure. It is instructive to note doses resulting in deterministic effects are to be recorded in units of rad or Gray (Gy). Unless stated otherwise, reported dose values are assumed to result from whole-body irradiations and reported as free-in-air doses (i.e., roentgen (R)), as per reference (f). Doses resulting in stochastic effects are to be recorded in units of rem.

2. Deterministic Skin Effects. Deterministic effects such as erythema (reddening of the skin), dry or moist desquamation (severe skin damage or peeling), and epilation (hair loss) usually occur because of localized high doses of penetrating or non-penetrating radiation to the skin including the scalp. These deterministic effects can occur as the result of significant skin contamination or handling of a bare radioactive source where the primary dose is from beta radiation. Some medical procedures can result in deterministic skin effects as well, such as extended use of fluoroscopy. Approximate doses for different deterministic effects, compiled from references (c), (f), and (g) are:

a. Epilation typically occurs at doses greater than 300 rad (3 Gy) with time of onset occurring 14 to 18 days from exposure. Permanent epilation due to destruction of hair follicles occurs in the dose range of 500-1,000 rad (5-10 Gy).

b. Erythema typically occurs between 600-1,000 rad (6-10 Gy) with time of onset occurring 14 to 21 days from exposure.

c. Dry desquamation (skin peeling) sets in between 800-1,500 rad (8-15 Gy) within 25 to 30 days from exposure.

d. Moist desquamation (epidermal skin loss) sets in at doses greater than 1,500 rad (15 Gy). It may be accompanied by blister formation and ulceration accompanied by injury of blood vessels, edema, severe pain, and likely permanent skin damage within 15 to 28 days from exposure.

3. Acute Radiation Syndrome (ARS). Also known as radiation toxicity or radiation sickness, ARS is an acute illness caused by irradiation of the whole-body or the majority of the body by a high dose of penetrating radiation in a very short period (usually seconds, minutes, or several hours). The major cause of this syndrome is depletion of immature parenchymal stem cells in specific tissues. Survivability is questionable at a whole-body deep dose of about 350-400 rad (3.5-4 Gy) where approximately 50 percent of a given human population exposed to that

dose will die within 60 days without medical treatment (reference (f)). This is referred to as the LD 50/60, where LD stands for "lethal dose," 50 represents 50 percent of the population and 60 represents maximum days to death if the individual does not receive medical care. There are three ARS sub-syndromes and four stages of ARS.

a. Three ARS Sub-syndromes Based on Whole Body Dose

(1) Bone Marrow or Hematopoietic Syndrome. The full syndrome will usually start around 70 rad (70 cGy) though mild symptoms may occur as low as 30 rad (30 cGy). The primary cause of death, if death occurs, is the destruction of the bone marrow resulting in infection and hemorrhage.

(2) GI Syndrome. The full syndrome will usually occur with a dose greater than approximately 1,000 rad (10 Gy) although some symptoms may occur as low as 600 rad (6 Gy). Destructive and irreparable changes in the GI tract and bone marrow usually cause infection, dehydration, and electrolyte imbalance, in conjunction with the full symptoms of hematopoietic syndrome. Death historically has occurred 8 to 14 days post-exposure.

(3) Cardiovascular (CV) or Central Nervous System (CNS) Syndrome. The full syndrome will usually occur with a dose greater than approximately 5,000 rad (50 Gy) although some symptoms may occur as low as 800 rad (8 Gy). Unconsciousness can occur within seconds to minutes. Death occurs within days. Death is likely due to collapse of the circulatory system, as well as increased pressure in the confining cranial vault, as the result of increased fluid content caused by edema, vasculitis, and meningitis.

Note: Additional radiation injuries can occur in skin (cutaneous), kidney, lung tissues, and can cause death. As radiation dose increases, multiple organs will show injury and results in multiple organ dysfunction syndrome (MODS).

b. Four Stages of ARS

(1) Prodromal Stage. The classic symptoms for this stage are nausea and vomiting, as well as anorexia and possibly diarrhea (depending on dose), which occur from minutes to days, post-exposure. The symptoms may last (episodically) for minutes up to several days. Table 6.1 shows the prodromal stage (immediate effects) of ARS and shows different biological markers for given doses adapted from references (c).

| Symptoms | Dose (rad) | | | | |
|---|---|---|---|---|---|
| | 100 - 200 | 200 - 400 | 400 - 600 | 600 - 800 | >800 |
| **Vomiting** | - | - | - | - | - |
| Onset | 4 hours | 1 - 2 hours | <1 hour | <0.5 hour | <0.17 hour |
| Incidence | 10 - 50% | 70 - 90% | 100% | 100% | 100% |
| **Diarrhea** | None | None | Mild | Severe | Severe |
| Onset | - | - | 3 - 8 hours | 1 - 3 hours | Minutes to 1 hour |
| Incidence | - | - | <10 % | >10 % | About 100 % |
| **Headache** | Slight | Mild | Moderate | Severe | Severe |
| Onset | - | - | 4 - 24 hours | 3 - 4 hours | 1 - 2 hours |
| Incidence | - | - | 50% | 80% | 80 – 90% |
| **Consciousness** | Unaffected | Unaffected | Unaffected | May be altered | Unconscious |
| Onset | - | - | - | - | Seconds to minutes |
| Incidence | - | - | - | - | 100% at 5,000 rad |
| **Body Temp** | Normal | Increased | Fever | High Fever | High Fever |
| Onset | - | 1 - 3 hours | 1 - 2 hours | <1 hour | <1 hour |
| Incidence | - | 10 - 80% | 80 - 100% | 100% | 100% |

Table 6.1. Deterministic effects of exposure to ionizing radiation

(2) Latent stage. In this stage, the person looks and feels generally healthy for a few hours or even up to a few weeks. It is important to note and advise the treating physician of this stage, so that care continues in lieu of discharging a sick, but otherwise healthy-looking patient.

(3) Manifest illness stage. In this stage, the symptoms depend on the specific syndrome (hematopoietic, GI, or CV or CNS) and last from hours up to several months.

(4) Recovery or death. The recovery process lasts from several weeks up to 2 years. Most people who do not recover will die within several months of exposure.

c. Treatment for any stage of ARS or other deterministic effects is to be led by the attending or treating physician and in consultation with the BUMED REAB.

# RADIOLOGICAL SURVEYS OF PERSONNEL AND AREAS

1. Background. Performing radiological surveys is a major part in the management of irradiated and contaminated personnel. It is vital that surveys be conducted in an appropriate manner to ensure the radiation and radioactive contamination levels are known, the spread of contamination is minimized, and irradiated or contaminated personnel receive appropriate medical treatment and are properly decontaminated. Surveys should be conducted by trained radiation health or safety personnel or under their supervision if necessary.

Notes: Commands must ensure that personnel who will be performing radiation area surveys or contamination surveys of personnel are adequately trained to do so. Radiological survey training should be conducted per command radiation safety or radiological training policy and instruction.

This enclosure does not supersede command policy, instruction, or requirements regarding the performance of contamination surveys during the management of contaminated personnel.

2. Radioactive Contamination and Radiation Area Surveys. A major objective of the on-scene medical assessment or triage is to identify individuals externally irradiated or externally or internally contaminated as soon as possible. Management of these individuals will likely require comprehensive general area or contamination surveys on-scene and contamination surveys at command or installation decontamination facilities and MTFs. Examples include surveys of contaminated individuals (e.g., a contaminated-injured person, an emergency responder, or a treating physician), including nasal, throat, or saliva swabs, and potentially contaminated areas (e.g., scene of incident, command or installation decontamination facility, or an MTF). A general description of how to perform an alpha and beta-gamma contamination survey of personnel, and a beta-gamma general area survey, respectively:

Note: It is imperative the correct RADIAC instrument and probe be used for the expected radiation type or contamination being surveyed. Tables 7.1 and 7.2 provide specific guidance for selecting the correct instrument.

a. General Guidance on Performing Alpha and Beta/Gamma Contamination Surveys of Personnel

(1) Check the RADIAC instrument's calibration sticker to validate proper calibration.

(2) Turn on the instrument and check the battery charge if applicable. Conduct a performance or constancy check of the instrument to verify the response is within acceptable tolerance (range) of the indicated value from the dedicated check source per manufacturer

guidelines (some instruments have a check source attached, or one should be obtained). Switch to the lowest setting if the instrument does not have an auto-scaling feature and engage audible monitor if available. Be aware of how different scales on the instrument may indicate different count rates.

(3) Obtain a background count rate reading in a low-background area away from any known radioactive materials or sources that could influence the count rate. When possible, the background should be taken in the general area, but not near the incident site. Subtract the background from the survey readings (i.e., count rate); this is the net counting rate (i.e., corrected counts per minute or ccpm). Be aware background count rates typically fluctuate over time and may require the surveyor to obtain periodic background count rates.

(4) Hold the detector probe approximately 1 cm (0.5 inch) from the surface being surveyed for beta-gamma radiation or 0.25 cm (0.125 inch) for alpha radiation. It is important to avoid touching the contaminated surface. However, occasional and incidental contact rarely leads to the detector becoming contaminated. Move the detector probe approximately 3 to 5 cm (one to two inches) per second.

Note: Direct measurements for alpha-emitting radionuclides are generally performed by placing the detector on or near the surface to be measured. The limited range of alpha particles, approximately 1 cm or 0.4 inch in air, means these measurements are generally restricted to relatively smooth, impermeable surfaces. In most cases, direct measurements of porous and volumetric material cannot meet the objectives of the survey. Because the detector is used in close proximity to the potentially contaminated surface, contamination of the detector or damage to the detector caused by irregular surfaces needs to be considered before performing direct measurements for alpha emitters.

(5) If the RADIAC instrument does not have an automatic scaling capability, turn the switch to lower scales until the meter reading is less than three-quarters of the full scale. Direct contamination surveys cannot be performed if the background level is too high (e.g., 300 cpm or higher on a beta-gamma probe) because a high background will generally interfere with the accuracy of the measurements. If the background is higher than 100 cpm, the survey rate should be slowed to provide accurate results.

(6) If the detector displays the results in count rate, use the instrument's calibration factor to convert measurements into activity measurements specified by applicable command radiological control manuals or SOPs.

Note: The calibration factor is typically specific to a single radionuclide. If this is not the same radionuclide involved in the accident, then the activity measurement will be erroneous. A health physicist can assist in determining an appropriate correction factor for the radionuclide or radionuclide mixture involved.

(7) Document the results using the appropriate contamination survey form. Contamination survey forms are located at https://www.med.navy.mil/directives/Pages/NAVMEDForms.aspx. Observe and document the presence of uneven surfaces, which could introduce shielding material between the contamination and detector and produce an artificially low survey result. This is especially important for alpha or low-energy beta contamination.

b. General Guidance on Performing a Beta-Gamma Radiation Area Survey

(1) Check the RADIAC instrument's calibration sticker to validate proper calibration.

(2) Turn on the instrument and check the battery charge, if applicable. Conduct a performance or constancy check of the instrument to verify the response is within acceptable tolerance (range) of the indicated value from the dedicated check source per manufacturer guidelines (some instruments have a check source attached or one should be obtained). Switch to the lowest setting and engage the audible monitor if available. Be aware of how different scales on the instrument may indicate different exposure or dose rates.

(3) Hold the instrument or detector probe about waist height and walk slowly through the area.

(4) Document the results using the appropriate survey form. Contamination survey forms are located at https://www.med.navy.mil/directives/Pages/NAVMEDForms.aspx. For areas which read background, the minimum detector reading should be recorded (i.e., less than 0.02 mR/hr) to indicate this area was surveyed.

3. External Contamination Assessment Guidance. Characterization of external contamination is necessary to assess the risk of radiation injury to the eyes, skin, and underlying tissues. It is also necessary to determine the potential for internal contamination because of absorption of radioactive material through the skin, from wounds or injection (e.g., shrapnel), or from intake by inadvertent ingestion and inhalation of radioactive material deposited on the skin and clothing. Characterization is also necessary for making decisions about treatment and decontamination. While a complete qualitative and quantitative characterization including gross counts, radioactive material chemical or physical state, and location on the body is ideal, the timely removal of external contamination usually takes precedence over any in-place characterization beyond a simple contamination survey.

a. Objectives for performing external contamination surveys are

(1) Locate areas of contamination on the body including body orifices such as eyes, ears, and skin folds. Contaminated areas should be documented for decontamination and subsequent monitoring.

(2) Evaluate potential for skin injury. Examine the person for wounds and abrasions that could be routes for intradermal and internal radioactive material depositions.

(3) Identify the nature of the contaminating sources, such as hot particles, metallic particles or shavings, and other debris.

(4) Determine whether skin contamination is loose and susceptible to being removed by washing or changing clothes or fixed in place.

(5) Identify the contaminating radioactive material.

(6) Assess the degree and extent of radioactive contamination on the person.

(7) Identify those personnel with possible internal contamination.

(8) Identify personnel for treatment and decontamination consideration.

b. Steps Recommended to Achieve Objectives

(1) Remove contaminated clothing and replace with clean clothing, a gown, or wrap in sheet or blanket as appropriate. Retain contaminated clothing in a segregated, labeled bag, or container for future analysis.

(2) Perform a survey including the hair and body orifices using the appropriate RADIAC instrument and probe to detect contamination, identifying the locations of the contamination on the body and the survey results. Assume the contamination is loose and susceptible to being spread around until proven to be fixed to the skin. The survey should be conducted in the order of body areas, keeping in mind the priority of preventing internal contamination:

Note: The parts of the body most likely to be contaminated externally are the hands and face (including body orifices), with less likely areas being the head, neck, hair, forearms, wrists, and torso. If the radioactive material is in liquid form, it could penetrate clothing, thereby increasing the possibility of contamination being on some of these latter parts of the body.

(a) Wounds or abrasions, if present.

(b) Face. A survey of the face may provide evidence of possible ingestion or inhalation.

(c) Hands. If the hands are suspected of being contaminated prior to the survey, it is recommended they be covered (e.g., with gloves or plastic bags) to prevent the individual from spreading contamination while steps (a) and (b) are being conducted first.

(d) Areas of suspected contamination

(e) Abdomen, chest, throat, and back

(f) The rest of body

Note: The external contamination assessment guidance provides a comprehensive evaluation of a potentially contaminated person. However, a spot-check survey vice a comprehensive whole-body survey should be conducted for rapid assessment of gross contamination and processing for decontamination on-scene if permitted, and prior to decontamination at the command or installation's decontamination facility or MTF. The spot-check survey normally is composed of areas (a) through (e) listed in paragraph 3b(2) of this enclosure. Following the decontamination evolution, a comprehensive whole-body survey must be completed prior to any individual being released from any potentially contaminated area or personnel processing area.

(3) Examine for contaminated metallic particles or shavings.

(4) Identify radionuclides with a portable spectroscopic or isotopic identification survey meter if equipment is available. This is usually accomplished by the analysis of clothing, dressing, and decontamination materials.

(5) If inhalation, ingestion, or both, are indicated from an external contamination survey, perform nasal, throat, and saliva swabs, as applicable, within 30 minutes from the time of the exposure unless exempted per subparagraph 2.f of enclosure (9). See enclosure (9) for instructions on performing nasal, throat, and saliva swabs and collection requirements.

(6) Document external contamination survey results to include applicable nasal, throat, and saliva swab results using the appropriate survey diagram located at https://www.med.navy.mil/directives/Pages/NAVMEDForms.aspx.

