Oak Ridge Institute for Science and Education
Shaping the Future of Science

REAC/TS

Radiation Emergency Assistance Center/Training Site

The Medical Aspects of Radiation Incidents

5th Edition

PO Box 117, MS-39 • Oak Ridge, TN 37831
Office: (865) 576-3131 • 24-hr Number: (865) 576-1005
https://orise.orau.gov/reacts

Foreword

The Radiation Emergency Assistance Center/Training Site (REAC/TS) has provided the U.S. Department of Energy (DOE)/National Nuclear Security Administration (NNSA) with expertise related to the medical management of radiation injuries and illnesses since 1976.

REAC/TS maintains a 24/7 national and international radiation emergency medical response capability that includes a staff of physicians, nurses, paramedics, and health physicists experienced in treatment of radiation injuries/illnesses, radiation dose estimation, radiation health protection and decontamination techniques. REAC/TS Cytogenetic Biodosimetry Laboratory (CBL) performs the gold standard, dicentric chromosome assay and other biodosimetry techniques for dose assessment.

REAC/TS provides ACCME AMA PRA Category 1 Credit™ continuing medical education on-site courses and tailored off-site courses. Visit: **https://orise.orau.gov/reacts/continuing-medical-education/index.html** and/or download the REAC/TS RadMed App for Android and iOS devices.

For information on scheduling a course at your site, please call **865-576-3131** during regular business hours.

REAC/TS may be reached in an emergency by calling the DOE Oak Ridge Operations Center at **865-576-1005**, ask for REAC/TS.

For non-emergencies, the REAC/TS phone number is: **865-576-3131**.

The Oak Ridge Institute for Science and Education (ORISE) is a DOE institute focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists. ORISE is managed by Oak Ridge Associated Universities (ORAU).

This document was produced under contract number DE-SC0014664 between the DOE and Oak Ridge Associated Universities by Wayne Baxter, BSN, RN, EMT-P; Joshua Hayes, PhD, NRRPT; Meghan Dieffenthaller, MS; Brittany Phillips, BSN, RN; AEMT; Kristy Diffenderfer-Stewart, MSN, RN; David Quillin, MBA, BSN, RN; James D Vogt BS; John Crapo, MS, ScD; Adayabalam Balajee, PhD; Ronald Goans, MD, PhD; Mark Ervin, MD; Carol Iddins, MD, FAADM.

Special thanks to the City of Oak Ridge Fire Department and Paramedic Austin Keathley for his assistance with the decontamination demonstration pictures.

Initial Response Actions

REAC/TS is available 24 hours a day by calling **865-576-1005** for emergencies. For routine inquiries, call **865-576-3131** (8 a.m. to 5 p.m. Eastern time).

International callers call **+01 865-576-1005**.

REAC/TS provides response, advice, and consultation regarding illnesses or injuries caused by ionizing radiation.

If you are a healthcare provider or a member of a response team calling, there is specific information that will help us provide the best assistance for your situation. We will ask:

1. Contact information, such as the caller's name, position/title, location, call back number, and email.
2. What happened?
3. Is anyone critically injured?
4. Was this an exposure or a contamination event?
5. What isotope or device was involved?

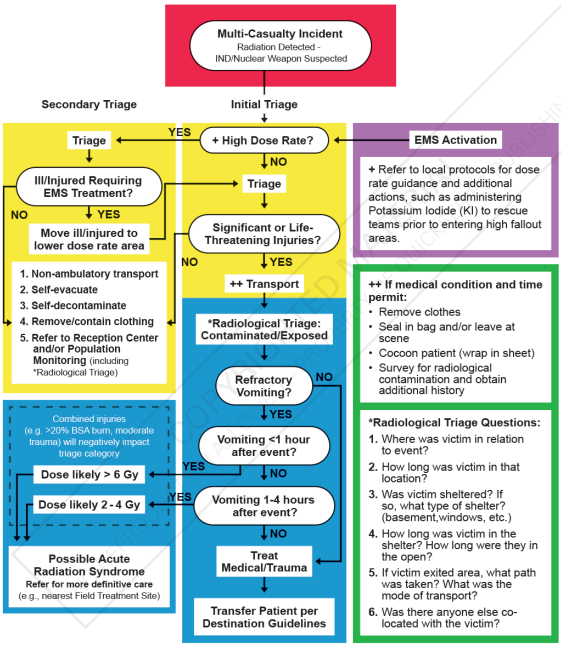
6. What is the patient's current medical status?
7. Does the patient have any pertinent medical history?
8. Have any labs or other diagnostic tests been conducted?
   a. Are laboratory results available?
9. Was the patient wearing a dosimeter?
10. If a contamination event, has the patient been surveyed for radiation?
    a. If so, what were the counts and what units were used?
11. Have any other agencies been contacted, such as state rad health, the Radiological Assistance Program (RAP teams), or the radiation safety officer at the site of the event?

Further information may be requested based on the specifics of the incident. We know you may not have all these answers, but the more information you have, the better we can assist you.

REAC/TS
Radiation Emergency Assistance Center/Training Site

Prehospital Radiological Triage

Version 1.1, March 2020



+ Refer to local protocols for dose rate guidance and additional actions, such as administering Potassium Iodide (KI) to rescue teams prior to entering high fallout areas.

++ If medical condition and time permit:

- Remove clothes
- Seal in bag and/or leave at scene
- Cocoon patient (wrap in sheet)
- Survey for radiological contamination and obtain additional history

***Radiological Triage Questions:**

1. Where was victim in relation to event?
2. How long was victim in that location?
3. Was victim sheltered? If so, what type of shelter? (basement,windows, etc.)
4. How long was victim in the shelter? How long were they in the open?
5. If victim exited area, what path was taken? What was the mode of transport?
6. Was there anyone else co-located with the victim?

Radiation Emergency Assistance Center/Training Site (REAC/TS)
After Hours Emergency Assistance
US Department of Energy Oak Ridge Operations Center: 865.576.1005
Phone: 865.576.3131 - orise.orau.gov/reacts

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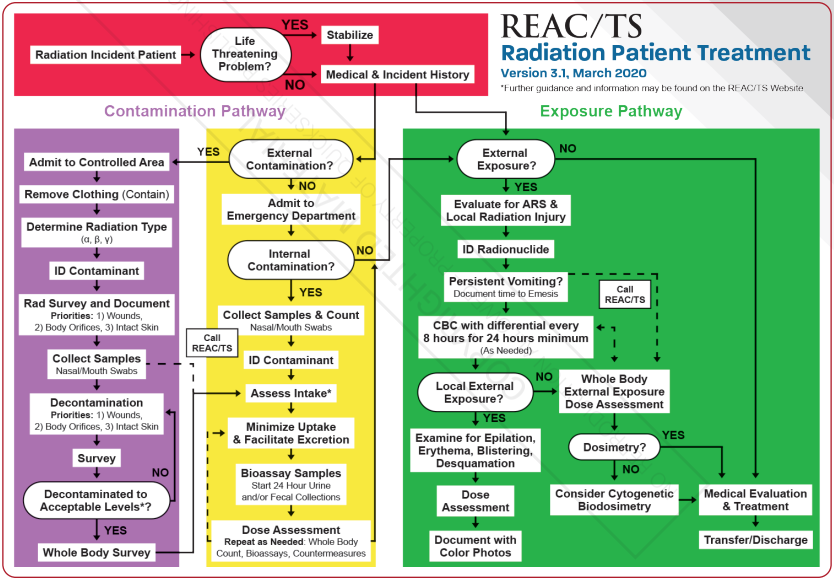
REAC/TS
Radiation Patient Treatment
Version 3.1, March 2020
*Further guidance and information may be found on the REAC/TS Website
Radiation Incident Patient
Life Threatening Problem?
YES
Stabilize
NO
Medical & Incident History
Contamination Pathway
Exposure Pathway
External Contamination?
YES
NO
Admit to Controlled Area
Remove Clothing (Contain)
Determine Radiation Type (α, β, γ)
ID Contaminant
Rad Survey and Document
Priorities: 1) Wounds, 2) Body Orifices, 3) Intact Skin
Collect Samples
Nasal/Mouth Swabs
Decontamination
Priorities: 1) Wounds, 2) Body Orifices, 3) Intact Skin
Survey
Decontaminated to Acceptable Levels*?
NO
YES
Whole Body Survey
Admit to Emergency Department
Internal Contamination?
NO
YES
Collect Samples & Count
Nasal/Mouth Swabs
Call REAC/TS
ID Contaminant
Assess Intake*
Minimize Uptake & Facilitate Excretion
Bioassay Samples
Start 24 Hour Urine and/or Fecal Collections
Dose Assessment
Repeat as Needed: Whole Body Count, Bioassays, Countermeasures
External Exposure?
NO
YES
Evaluate for ARS & Local Radiation Injury
ID Radionuclide
Persistent Vomiting?
Document time to Emesis
Call REAC/TS
CBC with differential every 8 hours for 24 hours minimum
(As Needed)
Local External Exposure?
NO
YES
Whole Body External Exposure Dose Assessment
Examine for Epilation, Erythema, Blistering, Desquamation
Dosimetry?
YES
NO
Dose Assessment
Consider Cytogenetic Biodosimetry
Medical Evaluation & Treatment
Document with Color Photos
Transfer/Discharge

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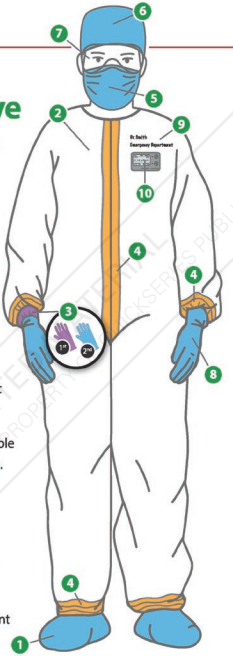
Putting on Protective Clothing (Donning)

1. Shoe Covers.
2. Coveralls or Isolation Gown: At minimum, fully cover torso from neck to knees, arms to ends of wrists. Fasten or secure appropriately.
3. First set of gloves underneath cuff of coveralls or gown.
4. Tape sleeves and trouser cuffs (as applicable). Tape any other potential areas of contaminant entry, such as an uncovered zipper.
5. Face Mask: Secure ties or elastic band. Fit flexible band to bridge of nose and secure below chin.
6. Head Covering.
7. Face Shield or Goggles.
8. Second set of gloves. Extend to cover wrist of coveralls or isolation gown.
9. Identifying Information: Name and role on front and back of protective wear.
10. Dosimeter (if available).