Note: Medical personnel must perform the nasal and saliva swabs, if readily available (i.e., available within 30 minutes). If not, radiation health or safety personnel trained on conducting nasal swabs may perform them. As an alternative, the contaminated individual may perform the swabs under direct supervision to ensure samples are collected within 30 minutes from the contamination event. However, nasal and saliva swabs should be performed even if takes longer than 30 minutes. Throat swabs may only be performed by qualified medical personnel.

| Instrument | Probe | Record results in: | Use for these surveys |
|---|---|---|---|
| General survey instrument | GM | ccpm | Contamination levels |
| Hand and foot monitor | GM | ccpm | Contamination levels on hands and feet when leaving a room |
| General survey instrument | Energy-compensated GM | mR $h^{-1}$ or ccpm | Radiation and contamination levels |
| General survey instrument | NaI scintillation | mR $h^{-1}$ or ccpm | Radiation and contamination levels |
| Ion chamber or micro-R meter | Ion chamber or micro-R meter | mR $h^{-1}$ or μR $h^{-1}$ | Radiation levels |
| Alpha survey instrument | Zinc sulfide | ccpm | Contamination levels |
| Portable spectroscopy survey meter | Germanium semiconductor | Output varies; radionuclide and activity determination | Radionuclide identification and possible quantification |

Table 7.1. RADIAC instrumentation used for contamination and radiation surveys

Note: Corrected counts per minute (ccpm) = counts per minute (cpm) per frisk minus background count rate.

| Survey | Survey type | Instrument and probe | Record results in: |
|---|---|---|---|
| Hands and feet (exiting room) | Contamination | Hand and foot monitor (GM) | ccpm |
| Smear wipe (swipe) | Removable contamination | Count wipes in well counter, or with meter | ccpm |
| Area survey | Radiation | Energy-compensated GM, ion chamber or micro-R meter | mR $h^{-1}$ or μR $h^{-1}$ |
| Spills, personnel surveys | Contamination | GM or alpha detector | ccpm |
| Radionuclide identification | Contamination | Portable spectroscopy survey meter | Output varies, radionuclide and activity determination |
| Personnel | Contamination | Portal monitor | See note. |

Table 7.2. Types of surveys and appropriate instruments

Note: Result type is instrument dependent. Some instruments may detect contamination and indicate pass or fail or provide results in nCi.

4. Personal Protective Equipment. It is important that PPE is used or worn correctly in a potentially contaminated area or personnel processing area to ensure adequate protection of those who perform radiological surveys. Respirators can only provide adequate protection if they are properly selected for the situation, fitted to the wearer, consistently donned (i.e., put on), and worn properly. Therefore, it is advisable the use of PPE be under the direction of trained experts.

a. PPE Guidance. The listed items of PPE in subparagraphs 4a(1) through 4a(7) are recommended, according to the risk and level of contamination known or expected.

(1) Gloves (e.g., nitrile or rubber).

(2) Outer shoe covers (rubber or surgical).

(3) Plastic booties.

(4) Coveralls (e.g., Tyvek and surgical gowns).

(5) Head or hair covering.

(6) Tape to close open ends of clothing.

(7) Respiratory protection. Respirator use should only be considered when surveying a contaminated person with very high levels of loose contamination.

Note: Proper donning (i.e., putting on) and doffing (i.e., removing) of anti-contamination clothing and equipment should be codified in the command's radiological control training manual or SOP.

# EXTERNAL CONTAMINATION AND DECONTAMINATION

1. An area of the body is considered to be externally contaminated if detectable counts on the skin are greater than two times background per reference (c). However, command radiological control manuals or SOPs may institute different contamination limits based on radiation type to define the contamination-action level, e.g., greater than 100 ccpm of a beta-gamma emitting contamination as measured under the area of DT-304 probe. In such cases, the command's contamination-action levels must be followed.

Note: In a large-scale radiological casualty or event, which would be expected following a reactor or nuclear weapons accident, nuclear detonation, or use of a radiological dispersal device; a large number of personnel may be contaminated, which could overwhelm decontamination capabilities. Under these circumstances, the goal of two times background becomes impractical and contaminated personnel may need to be released above two times background to perform further self-decontamination at a remote site or in their home. Therefore, the highly unlikely event of a large-scale radiological casualty may warrant establishing different release criteria regarding contamination levels. Contact the BUMED REAB and higher command authority if this becomes necessary.

2. Medical and External Contamination Evaluation. Depending on the person's physical condition and the extent of external contamination, the following actions must be taken if applicable:

a. Medical evaluation. Attend to life-, limb-, or vision-threatening injuries first.

b. Dosimetry collection. Following medical stabilization of the person, remove the dosimeter if worn. Radiological control personnel should survey (i.e., frisk) the dosimeter to determine if it is contaminated. If contaminated, decontaminate the dosimeter prior to shipping to the appropriate processing center. Obtain decontamination instructions from the dosimetry-processing center that has jurisdiction of the dosimeter. See enclosure (4), subparagraph 3(c) for the proper handling and submission of the dosimeter to the applicable dosimetry-processing center.

c. External contamination evaluation. It is usually necessary to interview the person and any witnesses to document a description of the events leading to external contamination. This is a qualitative evaluation to assist in planning the management of the person. It should answer questions such as the following: What is the extent of the skin contamination, is it likely internal contamination is involved, are clinical symptoms or signs expected, and is this an acute health problem? See enclosure (7) for instructions and guidance on conducting an external contamination evaluation or survey.

Note: Ensure the individual's modesty or privacy is maintained following the removal of their clothing for the skin contamination evaluation, i.e., their body remains appropriately covered or curtains or a shelter are used. Keep in mind the individual's mental state as the

contamination evaluation is being conducted. Effective communication that provides comfort and reduces the anxiety or concerns of the individual regarding the evaluation protocol, treatment, and potential radiation exposure is critical during this time.

3. External Decontamination Objectives and Priorities

a. The primary objective of external decontamination is to prevent internal contamination through ingestion or inhalation. Therefore, avoiding intake of radioactive contamination during external decontamination is critical. The contaminated areas should be covered using items such as coveralls (e.g., Tyvex suits), plastic bags, bandages, and gloves, until decontaminated to prevent ingestion or inhalation.

b. A secondary objective is to minimize the dose to the eyes and skin. Eye and skin decontamination should proceed with appropriate urgency to ensure eye and skin dose limits are not exceeded. Refer to enclosure (12) for the specific isotope's physical data to estimate the skin exposure rate and enclosure (6) for estimating any expected deterministic effects.

c. The listed steps should be taken while conducting external decontamination efforts to avoid the external and internal spread of radioactive contamination. The order below is the general priority of decontamination, but may be modified depending upon the circumstances presented, e.g., amount of contamination present in a wound, on the face, and other parts of the body (primarily derived from reference (g)). Enclosure (13) provides guidance and a list of supplies for the comprehensive decontamination of personnel.

Note: A contaminated-injured person who is ambulatory, stabilized, and has non-life, limb-, or vision-threatening injuries should be decontaminated on-scene or at the command or installation decontamination facility, if available, to expedite decontamination efforts prior to the contaminated-injured person receiving medical care at an MTF. However, to simplify decision-making and to best utilize available facilities, the individual may be transported directly to a MTF for decontamination. The medical status of the individual should be determined by medical personnel.

Remove all contaminated clothing and place carefully into plastic bags to reduce secondary contamination of the area. Ensure all removed clothing and other articles from the contaminated individual and material used during the decontamination evolution (e.g., towels, gauze, pre-moistened wipes ("baby wipes"), and facial (nose) tissues) are retained and properly segregated and labeled for future analysis.

(1) Decontaminate any contaminated open cuts or wounds. See enclosure (10) for guidance on wound decontamination.

(2) Decontaminate external and internal areas of the face (mouth, eyes, nose, forehead, and cheeks) and the ears if indicated.

Note: Decontamination of body orifices in and around the face poses a challenge in that easily applied methods are limited. Decontamination of any areas of the face, including inside the mouth and ears, should be supervised or performed by medical personnel if readily available. In the event medical personnel are unavailable, the person in charge of decontaminating these delicate areas must use good judgment. The exception to this guidance is that only qualified medical personnel may perform irrigation of the nasal passages.

(3) Decontaminate front and back of hands.

(4) Decontaminate all other contaminated areas of the body.

4. Eye Decontamination. Routine methods using tepid saline solution or water to irrigate the eyes are acceptable, but care should be taken to ensure the run-off is directed away from the eyes, nose, mouth, and ears (reference (g)).

5. Ear Decontamination. Routine methods using tepid saline solution or water to irrigate the ears are acceptable, but care should be taken to ensure the run-off is directed away from the eyes, nose, and mouth (reference (g)).

6. Hair Decontamination. Hair, on either the head or chest, can be decontaminated with soap and water. When washing head hair, take care not to allow the wash or rinse water to run onto the face. If washing hair on the head or chest is not successful, it may be necessary to remove the hair. The hair should be clipped rather than shaved to avoid disrupting the skin barrier and possibly enhancing absorption of the contaminating radionuclide. Keep in mind that the contaminated individual may be averse to having their hair cut so they should be asked if their hair may be clipped (reference (g)).

7. Skin Decontamination

a. An effective decontamination attempt is one that reduces the survey count rate by at least half (50 percent more). The decontamination methods listed below are based on available facilities and decontamination supplies. The methods chosen should primarily depend upon the type (e.g., liquid or solid) and location of the contamination. They do not need to be applied in specific order to be effective. Experience has shown that allowing the person to perform as much self-decontamination as possible is both faster and more productive. Also, using decontamination equipment similar to normal bathing items increases the person's comfort level and speeds decontamination efforts. In most cases, skin contamination is as easy to remove as common dirt.

b. Experience has shown small amounts of reactor corrosion products, chemically stable medical isotopes, and other isotopes used for industrial applications are easily removed by gentle scrubbing with soap and water, waterless hand cleaner, or pre-moistened wipes.

c. The extent of the decontamination effort should be a balance between the risk of injuring the skin by the decontamination process and the possibility of injury to the skin from the contamination itself. Multiple decontamination attempts or procedures to include mild or more aggressive methods should be performed with caution because skin irritation, abrasion, and possibly chemical burns may result. Abrading the skin may allow an entry point for radioactive materials deposited on its surface. Do not injure the skin. If available, medical personnel should monitor the skin during the decontamination process when multiple attempts or aggressive methods are used.

Note: Per reference (b), document and report the occurrence of external contamination using applicable forms located at https://www.med.navy.mil/directives/Pages/NAVMEDForms.aspx.

(1) Wash 1 to 3 minutes using soap and tepid water in a sink or shower. A washcloth or soft surgical scrub brush may be used to aid in removing contamination. If the contaminated person is able to perform self-decontamination under the guidance of trained personnel (e.g., health and medical physicists, medical personnel, and radiation health and control technicians), the person should decontaminate their hands or place surgical gloves on their contaminated hands prior to decontaminating other areas of the body.

Note: A face or splash shield should be used for personnel conducting decontamination methods that could generate splashing.

(2) Wash 1 to 3 minutes using waterless hand cleaner. Do not use waterless hand cleaner on the face or other areas where it can cause irritation.

(3) Use pre-moistened wipes to wipe from the area of lowest contamination to the area of highest contamination if applicable. These wipes are most useful when decontaminating delicate skin on the face.

(4) Apply self-adhering adhesive tape to lift removable material from the skin. This procedure works best for dry dust-type contamination. However, this should not preclude washing if washing is more convenient. Avoid using strongly adherent tape such as duct tape. Do not apply tape to areas with significant body hair. Do not apply tape on or near the eyelids or any other fragile tissue that are sensitive or may tear.

(5) Wash 1 to 3 minutes using a mild abrasive soap, e.g., mechanics hand soap, and water.

(6) If the contamination cannot be removed by washing, consider covering (e.g. wrap, bandage, or glove) the contaminated area to allow removal through sweating or skin sloughing. After 6 to 9 hours remove the wrapping or cover to measure the amount of contamination remaining. Wash the area again if significant amounts remain. Replace the covering as necessary.

8. Decontamination Methods at Research Facilities, Naval Nuclear Repair Shipyards, and Major Treatment Facilities. At facilities where large quantities, exotic, or chemically active isotopes are used, additional and more aggressive techniques such as the ones provided below may be used, provided there is supervision by medical and health physics personnel. These techniques do not have to be performed in any specific order. The procedures chosen should depend upon the location of the contamination, type of contamination, convenience of decontaminating material, etc.

a. Wash 1 to 3 minutes with 10 percent dilute bleach and then rinse with water.

b. Upon a physician's determination and supervision, a 20 percent dilution (5:1 dilution with water) of commercial bleaches (5 percent sodium hyperchlorite) may be used around the face, wounds, etc. Lesser dilution up to undiluted bleach may be used on other skin areas, such as hands or extremities.

c. Wash 1 to 3 minutes with a 1 percent citric acid solution.

d. Wash 1 to 3 minutes with a 1 percent ethylene diamine tetra acetic (EDTA) acid in detergents.

e. If symptom-producing exposures are expected and other methods have not been effective, wash for 30 seconds to 90 seconds with a saturated potassium permanganate ($KMnO_4$) in 0.2N solution of sulfuric acid, then rinse with water. Use fresh 5 percent solution of sodium acid sulfite to remove the potassium permanganate stain. Do not use this procedure on the face or other areas where it may produce an injury.

9. Clinical Symptoms. Transfer the person to a MTF for medical care and follow-up evaluation if clinical symptoms or signs are expected.

10. Release of Individuals Following External Decontamination. Following decontamination of a person, a detailed whole-body survey (i.e., frisk) or monitoring via portal monitor or equivalent, if available, must be completed to determine if the person can be released from established radiological controls per command or designated authority release requirements.

11. Dose Estimate or Evaluation. Providing appropriate medical care for externally contaminated personnel depends upon proper assessment of the clinical seriousness of the contamination. The expected biological response is dependent upon the dose received, the time over which the dose is received, the area contaminated, and the energy and type of radiation

involved. This problem is compounded if the contamination is loose or mobile so it can enter the body through absorption, inhalation, or ingestion. An estimated external or skin dose from contamination may be determined by a qualified health or medical physicist with experience using an appropriate dose calculation program (e.g., VARSKIN). Contact the BUMED REAB if any assistance is required in estimating the skin dose. Expected deterministic affects, if any, based on estimated dose due to contamination may be determined using information from enclosure (6).

12. BUMED REAB Assistance. If assistance is needed with decontaminating a person, clarifying the previously mentioned guidance or procedures are ineffective at removing the contamination, contact the BUMED REAB or radiation health or safety subject matter experts within the command's immediate superior in command, if applicable, for further guidance.

# INTERNAL CONTAMINATION AND DECONTAMINATION

1. Background. A person is considered to have internal contamination when unwanted radioactive material has gained access into the body through inhalation, ingestion, absorption, or wounds. Internal contamination can result in a higher aggregate dose compared to the same amount of external contamination, because of the slower removal time and potentially higher organ sensitivity to internal contamination. The personnel performing decontamination must understand the different types of radioactive material used at their command, how their instruments react to the radionuclides (internally, externally, and in wounds), and techniques on how to prevent or minimize internal contamination. In general, the items listed in subparagraphs 1a through 1b of this enclosure should be considered regarding internal contamination.

a. Radioactive materials used in industrial applications tend to have relatively long half-lives, are insoluble, and are absorbed into organs and excreted via normal body processes.

(1) Inhalation will tend to deposit insoluble radioisotopes in the lungs, which will be removed slowly via biological removal and radioactive decay.

(2) Ingested radioactivity will typically not result in a large uptake into the body and is excreted largely via the feces and urine.

(3) Wound contamination will not usually result in a large intake into the body and typically will be localized to the wound.

(4) Absorption of insoluble radionuclides is not normally a concern.

b. Most radioactive materials used in medical applications have relatively short half-lives and are soluble, circulate through the entire body and collect in a specific tissue, organ, or system. Inhalation, ingestion, absorption, and wounds can lead to internal contamination, which will be removed by radioactive decay and excretion via normal bodily functions.

2. Procedures. Depending on the exposed person's physical condition and the circumstances and extent of the exposure, the actions listed in subparagraphs 2a through 2g of this enclosure must be taken, as applicable.

a. Perform medical evaluation. Attend to life-, limb-, or vision-threatening injuries first.

b. Establish control of external contamination, i.e., take action to prevent additional internal contamination through inhalation or ingestion. Depending on the circumstances, this may mean removing or simply covering the external contamination.

c. Document a history of the exposure. Pay special attention to identify the time and duration of exposure, isotope involved, chemical form, and any indication of particle size.

d. Perform in vitro bioassay analysis if indicated. Bioassay sampling of urine and feces provides indirect measurement of internal contamination when direct measurement by in vivo bioassay (internal monitoring) is impractical or insufficiently sensitive. Collect appropriate urine samples, fecal samples, or both, if internal contamination by non-gamma emitting radioactivity is suspected or verified. Collection of these samples should begin as soon as possible after the internal contamination event, subject to the instructions and guidance in enclosure (11).

(1) An in vitro bioassay is the only acceptable assay technique for alpha and pure beta-emitting radionuclides, which cannot be assayed by an in vivo bioassay (internal monitoring). In general, in vitro bioassay analysis is typically not required to determine if there is internal contamination via gamma-emitting radionuclides, if in vivo bioassay analysis is readily available or will be available in the near future (i.e., following an aircraft carrier or submarine deployment).

(2) Depending on the isotope and chemical form, estimates of internal contamination may be made by collecting and counting excreta (urine, feces, or both). Consider transit times of radioactive materials within the body to ensure collection of a valid sample. For comparative purposes, normal background samples should also be taken from unexposed personnel. For questions regarding the applicability of taking samples, the BUMED REAB should be contacted.

e. For alpha and beta-emitting radionuclides, collect and monitor any coughed up mucus for contamination. Monitor any mucus from the person blowing their nose for contamination.

f. Nasal, throat, and saliva swabs can provide an early qualitative assessment of a significant inhalation or ingestion incident, respectively, and should be performed within 30 minutes following the contamination event for best results. While difficult to directly correlate to dose, swabs with detectable radioactivity are an indication that an intake may have occurred and follow-up in vivo bioassay (internal monitoring) analysis is necessary. Swabs are particularly indicated within 30 minutes of inhalation or ingestion of an alpha-emitting radionuclide, but of little value following inhalation or ingestion of a beta-gamma emitting radionuclide, if in vivo bioassay analysis is readily available or will be available in the near future (i.e., following a carrier or submarine deployment). If collected onsite, nasal, throat, and saliva swabs should be performed in a controlled area to prevent inadvertent contamination of the samples.

Note: Although taking nasal, throat, or saliva swabs within 30 minutes from the contamination event will provide the best qualitative results, the swabs should still be collected even if it takes longer than 30 minutes. Nasal, throat, and saliva swab results should not be used as the sole criterion when making decisions concerning dose intervention and mitigation for contaminated individuals, and should be followed up with appropriate in vivo or in vitro bioassay analysis.

(1) Nasal swabs should be performed as prescribed in subparagraphs 2f(1)(a) through 2f(1)(d) of this enclosure.

(a) Trained personnel should slightly moisten a cotton-tipped applicator, and gently rotate the swab about the accessible surface of the nostril. A separate swab must be used for each nostril.

Note: Medical personnel must perform the nasal swabs if readily available (i.e., available within 30 min). If not, radiation health or safety personnel trained on performing nasal swabs may perform them to ensure the samples are collected as close to the 30 minute window as possible. As an alternative, the potentially contaminated person may perform self-nasal swabs under proper supervision of medical, radiation health, or radiation safety personnel.

(b) Allow the swabs to completely dry and then place in an appropriate container.

(c) The information provided in subparagraphs 2f(1)(c)1 through (1)(c)3 of this enclosure should accompany the swabs.

1. Name of person and two other identifiers (e.g., DoD identification number, worker (badge) identification number, or birthdate as appropriate).

2. Time the swab was taken after estimated time of radiological casualty or event, and in which nostril.

3. Possible radionuclides of concern.

(d) Record counts on each dry nasal swab for later dose reconstruction and calculation. Contact the BUMED REAB for guidance on counting nasal swabs if necessary.

(2) A single throat or saliva swab should be performed as outlined in subparagraphs 2f(2)(a) through 2f(2)(e) of this enclosure.

(a) Throat swab. Medical personnel should slightly moisten a cotton-tipped applicator and gently swab the posterior oropharynx region of the throat.

Note: Qualified medical personnel may only perform throat swabs.

(b) Saliva swab. Trained personnel should slightly moisten a cotton-tipped applicator and gently swab the inside of a cheek. As an alternative to conducting a saliva swab, the potentially contaminated person may gently spit saliva onto a 4 inch x 4 inch gauze pad.

Note: A saliva swab may be performed by medical personnel and trained radiation health or safety personnel. As an alternative, the potentially contaminated person may perform a self-saliva swab under proper supervision of medical personnel or trained radiation health or safety personnel.

(c) Allow the nasal or saliva swab(s) to completely dry and then place in an appropriate container.

(d) Information requested in paragraph 2f(1)(c) of this enclosure should accompany the swabs.

(e) Record the counts on the swab(s) for later dose reconstruction and calculation. Contact the BUMED REAB for guidance on counting swabs, if necessary.

g. Perform dose evaluation for internal contamination

(1) A number of different approaches may be used to evaluate the extent and magnitude of internal contamination and therefore, estimate the committed effective dose equivalent (CEDE) from reference (h) or committed effective dose (CED) from reference (i). Reference (h) is available at https://www.epa.gov/radiation/federal-guidance-report-no-11-limiting-values-radionuclide-intake-and-air-concentration. In health physics practice, internal contamination results in an equivalent dose to the body calculated over the span of a 50-year period. Each radioisotope, based on chemical structure, will either deposit in a specific organ or organs (e.g., the thyroid selectively uptakes iodine) or disperse through the entire body and eventually be excreted. The committed dose equivalent (CDE), from reference (h) or the committed equivalent dose (CEqD), from reference (i) is calculated for a specific organ, the CED or CEDE is calculated for the whole body. These quantities, although calculated over a 50-year period, are assigned to the year of intake. Methods to calculate CEqD or CDE and CED or CEDE are listed in the next paragraph. The internal dose must be documented per reference (b), chapter 5.

Note: CEqD and CED will be the terms used for discussing internal dose for the remainder of the instruction.

(2) In no particular order, the methods listed in this paragraph may be used to determine internal radiation dose. Refer to references (b), (d), and (k) through (t) for additional information and more specific guidance for calculating internal dose using these methods.

(a) Calculation of CEqD and CED using annual limit on intake (ALI). This requires a representative air sample of airborne radioactivity or bioassay analysis measurements following inhalation and ingestion of a radionuclide(s). The inhalation and ingestion ALIs from reference (d) for each radionuclide must be used based on a CED of 5 rem (50 mSv) per year (stochastic ALI) or a CEqD of 50 rem (500 mSv) per year to the limiting organ or tissue (non-stochastic ALI) for radiation workers.

(b) Calculation of CEqD and CED using derived air concentration (DAC). This requires a representative air sample of airborne radioactivity. The inhalation DACs from reference (d) for each radionuclide must be used based on a CED of 5 rem (50 mSv) per year (stochastic ALI) or a CEqD of 50 rem (500 mSv) per year to the limiting organ or tissue (non-stochastic ALI) for radiation workers.

(c) Calculation of CEqD and CED using in vivo bioassay (internal monitoring), in vitro bioassay analysis, or both.

(d) Other methods as specified in chapter 5 of reference (b) or as determined in consultation with the BUMED REAB.

(3) Notify the BUMED REAB of the estimated dose immediately by telephone or IMMEDIATE message, for a sum of deep dose equivalent and CEqD for any organ or tissue exceeding 50 rem (500 mSv) or a total effective dose equivalent (TEDE) exceeding 5 rem (50 mSV) in a single incident. A follow-up NAVMED 6470/1 report must also be forwarded within 24 hours from the determination of such doses per reference (b). Per reference (b), a NAVMED 6470/13 must be completed.

(4) Evaluate the risk versus benefit of initiating action to reduce the internal contamination. If possible, consult with the BUMED REAB prior to initiating therapeutic (e.g., chelation therapy) procedures. The procedures chosen will depend upon the circumstances of the situation, health of the person, isotope(s) present, and chemical form.

(5) Document the exposure and report the occurrence of internal contamination per reference (b) and applicable radiological control program requirements.

3. Internal Decontamination Treatment Methods

a. When deciding on the methods of decontamination treatment or dose mitigation for internal contamination, a comparison must be made between the benefit of removing the radioactive contaminants using modalities associated with significant side effects, and the short- and long-term health effects of not treating the internalized radioactive material(s).

b. Treatment methods to mitigate the health effects of internal contamination fall into several major categories, which are the following (taken primarily from reference (f)):

(1) Reducing or inhibiting absorption of the isotope in the GI tract. In extremely rare cases, gastric lavage may be considered. At the MTF level, carefully consider the use of whole-bowel irrigation (WBI). WBI should not be attempted unless the listed criteria are met:

(a) Toxicology consultation is available.

(b) All necessary equipment is available.

(c) Significant exposure presenting in under 4 hours from incident time.

(d) There are no contraindications to WBI such as: craniofacial abnormalities; concomitant head, thoracic, or abdominal trauma; uncontrolled vomiting; current, or anticipated diarrhea; clinically significant GI hemorrhage; bowel obstruction, perforation, or ileus; volume depletion; hemodynamic instability; hemorrhage; or compromised unprotected airway. WBI should be used cautiously in patients with altered mental status.

Note: Associated risks of WBI include glycol electrolyte solution (PEG-ES) induced anaphylactoid reactions, esophageal perforation, aspiration with resultant acute respiratory distress syndrome (ARDS), transient hypoxia, nausea, vomiting, abdominal cramps, and bloating.

Caution: The use of cathartics (aka purgatives) should not be used (i.e., not indicated) as a method for reducing or inhibiting absorption of the isotope in the GI tract.

(2) Blocking uptake to the organ of interest. Example: within 4 hours of exposure, administer potassium iodide (KI) to block uptake of radioactive iodine by the thyroid.

(3) Diluting the isotope. Example: increase fluid hydration for internal tritium contamination.

(4) Altering the chemistry of the substance. Example: prevent deposition of uranium carbonate complexes in the renal tubules by use of sodium bicarbonate.

(5) Displacing the isotope from receptors. Example: administer stable iodine to displace technetium (Tc)-99m.

(6) Using traditional chelation techniques. Example: administer DTPA for internal deposition of plutonium and other transuranics and actinides.

(7) Using ion exchange techniques. Example: administer prussian blue to reduce or inhibit the absorption of cesium (Cs)-137 into the body via the GI tract.

(8) Excising radionuclides from wounds early to minimize absorption. See enclosure (10) for instructions on performing wound decontamination.

(9) Excising radionuclides from the nasal passages. Nose blows and nasal irrigation are two methods for removing radioactivity from the nasal passages.

(a) Nose blows. Nasal passages can be decontaminated simply by having the individual blow their nose to eliminate as much material as possible per reference (g). Medical personnel, if readily available, or radiation health or safety personnel must instruct the individual to blow their nose into a facial (nose) tissue. Multiple nose blows are permitted as long as a reduction of contamination is observed following each attempt.

(b) Nasal irrigation. Nasal passages can be irrigated with tepid saline or water and may only be performed by medical personnel. Irrigation of the nasal passages as a means of decontamination should only be considered if deemed absolutely necessary, i.e., the individual has a high concentration of radioactive material in the passages and nose blowing is not deemed effective. However, prior to the irrigation of the passages (if believed warranted), careful consideration by medical personnel should be given to the risk of forcing more radioactive material into the body via the oropharynx if irrigation is performed per reference (g).

(10) Excising radionuclides from the mouth. The mouth can be decontaminated with tepid saline or water. Instruct the individual to gently swish the solution or water for at least 1 minute then spit it out into a radioactive-waste container. Ensure the contaminated person does not gargle or swallow the solution. Multiple decontamination attempts are permitted as long as a reduction of contamination is observed following each attempt.

(11) Using bronchoalveolar lavage for severe cases of insoluble inhaled particles. This rarely used technique would be expected only in a case with a very large lung burden of an insoluble alpha emitter such as plutonium and other transuranics and actinides.

c. See enclosure (12) and references (c), (f), and (g) for guidance on the appropriate treatment methods or therapies for internal contamination for specific radionuclides.

# WOUND CONTAMINATION AND DECONTAMINATION

1. Background. A contaminated wound allows for an increased potential for the radionuclide to be retained in local tissues or, in rare instances, metabolized and deposited in target organs or tissues. The personnel supervising decontamination must understand the different types of radionuclides used at their command, how instruments react to the radionuclides (internally, externally, and in a wound), and techniques to prevent or minimize internal contamination. In general, the considerations listed in subparagraphs 1a and 1b of this enclosure should be made regarding wound contamination.

a. Radionuclides used in industrial applications tend to have relatively long half-lives and are insoluble. Wound contamination will not usually result in a large uptake into the body and will typically be localized to the wound.

b. Most radionuclides used in medical applications tend to have relatively short half-lives and are soluble, circulate through the entire body, and collect in a specific tissue, organ, or system. Wound contamination can lead to internal contamination where it will be removed by radioactive decay and excretion via biological methods.

2. Procedures. Depending on the exposed person's physical condition, circumstances, and extent of the exposure, the actions listed in subparagraphs 2a through 2c of this enclosure must be taken as applicable.

a. Perform medical evaluation. Attend to life-, limb-, or vision-threatening injuries first.

b. Determine location and levels of external contamination.

c. Monitor the wound for the presence of contamination.

(1) A direct survey (i.e., frisk) with a RADIAC instrument may be used for contamination emitting beta-gamma radiation. If counts are detected above two times background, then decontamination of the wound is required per reference (c).

Note: Command radiological control manuals or SOPs may institute different contamination limits based on radiation type to define the contamination-action level (e.g., greater than 100 ccpm of beta-gamma emitting contamination as measured under the area of a DT-304 probe). In such cases, the command’s approved contamination-action level must be followed.

(2) For alpha emitting contamination, dry swabs or surgical sponges should be used to probe the wound for contamination. Only qualified medical personnel may perform the probing. The material must then be thoroughly dried before effective alpha counting can be accomplished.

(3) Document relevant wound-survey results from the event using applicable survey forms located at https://www.med.navy.mil/directives/Pages/NAVMEDForms.aspx.

3. Decontamination Methods

a. Minor or superficial wound decontamination. Decontamination of a minor or superficial wound does not require the presence or supervision of medical personnel if medical personnel are not available within a reasonable period.

Note: A wound is considered minor if there is no bleeding or the bleeding can be readily stopped. The wound can be decontaminated without medical personnel present provided both the contaminated-injured person, and the person in charge, are in agreement that it does not require immediate medical attention, and the person in charge is confident the level of local resources and training of the decontamination team is appropriate to effectively decontaminate the minor wound.

(1) The minor wound should be irrigated with isotonic saline solution, sterile distilled water; or if the previous options are unavailable, potable water until contamination in the wound is removed or no change in contamination level is noted. If the wound and a small area around it are both contaminated, then both may be decontaminated simultaneously by washing without concern for washing more activity into the wound. A face or splash shield should be used for personnel conducting decontamination procedures that could generate splashing.