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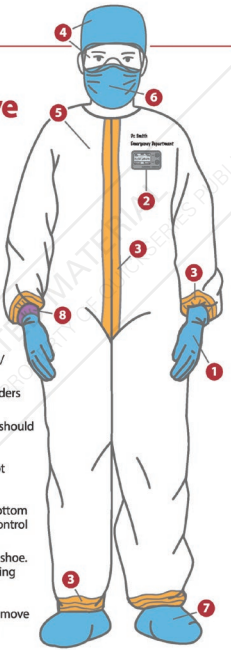
Removing Protective Clothing (Doffing)

The outside of all protective clothing should be considered contaminated.

1. Remove outer gloves, turning them inside out as they are pulled off.
2. Give dosimeter to the control line person.
3. Remove all tape at sleeves, trouser cuffs, and zipper (as applicable).
4. Remove head cover and face shield/goggles, pulling them back and away from the face.
5.
   - Coveralls: Unzip and remove by folding outward/downward, leaving shoe covers in place
   - Protective Gown: Pull away from the neck/shoulders and remove by turning inside out
   - Only the inside of protective coveralls or gowns should be touched.
6. Remove mask by grasping earpieces or ties. Do not touch the front of the mask.
7.
   - Remove shoe cover from one foot and survey bottom of shoe. If not contaminated, place foot across control line onto step-off area.
   - Remove other shoe cover and survey bottom of shoe. If not contaminated, stand in step-off area, keeping hands inside the control line.
8. While keeping hands inside the controlled area, remove inner gloves and place them in the contaminated trash receptacle.
9. Perform a head-to-toe radiological survey before leaving the step-off area.



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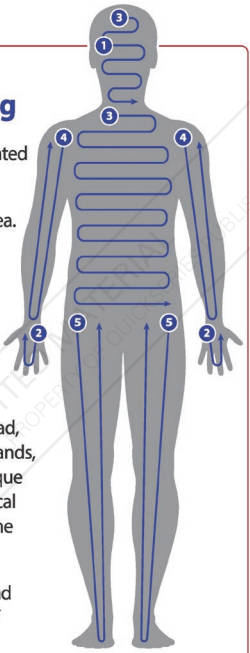
Personnel Monitoring

- Before stepping from contaminated area, survey soles of feet.
- Have person stand in step off area.
- Instruct the person to stand straight, feet spread slightly, arms extended with palms up and fingers straight out.
- Survey ❶ face and ❷ hands.
- Survey from the ❸ top of the head, covering the torso, ❹/❷ arms/hands, and ❺ legs. Good survey technique is essential. Use a slow, methodical technique to monitor 100% of the body surface area.
- Have the person turn around, and repeat the survey on the back of the body.



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How to use the Patient Survey Sheet:

2 Assessment Survey

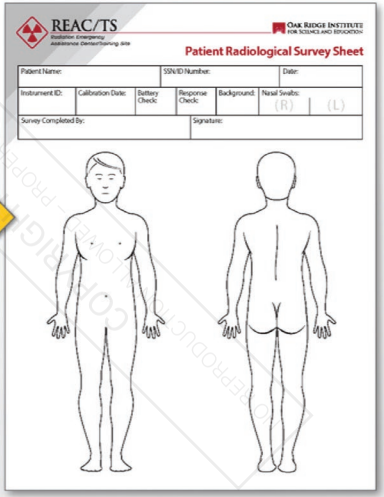
Survey when/where medical status and care allow

1. Wounds
2. Body Orifices
3. Intact Skin

- Document contamination readings

α, β, γ determination

- After decontamination procedures, repeat survey and document
- Thorough whole body survey



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Patient Radiological Survey Sheet

Patient Name:			SSN/ID Number:			Date:
Instrument ID:	Calibration Date:	Battery Check:	Response Check:	Background:	Nasal Swabs: (R)	(L)
Survey Completed By:			Signature:			

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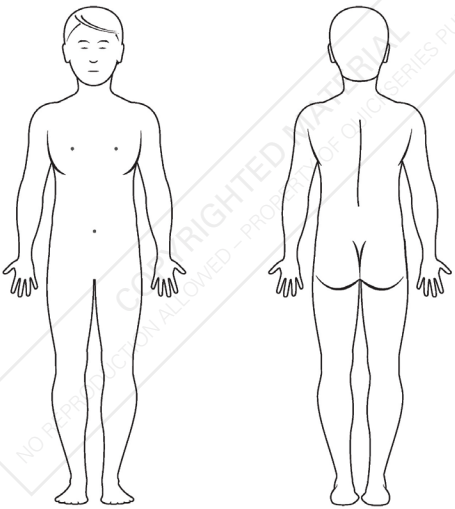
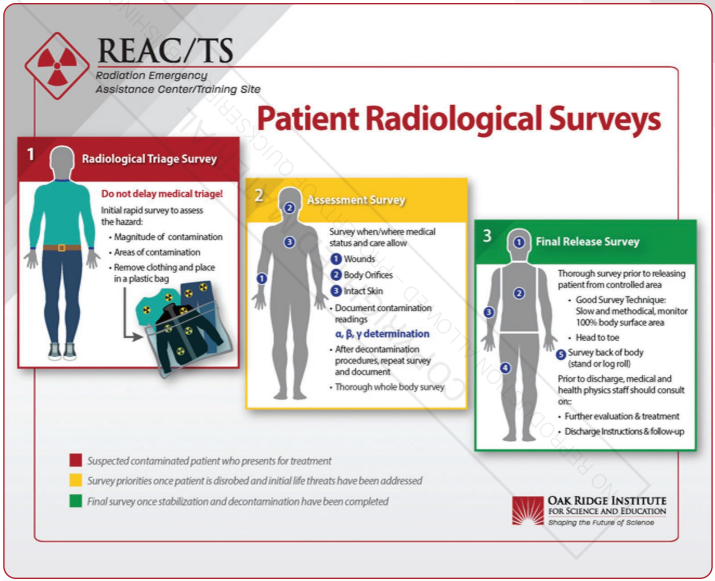
Patient Radiological Survey Sheet"

Y:\REACTS\Bowen\Logos and Graphics\Posters, Paperwork, and Handouts\REACTS Exercise Patient Chart.docx*1

Patient Name:			SSN/ID Number:			Date:
Instrument ID:	Calibration Date:	Battery Check:	Response Check:	Background:	Nasal Swabs: (R)	(L)
Survey Completed By:			Signature:			




REAC/TS
Radiation Emergency Assistance Center/Training Site
Patient Radiological Surveys
1
Radiological Triage Survey
Do not delay medical triage!
Initial rapid survey to assess the hazard:
• Magnitude of contamination
• Areas of contamination
• Remove clothing and place in a plastic bag
2
Assessment Survey
Survey when/where medical status and care allow
1 Wounds
2 Body Orifices
3 Intact Skin
• Document contamination readings
α, β, γ determination
• After decontamination procedures, repeat survey and document
• Thorough whole body survey
3
Final Release Survey
Thorough survey prior to releasing patient from controlled area
• Good Survey Technique: Slow and methodical, monitor 100% body surface area
• Head to toe
5 Survey back of body (stand or log roll)
Prior to discharge, medical and health physics staff should consult on:
• Further evaluation & treatment
• Discharge Instructions & follow-up
Suspected contaminated patient who presents for treatment
Survey priorities once patient is disrobed and initial life threats have been addressed
Final survey once stabilization and decontamination have been completed
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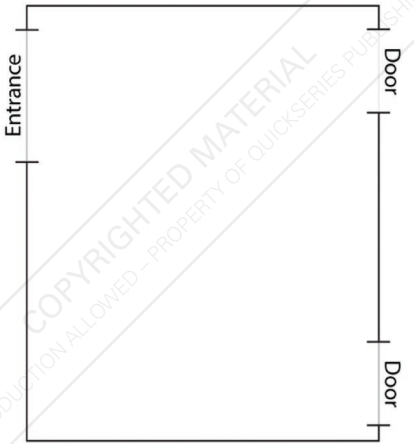
Area Radiological Survey Sheet

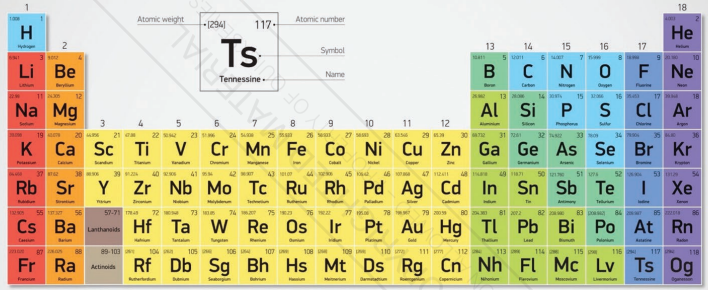
Area(s):				Date:
Instrument ID:	Calibration Date:	Battery Check:	Response Check:	Background:
Survey Completed By:			Signature:	

Perform survey instrument checkout process
Be systematic
Focus on high-touch areas
Document on survey sheet



Comments:

PERIODIC TABLE OF THE ELEMENTS



Element 117 was discovered by a US-Russia team in 2010. The name tennessine (Ts) recognizes the contributions of Oak Ridge National Laboratory (ORNL), Vanderbilt University, and the University of Tennessee, Knoxville, to superheavy element research, including the discovery of moscovium and tennessine and the production of unique actinide target materials to support the discovery of nine elements. This periodic table was donated to the school by UT-Battelle LLC, which operates ORNL for the U.S. Department of Energy.

Bill Haslam, Governor
State of Tennessee

Thomas E. Mason, Director
Oak Ridge National Laboratory

OAK RIDGE National Laboratory

Introduction and Radiation Basics

The most important consideration in evaluating people involved in a radiation incident is medical stability. The relative magnitude of the situation and the resources needed to address the emergencies are also important considerations.

- **Small-scale** incidents are those occurring in laboratories, hospitals, nuclear power plants, etc., involving small amounts of radioactive materials with the potential exposure and/or contamination of one or a few individuals.
- **Large-scale** incidents are those involving relatively large quantities of radioactive materials and the potential exposure and/or contamination of large numbers of people (e.g., mass casualty incidents and radiological dispersal devices (RDD), radiation exposure devices (RED), nuclear weapons detonation, and large-scale nuclear power plant (NPP) incidents.

As with all emergency response situations, safety of the responder is a primary concern. **Universal scene safety precautions will protect the first responder from most radiological incidents while providing lifesaving measures.** A site known to be radiologically contaminated should be assessed before entry and responders should be advised to limit their time in high dose-rate areas. There is minimal risk typically associated with handling a radiologically contaminated casualty.