Note: An effective decontamination attempt is one that reduces the survey count rate by 50 percent or more.

(2) If at any point the injured person's condition changes, or the person in charge or contaminated-injured person no longer feels the situation constitutes a minor wound, the person in charge must contact local medical resources, if not already on-scene. In all cases, the contaminated-injured person should be referred to a designated MTF on a non-emergent basis after successful decontamination for a medical evaluation of the wound.

b. Major wound decontamination. Decontamination of any wound other than a minor wound as defined in subparagraph 3a of this enclosure requires the presence and supervision of medical personnel (e.g., physician, nurse, nurse practitioner, physician assistant, corpsman, or emergency medical technician). Decontamination of a wound in this case should follow standard precautions for infection control and pain management. Decontamination procedures for wounds requiring medical personnel supervision are:

(1) The wound should be irrigated with isotonic saline solution, sterile distilled water or, if the previous options are unavailable, potable water until contamination in the wound is removed or no change in contamination level is noted. If the wound and a small area around it are both contaminated, then both may be decontaminated simultaneously by washing without concern for washing more activity into the wound. A face or splash shield should be used for personnel conducting decontamination procedures that could generate splashing.

Note: An effective decontamination attempt is one that reduces the survey count rate by 50 percent or more.

(2) A contaminated abrasion or burn can be cleaned with a mild soap or detergent solution. If necessary, the medical person in charge can use a topical anesthetic to allow more vigorous cleaning.

(3) In MTFs with wound cleansing equipment or sprays, the use of pressurized cleansing fluids within the pressure range of 4 to 15 pounds per square inch have demonstrated an increased efficiency of removing certain contaminants in wounds.

(4) Depending on the radioisotope, chelating agents such as diethylentriamine-pentaacetate (DTPA) for actinides can increase the effectiveness of decontamination by irrigation. However, care should be given to prevent an overdose of chelating agents, as it is impossible to measure the amount that is absorbed by the body. To identify chelating agents for specific radionuclides regarding wound decontamination refer to enclosure (12). The medical person in charge should contact the BUMED REAB prior to administering any chelating agents for wound decontamination.

(5) If residual contamination remains in the wound, the decontamination process should be repeated until no further progress is made. If the contamination levels continue to be elevated and decontamination progress is overly slow or nonexistent, the attending or treating physician should explore the wound for foreign bodies. Minor wet debridement may be necessary. However, careful consideration must be exercised to evaluate the potential risk versus the possible benefit to the injured person. This evaluation should specifically consider the potential radiation dose resulting from the residual contamination. Keep in mind that wounds will still need to be irrigated before closure for infection control purposes. This may remove the remaining contamination. In general, small amounts of contamination in a wound do not override the concerns for proper infection control and cosmetic effect. Consult the BUMED REAB if there is doubt regarding decontamination effectiveness.

Note: If residual contamination remains after it has been determined that no further progress can be made, the NCRP recommends a relative innocuous intervention. This includes administration of DTPA or another chelating agent, if the dose expected from a contaminated

wound is 1 to 10 times the annual exposure limit (i.e., 5 rem). The NCRP also recommends more drastic intervention, such as surgical excision, may be appropriate if the dose expected from a contaminated wound is more than 10 times the annual limit as outlined in reference (u).

(6) Under no circumstances should radical or function impairing surgical procedures be undertaken because of radioactive contamination without the medical person in charge first contacting the BUMED REAB.

c. Coordinate with the BUMED REAB if there are any questions or concerns regarding documentation of contamination details, medical treatment, decontamination procedures, and dose calculation.

# COLLECTION AND PROCESSING OF BIOASSAY AND BIO-DOSIMETRY SAMPLES

1. In vitro bioassay monitoring includes analysis of urine and fecal samples to determine the nature, activity, location, or retention of radionuclides in the body. The dose from internal contamination is calculated as part of the analysis.

2. Bio-dosimetry is the use of physiological, chemical, or biological markers of exposure to ionizing radiation in tissues (such as blood, nail, or hair clippings) for the purposes of reconstructing doses. Bio-dosimetry is most commonly used to estimate doses from incidents (e.g., criticality accident) that could result in high doses to personnel.

3. Assistance with Sample Collection and Analysis. Contact the BUMED REAB for assistance with obtaining in vitro bioassay and bio-dosimetry analyses services, sample collection, or for any questions or guidance regarding sample collection and analysis.

4. Responsible Party for Sample Collection. MTFs are responsible for the physical collection of bioassay and bio-dosimetry samples. Applicable medical department representatives (e.g., qualified health physicist or medical physicist, or medical provider (e.g., physician or nurse)) must ensure proper collection procedures are used and familiarize themselves with the laboratory's instructions and guidance provided in reference (c) to include techniques, collection timelines, and sample collection supplies required.

5. Collection of Samples. Collection of required samples must be conducted based on the instructions or guidance provided by the bioassay or bio-dosimetry laboratory or qualified health physicists (i.e., skilled in bioassay and bio-dosimetry sample collection). The instructions provided by the laboratory should include, but may not be limited to, sample size, total number of samples required, and periodicity and duration of sample collection. Apart from specific instructions provided by the laboratory, the basic information and guidance on the specific type of samples to be collected are listed in subparagraphs 5a through 5d of this enclosure.

a. Urine samples

(1) In general, urine samples should be collected as soon as possible after exposure, and should be collected again after appropriate time intervals. The time interval depends on the biokinetics and the physical half-life of the radionuclide involved. There are several collection protocols for urinalysis to include single void or spot, partial day, total 24 hour, and 24 hour. Reference (c) provides more information about each protocol.

(2) The sample size required for analysis is variable, and can range from a few milliliters for tritium to total 24 hour samples for actinides, such as plutonium or americium. Ensure the individual understands the instructions from the bioassay laboratory regarding sample collection. Also, ensure the individual is provided clear instructions to collect samples in a

contamination-free or "clean" area, and that only individuals with clean hands should handle the samples. Refrigerate or store samples in a freezer if not processed immediately after collection (taken from reference (c) with permission from the NCRP).

b. Feces samples. Fecal samples collected need to be total voidings, not simply stool smears or swabs. If possible, feces should be collected for 3 to 4 days and the results of the samples used to assess the intake and body content. Be prepared to collect subsequent samples for large intakes of radioactive material. Ensure the individual is provided clear instructions on how to collect samples in a contamination-free or "clean" area, and that only individuals with clean hands should handle the samples, per reference (c).

c. Blood samples

(1) The frequency of blood samples is dependent on the type of bio-dosimetry assay method to be performed.

(a) For a complete blood count with differential, the first blood sample should be collected immediately with subsequent samples taken every 8 hours, for 2 to 3 days. Based on clinical findings, subsequent samples may be required (e.g., every 12 hours) for the next 3 to 6 days.

Note: Serial CBCs with differential should be taken in the case of a suspected radiation exposure.

(b) For cytogenetic assays, blood samples should be collected between 24 hours after exposure. However, blood samples collected from a few days to 4 weeks can be processed without requiring the utilization of a correction factor to estimate the dose except for cases involving very high doses (greater than 800 rad (8 Gy)), where early collection of blood samples is recommended.

(c) For blood chemistry assays, blood samples should be collected between 24 hours (serum amylase and CRP) and 3 to 4 days (Flt-3 ligand) after exposure.

(2) The volume of blood and type of collection tube required are also dependent on the type of bio-dosimetry assay to be performed. See Table 11.1 for the volume of blood and type of collection tube required based on the bio-dosimetry assay method. All information in this table was provided by the Armed Forces Radiobiology Research Institute. Volume provided is enough to do each test in duplicate at a minimum. Blood samples should be collected after obtaining signed informed consent and sent to qualified laboratory at room temperature with caution to avoid overheating and freezing the sample.

| Bio-dosimetry Assay | Blood Collection Tube Type | Blood Volume (ml) |
|---|---|---|
| Lymphocyte count and kinetics or CBC with differential | EDTA | 3-5 ml |
| Serum amylase activity | Serum separator tube | 2-3 ml |
| Plasma CRP and Flt-3 ligand | EDTA | 3-5 ml |
| Cytogenetic bioassays | | 6-10 ml |
| Dicentric - conventional analysis (1,000 spreads) | Sodium heparin | 2-3 ml |
| Premature Chromosome Condensation-dicentrics | Sodium heparin | 2-3 ml |
| Premature Chromosome Condensation-excess fragments or rings | Sodium heparin | 2-3 ml |

Table 11.1. Biodosimetry Assay with Recommended Blood Collection Tubes and Volumes.

Note: Blood samples may require the addition of an anticoagulant such as EDTA at the time of collection to minimize clotting and to ensure uniformity in aliquots removed for duplicate analysis.

(3) Blood samples should be placed in an appropriate insulated shipping container for preservation during storage and transit. The samples should not be placed in direct contact with a coolant pack to prevent freezing the blood.

d. Nail and hair clippings. These samples only need to be collected one-time post exposure and should be collected as soon as practical. Unless noted differently in the instructions from the laboratory, an adequate sample collection size is a minimum of at least 2 nail clippings and at least 13 cm or 5 inches total of a single thread of hair with the shortest permissible length for a single thread of hair to be not less than 0.6 cm or 0.25 inches. Nail samples should be kept cool once collected.

6. Required Information. Absent specific instructions from the laboratory regarding information requirements for samples collected as directed in subparagraphs 6a through 6h of this enclosure should be included with each sample.

a. Full name of individual.

b. Identification number (e.g., DoD identification number, worker (badge) identification number, or birthdate as appropriate).

c. Date and start time, and date and end time for collection of each urine sample if applicable.

d. Date and time of collection of each fecal sample and time or time interval since last voiding, if applicable. In addition, the time interval between the first void and time of the contamination incident should be documented.

e. Date and time of collection of each blood sample, if applicable.

f. Date and time of collection of nails and hair, if applicable.

g. Approximate time of sample collection following exposure.

h. Any internal contamination or dose mitigation therapy the individual has received to hasten the elimination of a radionuclide such as chelation therapy.

7. Shipping. Ensure the bioassay and bio-dosimetry samples are packaged under the proper environmental conditions (e.g., with cold packs). Shipping containers containing any type of bio-dosimetry samples should not be placed through a mail and package x-ray scanner because the irradiation of the container will result in inaccurate analysis. Therefore, DO NOT X-RAY or similar labels must be placed on the outside of each container.

8. Analysis. Analysis of bioassay and bio-dosimetry samples must be performed at Department of Defense-approved laboratories. Contact the BUMED REAB for approved laboratories and coordination of services.

9. Dose Determination and Reporting Requirements. For the Navy's nuclear capable shipyards, fleet maintenance activities, and prototype sites, dose analysis and calculations may be performed on site and approved by the cognizant command authority (e.g., Director of Radiation Health, code 105.5, or designated authority). Per reference (b), chapter 5, for all other commands or activities, the Naval Dosimetry Center must be contacted for concurrence on all analysis reports, to include all dose estimate calculations.

# INFORMATION ON SELECT RADIONUCLIDES

1. Background. Table 12.1 was developed to provide a quick reference on relevant information for radionuclides commonly or potentially encountered by Navy and Marine Corps personnel, who perform radiological-related work. It is largely adapted from references (c) and (g). Information provided includes the radionuclide origin, radiation decay types, physical characteristics, and internal dose mitigation. In addition, this enclosure includes more detailed information, instruction, and guidance on key radionuclides associated with radiological-related operations performed within the Navy and Marine Corps. The radionuclides are chromium (Cr), cobalt (Co), depleted uranium (DU), iodine (I), plutonium (Pu), radium (Ra), tritium (H-3), and technetium (Tc).

2. In an incident involving fallout (such as a radioactive plume following a nuclear reactor accident), many radionuclides may be present. The most prevalent radionuclides are likely to be isotopes of iodine, cesium (Cs)-137, Cs-134, strontium (Sr)-90, and yttrium (Y)-90.

3. The treating physician or designated medical personnel, if possible, should contact the BUMED REAB prior to the administration of blocking agents, chelating agents, or other methods for internal dose mitigation listed in this enclosure with this exception: the administration of KI as a blocking agent may be performed without contacting the BUMED REAB.

| Isotope | Origination | Decay | Energy (MeV) | Half-life | External Dose | | Internal Dose | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Gamma Constant (mSv-$m^2$/ hr-MBq) | Gamma Constant (rem-$m^2$ / hr-Ci) | Target Organ | Internal Dose Mitigation |
| Tritium (H-3) | Military, Power reactor | $\beta^-$ | $\beta^-$: 0.019 (max) | 12.3 y | N/A | N/A | Whole body | Water diuresis (force fluids), Diuretics |
| Chromium-51 (Cr-51) | Military, Power reactor | $\gamma$, Electron capture | $\gamma$: 0.320 | 27.7 d | 6.32 E-6 | 2.34 E-2 | Whole body | DTPA, EDTA, NAC, (antacids are contraindicated) |
| Cobalt-60 (Co-60) | Military, Power reactor, Radiography | $\beta^-$, $\gamma$ | $\beta^-$: 0.318 (max) $\gamma$: 1.17; 1.33 | 5.27 y | 3.70 E-4 | 1.37 E 0 | Whole body | DTPA, DMSA, EDTA, NAC |
| Zinc-65 (Zn-65) | Military, Power reactor | $\beta^+$, $\gamma$ | $\beta^+$: 0.325 (max)[5] $\gamma$: 1.12; | 244 d | 8.92 E-5 | 3.30 E-1 | Whole body | CaDTPA, CaEDTA, Zinc Sulfate as a diluting agent |

| | | | | | External Dose | | Internal Dose | |
|---|---|---|---|---|---|---|---|---|
| Strontium-90 (Sr-90) and Yttrium-90 (Y-90) | Military, Medical, Power reactor, Fallout | $\beta^-$ | $\beta^-$: 0.546 (max) (Sr-90); $\beta^-$: 2.28 (max) (Y-90) | 28.8 y (Sr-90); 64.1 h (Y-90)[6] | N/A | N/A | Bone surface | Aluminum hydroxide, Calcium chloride, Calcium gluconate |
| Isotope | Origination | Decay | Energy (MeV) | Half-life | Gamma Constant (mSv-$m^2$/ hr-MBq) | Gamma Constant (rem-$m^2$/ hr-Ci) | Target Organ | Internal Dose Mitigation |
| Technetium-99m (Tc-99m) | Medical, Power reactor | $e^-$, $\gamma$ | $e^-$: 0.002, 0.143 $\gamma$: 0.141 | 6.01 h | 3.32 E-5 | 1.23 E-1 | Whole body | Potassium Perchlorate |
| Iodine-125 (I-125) | Medical, Power reactor, Fallout | $\gamma$ | $\gamma$: 0.0355 | 59.4 d | 7.43 E-5 | 2.75 E-1 | Thyroid | Potassium iodide |
| Iodine-131 (I-131) | Medical, Power reactor, Fallout | $\beta^-$, $\gamma$ | $\beta^-$: 0.606 (max) $\gamma$: 0.365 | 8.02 d | 7.64 E-5 | 2.83 E-1 | Thyroid | Potassium iodide |
| Cesium-137 (Cs-137) | Medical, Power reactor, Radiography, Fallout | $\beta^-$, $\gamma$ | $\beta^-$:0.514 (max) $\gamma$: 0.662 | 30.1 y | 1.02 E-4 | 3.76 E-1 | Whole body | Prussian blue |

| | | | | | External Dose | | Internal Dose | |
|---|---|---|---|---|---|---|---|---|
| Iridium-192 (Ir-192) | Radiography | $\beta^-$, γ | $\beta^-$: 0.672 (max); 0.535<br>γ: 0.317, 0.468 | 73.8 d | 1.60 E-4 | 5.91 E-1 | Whole body | Consider DTPA, EDTA |
| Selenium-75 (Se-75) | Radiography | γ | γ: 0.136, 0.265, 0.280 | 119.8 d | 2.32 E-4 | 8.58 E-4 | Whole body | Consider WBI |
| Isotope | Origination | Decay | Energy (MeV) | Half-life | Gamma Constant (mSv-$m^2$/ hr-MBq) | Gamma Constant (rem-$m^2$/ hr-Ci) | Target Organ | Internal Dose Mitigation[2] |
| Radium-226 (Ra-226) | Medical | γ, α | γ: 0.269, 0.154, 0.324<br>α: 5.72, 5.61 | 1600 y | 8.79 E-5 | 3.25 E-1 | Bone surface | Aluminum hydroxide, Calcium chloride, Calcium gluconate |
| Uranium-235 (U-235) | Military | γ, α, Spontaneous fission | γ: 0.186, 0.144<br>α: 4.40, 4.37 | 7.04 E8 y | 9.16 E-5 | 3.39 E-1 | Bone surface, liver, kidney | Bicarbonate, consider dialysis |
| Uranium-238 (U-238) (DU) | Military | γ, α, Spontaneous fission | γ: 0.0496<br>α: 4.15, 4.20 | 4.47 E9 y | 1.76 E-5 | 6.52 E-2 | Bone surface, liver, kidney | Bicarbonate, consider dialysis |

| | | | | | External Dose | | Internal Dose | |
|---|---|---|---|---|---|---|---|---|
| Plutonium-239 (Pu-239) | Military | γ, α, Spontaneous fission | γ: 0.0516<br>α: 5.11, 5.14, 5.16 | 2.41 E4 y | 8.15 E-6 | 3.01 E-2 | Bone surface | DTPA, DFOA, EDTA, DTPA and DFOA together |
| Americium (Am-241) | Military | γ, α, Spontaneous fission | γ: 0.0595, 0.0263 – 0.955<br>α: 5.44, 5.49 | 433 y | 8.48 E-5 | 3.14 E-1 | Bone surface | DTPA |

Table 12.1. Information on Select Radionuclides Associated with Navy and Marine Corps Radiological-Related Operations

Note: External dose gamma constant values relevant only to emitted gamma rays (i.e., does not consider any on-contact dose from beta or alpha particles, if applicable) from an isotropic point source; adapted from Specific Gamma-Ray Dose Constants for Nuclides Important to Dosimetry and Radiological Assessment, Unger L & Trubey D, Oak Ridge National Laboratory, 1982.

Note: DTPA: diethylenetriaminepentaacidic acid, DMSA: dimercaptosuccinic acid, EDTA: ethylenediaminetetraacetic acid, NAC: N-acetyl-L-cysteine, BAL: British Anti-Lewisite (or dimercaprol), WBI: whole-bowel irrigation, and DFOA: Deferoxamine.

Note: Diuretics should only be provided when the patient is expected to greatly exceed the yearly dose limit.

Note: For Zn-65, gamma radiation must be detected due to low yield beta radiation.

Note: Sr-90 is in secular equilibrium with Y-90.

Note: The target organ(s) for uranium depends on the solubility of the uranium compounds. For inhalation of insoluble compounds, uranium is generally deposited in the lungs and can remain there for long periods (months or years). Ingested insoluble compounds are poorly absorbed from the GI tract and are only retained in the body for a short time. For inhalation or ingestion of soluble or moderately soluble compounds, the uranium enters the bloodstream. For DU shrapnel fragments that are embedded in a wound and cannot be surgically removed, the remaining DU will become soluble over time and be absorbed into the bloodstream. Once uranium enters into the bloodstream, the primary target organs are the kidneys, liver, and bone surfaces.

4. Chromium

a. Background. Cr-51, with element number 24, has a physical half-life of 27.7 days and decays by emitting a gamma ray [0.320 MeV (9%)]. If ingested, chromium is not readily absorbed through the wall of the intestine.

(1) As a skin contaminant, the dose rate to the germinal cell layer is approximately 1/60th of that for the same amount of Co-60. As a surface contaminant, the resuspension factor is approximately l/80th of that for Co-60. (Note: A "resuspension factor" relates surface contamination to airborne concentration.) In addition, the dose rate from internally deposited Cr-51 is approximately l/70th of that for Co-60. Consequently, Cr-51 contamination is not as serious a concern as for Co-60. This is reflected in the higher water and airborne concentration limits.

(2) Perhaps of more importance than the radiation insult of Cr-51 are its chemical effects on living systems. Potassium chromate is a chemical toxin.

(a) Inhalation causes local irritation of mucous membranes; continuing nose irritation can result in perforation of nasal septum. Potassium chromate as an aerosol is a severe irritant at concentrations below the Occupational Safety and Health Act (OSHA) and Navy Occupational Safety and Health (NAVOSH) levels of 100 and 50 micrograms/$m^3$ respectively. The NAVOSH aerosol toxin standards are more restrictive than the radiation protection standards at the chromium radioactivity levels commonly seen in the Navy.

(b) Ingestion may cause violent gastroenteritis, circulatory collapse, vertigo, coma, and toxic nephritis; ingestion of excessive quantities can be fatal.

(c) Contact with eyes causes severe irritation and conjunctivitis. Repeated or prolonged exposure to dust, mist, or solutions may cause dermatitis. Contact with breaks in the skin may cause "chrome sores" appearing as slow-healing, hard-rimmed ulcers that leave the area vulnerable to infection.

Note: An individual will readily recognize when he or she is approaching the toxic level for chromium because of irritation to the skin, nasal passages, or the eyes. Ultimately, an individual will have problems with chromium as a chemical toxin before it becomes a true radiological hazard.

b. External Contamination. Table 12.2 converts instrument readings from corrected counts per minute (ccpm) to activity and dose rate. The numerical values are based on a dose rate of 0.075 rad/hr/$\mu Ci/cm^2$ to the germinal layer of the skin (0.07 mm depth) from Cr-51 uniformly distributed over the skin.

| Probe | Net Count Rate (ccpm) | Dose Rate $\left(\frac{\text{mrad}}{\text{hr}}\right)$ | Number of Days for 5 rads | Number of Days for 50 rads | Contamination $\left(\frac{\text{pCi}}{20\ \text{cm}^2}\right)$ |
|---|---|---|---|---|---|
| DT-304 or equivalent probe | 100<br>7,000<br>50,000 | 0.1<br>7.8<br>50.0 | 2083<br>26.7<br>4.2 | 20,830<br>267<br>42 | 30,000<br>2,100,000<br>15,000,000 |
| PRM-5 with SPA-3, HV2/Gross mode, or equivalent instrument and probe | 1,000,000 | 150.0 | 1.4 | 14 | 40,000,000 |
| PRM-5 with SPA-3, HV2/PHA mode, or equivalent instrument and probe | 1,000,000 | 176.0 | 1.2 | 12 | 53,000,000 |

Table 12.2. Dose table for Cr-51 contamination

Note: Number of days for 50 rads for all net count rates is based on a worst case scenario. These values ignore the fact that the skin normally sloughs in 2 to 20 days depending on the body location.

Note: PRM-5/SPA-3, HV2/Gross mode, calibrated in the standard calibration mode, HV1 Co-60, HV2 cadmium-109. This conversion factor should not be used in the presence of other isotopes due to the summing of counts over the entire spectrum.

Note: PRM-5/SPA-3, HV2/PHA mode, calibrated in the special calibration mode, HV1 Co-60, HV2 barium-133.

c. Internal contamination

(1) In vivo bioassay (internal monitoring) analysis. The presence of internal contamination may be verified by internal monitoring by performing partial or whole-body counting. Review enclosure (9) for guidance on performing internal monitoring. If an in vivo bioassay (internal monitoring) facility is not readily accessible, contact the BUMED REAB for guidance.

Note: An in vivo bioassay to detect Cr-51 usually requires specialized procedures or calibrations due to the very low energy gamma.

(2) In vitro bioassay analysis. The presence of internal contamination may be verified by performing in vitro bioassay analysis of urine and feces. See enclosure (11) for instructions on collecting bioassay samples for analysis.

d. Therapy

(1) External decontamination. See enclosure (8) for instructions on performing external decontamination.

(2) Wound decontamination. See enclosure (10) for instructions on performing wound decontamination.

(3) Internal decontamination. See Table 12.1 of this enclosure for the appropriate therapy to hasten the elimination of Cr-51. Antacids are not recommended as a treatment for ingestion of Cr-51. Antacids increase slightly the absorption of chromium through the wall of the intestine.

5. Cobalt

a. Background. Cobalt, element number 27, has 14 radioactive isotopes, Co-54 to Co-64. The radionuclides most likely to be encountered are Co-60, Co-58, and Co-57. Co-60 is the activation product produced by the bombardment of stable Co-59 by neutrons. Its half-life is 5.3 years and it decays by emitting a beta particle (maximum energy = 0.31 MeV, average energy is 0.091 MeV (99+%)) and gamma rays of two energies, 1.17 MeV (100%) and 1.33 MeV (100%). The other isotopes have shorter physical half-lives, Co-57, 271 days, and Co-58, 71 days. Both decay with the emission of penetrating gamma rays. Co-60 is the principal cobalt radionuclide of concern because it is the predominant radionuclide present in nuclear reactor corrosion products, has a relatively long half-life, and emits high-energy gammas.

b. Dose estimate or evaluation

(1) External exposure. The seriousness of the radiation exposure may be estimated by evaluating the amount of exposure, and using information provided in enclosure (6) for external exposure to penetrating radiation for whole body exposures, and to non-penetrating radiation exposure for small area exposures. The amount of exposure may be determined by processing personnel dosimeters, or estimated, based on exposure rate and time in the area, or by reconstructing the exposure and taking physical measurements. See enclosure (4) for instructions on processing dosimeters, and enclosure (5) for guidance on determining external radiation dose.

(2) External contamination. External contamination is generally not a serious clinical problem because of the relatively low dose rate to the germinal layer of the skin. The primary concern is to control the contamination to prevent ingestion, absorption, or inhalation. Co-60 uniformly distributed on a 20-square centimeter area of skin delivers approximately 4.3

rad/hr/μCi/cm$^2$ to the germinal layer of the skin, i.e., 0.09 mrad/hr/100 ccpm measured with a GM multifunctional RADIAC instrument (i.e., a MFR and DT-304 probe or equivalent instrument and probe). Dose rate values in the literature vary from approximately 1 to 7.5 rad/hr/μCi/cm$^2$ depending on the assumptions made in the calculation and the dose model used. Table 12.3 converts instrument readings from ccpm to activity and dose equivalent rate. Use caution when interpreting the results of instrument readings for unknown geometry, detection efficiencies, and calibration conditions.

| Probe | Net Count Rate (ccpm) | Dose Rate $\left(\frac{\text{mrad}}{\text{hr}}\right)$ | Number of Days for 5 rads | Number of Days for 50 rads | Contamination $\left(\frac{\text{pCi}}{20\ \text{cm}^2}\right)$ |
|---|---|---|---|---|---|
| DT-304 | 100 | 0.1 | 2083 | 20,830 | 450 |
| or equivalent | 8,700 | 7.8 | 26.7 | 267 | 39,000 |
| probe | 50,000 | 45.0 | 4.6 | 46 | 225,000 |

Table 12.3. Dose table for Co-60 contamination

Note: Dose rates are calculated based on a dose rate of 4.3 rad/hr/μCi/cm$^2$ to basal cell layer from Co-60 uniformly distributed over the surface. The accuracy of the above conversions is believed to be within 25 to 50 percent, which is sufficiently accurate to evaluate the seriousness of the exposure.

Note: Number of days for 50 rads for all net count rates is based on a worst case scenario. These values ignore the fact that the skin normally sloughs in 2 to 20 days depending on the body location.

(3) Internal contamination. The seriousness of internal contamination may be judged by estimating the activity, the organ dose, and whole-body dose from penetrating radiation to determine the potential biological effect.

(a) For ingestion, the rules listed in subparagraphs (3)(a)1 through (3)(a)2 of this enclosure can be used to estimate dose:

1. Cobalt salts and particularly reactor corrosion products transit through the GI tract up to approximately 42 hours.

2. Swallowing 1μCi of Co-60 will result in a CEqD to the GI tract of approximately 20 mrem (0.20 mSv) and a CED of approximately 10 mrem (0.10 mSv).

(b) The greatest likelihood of Co-60 intake is from inhalation.

1. Assuming the Co-60 inhaled is solubility type S (insoluble) and 5 micron Activity Median Aerodynamic Diameter (AMAD), approximately 1/16 of the Co-60 intake will remain in the lungs after 24 hours.

2. 1μCi of Co-60 still remaining in the lungs 24 hours after inhalation will result in a committed dose to the lungs of approximately 6 rem (60 mSv), and a CED of approximately 1 rem (10 mSv), of which about 1/3 is accumulated in the first year.

3. Breathing air containing $1x10^{-9}$ μCi/ml of Co-60 for one 40-hour week will cause a CEqD to the lungs of approximately 20 mrem (0.2 mSv) at 0.5 mrem/hour and a CED of 3 mrem (0.03 mSv) at 0.075 mrem/hour.

Note: Partial or whole-body counts obtained within the first 24 hours are useful for determining the presence of internal contamination and estimating the resulting dose. Lung clearance rates for insoluble Co-60 vary significantly from individual to individual. Consequently, early measurement of internally deposited radioactivity in conjunction with use of the above thumb rules is valuable, but provides only an initial rough dose estimate. This initial estimate is useful for determining whether a clinically significant exposure has occurred. The initial estimates are also useful for the management of non-clinically significant exposures in making near term decisions for controlling further exposure within occupational limits as the individual returns to work.

(c) The thumb rules listed in subparagraph 5b(3) of this enclosure are not appropriate for the final assignment of exposure for record or documentation purposes. Total dose assignment should be based upon measurements made over an extended time, i.e., weeks, months, or years. Such assignments should be made upon consultation with the BUMED REAB. The guidelines listed in subparagraphs 5b(3)(c)1 through 5b(3)(c)3 of this enclosure may be used to estimate the amount of internal contamination.

1. Use of an in vivo bioassay (internal monitoring) facility for partial or whole-body counting or other gamma scintillation techniques with a single- or multi-channel analyzer is the preferred method of internal monitoring.

Note: For all commands or activities except for NNPP-associated commands and fleet commands, contact the BUMED REAB for support if a partial or whole-body counting (internal monitoring) facility is not readily accessible.

2. To determine whether surface contamination exists on the chest or abdomen, readings with an approved GM RADIAC instrument and beta-gamma probe with a beta window may be made with the beta window open and closed at a distance of approximately 1 cm or 0.5 inch. If the two readings are the same, surface contamination is sufficiently low to permit monitoring for internal contamination. If a DT-304 or equivalent probe is used, a piece of 1 millimeter or thicker plastic may be added between the skin and the detector to distinguish between contamination on the surface and internal contamination.

3. One microcurie of Co-60 in the lungs or digestive system will produce a gamma exposure rate of approximately 0.04 mR/hr above background when measured with the MFR and gamma probe (or equivalent instrument and probe) on contact with the chest or abdomen, or about 100 counts per minute above background with a DT-304 or equivalent probe. Readings should be taken in an area with low background radiation, i.e., less than 0.02 mR/hr or less than 100 counts per minute.