Potential Scenarios

- **Radiation Exposure Device (RED):** Radioactive material, in a sealed source or within a container, intended to expose people in the vicinity of the device to a high-level external dose. Some materials that could be used as a RED include radioactive sources used in commercial equipment or industrial radiography sources. A RED does not result in contamination but can have a medically significant radiological exposure.
- **Radiological Dispersal Device (RDD):** Any device that causes intentional dissemination of radioactive material without a nuclear detonation. A RDD can cause internal dose through inhalation or ingestion of released radioactive material and external dose because of surface contamination. A RDD that disperses radioactive material through an explosive device would likely result in contamination of any injuries associated with blasts and heat. RDDs are commonly called "Dirty Bombs."
- **Improvised Nuclear Device (IND):** A device designed by terrorists to produce a nuclear detonation. At full or partial yield, an IND is physically the same as a nuclear weapon: blast, burns, and radiation are the forms of energy and also cause injury. An IND exposes people to trauma, high-level external dose, inhalation and ingestion of radioactive materials, and skin contamination. Should an IND fail to detonate properly, the high explosives may disseminate the nuclear material around the environment, becoming a RDD.

Exposure limits are on the next two tables. These are based on the amount of radiation a declared radiation worker can receive in a year without exceeding regulatory limits. The second table is the amount of radiation a member of the general public can receive in a year.

A person receiving these doses is unlikely to have any acute medical consequences.

Occupational Limits	US NRC		ICRP 103	
	rem	mSv	rem	mSv
Whole body (internal + external)	5	50	2	20
Any individual organ	50	500	-	-
Lens of the eye	15	150	2*	20*
Skin	50	500	50	500
Extremities	50	500	50	500
Fetal dose (declared pregnancy)	0.5	5	0.1	1

*Non-Occupational Annual Exposure Limits (NRC/ICR)

Occupational Limits	US NRC		ICRP 103	
	rem	mSv	rem	mSv
General Public	0.1	1	-	-
Whole body (internal + external)	-	-	0.1	1
Lens of the eye	-	-	1.5	15
Skin	-	-	5	50

Five Types of Radiation

1. **Alpha (α) particles:** Heavy charged particles emitted from heavy nuclei including uranium, plutonium, and americium. Alpha particles can travel a few centimeters in air and a few micrometers in human tissue. Thin clothing, or even a sheet of paper, is an effective shield for alpha particles. Radionuclides that emit alpha particles are therefore a negligible external hazard but can be important in an inhalation or ingestion incident since they are more efficient at damaging tissue when internalized. Regulatory limits on intakes of alpha particle emitting radioisotopes are typically much more restrictive than for other radiation types.
2. **Beta (β) particles:** Negatively charged particles that are several thousand times smaller than alpha particles. They are more penetrating into tissue and skin. Beta particles can travel a few millimeters in tissue and up to a couple of meters in air. Most beta particles can be shielded by a thin layer of plastic. Large quantities of beta-emitting radioactive materials deposited on the skin can damage the basal layer of the epidermis, or deeper, and cause what are commonly referred to as beta burns. Beta-emitters such as tritium (H3) and strontium 90 are both external and internal hazards.
3. **Gamma (γ) rays:** Non-particulate electromagnetic ionizing radiation that are emitted from the nucleus of various radioisotopes. They are highly energetic and can pass through matter easily. Dense materials such as lead and concrete are used to shield gamma rays. Gamma emitters such as cesium 137, cobalt 60, and iridium 192 are both internal and external hazards.

4. **X-rays:** Different from gamma rays only in their point of origin: within the electron cloud as opposed to within the nucleus.
5. **Neutrons:** Uncharged particles emitted during the fission process and in some nondestructive testing procedures. They are not as commonly encountered as the other four types of radiation. Neutrons have five to 20 times more risk of future effects than gamma rays, depending on their energy. Neutrons are the only of these five types that can make something else radioactive (neutron activation) without contamination.

In the event of a criticality accident, neutrons can be captured by atoms, such as sodium and phosphorous, in the body and cause them to become radioactive in a process called neutron activation. This is the only instance in which a patient who is irradiated becomes radioactive themselves. Though this is an extremely rare circumstance, it can happen, and extra precautions will need to be taken for the safety of the healthcare providers.

Healthcare providers will need to make use of the principles of time, distance, and shielding whenever possible while treating the patient: Decrease time, increase distance, and increase shielding. The most practical applications of these radiation safety principles will only be in the patient treatment room, when necessary, to prevent unnecessary personnel into the room or near the patient, and to rotate the medical staff who are treating the patient to decrease the overall exposure each person receives. Since sodium is one of the elements that undergoes activation, healthcare providers will need to be aware of bodily fluids, such as sweat, that come off the patient.

Regulatory Limits

During radiation emergencies first responders, rescuers, healthcare providers, and workers may receive a dose of radiation. This guideline acknowledges that and provides the incident commander the ability to avoid medically significant or life-threatening radiation doses.

Gamma Dose Rate	"Stay Time Table" Time to stay to receive this dose				
	1 rem/ 0.01 Sv	5 rem/ 0.05 Sv	10 rem/ 0.1 Sv	25 rem/ 0.25 Sv	**100 rem/ 1 Sv**
1 mR/hour	6 weeks	30 weeks	1 year		
5 mR/hour	200 hours	6 weeks	12 weeks	30 weeks	**2 years**
100 mR/hour	10 hours	50 hours	100 hours	250 hours	**6 weeks**
1 R/hour	1 hour	5 hours	10 hours	25 hours	**100 hours**
10 R/hour	6 minutes	30 minutes	1 hour	2.5 hours	**10 hours**
100 R/hour	36 seconds	3 minutes	6 minutes	15 minutes	**1 hour**

United States EPA Guidelines for Emergency Exposures		
Dose Limit	Activies	Condition
5 rem / 0.05 Sv	All	**As low as reasonably achievable** (ALARA)
10 rem / 0.1 Sv	Protection of major property	When lower dose is not possible
25 rem / 0.25 Sv	Lifesaving and protection of large population	When lower dose is not possible
> 25 rem / > 0.25 Sv	**Lifesaving protection of large population**	**Fully aware of risk/ voluntary**

First Responder Dose NCRP Commentary 19	Activity	Operational Guidelines
5 rem/ 50 mSv	All occupational exposures	ALARA and minimizing dose
10 rem/ 100 mSv	Protection of valuable property	Monitor and medical management
25 rem/ 250 mSv	Lifesaving or critical protection of populations	Monitor and medical management
>25 rem/ >250 mSv	Lifesaving or critical protection of populations	Fully aware of risks, older workers, volunteers
50 rad/ 500 mSv	Lifesaving or critical protection of populations	Cumulative absorbed dose to an emergency responder reaches 0.5 Gy (50 rad), a decision needs to be made on whether to withdraw the emergency responder. **This is a decision dose, not a dose limit.**

Radioactive Materials of Interest

There are over 3,000 isotopes, but only 10-15 are important in the military, industrial, and civilian sectors. Certain isotopes are commonly found during incidents involving radioactive materials.

"University Five" – Carbon 14, phosphorus 22, iodine 135, iodine 131, and californium 252 are used for isotopic labeling in biochemistry laboratories, and in medicine. Hydrogen^{3} (Tritium) is also common.

"Industrial Three" – Iridium 192, cesium 137, cobalt 60. Iridium 192 is widely used in industrial radiography to inspect for cracks in welds and metals. Cesium 137 and cobalt 60 are used in industry because of their penetrating gamma rays and are prime agents for terrorism incidents.

"Military Five" – Tritium (hydrogen^{3}), uranium 235, uranium 238, plutonium 239, and americium 241 are isotopes primarily used in the production of weapons. Depleted uranium has been used as armor and in the production of projectiles.

Fission/Activation Products – These are encountered in response to a nuclear detonation (either an improvised nuclear device [IND] or a weapon), a reactor accident, or a waste transportation incident. Some are volatile and, depending on the activity, can pose a significant risk to the populace. Fission products have multiple radioisotopes that are centered around atomic numbers of 90 and 135 as well as heavier isotopes. Common radioisotopes are strontium, iodine, cesium, uranium, barium, xenon, krypton, and plutonium.

Depleted Uranium Disclaimer from REAC/TS

REAC/TS has received numerous calls for assistance regarding depleted uranium (DU) exposure during military actions or conflicts. DU is primarily a heavy metal hazard, and REAC/TS does not assign doses for exposures to DU.

For more information on DU or DU compensation, contact the U.S. Department of Veterans Affairs public health, or the International Atomic Energy Agency (IAEA).

U.S. Department of Veterans Affairs:

www.publichealth.va.gov/exposures/radiation/how-va-confirms-exposure.asp

Call **800-827-1000** or **800-829-4833**
(TDD for hearing impaired)

International Atomic Energy Agency:

www.iaea.org/topics/spent-fuel-management/depleted-uranium

In the event that this information changes following the printing of this pocket guide, the up-to-date information can be found on our website and app.

Means of Exposure

An individual may receive a radiation dose from an external source, or by loose radioactive material deposited on the skin or equipment, or by ingesting or inhaling radioactive particulates. Ingestion or inhalation may cause an internal dose to the whole body or to a specific organ over time.

Irradiation/Exposure vs. Contamination

A person is irradiated when they are "exposed" to ionizing radiation in much the same way a person is "exposed" to light when someone shines a flashlight on them. In the case of irradiation, there is no material transferred. This means that an irradiated patient has no radioactive material on them and poses no radiological hazard to the treatment team.

When people have radioactive materials on/in them, they are described as contaminated. Note that a person is not contaminated with alpha particles, for instance, but with radioactive materials such as americium-241 that emit alpha particles. A good way to think of this is to imagine a sealed container of radioactive baby powder that emits gamma rays. A person can hold the container and be exposed to the gamma rays penetrating through the walls of the container without getting the baby powder on their hands. Should a leak develop around the lid, allowing some of the material to escape, the person may then have the powder on their hands, resulting in contamination.

Controlling radioactive contamination is very similar to controlling loose baby powder. Utilize protective clothing, control entry and exit to/from a contaminated area, minimize the amount of material dispersed into the air, and practice proper personnel monitoring.

Other methods of contamination control include the use of negative pressure rooms, avoiding actions that may re-suspend the material, covering or removing unnecessary items from the area, and clothing removal.

Units of Measurement

Conventional units such as ounces, grams, etc., should not be used to quantify the amount of radioactive material present. The basic unit of radioactivity used in the U.S. is the curie (Ci), defined as 3.7×10^{10} becquerels (Bq). The becquerel, one disintegration per second (dps), is the basic SI unit. Activity is the concept used to quantify the amount of radioactive material present. For instance, 1 gram of cobalt 60 is a little over 1,100 Ci (~40,000 GBq), while 1 gram of uranium 235 is about 2.1 µCi (~ 78 kBq).