(4) Wound contamination. Wound contamination is generally not a serious clinical problem from the viewpoint of hindering the healing of the wound (requires 50 to 100 rad/day) or from causing acute necrosis (requires 200 or more rad/day). It is of concern because of the psychological effect on the individual, possible long-term effects from internal contamination, and the ability of the individual to clear a survey or frisking station upon returning to work. The amount of activity in a wound is difficult to quantify because of the unusual geometry and because the tissue shields the betas. The guidelines listed in subparagraphs (4)(a) through (4)(c) of this enclosure may be used to estimate the activity in a wound based on type of RADIAC instrument used:

(a) MFR instrument with DT-304 probe or equivalent instrument and probe. For 100 corrected counts on a DT-304 probe counting Co-60, 5 to 10 counts are from gamma interactions and 90 to 95 counts are from beta interactions. The amount of Co-60 in a wound may be estimated by first frisking the wound, then add approximately 1 millimeter of plastic or equivalent (enough material to absorb the Co-60 betas) between the skin and the probe, and frisk again. Finally, the results of the two frisks should be compared. If both results are approximately (+10 percent) the same, then the activity is likely in the wound, localized to an area of 20 cm2 or less, and may be estimated by using Table 11.3 for Co-60 giving activity as a function of instrument response. The activity must be multiplied by 20 to correct for the lower response of the probe to the Co-60 gamma photons, i.e., if the betas are shielded by tissue, 100 ccpm with the DT-304 probe corresponds to approximately 9,000 pCi (μμCi) of Co-60 under the area of the probe. If the difference between the results of the two frisks is greater than +10 percent, then some portion or the entire radioactivity is on the surface of the skin. However, this does not preclude that activity is in the wound.

Note: If there is any doubt whether there is wound contamination, decontamination of the wound must be performed to ensure the maximum amount of activity possible is removed.

(b) PRM-5/SPA-3 or equivalent system. A point source of 1,500 pCi (or μμCi) produces 90 to 100 counts per minute above background at 1 cm or approximately 0.5 inch from the face of the probe on the HV1/PHA scale. The minimum detectable activity is approximately 1,500 pCi (μμCi).

(c) Gamma scintillation counting. The amount of Co-60 in a wound can most accurately be determined by gamma scintillation counting due to the high sensitivity of gamma scintillation counting. If the efficiency (counts/pCi (or μμCi)) for the detector is known and the

detector is shielded to limit the field of view of the probe to the area under the face of the probe, an estimate can be made in conjunction with a beta-gamma probe (betas not shielded) to determine if the activity is on the surface or in the wound.

c. Therapy

(1) External exposure. Treat the patient symptomatically if the external exposure is expected to be high enough to cause deterministic effects. See enclosure (6) for information on deterministic effects expected based on dose received from non-penetrating and penetrating radiation.

(2) External decontamination. See enclosure (8) for instructions on performing external decontamination.

(3) Wound decontamination. See enclosure (10) for instructions on performing wound decontamination. Washing, probing with a magnet, and simple debridement may be performed to remove Co-60 contamination from within a wound. Procedures that are more extensive must be coordinated with the BUMED REAB.

(4) Internal decontamination. WBI should be attempted for insoluble forms of cobalt. Chelation therapy should not be initiated until the residual cobalt load has been removed from the GI tract. See Table 12.1 of this enclosure for the appropriate therapy to hasten the elimination of Co-60 and see enclosure (9) for guidance on WBI. Due to the risk of cardiomyopathy from cobalt toxicity, a baseline electrocardiogram (EKG) for later comparison is recommended.

Note: WBI should be considered for any clinically significant ingestion of insoluble forms of cobalt based on symptoms, dosimetry results, in vivo bioassay (internal monitoring) results, or the presence of radio-opaque material on plain radiographs or CT images of the abdomen.

6. Depleted Uranium

a. Background. Natural uranium is a silver-colored metal that is radioactive and nearly twice as dense as lead. Small amounts of uranium naturally occurring in soil, water, air, plants, and animals contribute to our natural background radiation. Natural uranium is made up of the three radioisotopes: U-238 (>99 percent); U-235 (0.72 percent); and U-234 (0.005 percent). Enriched U-235 is used in nuclear weapons and as fuel in nuclear reactors. The enrichment process increases the percentage of U-235. One byproduct of the enrichment process is depleted uranium (DU) that contains a larger percentage of U-238 than natural uranium. DU retains uranium's natural toxicological properties and approximately half of its radiological activity. Because of its high density and strength, DU is used by the U.S. military in ammunition for armored shore vehicles, aircraft, and ships; as armored shielding for tanks; as counterweights in aircraft; and as radiation shielding in hospital nuclear medicine and radiation therapy clinics.

(1) Health risks. The health risks associated with using DU in the peacetime military are minimal because the DU is shielded, intact, or both. This includes risks associated with transporting, storing, and handling intact DU munitions and armor. The Nuclear Regulatory Commission, via Naval Radioactive Material Permits (see OPNAVINST 6470.3B and Marine Corps Order 5104.3C), regulates the majority of peacetime Navy and Marine Corps DU applications.

(2) Toxicity. During combat operations, there is a possibility of personnel casualties being contaminated with DU, as occurred during Operation Desert Storm. Additionally, foreign militaries now have access to DU munitions. If the integrity of DU materials is compromised, such as when munitions are fired or armor is pierced, uranium can then react with other elements contiguous to it in the environment. This can create chemical reactions that may yield compounds with various chemical toxicities. Toxicologically, DU poses a health risk when internalized. Radiologically, the radiation emitted by DU results in health risks from both external and internal exposures. However, the external exposure risk is very low. DU ingestion is minimized by not eating, drinking, or smoking in DU contaminated areas.

b. Medical Priorities. DU is one of many harmful substances encountered on the battlefield, such as lead, petroleum, radium, and tritium. The health risks from known or possible DU exposure should be addressed only after management of a patient's immediate medical needs. A patient contaminated with DU poses no special hazard to others, including medical personnel. Normal attention to antiseptic and infection control procedures or taking standard precautions is adequate to protect medical personnel from DU intake. Marines and Sailors can internalize other toxic substances in a combat environment that present greater health risks than DU, and these must not be neglected or downplayed because of internalized DU. Higher-level risks than those posed by DU, including exposure to other more toxic substances and serious injuries and wounds, must receive higher patient care priority.

c. External Contamination. Naturally occurring uranium decays by alpha emission. However, the primary external hazards from DU are beta and gamma radiation. These radiations are generated by radioactive decay of trace levels of uranium daughter products. All U.S. DU weapon systems are shielded to control beta radiation. During combat, this shielding may be compromised. Consequently, RADIAC instruments that measure beta and gamma radiation are the instruments of choice for detecting DU. Specifically, the AN/VDR-77 (used by the Marine Corps), an MFR with DT-304 probe, or other equivalent instrument and probe, are widely available for detection of DU. Externally contaminated personnel should be decontaminated as soon as practical to minimize the potential ingestion pathway. Enclosure (8) provides guidance on conducting an assessment or surveys for external contamination.

d. Surface Dose Rate. Unshielded DU material, e.g. a spent DU ammunition round, in contact with the skin delivers a skin dose (beta and gamma) of approximately 200 mrem (2 mSv)/hr. The current skin occupational exposure limit for beta-gamma radiation is 50 rem (0.5 Sv)/yr. Consequently, DU metal fragments and spent ammunition should be treated as low-level radioactive waste and properly disposed of by radiation health or safety personnel.

e. Wound Contamination. Regular wound cleaning procedures should be effective in managing DU wound contamination. However, the RADIAC instruments described in subparagraph 6c of this enclosure may be useful in determining wound cleaning efficacy. Similarly, DU embedded fragments are removed through standard surgical procedures. As previously noted, DU fragments should be treated as low-level radioactive waste.

f. Internal Contamination. The magnitude of toxicological and radiological health risks of internalized DU is dependent on the amount internalized, the chemical form, and the route of entry into the body. Depleted uranium can be internalized through inhalation, ingestion, wound contamination, as in the case of embedded fragments, and injection. Depleted uranium is a heavy metal, similar to lead, cadmium, nickel, cobalt, and tungsten in its toxicological effects. The solubility of DU-containing material in bodily fluids is the primary determinant of the rate at which the uranium moves from site of internalization (lung for inhalation, GI tract for ingestion, or the injury site for wound contamination and injection) into the blood stream, and then to the body organs. In most instances, solubility also determines how quickly the body eliminates uranium in urine or feces.

(1) Table 12.4 provides a comparison of the relative radiation dose per unit mass internalized between DU and other substances. Data was obtained from the U.S. Army Environmental Policy Institute Technical Report of 1995.

| Isotope | Relative Radiation Dose |
|---|---|
| Depleted uranium | 1.0 |
| Naturally occurring uranium | 1.7 |
| Radium (Ra)-226 | 200,000 |
| Americium (Am)-241 | 30,000,000 |

Table 12.4. Relative radiation dose per unit mass internalized for DU and other substances.

(2) In vitro bioassay analysis. The most common form of DU found on the battlefield is triuranium octaoxide ($U_3O_8$). This is a relatively insoluble heavy metal molecule. The target organs are kidneys, bones, and liver. The kidney is the most sensitive organ to DU toxicity. There are no approved methods to reduce the chemical toxicity of DU in the body. Immediate and follow-up assessment of DU levels can help medical personnel assess the potential for chemical toxicity and radiation exposure by estimating the fractions of insoluble and soluble DU. Because the body eliminates much of the soluble internalized DU within a few days, delays in sampling reduce the accuracy of the estimates. Internalized DU is assessed by a standard urine sample. See enclosure (11) for instructions on collecting bioassay samples for analysis.

g. Therapy

(1) External decontamination. See subparagraph 6c of this enclosure for background information on external contamination. See enclosure (8) for instructions on performing external decontamination.

(2) Wound decontamination. See subparagraph 6e of this enclosure for background information on wound contamination involving DU. See enclosure (10) for instructions on performing wound decontamination. Notify the BUMED REAB if wound decontamination involving the removal of DU fragments is required.

(3) Internal decontamination. See subparagraph 6f of this enclosure for background information on internal DU contamination. See Table 12.1 of this enclosure for the appropriate treatment to hasten the elimination of DU.

(4) Respiratory protection. Since there are a limited number of therapies available to treat DU inhalation (e.g., bronchoalveolar lavage) and the success of the therapy depends on having adequate health care available, prevention of inhalation by respiratory protection is critical. Studies of the dispersal of aerosol particles of uranium, after a DU round hits a hard target, demonstrate 60-90 percent of particles are less than 10 microns in size. Further studies demonstrate 90 percent of the airborne DU remains within 50 meters of a burning tank struck by DU rounds. Personnel accessing potential airborne DU areas should minimize exposure to skin and wear protective gas masks capable of removing micron-sized particles.

7. Iodine

a. Background. Of the more than 20 radioactive isotopes of iodine (I), about half occur as fission products, and among them, I-131 contributes an increasingly important portion of the total activity starting at several hours after fission due to its relatively long half-life compared to other isotopes of iodine. The dominant internal exposure after a reactor accident or nuclear weapons detonation, criticality, or any event involving fresh fission products is likely to be from I-131.

(1) I-131 has a physical half-life of about 8 days and an effective half-life in humans of about 7.6 days. It decays by emitting four beta particles ($E_{max}$ of 0.25 to 0.81 MeV; the predominant beta has an $E_{max}$ of 0.61 MeV (87.2 percent)) and gamma rays of five energies (0.08 to 0.82 MeV; the predominant gamma having an energy of 0.36 MeV (79 percent)). Most of the iodine in reactor accidents will be soluble and capable of being quickly absorbed via inhalation, ingestion, absorption through the skin, or any combination of these. Inhaled iodine reaches equilibrium with body fluids in about half hour. The thyroid gland, located just above the supra-sternal notch (just below the adam's apple), concentrates iodine. The iodine concentration is highest about 48 hours after exposure. The percentage of radioiodine uptake in the thyroid gland 1 day after ingestion is similar for children and adults; however, the dose to the child's thyroid is larger due to the smaller size of the thyroid gland.

(2) For those in the immediate area of a reactor accident or otherwise directly exposed to the radioactive plume, inhalation of radioiodines may be a significant contributor to individual and population radiation exposures.

(3) Experience from a number of epidemiological studies, as well as experience from the Chernobyl reactor accident indicates the thyroid of the fetus and child is quite sensitive to the induction of thyroid cancer following radiation exposure. Hence, pregnant women and children are the most at risk group from radioactive iodine uptake. Fortunately, therapeutic administration of stable iodine (e.g. potassium iodide (KI)) can reduce or block the uptake of radioactive iodine in the thyroid of exposed individuals.

Note: The use of KI is intended to supplement, not to replace, other protective measures. Sheltering or evacuating personnel from the affected area are considered the best methods for reducing exposure, because radioiodine represents a few of the many radioactive fission products that contribute to dose from a reactor accident.

b. Dose Estimate or Evaluation

(1) One microcurie at peak concentration in the thyroid from an acute exposure will produce a dose to the thyroid of approximately 6.5 rad (6.5 cGy), with a radiation weighting factor ($W_R$) of 1 for photons. This results in a CED of 325 mrem (3.25 mSv).

(2) When a person has been exposed to radioiodine, the dose to the thyroid may be estimated by monitoring the thyroid gland. Approximately 50 percent of the peak uptake will occur 6 hours after the exposure; approximately 90 percent of the peak uptake will occur after 24 hours. The maximum uptake and consequently the maximum readings will be observed about 48 hours after exposure.

(3) The thyroid gland can be monitored for radioactivity by holding a beta-gamma probe or a sodium-iodide detector close to the suprasternal notch. Quantitative estimates of the thyroid dose may be performed with current field instruments.

(a) A dose estimate from radioactivity following a fission product release may be obtained using the appropriate instrument and gamma probe that measures in counts per minute (e.g., DT-304 or equivalent probe) by holding the probe between the adam's apple and suprasternal notch. The dose estimate may be performed by using the conversion: 500 counts per minute equal to 1 μCi plus or minus 50 percent. Minimum detectable activity is approximately 0.2 μCi (100 counts per minute is approximately equal to 1.3 rad (1.3 cGy)), with a $W_R$ of 1 for photons. This results in a CED of 65 mrem (0.65 mSv).

(b) An estimate of radioactivity may be performed using the AN/PDQ-3 RADIAC instrument with DT680/PDQ gamma probe or equivalent instrument and probe that measures in mrem/hour. By holding the probe between the adam’s apple and suprasternal notch, an estimate of the activity can be determined by the conversion: 0.8 mrem/hour equal to 1 μCi plus or minus 50 percent. The minimum detectable activity is approximately $1.25 \times 10^{-2}$ μCi and mrem/hr is approximately equal to 8 rad (8 cGy).

(c) If a PRM-5/SPA-3 or equivalent instrument and probe, calibrated in the standard manner for cobalt-60, i.e., HV1 cobalt-60, HV2 cadmium-109, is held between the adam's apple and suprasternal notch, a dose estimate may be performed using the conversion: 190,000 counts HV2-Gross mode equal to1 μCi plus or minus 50 percent. The minimum detectable activity is approximately 0.07 μCi (30,000 counts HV2-Gross mode is approximately equal to 1 rad (1 cGy), with $W_R$ of 1 for photons. This results in a CED of 50 mrem (0.5 mSv).

(d) Thyroid uptake of radioactive iodine may be determined with a sodium-iodide crystal or germanium detector and pulse height analyzer calibrated with a phantom.

c. Therapy

(1) External exposure. Treat the patient symptomatically if the external exposure is expected to be high enough to cause deterministic effects. See enclosure (6) for information on deterministic effects expected based on dose received from non-penetrating and penetrating radiation.