G = giga (1×10^9 or 1,000,000,000)

M = mega (1×10^6 or 1,000,000)

k = kilo (1×10^3 or 1,000)

m = milli (1×10^{-3} or 0.001)

µ = micro (1×10^{-6} or 0.000001)

n = nano (1×10^{-9} or 0.000000001)

Activity Conversions

Useful Activity Conversions			
1 terabecquerel	1 TBq	27 curies	5.99×10^{13} (59,900,000,000,000) dpm
1 gigabecquerel	1 GBq	27 milicuries	5.99×10^{10} (59,900,000,000) dpm
1 megabecquerel	1 MBq	27 microcuries	5.99×10^{7} (59,900,000) dpm
1 kilobecquerel	1 kBq	27 nanocuries	5.99×10^{4} (59,900) dpm
1 becquerel	1 Bq	27 picocuries	5.99×10^{1} (59,9) dpm
1 kilocurie	1 kCi	37 terabecquerels	2.22×10^{15} (2,220,000,000,000,000) dpm
1 curie	**1 Ci**	**37 gigabecquerels**	**2.22×10^{12} (2,220,000,000,000) dpm**
1 milicurie	**1 mCi**	**37 megabecquerels**	**2.22×10^{9} (2,220,000,000) dpm**
1 microcurie	**1 µCi**	**37 kilobecquerel**	**2.22×10^{6} (2,220,000) dpm**
1 nanocuries	1 nCi	37 becquerels	2.22×10^{3} (2,220) dpm

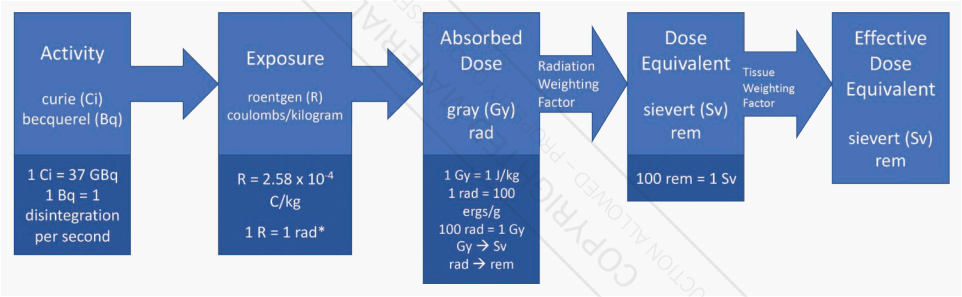
The amount of time it takes for the activity to decrease to half its original value is called the half-life. Half-life cannot be altered by outside forces.

Exposure relates to the potential to create ionization in air. The units are the **roentgen (R)** in the U.S. and **coulombs per kilogram (C/kg)** in SI units. These units are for "ionization in air," so they are not extremely useful when applied to the medical management of radiation incident victims. Once energy is deposited into tissue, it is known as absorbed dose.

Absorbed dose is a measure of the energy deposited in tissue by ionizing radiation. The U.S. unit is the **rad**. One rad is equal to 100 ergs (1×10^{-7} joules) of energy deposited into 1 gram of tissue. The SI unit for absorbed dose is the **gray (Gy)**, which is equal to 1 joule of energy deposited into 1 kilogram of tissue. When assessing acute medical effects, it is widely considered that the most appropriate unit to use is the rad or Gy since the acute effects are largely driven by the amount of energy deposited into specific tissue.

$$1 \text{ Gy} = 100 \text{ rad}$$

$$1 \text{ centigray (cGy)} = 1 \text{ rad}$$



*For emergency purposes, 1 R = 1 rad to allow for quick dose estimations, whereas in actuality, 1 R = 0.877 rad

The differences in the future risk (e.g., risk of future cancer induction) between the different radiation types are approximated by use of a quality factor (QF, for dose equivalent, used in the U.S.) or a radiation weighting factor (w_R, for equivalent dose, used internationally).

Quality/Radiation Weighting Factors	
Gamma, Beta, Positron 1	Proton 2
Alpha 20	Neutrons* 5-20

*For neutrons of unknown energies, assume weighting factor of 10

Another way to think of this is that it is a comparison of a dose of one type of radiation required to produce a given effect to the dose of a different type of radiation required to produce the same effect.

The difference in dose equivalent (uses QF) and equivalent dose (uses w_R) is found in the definitions used by differing International Commission on Radiation Protection (ICRP) reports. In simple terms, the QF and w_R represent how much more risk is associated with one radiation type versus the standard (gamma, x-ray where the w_R and QF = 1). The dose in Gy times the w_R yields the equivalent dose, measured in sieverts (Sv). The corresponding U.S. unit for the sievert is the rem. The w for x-ray or gamma radiation is 1, so for pure gamma radiation:

Gamma Rays, Beta Particles, Positrons:

100 rad =100 rem, or 1 Gy = 1 Sv

Alpha: 100 rad = 2,000 rem, or 1 Gy = 20 Sv

Neutrons: 100 rad = 1,000 rem, or 1 Gy = 10 Sv

Occupational dose limits, related in rem or Sv, are in place primarily for risk limitation and fall below the normal thresholds associated with acute medical effects. It is sometimes helpful to reference regulatory limits as a comparison point when trying to explain the magnitude of the dose that may have been received by a patient or when in conversations with other interested parties.

Specific Gamma Ray Constant

The gamma constant for an isotope is the gamma ray exposure rate in mSv per hour at a distance from a one MBq point source (for approximate R/hr/mCi, multiply by 3.7). Three common radioisotopes used in industry are iridium 192, cesium 137, and cobalt 60. The following are the approximate gamma constants for these common radioisotopes:

Specific Gamma Ray Constant (U.S. Units)

Nuclide	Gamma Constant R/mCi-hr at 1 cm	Surface R/min per Ci*	1 cm Tissue Depth R/min per Ci**
Cs 137	3.43	113	28
Co 60	12.9	609	114
Ir 192	4.60	180	43

Specific Gamma Ray Constants (SI Units)

Nuclide	Gamma Constant mSv/MBq-hr at 1 cm	Surface mSv/min per GBq*	1 cm Tissue Depth mSv/min per GBq**
Cs 137	0.927	30.5	7.6
Co 60	3.48	164.6	30.8
Ir 192	1.24	48.7	11.6

*Primarily due to electron buildup in the capsule wall. From Waller, et.al, IRPA 13 poster (abstract 2350443)

**From U.S. National Council for Radiation Protection and Measurements (NCRP) Report No. 40, Appendix B, Table 6

Along with the medical assessment, early estimation of the magnitude of the radiation/contamination event and identification of the radioisotope(s) in question are of paramount importance in the medical management of the irradiated patient. These principles strongly influence subsequent treatment decisions.

Personnel Protection

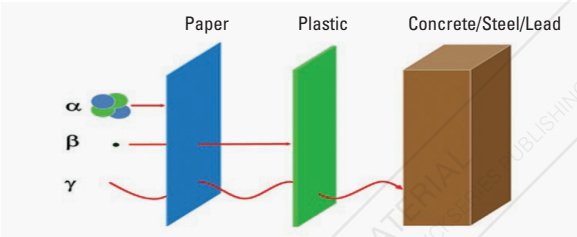
As low as reasonably achievable (ALARA) is the philosophy associated with personnel protection from ionizing radiation. It means that personnel should avoid exposing themselves to radiation without the benefit outweighing the risk. Time, distance, and shielding are the basis of radiation protection. Minimize time exposed to source, maximize distance from source, and utilize proper shielding.

Personal dosimetry should be used to monitor external doses. Personal dosimeter types include direct read-out dosimeters and cumulative dose trackers. Cumulative dose trackers include film badges, thermoluminescent dosimeters (TLD), and optically stimulated luminescent dosimeters (OSL). TLDs, OSLs, and film badges must be read by special equipment. Direct read-out dosimeters allow the user to continually track their accumulated dose and in the case of some electronic dosimeters, alarms can be set when a certain dose rate is reached.

If a dosimeter's alarm goes off, assess if there are potential sources of radiation in the area. If the contaminated person has clothing, cut them out of it. Clothing typically contains 90% of contamination. If alarms continue to go off, back up to increase distance. If backing up does not cause the alarms to quiet, leave the room and reassess. Primarily focus on increasing healthcare providers' distance from the patient when possible and decreasing time with the patient.

Radiologically exposed patients generally pose no danger to healthcare personnel due to irradiation. Radiologically contaminated patients may present a danger to healthcare providers, but this is source and activity-dependent. Medical providers should prioritize lifesaving medical and trauma treatment over radiological decontamination.

Shielding Summary



Personal protective equipment (PPE) is used to protect the medical provider from external contamination by keeping the radioactive material off skin or personal clothing. Coveralls and surgical attire, for example, are acceptable forms of protective clothing. Concerns for heat stress should be considered since most people are not conditioned to working in extra layers of clothing.

Medical personnel should be surveyed for radiological contamination and, if necessary, decontaminated as needed. This can follow the treatment and decontamination of contaminated patients. Standard issue particulate protective masks (respirators) afford protection from inhalation and ingestion of most radioactive material.

Respiratory protection devices are typically designed to filter particulates. Radioactive gases (radon and tritium) will pass through the filters. However, short exposures to these nuclides are not usually medically significant. Keep in mind that surgical masks do not provide an airtight seal. Respiratory protection pre-planning is crucial.

Initial Medical Response

Lifesaving Medical and Trauma Care is a Priority

Multi-Parameter Triage

Patients should be evaluated and treated based on current triage standards. Lifesaving interventions take priority over contamination concerns. The use of universal precautions by healthcare professionals has been shown to mitigate most radioactive contamination concerns. A non-contaminated patient who has only been irradiated poses no radiological hazard to the healthcare provider.

Healthcare Considerations

Victims of a radiological incident require prompt medical evaluation, diagnosis, and treatment of radiation-related injuries.

Healthcare providers are extremely unlikely to receive a medically significant acute radiation dose when providing patient care to casualties contaminated with radioactive materials on clothing, skin, or in wounds provided they observe standard **as low as reasonably achievable** (ALARA) principles.

The possibility of contamination should be reviewed as standard operating procedure. Significant contamination of healthcare providers is unlikely provided they use universal precautions and follow proper contamination control guidelines. First responders need to follow all hazards approach until more information is available.

Clinical signs and symptoms (or prodrome) can be used to estimate a radiation dose to a patient.

Quick Triage Using Time to Vomiting

Dose in Gray (Gy)	Time to Vomiting (hours)	% of Victims	Survivability LD 50/60
0	0	-	
1	N/A	19	
2	4	35	
3	3	54	
4	2	72	With intense treatment
5	1 ½	86	
6	1	94	
7	45 minutes	98	
8	30-45 minutes	99	
9	30 minutes	100	
10	Immediately to 30 minutes	100	

Modified from *Biodosimetry Based on Acute Photon-Equivalent Exposure; Waselenko JK; Goan RE.* "Medical Management of the Acute Radiation Syndrome; Recommendations of the Strategic National Stockpile Working Group." Ann Internal Medecine, 2004

Recommended Anti-Emetic Medications:

Selective 5-HT3 receptor antagonists or anti-dopaminergic are recommended for radiation-induced emesis:

- **Ondansetron:** Zofran®, Zofran ODT®
- **Metoclopramide:** Reglan®

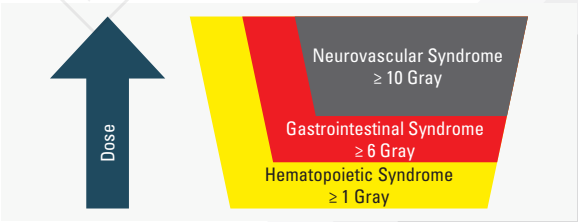
Acute Radiation Syndrome

Acute radiation syndrome (ARS) is an illness that is related to radiation damage to the whole body that occurs with an absorbed dose greater than 1 Gy (100 rem). Whole-body irradiation is defined by the U.S. Nuclear Regulatory Commission (NRC) as proximal to the knees and elbows, to include the head, but is generally to be considered to the entire body, similar to bone marrow ablation prior to bone marrow transplant. Partial-body irradiation is when part of the body is shielded. Internally deposited radionuclides can produce ARS symptoms in rare cases.

Pathophysiology

Radiation damage to cells occurs within microseconds of exposure. The most consequential damage to the cell is radiation injury to the DNA, either directly, or indirectly from free radical formation. Cellular damage is generally most severe in immature and rapidly dividing cell types. Stem cells in the bone marrow, intestinal crypt cells, endothelial cells, and epithelial cells are particularly susceptible to radiation injury.

All of the organ systems will be affected in ARS, though in the acute stages, we focus on the organs seen in the figure below. These thresholds in the figure indicate the classic signs and symptoms for each organ system. ARS involves aggressive inflammation which may result in systemic inflammatory response syndrome (SIRS), multiple organ dysfunction (MOD), and multiple organ failure (MOD).



ARS and DOSE

The classical clinical course of ARS includes an initial prodrome of generalized signs/symptoms, a latent period where earlier symptoms appear to resolve, and eventually a period of manifest illness and the delayed effects of acute radiation exposure (DEARE), which may end in recovery, chronic illness, or death. Organ and tissue involvement may be variable based on the absorbed dose, dose rate, type of radiation, and location on the body.

Prodromal signs and symptoms include the following:

- Nausea and vomiting
- Diarrhea
- Transient erythema (redness) of skin
- Fever
- Conjunctivitis
- Anorexia
- Lymphocyte depletion related to hematopoietic syndrome
- Doses less than 1 Gy will be detectable with laboratory tests and cytogenetic biodosimetry but will have minimal to no signs and symptoms.

Hematopoietic Syndrome (1 Gy or greater)

- Under 2 Gy will have minimal physical signs and symptoms
- Blood producing bone marrow may be damaged
- Early loss of lymphocytes
- Eventual neutropenia, erythropenia, and thrombocytopenia
- Pancytopenia (decrease in all blood cell lines)

- Decrease in thrombocytes (platelets) and activation of Complement Cascade may result in hemorrhage and Disseminated Intravascular Coagulation (DIC)
- Immune system dysfunction
- Fever

Gastrointestinal Syndrome (≥ 6 Gy)

- Vomiting
- Diarrhea
- Ileus
- Malabsorption
- Gastrointestinal bleeding/hemorrhage
- Fluid and electrolyte shifts
- Bacterial translocation
- Sepsis

Neurovascular or Cerebrovascular Syndrome (≥ 10 Gy)

- Likely non-survivable (whole-body dose)
- Early nausea/vomiting/diarrhea
- Mental status change without other cause
- Ataxia
- Cerebral edema with potential increase in intracranial pressure
- High fever
- Hypotension
- Coma
- Death

If patients survive the acute phase of ARS, they may experience DEARE within months of the incident and may exhibit chronic injury to other organs, such as kidneys and lungs.

Current research has the LD50/60 (50% of the population surviving at 60 days) around 3.5-4 Gy, without any advanced medical treatment. Although death from mostly whole-body radiation exposure greater than 8 Gy has historically occurred within several weeks of the incident without modern medical care, the survival period can be extended with aggressive intensive care. The highest survival rates will come from those with less than 6 Gy dose without co-morbidities. Combined injuries (acute radiation illness in the presence of physical trauma and/or thermal burns) increase mortality.

Approximate Dose Thresholds for Acute Radiation Syndrome

Dose	Syndrome	Potential Signs/Symptoms*
0-100 rads (0-1 Gy)	Preclinical	Generally asymptomatic, anorexia (much greater than 1 Gy), nausea, vomiting (rate)
≥ 100 rads (≥ 1 Gy)	Hematopoietic	Lymphocytopenia seen early with much higher doses, along with later neutropenia, thrombocytopenia
≥ 600 rads (≥ 6 Gy)	Gastrointestinal	Early severe nausea, vomiting, watery diarrhea, pancytopenia
≥ 1000 rads (≥ 10 Gy)	Neurovascular	Nausea/vomiting within first hour, mental status change, ataxia, coma

*At higher radiation doses, the onset of signs and symptoms may be quicker.

Medical Management of ARS

Hematopoietic Syndrome

Two main goals of medical management are efforts to prevent neutropenia and sepsis. Early complete blood cell (CBC) count with differential (diff) repeated every 6-12 hours will allow calculation of the absolute lymphocyte count (ALC) and absolute neutrophil count (ANC), with a rapid and deep decrease in the ALC indicating a high dose.

As neutropenia worsens, the risk of infection increases, especially as the absolute neutrophil count drops below 500/mm^3. Patients with immunosuppression may only show subtle signs and symptoms, they may need extended treatments to resolve the infections.

- The World Health Organization (WHO) consultancy made an evidence-based recommendation for patients with a whole-body dose ≥ 2 Gy. They should be given colony-stimulating factors (CSF) to reduce the infectious complications during the time of neutropenia and immunocompromise while waiting for the mobilizing peripheral blood cell lines.
- The U.S. Food and Drug Administration (FDA) approved CSFs for management of ARS-associated neutropenia are recombinant forms of G-CSF or filgrastim (Neupogen®, pegylated G-CSF, or pegfilgrastim (Neulasta®), Granulocyte-macrophage colony-stimulating factor (GM-CSF) or sargramostim (Leukine®), and a biosilimar, pegfilgrastim-jmdb (Udenyca®/Fulphila®). Udenyca® and Fulphila® are uniquely being dispensed as an autoinjector syringe. It is likely that other biosimilars may receive U.S. FDA Emergency Use Authorization (EUA), if needed and off-label use of these medications will likely occur in a large incident.

Continued on next page...

- Romiplostim (N-plate®), a U.S. FDA thrombopoietin receptor agonist, is approved for thrombocytopenia in ARS and appears to be synergistic when given with G-CSF.
- Following the current Infectious Diseases Society of America (IDSA) guidelines or National Comprehensive Cancer Network (NCCN) for high-risk neutropenia is recommended.

Reactivation of previous dormant infections such as herpes simplex virus (HSV), varicella (herpes) zoster virus (VZV, HZV), tuberculosis and cytomegalovirus) and other common infections seen with an immunocompromised patient (pneumocystis jirovecii) may also occur. Antimicrobial agents should be administered promptly to those with febrile neutropenia, afebrile neutropenia with subtle pain, or clinical signs of infection without neutropenia. Breeches in the skin and gastrointestinal (GI) mucosa permit translocation of bacteria and other infectious agents to the circulation where they flourish in the setting of severe neutropenia and lymphopenia.

Table 5 – Recommendations for Prophylaxis: Infectious Disease consultation should be sought for most up-to-date recommendations

Prophylaxis	Recommended	Other Considerations
Antibiotics	Levofloxacin	Cefepime or Vancomycin may be considered
Antifungals	Fluconazole or Posaconazole	Posaconazole
Antivirals	HSV – Acyclovir VZV – Acyclovir CMV – Letermivir Maribavir (resistant)	Valcyclovir Valcyclovir

U.S. FDA Dose Recommendations		Pediatric Dosage
Filgrastim (G-CSF)	10 µg/kg daily subcutaneously	5 µ/kg once a day. Subcutaneous injection or short IV infusion until ANC nadir reaches 10,000 mm^3. Consult with pharmacy.
Sargramostim (GM-CSF)	5-10 µg/kg daily subcutaneously or (200-400 µg/m^2/d)	May administer to ages 2 and older with pharmacy dose recommendations.
Pegfilgrastim (pegylated G-CSF)	6 mg each subcutaneously one week apart for two doses	Dosage based on body weight of child. Refer to pharmacy recommendations.
Pegfilgrastim-uvqb (pegylated G-CSF)	6 mg autoinjector subcutaneously one week apart, two doses	

Gastrointestinal Syndrome

Management of GI syndrome includes symptomatic treatment of nausea and vomiting with a serotonin receptor antagonist (5-HT3), ondansetron or a dopamine receptor agonist, metoclopramide. Diarrhea may be managed with loperamide, or other anti-diarrheals. GI syndrome will require intensive care, to include fluid and electrolyte management, stress ulcer prophylaxis, antimicrobial/antifungal therapy, sepsis protocols, and enteral or parenteral nutrition, consideration of bile acid neutralization, management of bleeding, and other standards of GI critical care.

Neurovascular Syndrome

Acute, irreversible neurovascular syndrome occurs at doses ≥ 10 Gy. Since mortality may approach 100%, supportive care is recommended with antiemetic therapy, anti-seizure medications, management of intracranial pressure (mannitol and furosemide), anxiolytics, and analgesics that may include opiate medications at a sufficiently high dose to relieve pain and provide comfort.

Cutaneous Radiation Syndrome and Injuries (CRS/CRI)

Cutaneous radiation syndrome (CRS) is an organ sub-syndrome of ARS. CRS occurs when there is a large enough affected body surface area and/or deep enough tissue injury to be a potentially fatal sub-syndrome of ARS. More often seen are cutaneous radiation injuries (CRI) which may occur in a more localized anatomical area, such as fingers and hands. CRIs are commonly seen in the industrial sector where radiation devices may be closely handled.