(2) External decontamination. See enclosure (8) for instructions on performing external decontamination.

(3) Wound decontamination. See enclosure (10) for instructions on performing wound decontamination. Washing may be performed to remove iodine contamination from within a wound. Procedures that are more extensive must be coordinated with BUMED REAB.

(4) Internal decontamination. See subparagraph 7e of this enclosure for the appropriate therapy to prevent or mitigate the uptake of radioactive iodine.

d. Potassium Iodide Use in Radiation Emergencies. In the event of an actual release of radioiodine to the environment, KI is provided for the individuals listed in subparagraphs 7d(1) through 7d(2) of this enclosure.

(1) Emergency responders who may need to enter an area where there is a reasonable probability of inhalation of radioactive iodine, regardless of projected thyroid dose. Emergency responders should be administered one 130 mg dose of KI before entering the area.

(2) All command personnel on the installation who may exceed threshold thyroid-dose levels are listed in Table 12.5.

| Risk group | Predicted Thyroid Exposure (cGy) | KI dose (mg) | Number of 130 mg tablets | Number of 65 mg tablets |
|---|---|---|---|---|
| Adults over 40 yrs | ≥500 | 130 | 1 | 2 |
| Adults over 18 through 40 yrs | ≥10 | 130 | 1 | 2 |
| Pregnant or lactating women | ≥5 | 130 | 1 | 2 |
| Adolescents over 12 through 18 yrs | ≥5 | 65 | 1/2 | 1 |
| Children over 3 through 12 yrs | ≥5 | 65 | 1/2 | 1 |
| Over 1 month through 3 yrs | ≥5 | 32 | 1/4 | 1/2 |
| Birth through 1 month | ≥5 | 16 | 1/8 | 1/4 |

Table 12.5. Threshold thyroid radioactive exposure and recommended daily dose of KI for different risk groups

e. Potassium Iodide Administration Protocol and Dosage. The Food and Drug Administration (FDA) provides guidance on its website regarding the use of KI as a thyroid-blocking agent. The guidance includes information about dosage and projected radiation exposures at which such drugs should be used and is provided in Table 12.5. Note: Pregnant or breastfeeding women must only take a single dose (130 mg) of KI in total (i.e., a total maximum dose of 130 mg).

Note: Adolescents approaching adult size (> 70 kg) should receive the full adult dose (130 mg).

Note: Newborn infants (less than 1 month old) must only take a single dose (16 mg) of KI in total. Infants who receive more than one dose of KI are at risk for developing a condition known as hypothyroidism (thyroid hormone levels that are too low).

(1) A daily oral dose of KI should be given until the risk of significant exposure to radioiodine no longer exists. For optimal protection against inhaled radioiodines, KI should be administered before (ideally an hour before) passage of the suspected plume. Administration of KI will still have a substantial protective effect even if taken 3 or 4 hours after exposure and will be of some value even as long as 24 hours after intake of radioactive iodine. See Table 12.6 for the percentage of thyroid protection based on a single dosage and time KI was administered before and after I-131 exposure. Data was compiled from the National Research Council 2004 article, Distribution and Administration of Potassium Iodide in the Event of a Nuclear Incident.

Note: Prevention of thyroid uptake of ingested radioiodine, once the plume has passed and radiation protection measures (including KI) are in place, is best accomplished by food control measures and not by repeated administration of KI.

| **Time of KI with Respect to $^{131}$I Exposure (hours)** | **Protection Afforded KI Ingestion (% of control)** |
|---|---|
| -96 | Very little |
| -48 | ~80 |
| -1 | ~100 |
| 0 | 98 |
| 2 | 80 |
| 3 | 60 |
| 8 | 40 |
| 24 | 16 |

Table 12.6. Percent Thyroid Protection from I-131 after a single 130 mg dosage of KI

Note: Data at 0 and 3 hours is from experimental observations and other data derived from models of iodine metabolism.

(2) KI should be administered to emergency response personnel per the command's local emergency response plan. The command's director of occupational medicine or an authorized medical official must endorse the plan. An appropriate local medical authority or designated representative may distribute KI upon the activation of the plan due to a radiological casualty involving the release of iodine.

Note: A designated representative for KI distribution may be a medical or non-medical authority (e.g., radiation health or safety personnel or emergency responders). The non-medical authority must be adequately trained to meet the medical requirements or guidelines to distribute KI (i.e., to recognize the symptoms of a KI allergy).

(3) Training and medical information on the use of KI must be provided to all medical and non-medical personnel involved in the administration or distribution of KI to personnel.

(4) Personnel administering the KI must ask if the individual is allergic to iodine. Individuals intolerant of KI at protective doses, and neonates, pregnant and lactating women should be given priority with regard to other protective measures (e.g., sheltering, evacuation, and control of the food supply). If an individual is not allergic to iodine, KI may be issued. For all Navy and Marine Corps personnel, including emergency response personnel, the name, date of issue, and amount of KI issued to each individual must be recorded on a SF 600 Chronological Record of Medical Care. The SF 600 must be maintained in the individual's health care treatment record.

(5) Pregnant women should be given KI for their own protection and for that of the fetus. However, because of the risk of blocking fetal thyroid function with excess stable iodine, repeat dosing with KI of pregnant women should be avoided. Therefore, pregnant women must only take a single dose (130 mg) of KI in total, i.e., a total maximum dose of 130 mg. Women who are breastfeeding must also take only a single dose of 130 mg of KI total due to the risk of the nursing newborn child developing hypothyroidism.

(6) When personnel are actually exposed to radioiodine, notify the BUMED REAB so a medical follow-up program can be recommended, based on the estimated dose to the thyroid.

f. Potassium Iodide Side Effects. Possible side effects include skin rashes, swelling of the salivary glands, and iodism (metallic taste, burning mouth and throat, sore teeth and gums, symptoms of a head cold, and sometimes an upset stomach and diarrhea). A few people may have allergic reactions with more severe symptoms. These could be fever and joint pains, swelling of parts of the face and body, and at times severe shortness of breath requiring immediate medical attention. Manifestation of these side effects would be expected to be negligible under the dose regimen stated above. FDA maintains that KI is a safe and effective means by which to prevent radioiodine uptake by the thyroid gland, under certain specified conditions of use, and thereby remove the risk of thyroid cancer in the event of a radiation emergency.

g. Inventory Management

(1) To enhance early access to KI, it may be stored near likely issue points provided the locations are identified in the facility's local emergency response procedures. If medical spaces are not available at these issue points, storage in non-medical spaces is permissible as long as the KI is appropriately safeguarded.

(2) For U.S. nuclear-powered submarines, KI should at a minimum be stored in the medical department offices and each watertight compartment adjacent to the reactor compartment with sufficient supplies to administer to watchstanders and others normally expected to be in those spaces.

(3) The KI can be obtained from the Defense Logistics Agency (DLA) Troop Support Medical (National Stock Number 6505-01-616-5133). This KI has been approved by the FDA for use as a thyroid-blocking agent and contains 130 mg of potassium iodide per tablet. An insert containing information for the patient comes with each package of tablets. Each package contains approximately 14 tablets, an amount sufficient or a 2-week period when administered at the rate of one tablet per day. The cognizant medical authority will provide guidance on recommended dosage and duration of treatment as directed.

Note: Keep the KI packages dry and foil packets intact. Keep KI packages out of direct light exposure including direct sunlight. The KI should normally be stored within a temperature range between 15 degrees Celsius and 30 degrees Celsius (59 degrees Fahrenheit and 86 degrees

Fahrenheit). If unable to consistently maintain storage temperature within this range, commands must: disclose to Naval Medical Logistics Command and follow testing guidance per reference (v). Reference (v) is available at https://www.med.navy.mil/directives/Pages/BUMEDInstructions.aspx; inspect the KI annually to determine if any degradation (e.g., discoloration, fragmentation, or irregular surfaces) has occurred; and coordinate with Naval Medical Logistics Command to submit a representative sample (at least two packets from the oldest batch in inventory) of KI to the FDA once every three years for stability testing to ensure continued efficacy.

(4) For ships, the amount of KI required to be maintained is defined in the authorized medical allowance list (AMAL) with additional guidance, where appropriate, from BUMED or fleet commanders. Shore-based commands should determine the amount of KI to be maintained based upon the number of potential emergency response personnel and any additional guidelines outlined in this instruction or appropriate NNPP directives.

(5) Ensure all on-hand inventories of KI are accurately entered into the Shelf Life Extension Program (SLEP) database per reference (v). Update inventory records every 90 days even if on-hand quantities have not changed.

(6) Nominally, the expiration date for potassium iodide tablets is up to 5 years from date of manufacture. The actual expiration date will vary with differing manufacturer's lot numbers. Medical Department representatives should be aware of these dates and obtain replacement items prior to expiration of current inventory. If replacement cannot be accomplished, an extension of the expiration date of a given lot number can be obtained through the SLEP.

Note: The acquisition time, including purchase and receipt, for KI utilizing the Defense Supply Center may take several months (e.g., 6 months); therefore, purchasing of KI should be performed early enough to ensure new KI is received before the expiration of the current stock.

(a) SLEP. A key component of the medical readiness strategic plan (MRSP) developed by DoD Health Affairs and the military medical departments for conservation of military medical resources. SLEP defers replacement cost of military significant medical material by extending its useful life. BUMED specific requirements for all ships, stations, and MTFs regarding inventory, maintenance, and testing of various pharmaceuticals including KI is contained in reference (v).

` (b) If the current expiration date will be or has been reached before a shelf life extension has been provided by the SLEP, do not issue this item except in the case of an emergency. In the case of a true emergency, expired potassium iodide tablets may be issued to personnel if they demonstrate no evidence of degradation (e.g., discoloration, fragmentation, or irregular surfaces). The BUMED REAB should be notified of this decision as soon as conditions allow. If expired tablets are issued to personnel, this must be documented with all of the factors involved in making this decision adequately described.

(c) It is recommended that if a given lot number(s) of KI is being submitted for consideration by the SLEP that this occur at least 12 months prior to the current expiration date of the item to allow sufficient time for a determination to be made by the board. The BUMED REAB should be consulted before submitting such a request to ensure it complies with current policy and directives.

8. Plutonium

a. Primary Characteristics. Pu-239, element number 94, has a physical half-life of 24,400 years, a biological half-life of 20 years for the liver and 50 years for the bone. It emits two principal alpha rays [5.16 MeV (88 percent) and 5.11 MeV (11 percent)]. Pu-239 is the principal radioactive material of concern when considering radioactive contamination from nuclear weapon accidents. The lung, liver, and bone are the primary organs of concern for a plutonium exposure. The alpha radiation will not penetrate the dead outer layer of skin; therefore, poses no external hazard. Removal of external alpha contamination is necessary to eliminate the potential for internal contamination via inhalation, ingestion, or breaks in the skin. Pu-239 contamination encountered in the Navy will most likely be in an insoluble form. Plutonium is not readily absorbed by ingestion. Exposures of most concern are by inhalation or contaminated wounds. It is noted that in the case of nuclear weapons, plutonium is normally in a "weapons grade plutonium" configuration. While Pu-239 is the predominant radioisotope of interest, other isotopes will be present (such as americium-240 and americium-241). In many cases, the most efficient way to monitor for weapons grade plutonium is to monitor for the Am-241 60 keV gamma ray as it is easier to detect than the lower energy X-ray emitted by Pu-239. Specialized instruments are available to monitor for both of these low energy photons.

b. Dose Evaluation

(1) Internal contamination. An alpha particle of greater than 7.5 MeV is necessary to penetrate the outer layer of dead skin (stratum corneum). Since the energy of the plutonium alpha particle is only 5.15 MeV, the biological hazard from plutonium is strictly internal.

(2) Internal monitoring.

(a) Nasal, throat, and saliva swabs. Should be conducted, if required, within 30 minutes from exposure and monitored for alpha contamination after being dried. The presence of alpha contamination in any of these samples is an indication plutonium inhalation or ingestion may have occurred. Therapy using DTPA to hasten the elimination of Pu-239 should be initiated immediately by an MTF if Pu-239 intake is indicated (e.g., from contamination surveys of the nose or mouth or by positive nasal and throat swabs) (primarily taken from reference (c) with permission from the NCRP). See enclosure (9) for instructions on performing nasal, throat, and saliva swabs. See enclosure (12) for the appropriate internal decontamination or dose mitigation therapy.

Note: Throat swabs may only be performed by qualified medical personnel.

(b) In vivo bioassay (internal monitoring) analysis. If internal alpha contamination is suspected, the patient may have to be transferred to an in vivo bioassay (internal monitoring) facility. Lung contamination may be directly measured by the use of sophisticated gamma scintillation systems that can detect the low energy x-rays emitted. Consult with the BUMED REAB if uncertainty exists concerning the need to transfer a patient for internal monitoring.

(c) In vitro bioassay analysis. Insoluble plutonium contamination that has been ingested or inhaled can be monitored by performing a bioassay of urine and fecal samples. See enclosure (11) for instructions on collecting bioassay samples for analysis.

(d) Plutonium levels in the body can be monitored over a long period by repeated urine, fecal, and in vivo bioassay (internal monitoring) techniques.

(3) RADIAC instrument guidelines. The alpha probe of the MFR is calibrated so that 8 corrected counts per minute measured l/16 to 1/8 inch above the surface is equivalent to 50 pCi (or μμCi) or 0.01 μgm/$m^2$ of Pu-239 under the area of the probe, i.e., 100 $cm^2$.

c. Therapy

(1) External decontamination. The portal of entry of plutonium into the body is the chief determinant of the course of the subsequent contamination and appropriate therapeutic efforts. Washing with waterless hand cleaner, water, detergents, and occasionally other agents easily remove plutonium contamination from intact skin. See enclosure (8) for guidance on performing external or skin decontamination.

(2) Wound decontamination. See enclosure (9) for guidance on performing wound decontamination. For wounds contaminated with plutonium, consideration should be given to irrigating the wound with DTPA. Wounds contaminated with plutonium should be decontaminated to the point where repeated swabs show no detectable alpha contamination when monitored with a MFR and alpha probe (or equivalent instrument and probe). The swabs must be dried before counting. Qualified medical personnel may perform simple wet debridement if after several decontamination attempts (up to three) the swabs indicate contamination remains in the wound. Consult with the BUMED REAB before additional surgical procedures are initiated.

(3) Internal decontamination. See Table 12.1 of this enclosure for the appropriate treatment to hasten the elimination of plutonium.

9. Radium

a. Background. Radium (Ra), element 88, is a radioactive element occurring in each of the major series of natural radionuclides and transuranic elements. Ra-226, a member of the decay chain of uranium-238, has a physical half-life of 1,600 years. The most important daughter products of Ra-226 are radon-222 (3.8 day physical half-life, alpha emitter, gaseous), bismuth-214 (20 minute physical half-life, alpha and gamma emitter), and lead-210 (22 year physical

half-life, beta and gamma emitter). After ingestion, about 30 percent of the Ra-226 is absorbed. Most of that absorbed is excreted within a few days, 95 to 98 percent is eliminated in the feces and 2 to 5 percent in the urine. The remainder is deposited almost entirely in the skeleton. The effective half-life of radium is about 4.5 years for bone and 900 days for the whole body.

b. Dose Estimate or Evaluation

(1) Internal Contamination. A dose estimate may be performed from analysis of excreta (feces or urine) or from radon breath samples. The BUMED REAB must be contacted for guidance and location where analysis may be performed. Based on ALI values for Ra-226, classification W (clearance half times from 10 to 100 days), one microcurie of Ra-226 results in a CEqD to the bone surface of 25 rem (0.25 Sv) and a CED of 0.75 rem (7.5 mSv), if ingested, or 8.3 rem (83 mSv), if inhaled.

c. Therapy

(1) External decontamination. See enclosure (8) for guidance on performing external or skin decontamination.