Approx. Dose	Predicted Effect	Time Post-Exposure
300 rads (3 Gy)	Epilation (temporary hair loss)	14-21 days
600 rads (6 Gy)	Erythema (redness)	Prodromal, then 14-21 days later
1000-1500 rads (10-15 Gy)	Dry Desquamation	2-3 Weeks
1500-2500 rads (15-25 Gy)	Moist Desquamation	2-3 Weeks
> 2500 rads (> 25 rad Gy)	Deep Ulceration/ Necrosis (tissue death)	Dose dependent

CRS/CRI History and Physical

The medical history is particularly important in diagnosing the extent of cutaneous injury since signs and symptoms generally take days to months to fully manifest.

- Signs and symptoms
- Time of initial signs/symptoms
- Description of injury and mechanism of injury
- Serial color photographs of area
  - Dermatological photomapping preferred, or blue background, date, with white paper for color correction
  - Measuring device (ruler)
  - Photo of affected and unaffected limb or area, if possible
  - Photo release to REAC/TS
- Contact REAC/TS for consultation
- Patient history and physical
  - The neurological exam will be especially important
  - As these are often occupational injuries, they will need to be given work restrictions to stay out of radiation area and to limit use of affected area

The patient should be cautioned that while initially the wound may look harmless, these types of injuries may become very complex when above necrosis thresholds and if large total body surface areas/deep tissues are involved.

Mechanism of Injury with CRS/CRI

- Incident history
- Make/model/type of device/radiation source
- Radioisotope, if applicable
- Activity of source
- Age of source (if available, to calculate decay)
- Dosimetry, if available
- Time exposed to source
- Distance to source
- Shielding
- Date/time/duration of incident
- Diagnosis of high-level skin dose has generally been estimated by observing the serial evolution of symptoms

Diagnosis may require the use of other diagnostic tools such as magnetic resonance imaging (MRI), ultrasound visualization of the lesion, and Doppler- or laser-blood flow profiles. Cytogenetic biodosimetry has limited use in a localized cutaneous injury but can give indications of an underlying whole-body radiation dose. **Cutaneous radiation injuries may also affect tissue and organs that are distant from the obvious injuries.**

Management of CRS/CRI

The key management issues with cutaneous radiation injury are infection control, state-of-the-art wound care, and appropriate pain management. A burn or reconstructive plastic surgeon should be consulted early in the clinical course.

Radiation-induced skin radionecrosis and underlying tissue/organ fibrosis are delayed complications and occur at or above the necrosis threshold of a 25 Gy absorbed dose. Typical medical management includes eliminating infection, local, and general aggravating factors, and controlling acute and chronic inflammation.

Treatments to Consider for Cutaneous Radiation Injuries**		
Topical medications	Oral medications	Other treatments - *(research)
Class II, III steroids	Pentxifylline	Hyperbaric oxygen therapy
Antihistamines	Alpha-tocopherol	Artificial skin/skin substitutes/constructs
Silver-based therapies (Silverlon®)		Hydrocolloidal dressings
Alpha-tocopherol		*Stem/stromal cell use
Aquaphor®		*Growth factors

Treatment of CRI includes topical class II-III steroids, topical antibiotics/antihistamines, and topical silver-based ointment. Silverlon® is a U.S. FDA-approved device for CRI. More severe lesions (chronic ulcerations and necrosis) may require surgical debridement, which may be followed by application of skin grafts with autologous skin and/or flaps, artificial skin (such as Integra®), and/or xenografts. Pentoxifylline has anti-inflammatory and antioxidant properties. When used for CRI and with oral and/or topical alpha tocopherol, it may have a synergistic effect. Hyperbaric oxygen (HBO) may also be effective. If hyperbaric oxygen therapy is used, it will normally require many more treatments than normal wound care.

Clinical trials in France, Japan, and one case in the U.S., involved injection of mesenchymal stem cells (MSC) or stromal vascular fraction (SVF) directly into and around lesions and appear to reduce intractable, neuropathic pain, and appears to promote wound healing.

Uranium Hexafluoride

Note: Uranium hexafluoride (UF6) is a common chemical at U.S. Department of Energy facilities.

Upon exposure to air, UF6 will generate hydrogen fluoride and uranyl fluoride. Hydrofluoric acid burns require immediate and specialized first aid and medical treatment. Symptoms may be delayed for up to 24 hours. Skin exposures can be treated with calcium gluconate. Conditions such as hypocalcemia, hypomagnesemia, and cardiac arrhythmias may occur.

Internally Deposited Radionuclides
Internal Contamination – Early Rapid Assessments

The following information is needed for internal contamination assessment:

- Wound counts
- Nasal swabs counts
- Mouth swabs counts
- Direct reading of target organs
- Whole-body count
- Bioassays
- Isotope, if unknown characteristics of radiation detected
- State of the matter (solid, liquid, or gaseous)

Internal contamination occurs when unprotected personnel ingest, inhale, or have wounds contaminated with radioactive material. Externally contaminated casualties should be evaluated for internal contamination. Internal contamination is more likely if significant contamination is found on the face, in/around the nostrils or mouth, or in/around open wounds.

Internal doses are based on the intake, or the amount of radioactive material that initially enters the body. Bioassays to determine spot estimations as well as long-term quantifiable bioassays may be done. Calculations are then performed to determine how much activity initially entered the body to result in the concentration of radioactive material in the urine at the present time.

The same applies to whole-body counts, lung counts, or other methods for internal dose assessment. The concept of committed dose accounts for the fact that internal doses are protracted. The committed dose is the dose received over a 50-year period of an internally deposited radionuclide. For regulatory purposes, once the 50 years' worth of dose is calculated, it is assigned for the year the intake occurred.

When the radioactive material deposits into the target organ, it remains until it decays, or the body removes it through normal biokinetic processes. These two processes are both at work independently of each other. The effective half-life takes radioactive decay and biological elimination into account.

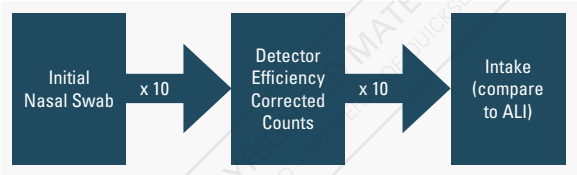
Collection of Nasal Swabs

Samples should be collected by using a dry cotton swab on the anterior nares (with separate swabs for each nare). Nasal swabs should be obtained as soon after the suspected intake as possible, preferably within the first hour. Each swab should be counted with a handheld detector and the counts from each nare will be added together. Delays in obtaining nasal swabs will affect intake estimation since the nose clears foreign materials quickly.

Each swab must be counted individually since most people do not breathe evenly through their nose. Therefore, a significant difference in the count rates may indicate cross-contamination (a contaminated hand or deviated nasal septum).

Once the combined count rate is converted to an activity (for β/γ emitters this is usually done by assuming a 10% counting efficiency – until otherwise verified – which means the count rate is divided by 10%, or 0.10) it is assumed to represent 10% of the initial intake.

Since regulatory limits – Annual Limits on Intake (ALIs) found in Environmental Protection Agency (EPA) Federal Guidance Report No. 11 – are based on intake, they are an objective benchmark to which to compare patient estimated intake. Early magnitude estimation for medical decision-making is based on U.S. ALIs. International recommendations for intake limitation can also be used for benchmarking.



If Radioisotope is UNKNOWN:

Radiation Type Detected	Assumed Isotope
Alpha	Americium 241
Beta	Strontium 90
Gamma	Cesium 137

In a case where the radioisotope is unknown, if the emission (α, β, γ) can be determined, one can use the most restrictive annual limit of intake to make assumptions on the severity of the contamination. For example, if an unknown alpha-emitter is encountered, until the isotope can be identified, it is usually a safe bet to assume americium 241 for dose magnitude estimation purposes.

It may not always be correct, but it ought to get the magnitude estimation in the right neighborhood. ALIs for common isotopes are below. Intake estimates should be verified by appropriate bioassay techniques. This is a method to help determine dose magnitude and is therefore essentially a triage tool. It is not intended to determine an accurate internal radiation dose, so estimates should be verified by appropriate bioassay techniques.

If unknown radioisotope

Assumed Nuclide	Inhalation ALI [Bq]	[dpm]	ALI in Curies-Inhalation	Ingestion ALI [Bq]	[dpm]	ALI in Curies-Ingestion
Am-241	3.7×10^2 (370)	2.2×10^4 (22,000)	.01 µCi	3.7×10^4 (37,000)	2.2×10^6 (2,200,000)	1 µCi
Sr-90/ Y-90	7.4×10^4 (740,000)	4.4×10^7 (44,000,000)	20 µCi	1.48×10^6 (1,480,000)	8.88×10^7 (88,800,000)	40 µCi
Cs-137	7.4×10^6 (7,400,000)	4.4×10^8 (440,000,000)	200 µCi	3.7×10^6 (3,700,000)	2.22×10^8 (222,000,000)	100 µCi

Note: Strontium's daughter product is Yttrium, it has an energetic beta that has a low ALI.

Example of estimation of internal intake from a nasal swab:

Facial contamination is detected on an individual. Nasal swabs are quickly taken, the sum of both nares is 15,000 counts per minute (cpm). To account for detector efficiency, convert from cpm to disintegrations per minute (dpm) by doing 15,000/0.1, so 150,000 dpm. Then to estimate the initial intake: 150,000/0.1, or 1,500,000 dpm – or about 0.7 µCi (~ 26 kBq).

Let's assume the contaminant is cesium 137. The inhalation ALI for cesium 137 is 200 µCi (7.4 MBq). Our estimate is significantly below the U.S. annual regulatory limit, so this intake is not expected to be medically significant. Again, the ALI as used here is a U.S. regulatory limit, not a medically derived limit. It does, however, make for a good comparison point that can help guide early medical management.

U.S. Inhalation Annual Limits of Intake for Common Radionuclides

Nuclide	U.S. ALI and Solubility Class	Disintegrations Per Minute (DPM)
Am-241	0.01 µCi/370 Bq – W	2.2×10^4 (22,000)
Sr-90/Y-90	20 µCi/7.4 MBq – D	4.4×10^7 (44,000,000)
Cs-137	200 µCi/7.4 MBq – D	4.4×10^8 (440,000,000)
H-3	80,000 µCi/3 GBq – (Water Vapor)	1.8×10^{11} (180,000,000,000)
Co-60	30 µCi/1.1 MBq – Y	6.7×10^7 (67,000,000)
U-235, 238	0.04 µCi/1.48 kBq – Y	8.9×10^4 (89,000)
Natural Uranium	0.05 µCi/1.85 kBq – Y	1.1×10^5 (110,000)
Pu-239	0.006 µCi/0.2 kBq – W	1.3×10^4 (13,000)
Cf-252	0.04 µCi/1.47 kBq – W	8.8×10^4 (88,000)

The solubility classes refer to the retention time of the material in terms of days (D), weeks (W), or years (Y). Days are the shortest retention time, and therefore the greater solubility, and years are the longest retention time, so the lowest solubility.

Derived Reference Level for Wounds

- Guidance for wounds – Derived Reference Level (DRL):
  - Open wounds present another route for radioactive contamination to enter the body. NCRP Report No. 156, *Development of a Biokinetic Model for Radionuclide-Contaminated Wounds and Procedures for their Assessment, Dosimetry, and Treatment* (2006), was consulted to calculate dose conversion factors for various radioisotopes and contaminant/wound types using the Activity and Internal Dose Estimates (AIDE, Bertelli) internal dosimetry software. Dividing the applicable regulatory dose limit by the dose conversion factor (DCF) results in what can be termed a DRL – similar to an ALI, which is not defined for wounds (Toohey, et al., Health Physics – May 2011).
- The DRL can be used as a reference point in much the same way as the ALI is used above but is specific to contaminated wounds. To apply this concept, simply obtain an early wound count, convert the count rate to an activity (dpm), and compare it to the appropriate DRL below. Remember that contamination levels higher than the DRL do not necessarily mean there is a significant medical issue, but simply that the contamination levels may result in an internal dose close to the regulatory limit.
- The dose conversion factors were based on effective dose (international guidance). This should not affect the use of the table below for dose magnitude estimation. Remember that the goal is to determine a point with which comparisons can be made. These comparisons can then be used to help guide medical decisions. International guidance will use different dose limits resulting in different DRLs (20 mSv – or 2 rem – divided by the appropriate DCF). Refer to NCRP Report No. 156 (2006) or contact REAC/TS for further guidance.

Derived Reference Level for Wounds

Isotope	Reference Organ	Weak	Moderate	Strong	Avid
Cobalt 60	ED	1.54E+08	1.54E+08	1.65E+08	2.01E+08
Strontium 90	BS	2.20E+07	2.20E+07	2.25E+07	2.38E+07
Technetium 99m	ED	2.20E+11	2.56E+11	9.33E+11	8.78E+11
Iodine 131	THY	7.06E+07	8.01E+07	1.26E+08	3.46E+08
Cesium 137	ED	2.20E+08	2.20E+08	2.23E+08	2.34E+08
Iridium 192	ED	4.49E+08	4.66E+08	6.21E+08	1.69E+09
Uranium 235	BS	8.23E+05	8.23E+05	8.29E+05	8.46E+05
Uranium 238	BS	8.55E+05	8.55E+05	8.63E+05	8.78E+05
Plutonium 239	BS	1.81E+03	1.81E+03	1.85E+03	1.92E+03
Amerium 241	BS	1.65E+03	1.65E+03	1.68E+03	1.74E+03
Californium 252	BS	5.14E+03	5.15E+03	5.75E+03	7.96E+03

Note: ED-Effective Dose, BS-Bone Surface, THY-Thyroid. Effective Dose reference point=5 rem committed dose. Organ Dose reference point=50 rem committed dose. If solubility is not known, use the lowest limit to determine the derived reference level.

Clinical Decision Guides

Many radiation protection professionals may not be aware of the **Clinical Decision Guides** (CDGs) introduced in NCRP Report No. 161, *Management of Persons Contaminated with Radionuclides* (2008). The CDG can be used as an alternative to the rapid dose estimation tool, **Annual Limits of Intake (ALI)**, as a comparison point when assessing internal dose magnitude. It is intended to provide a measurement a physician or agencies/authorities can use to help guide their decision regarding recommendations of the use of medical countermeasures after an intake of radioactive material.

Selected CDG Information from NCRP-161

Radioisotope	Method of Intake	Form/ Solubility	Activity in DPM of 0-24 hour urine indicating 1 CDG	Activity in DPM of nasal swabs indicating 1 CDG
Cobalt 60	Inhalation	Type M	4.2e + 7	1.1e + 8
		Type S	Not recommended	4.4e + 7
Strontium 90	Inhalation/ ingestion	Type F	3.4e + 7	2.5e + 7
		Soluble	3.0e + 7	Not applicable
Cesium 137	Inhalation/ ingestion	Type F	7.7e + 7	1.7e + 8
		Soluble	7.6e + 7	Not Applicable
Plutonium 239	Inhalation	Type M	9.6e + 1	2.3e + 4
		Type S	3.8e + 0	8.9e + 4
Americium 241	Inhalation	Type M	1.0e + 3	2.8e + 4

Nasal swab collection time is defined as "early hours." This assumes 5% of the total intake will be found on the swabs. Urine and fecal bioassays should be collected as appropriate.

Note that for the solubility types, Type F is fast solubility (greatest solubility), Type M is moderate solubility, and Type S is slow solubility (least soluble).

Definition

Stochastic effects: Occur by chance, generally without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose. In the context of radiation protection, the main stochastic effects are cancer and genetic effects.

Deterministic effects have a threshold dose that must be exceeded for the effects to occur. The severity of deterministic effects increases with dose.

Examples of deterministic effects include: cataracts, erythema, and sterility. Dose limits have been established to avoid the deterministic effects.

- The Clinical Decision Guideline considers the stochastic risk based on effective dose over 50 years for adults or until age 70 for children. The stochastic risks considered are in the range of risks associated with the dose recommendations for emergency responders found in the U.S. Environmental Protection Agency (EPA) Protective Action Guides and Planning Guidance for Radiological Incidents (PAGs).
- The avoidance of deterministic effects is based on 30-day relative biological effectiveness (RBE)-weighted marrow and lung doses and is also considered in the formulation of the CDG for a specific radioisotope.
- The CDG for radioiodine is defined somewhat differently, the organ at primary risk is the thyroid gland, and the FDA and EPA have provided specific guidance for projected thyroid doses.
- CDGs are provided for inhalation and ingestion intakes.
- Inhalation CDG tables should only be compared to nasal swabs.

Medical Management of Internal Contamination

Medical management is specific and isotope-dependent. Therefore, identifying the isotope is crucial. Both radioactive decay and biological elimination rid the body of radioactive materials. Combining both elimination rates provides the effective half-life, which is always shorter than both the radiological and the biological half-life. Metabolism and elimination kinetics of the non-radioactive analog determine the metabolic pathway of the radionuclide. The major routes of intake are inhalation, ingestion, injection (shrapnel/foreign debris), absorption through an open wound (contamination), retained contaminated foreign debris or fragmentation in a wound, and transdermal absorption.

Definition

Effective Half-Life: The time required for the activity of a particular radioisotope deposited in a living organism, such as a human or an animal, to be reduced by 50 percent because of the combined action of radioactive decay and biological elimination.

Biological Half-Life: The time required for a biological system, such as that of a human, to eliminate, by natural processes, half of the amount of a substance (such as a radioactive material) that has entered it.

Radiological Half-Life: The time required for half the atoms of a particular radioisotope to decay into another isotope. A specific half-life is a characteristic property of each radioisotope. Measured half-lives range from millionths of a second to billions of years, depending on the stability of the nucleus.

United States Nuclear Regulatory Commission (US NRC)

The medical management of internal contamination falls into several major categories:

- Reduction and/or inhibition of absorption of the isotope in the gastrointestinal (GI) tract (e.g., Prussian blue, aluminum hydroxide).
- Block uptake to the organ of interest (e.g., 4-6 hours prior to exposure, administer potassium iodide [KI] to block uptake of radioactive iodine by the thyroid).
- Isotopic dilution (e.g., increase fluid hydration for internal tritium contamination).
- Alter chemistry of the substance (e.g., prevent binding of uranyl ions with the renal tubule surface proteins by use of sodium bicarbonate that causes alkalinization of the urine).
- Isotope displacement from receptors (e.g., using calcium to compete with strontium).
- Chelation techniques (e.g., administer diethylene triamine pentaacetate [DTPA] for internal deposition of plutonium, americium, and curium).
- Excision of radionuclides from wounds to minimize absorption (use with actinides and lanthanides or easily shielded alpha emitters).
- Bronchoalveolar lavage for insoluble, inhaled particles. This is rarely done and only in a case with an expected large lung burden of an insoluble alpha emitter, such as plutonium.

Report No. 65, U.S. National Council for Radiation Protection and Measurements (NCRP) (1980) is an older reference document for healthcare providers who need to employ decorporation therapy in patients with internal deposition of radioactive materials and the updated NCRP Report No. 161 (2010) provides significant additional information and health physics guidelines for the management of internal contamination.

NCRP Report No. 161 (2010) also addresses the use of spot urine samples. Care should be taken when analyzing spot urines:

1. Has there been adequate time for the radionuclide to become systemic and to allow for excretion?
2. If using a handheld meter for counting the specimen, is the radiation of a type that can be detected?
3. Is the excretion pathway appropriate for the chemical characteristics of the radioisotope?

As stated in *Generic Procedures for Medical Response During a Nuclear or Radiological Emergency* (IAEA, 2005), when deciding on the treatment for internal contamination, comparison is to 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 the internalized radioactive materials without treatment.

Decorporation Therapy Recommendations for Radionuclides of Concern

(NCRP Report No. 161, 2010)

Note: Prior to administering medications for internalcontamination, please contact REAC/TS at **865-576-1005** for consultation.

U.S. FDA-APPROVED TREATMENTS FOR INTERNAL CONTAMINATION:

Diethylene triamine pentaacetate (DTPA)

Potassium iodide (KI)

Prussian Blue

NON-U.S. FDA-APPROVED TREATMENTS:

Note: Many NON-U.S. FDA-approved treatments may have significant adverse side effects; risk-benefit should be analyzed.

Aluminum Hydroxide: A common oral antacid.

British Anti Lewisite (BAL), also known as Dimercaprol: This is an agent that is used for heavy metal poisoning such as arsenic, mercury, gold, and lead.

Deferoxamine, desferal (DFO, DFOA): An iron chelator.

Dimercaptosuccinic acid, Chemet (DMSA): A non-toxic, water-soluble treatment for heavy metal toxicity.

Diethylene triamine pentaacetate (DTPA): A medication that can bind to certain radioisotopes to remove them from the body by chelation. DTPA comes in two forms, calcium DTPA and zinc DTPA. The trade name for this medication is Pentatate (Calcium or Zinc) Trisodium Injection. DTPA is not labeled DTPA. DTPA is U.S. FDA-approved for plutonium, americium, and curium. Any other use is off label.

Ethylenediaminetetraacetic acid (EDTA): A medication used in the management and treatment of heavy metal toxicity. It is a chelator.

Penicillamine, cupramine, or trientene: Used as a chelating agent. Commonly used to remove copper from the body in Wilson's disease.