(2) Wound decontamination. See enclosure (10) for guidance on performing wound decontamination.

(3) Internal decontamination. See Table 12.1 of this enclosure for the appropriate therapy to hasten the elimination of Ra-226. Cumulative mean skeletal doses below 1,000 rad have not been associated with clinically significant radiobiological injury. Immediate gastric lavage with a 10-percent magnesium sulfate solution is recommended in patients who have just ingested significant quantities of radium, i.e., greater than 0.01 μCi, when WBI is not available.

Note: WBI should be considered for any clinically significant ingestion of insoluble forms of radium based on symptoms, dosimetry results, *in vivo* bioassay (internal monitoring) results, or the presence of radio-opaque material on plain radiographs or CT images of the abdomen.

(4) Gastric lavage should not be attempted unless the criteria listed in subparagraphs 9c(4)(a) through 9c(4)(e) of this enclosure are met.

(a) A provider with extensive clinical expertise with gastric lavage is available to perform the procedure.

(b) All necessary equipment is available.

(c) There is a contraindication to WBI.

(d) The procedure can be performed within one hour of ingestion. In cases of massive ingestion or ingestion of material forming a concretion, the lavage can be performed within 4 hours of ingestion.

(e) There are no contraindications to gastric lavage, including but not limited to: craniofacial abnormalities; concomitant head, thoracic, or abdominal trauma; unprotected airway (depressed level of consciousness without endotracheal intubation); ingestions with a high risk of aspiration (such radionuclides in liquid suspension); recent hemorrhage or GI perforation due to pathology; recent surgery; coagulation disorder, platelet disorders, or other bleeding diathesis. Patient combativeness is a relative contraindication.

10. Tritium

a. Background. Tritium (H-3) is the only radioactive isotope of hydrogen. It decays to helium 3 by emitting a beta particle with a maximum energy of 0.018 MeV and an average energy of 0.0057 MeV. Its physical half-life is 12.3 years. Its biological and effective half-life is 12 days. Tritium may enter the systemic circulation of the human body as tritiated water (HTO) or in gaseous form from inhalation or ingestion or by penetration of the skin. When it is incorporated in chemical compounds, the distribution and retention of H-3 in the body can be influenced markedly. As a gas, H-3 is not significantly absorbed into the body and does not exchange significantly with the hydrogen in body compounds. In HTO, H-3 entering the lungs or GI tract is completely absorbed, and is rapidly dispersed throughout the body.

b. Determination of H-3 Intake. The seriousness of the radiation exposure may be judged by estimating the whole-body dose and using the information contained in enclosure (6) for external exposure to penetrating radiation. Tritium is primarily of concern as an internal contaminant. Exposure is measured directly from tritium levels in urine or estimated based on air concentration and duration of exposure. If an exposure is suspected, the actions listed should be taken:

(1) Liquid scintillation analysis

(a) If liquid scintillation counting services are available, collect a valid single-void urine sample 2 to 24 hours post exposure and after the initial void. The individual should hydrate (e.g., drink 2 to 3 glasses of water) to ensure a valid urine sample can be obtained within the 2 to 24 hour period per reference (v). Urine samples should also be collected from known unexposed personnel to be used as controls to establish background values. Following the collection of urine samples, the urine should be distributed in 100-milliliter aliquots into appropriate containers for shipping and analysis.

Note: Since tritium emits only a very weak beta particle, it is very difficult to detect even with normal RADIAC instrumentation. In fact, the most common portable RADIAC instruments, such as a GM counter and ionization chamber, are usually not capable of detecting

tritium. The most reliable and widespread method for detecting tritium is liquid scintillation counting and involves mixing tritium samples with a phosphor-containing fluid in vials, and then placing the vials into a liquid scintillation counter for analysis.

Note: Liquid scintillation counting should be performed as soon as possible to determine if tritium intake occurred to allow the therapeutic process to begin within the first 24 to 48 hours of exposure to reduce the dose to the individual.

(b) Liquid scintillation counting operations can be performed at hospitals, shipyards, research facilities, weapon stations, or strategic weapon facilities. If services cannot be acquired at those institutions, contact the BUMED REAB for assistance. If samples are to be shipped for analysis, the listed information should be included with the samples: the command address, designated point of contact for providing additional information and receiving official results, the time and duration of suspected exposure, and information regarding the most likely and least likely samples to have H-3.

(c) For liquid scintillation analysis, the identifying information listed in subparagraph 10b(1)(c)1 through 10b(c)3 of this enclosure should be provided on each 100-milliliter aliquot to be shipped.

1. Name of individual.

2. Identification number (e.g., DoD identification number, worker (badge) identification number, or birthdate as appropriate).

3. Date and time after exposure urine was collected.

(2) In vitro bioassay analysis. If internal exposure to H-3 is suspected to have exceeded levels requiring internal monitoring by reference (b), chapter 3, proceed to collect valid urine samples from the exposed individual based on the laboratory's instructions to determine the dose. Ensure the individual(s) has voided their urine completely after the exposure and discarded it. See enclosure (11) for instructions on collecting samples for analysis.

Note: For a single acute exposure, 1 μCi/liter of tritium in urine at peak concentration is indicative of a TEDE of about 10 mrem (0.1 mSv) for the average person, if no internal dose mitigation treatment is instituted.

c. Dose Estimate or Evaluation. The two methods listed in subparagraphs 10c(1) and 10c(2) of this enclosure may be used to estimate dose from H-3 intake.

(1) The CED can be estimated from tritium oxide air concentration levels and time in the area. Based upon the DAC and stochastic (5 rem) ALI limits for H-3 use, CED (rem) = 125 x air concentration (μCi/ml) x time (hr).

Note: Based on ALI values for H-3 from reference (d), one microcurie ingested or inhaled results in CED of 6.25 x $10^{-5}$ rem (0.000625 mSv).

(2) In vitro bioassay analysis. See subparagraph b(2) pertaining to H-3 for instructions.

d. Therapy

(1) External decontamination. See enclosure (8) for guidance on performing external or skin decontamination.

(2) Wound decontamination. See enclosure (10) for guidance on performing wound decontamination.

(3) Internal decontamination. See Table 12.1 of this enclosure for the appropriate therapy to hasten the elimination of H-3. Water diuresis (i.e., forced fluids) via increased fluid intake of 2 to 4 liters per day may be initiated under medical supervision. This will reduce the biological half-life and the total dose to about 1/3 to 1/2 of the normal value. The half time may be determined by taking daily urine samples. Prolonged forced fluids may cause an electrolyte imbalance. Diuretics may be used when a physician supervises the therapy. One should bear in mind there could be harmful effects from therapy that is too aggressive for the clinical indications. Water imbalance can be dangerous and diuretics have other possible deleterious side effects. Thus, treatment involving diuretics should only be provided if the patient is expected to well exceed the yearly dose limit. Contact with the BUMED READ is required if internal decontamination is necessary. However, if an internal exposure to tritium has been assessed (i.e. using liquid scintillation counting), forced fluids or diuretics can take place under medical supervision at the same time that contact with the BUMED READ is made.

11. Technetium

a. Background. Technetium (Tc)-99, element 43, is a radioactive element and all of its isotopes are radioactive. Nearly all technetium is produced synthetically, and only trace amounts are found in the Earth's crust. Naturally occurring Tc-99 is due to spontaneous fission from uranium ore or neutron capture in molybdenum ores. Tc-99 is a transition metal, silver-gray in appearance with a half-life of $2.111\times10^5$ years. It is used as a gamma-ray-free source of beta particles. Its isotopes are produced commercially from by-products of fission of uranium-235 in nuclear reactors and are extracted from nuclear fuel rods. The most important one regarding this instruction is Tc-99m, a short-lived gamma ray-emitting nuclear isomer that is used in nuclear medicine for a variety of diagnostic tests. Tc-99m ("m" indicates this is a metastable nuclear isomer) is well suited for this role in nuclear medicine because it emits readily detectable 140 keV gamma rays, and has a short half-life of 6.01 hours. The chemistry of technetium also allows it to bind to a variety of biochemical compounds, each of which determines how it is

metabolized and deposited in the body. This single isotope can be used for a multitude of diagnostic tests. More than 50 common radiopharmaceuticals are based on Tc-99m for imaging and functional studies of the brain, heart muscle, thyroid, lungs, liver, gall bladder, kidneys, skeleton, blood, and tumors.

b. Dose Estimate or Evaluation

(1) External contamination. As a skin contaminant, Tc-99m presents many difficulties in dose assessment as well as decontamination. Consequently, it is recommended that a knowledgeable health or medical physicist calculate the estimated dose by using an approved computer code such as VARSKIN. Dose to the extremities (e.g., hand) of nuclear medicine technologists is commonly recognized to be of concern because technologists typically handle syringes containing millicuries (mCi) quantities of photon emitters for injection into patients. Thus, a small extremity dosimeter (i.e., finger ring) is normally worn on one of the fingers to assess the external dose. However, standard monitoring methods are not suitable for determining the dose to the basal cell layer of the epidermis if the contamination is directly on the skin.

(2) Internal contamination

(a) In vivo bioassay (internal monitoring) analysis. See enclosure (9) for guidance on performing internal monitoring. If an in vivo bioassay (internal monitoring) facility is not readily accessible, contact the BUMED REAB for assistance.

(b) In vitro bioassay analysis. The dose may be estimated by in vitro bioassay analysis of urine samples. See enclosure (11) for instructions on bioassay sample collection for analysis. Contact the BUMED REAB before collecting samples.

c. Therapy

(1) External decontamination. See enclosure (8) for guidance on performing external or skin decontamination.

(2) Wound decontamination. See enclosure (10) for guidance on performing wound decontamination.

(3) Internal decontamination. Due to the short half-life (6.01 hours) of this radionuclide, unless the expected internal dose is life threatening, no additional actions should be taken to remove activity from the body. However, if necessary, see Table 12.1 of this enclosure for the appropriate therapy to hasten the elimination of Tc-99m.

# SUPPLIES FOR PERSONNEL DECONTAMINATION

1. The amount of dedicated decontamination material or supplies to be maintained depends upon the type of work being performed and the probability for a contaminating event. Normally, aboard ships, enough dedicated material to decontaminate approximately one tenth of the occupationally exposed personnel is more than adequate. At shore facilities, the amount of dedicated material will be dependent on the type and extent of work.

2. The command's response plan should include a list of required decontamination supplies, including quantities, specific to radioactive material or radioisotopes maintained by the command, and customized to the command's abilities and internal resources, availability of outside resources, and per higher authority requirements and guidance.

3. This paragraph provides a list of recommended supplies or items for decontaminating individuals, per reference (c). The list is not meant to be exhaustive or prevent personnel, who perform decontamination, from adapting to changing conditions during a response.

a. The list of supplies or items in subparagraph 3a(1) through 3a(8) of this enclosure may be used, as necessary, according to the risk and level of contamination.

(1) Dosimetry.

(2) Coveralls or surgical scrub suits.

(3) Plastic aprons.

(4) Surgical caps.

(5) Surgical gloves.

(6) Shoe covers.

(7) Face and splash shields. Face protection should be used for personnel conducting decontamination methods that could generate splashing (e.g., wound or skin irrigation using saline solution or water, or rinsing hands in a sink basin using water from a faucet).

(8) Respiratory protection. Respirator use should only be considered when treating a patient in a MTF with very high levels of loose contamination. Wearing respiratory protection is optional if exposure of medical personnel to airborne radionuclides is minor or of short duration. The highest priority should be maintaining effective communication between patient and medical personnel (reference (c)).

Note: Ensure decontamination supplies with expiration dates are valid (i.e., not expired).

b. Listed in subparagraphs 3b(1) through 3b(16) of this enclosure are recommended items for comprehensive decontamination.

(1) Sterile applicators and miscellaneous dressings.

(2) Waterproof dressings or bandages.

(3) Irrigation syringes.

(4) Bar or liquid soap.

(5) Waterless hand cleaner.

(6) Mild abrasive soap (e.g., mechanics hand soap).

(7) Shampoo.

(8) Surgical brushes.

(9) Laundry detergent.

(10) Sterile water.

(11) Hair clippers.

(12) Trauma scissors.

(13) Towels.

(14) Washcloth.

(15) Pre-moistened wipes (baby wipes).

(16) Facial (nose) tissues.

c. Additional suggested items are:

(1) Anatomical forms for documenting contamination information.

(2) Notebooks, paper, and pens.

(3) Cotton-tipped applicators.

(4) Specimen containers.

(5) Radiation-related signs and tape.

(6) Masking tape (5 cm or 2 inches wide).

(7) Self-adhesive labels.

(8) Plastic bags of various sizes.

(9) Absorbent material or pads (chux pads).

(10) Basins to collect drainage from decontamination efforts.

(11) Trash cans.

(12) Modesty clothing (long patient gowns, Tyvex suits, etc.).

(13) Blankets.

(14) Rolling cart for supplies.

(15) Magnet(s) for removing metallic fragments.

(16) Material to cover the ground for contamination control.

## CONTACT LIST

| Command | Address | Telephone/Fax | E-mail |
|---|---|---|---|
| BUMED REAB | 7700 Arlington Boulevard<br>Falls Church, VA 22042 | CDO: (P) (202) 714-0131<br><br>Head, Undersea Medicine and Radiation Health:<br>(P) (703) 681-9286<br>(F) (703) 681-5406<br><br>Head, Ionizing Radiation<br>(P) (703) 681-9285 | |
| NDC | Officer in Charge<br>Bldg. 84T<br>4975 North Palmer Road<br>Bethesda, MD 20889-5629 | (P) (301) 295-5410 | dod.bethesda.dod.mbx.navdoscen2@mail.mil |
| Portsmouth Naval Shipyard (PNS) | Portsmouth Naval Shipyard<br>Radiation Health Division<br>(Code 105.5)<br>Building H-1<br>Portsmouth, NH 03804-5000 | (P) (207) 438-2588<br>(F) (207) 438-1798 | port_ptnh_fleet_dt702@navy.mil |
| Norfolk Naval Shipyard (NNSY) | Norfolk Naval Shipyard<br>Attn: Director of Radiation Health<br>(Code 105.5)<br>Bldg. 269<br>Portsmouth, VA 23709-5000 | (P) (757) 396-1991<br><br>(F) (757) 396-1277 | nfsh_nnsy_c105.5_help_desk@navy.mil |
| Puget Sound Naval Shipyard (PSNS) | Puget Sound Naval Shipyard<br>Radiation Health (Code 105.5)<br>Building 940<br>1400 Farragut Ave<br>Bremerton, WA 98314-3001 | (P) (360) 476-3276<br>(F) (360) 476-5608 | psns-imf-fleetdt702@navy.mil |
| Pearl Harbor Naval Shipyard (PHNS) | Commander (Code 105.5)<br>Pearl Harbor Naval Shipyard and IMF<br>667 Safeguard St, STE 100<br>JBPHH, HI 96860-5033 | (P) (808) 473-8000, ext. 3820<br>(F) (808) 473-3946 | prlh_phns_dosimetry_fleet_support@navy.mil |

Table 2.1. Point of Contact List of Pertinent Commands

Note: Table 2.1 provides point of contact information of various commands for consultation or services that may be required for responding to a radiological casualty or emergency. The BUMED REAB will annually verify the accuracy of this contact list and provide an updated list, as necessary, to applicable commands.