Radionuclides	Treatment	Preferred Treatment
Actinium (Ac)	Consider DTPA	Consider DTPA
Americium (Am)	DTPA	DTPA
Antimony (Sb)	BAL, penicillamine	BAL
Arsenic (As)	BAL, DMSA	BAL
Barium (Ba)	Ba, Ca therapy	**Oral Ingestion:** Magnesium or sodium sulfate cathartics, gastric lavage in the first hour. Forced diuresis with IV saline and furosemide to keep urine flow to 3-6 ml/kg per hour. Hemodialysis may be useful.
Berkelium (Bk)	DTPA	DTPA
Bismuth (Bi)	BAL, penicillamine, DMSA	DMSA
Cadmium (Cd)	DMSA, DTPA, EDTA	DMSA
Californium (Cf)	DTPA	DTPA
Calcium (Ca)	Ba, Ca therapy	Calcitonin as for hypercalcemia. Hemodialysis may be useful.
Carbon	No treatment available	
Cerium (Ce)	DTPA	DTPA
Cesium (Cs)	Prussian blue	Prussian blue
Chromium (Cr)	DTPA, EDTA (antacids are contraindicated)	DTPA
Cobalt (Co)	DMSA, DTPA, EDTA, NAC	DTPA
Copper (Cu)	EDTA, pencillamine, trientine	Penicillamine
Curium (Cm)	DTPA	DTPA
Einsteinium (Es)	DTPA	DTPA
Europium (Eu)	DTPA	DTPA
Fission Products (Mixed)	Management depends on predominant isotopes present at time.	Varies, early in incident KI may be needed for rescuers prior to entering area (if available). Local authorities should recommend use of KI.
Fluorine (F)	Aluminum hydroxide	Aluminum hydroxide
Gallium (Ga)	Consider penicillamine	Penicillamine
Gold (Au)	BAL, penicillamine	BAL
Indium (In)	DTPA	DTPA
Iodine (I)	Potassium iodide (KI)	KI may be needed for rescuers prior to entering area. (If available, may be recommended by local authorities.)

Radionuclides	Alternatives	Preferred Treatment
Iridium (Ir)	Consider DTPA, EDTA	Consider DTPA
Iron (Fe)	Deferoxamine (DFOA), defarasirox, DTPA, DFOA and DTPA together	DFOA
Lanthanum (La)	DTPA	DTPA
Lead (Pb)	DMSA, EDTA, EDTA with BAL	DMSA
Manganese (Mn)	DFOA, DTPA, EDTA	DTPA
Magnesium (Mg)	Consider strontium therapies	Consider strontium therapies
Mercury (Hg)	BAL; EDTA; penicillamine; DMSA	BAL
Molybdenum	Limited clinical experience	
Neptunium (Np)	Consider DFOA and/or DTPA	Consider DFOA and/or DTPA
Nickel (Ni)	BAL, EDTA	BAL
Niobium (Nb)	DTPA	DTPA
Palladium (Pd)	Penicillamine, DTPA	Penicillamine
Phosphorus (P)	Hydration and oral phosphate binders	Calcium carbonate 0.5 to 1 Gm orally (TUMS™); aluminum hydroxide oral; potassium phosphate dibasic orally; or sevelamer HCL
Plutonium (Pu)	DTPA, DFOA, EDTA, DTPA and DFOA together	DTPA
Polonium (PO)	BAL, DMSA, penicillamine	BAL
Potassium (K)	Diuretics	Diuretics
Promethium (Pm)	DTPA	DTPA
Radium (Ra)	• **Aluminum hydroxide:** PO 60-100 ml once • **10% Calcium chloride suspension:** Adults: IV 200 mg to 1G every 1-3 days, slow IV (not to exceed 1 ml/min)	**Alternative medications:** • Sodium glycerophosphate • Neutral sodium phosphate • Neutral potassium phosphate • Calcium carbonate • Parathyroid extract

	• **Calcium gluconate:** PO 1G powder in 30 cc vial, add water and drink	• Barium sulfate • Sodium alginate • Sevelamer HCL
Rubidium (Rb)	Prussian Blue	Prussian Blue
Ruthenium (Ru)	DTPA, EDTA	DTPA
Scandium (Sc)	DTPA	DTPA
Silver (Ag)	No specific therapy. Consider gastric lavage and purgatives	
Sodium (Na)	Diuretic and isotopic dilution with 0.9% normal saline IV	Diuretic and isotopic dilution with 0.9%; normal Saline IV
Strontium (Sr)	• **Aluminum hydroxide:** PO 60-100 ml once • **10% Calcium chloride suspension:** Adults: IV 200 mg to 1G every 1-3 days, slow IV (not to exceed 1 ml/min • **Calcium gluconate:** PO 1G powder in 30 cc vial, add water and drink	**Alternative medications:** • Sodium glycerophosphate • Neutral sodium phosphate • Neutral potassium phosphate • Calcium carbonate • Parathyroid extract • Barium sulfate • Sodium alginate • Sevelamer HCL
Sulfur (S)	Consider sodium thiosulfate	Consider sodium thiosulfate
Technetium (Tc)	Potassium perchlorate	Potassium perchlorate
Thallium (Tl)	Prussian Blue	Prussian Blue
Thorium (Th)	Consider DTPA	Consider DTPA
Tritium (3H)	Increase fluids	Water diuresis
Uranium (U)	Sodium bicarbonate to alkalinize the urine. Consider dialysis	Bicarbonate or dialysis
Yttrium (Y)	DTPA, EDTA	DTPA
Zinc (Zn)	DTPA, EDTA, zinc sulfate as a diluting agent	DTPA
Zirconium (Zr)	DTPA, EDTA	DTPA

Note: The U.S. FDA only approves DTPA for americium, curium, and plutonium. Any other use is off label.

Countermeasure	Dose	Cautions/Side Effects
DTPA (Diethylenetriamine pentaacetate) Calcium or Zinc -	• **Adults:** IV 1G in 5 ml slow IV push over 3-4 min or IV infusion over 30 min diluted in 250 ml of D5W, RL, or NS • **Children under 12 years:** 14 mg/kg IV as above, not to exceed 1G • **IM:** IG can be given with procaine to reduce pain (not FDA-approved) • **Nebulized inhalation:** 1G in 1:1 dilution with sterile water or NS (Use for inhaled isotope, use with caution with asthma) • **Wound irrigation:** 1G diluted with 100 ml D5W or NS (may add 2% lidocaine for pain) **NOTE:** This is not a treatment dose.	• **NOTE:** THERE ARE NO LISTED CONTRAINDICATIONS BY THE U.S. FDA calcium DTPA more effective than zinc DTPA for *initial* chelation (first 24 hours after contamination) and for soluble internal contaminant, initiate treatment within 2 hours, if possible. • Administer zinc DTPA for subsequent doses due to depletion of zinc, maganese, and magnesium. Consider monitoring trace elements and administer zinc DTPA for repeated doses. • Side effects may include nausea, vomiting, diarrhea, chills, fever, itching, and muscle cramps.
KI (Potassium iodide)	• **Adults:** >40 years of age – 13 g/day • **Adults:** 18-40 years of age – 130 mg/day • **Pregnant or lactating women:** 130 mg/day • **Children and adolescents:** 3-18 years of age – 65 mg/day • **Infant:** 1 month-3 yrs of age – 32 mg/day • **Neonates:** from birth to 1 h – 16 mg/day	• Most effective when taken within 4-6 hours of exposure. • Use cautiously in pregnancy and neonates due to thyroid function suppression. • Side effects include skin rashes, swelling of salivary glands, fever, joint pain, metallic taste in mouth, burning mouth and throat, sore teeth, and gums.
Prussian Blue (Radiogardase)	• **Adults:** 3G orally TID • **Child:** 1G orally TID	• Side effects include blue feces, upset stomach, constipation (use mild fiber-based laxative and increase fluids). • Begin treatment as soon as possible.
Aluminum Hydroxide (not FDA-approved for this indication)	• PO 60-100 ml once	
Calcium Treatments (not FDA-approved for this indication)	**10% Calcium chloride suspension:** Adults: IV 200 mg to 1G every 1-3 days, slow IV (not to exceed 1 ml/min • **Calcium gluconate:** PO 1G powder in 30 cc vial, add water and drink	• Cardiac monitoring recommended if IV calcium administered. • Calcium gluconate topically for uranium hexafluoride injuries.

KI Blockage of the Thyroid

Note: Potassium iodide (KI) should only be taken when instructed by authorities.

Radioactive iodine is handled exactly as non-radioactive iodine in the body. Radioactive iodine is a fresh fission product released from a nuclear power plant or nuclear detonation.

KI or PI blocks radioactive iodine uptake by the thyroid gland. Oral KI is most effective when taken within 12 hours prior to entering an area contaminated with radioactive iodine or if unable to premedicate, within 6 hours after entrance into the area or after the release. A dose of KI will last for 24 hours. If individuals are unable to be in a proper shelter, evacuate (by order of authorities), or have a protected water/food/milk supply, they may need to continue dosing with KI. The most sensitive populations include fetuses, neonates (birth to one month), and children less than 18 years of age, with females exhibiting more sensitivity than males.

Children are particularly susceptible to the potential for thyroid cancer following exposure to radioactive iodine. Two populations will quickly become hypothyroid: fetuses from maternal doses of KI and neonates. It is imperative to monitor thyroid function tests in these situations.

The hazard to the general public and children is mostly through the environment, particularly the water and the food chain where radioiodine might deposit on crops and enter milk via dairy cows consuming contaminated grass. Response actions are designed to circumvent this hazard through a food interdiction program that involves the cooperation of farms and dairies.

KI is available prior to a nuclear incident from commercial sources and pharmacies but should not be purchased by the general public and should not be taken without recommendation by authorities.

People with iodine sensitivity should avoid KI, as should individuals with dermatitis herpetiformis and hypocomplementemic vasculitis, extremely rare conditions associated with an increased risk of iodine hypersensitivity. A seafood or shellfish allergy does not necessarily mean that you are allergic or hypersensitive to iodine.

KI Recommended Doses Modified from the U.S. FDA Prescribing Information

KI Recommended Dose	U.S. FDA
Adults over 40 years of age with thyroid exposure ≥ 5 Gy (500 rad or 5 Sv)	130 mg daily
Adults 18 to 40 years of age with thyroid exposure of ≥ 0.1 Gy (10 rad or 100 mSv)	130 mg daily
Pregnant or lactating women with thyroid exposure of ≥ 0.05 Gy (5 rad or 50 mSv)	130 mg daily
Children and adolescents 3-18 years of age with thyroid exposure of ≥ 0.05 Gy (5 rad or 50 mSv)	65 mg daily
Infants 1 month to 3 years of age with thyroid exposure of ≥ 0.05 Gy (5 rad or 50 mSv)	32 mg daily
Neonates birth-1 month in age with thyroid exposure of ≥ 0.05 Gy (5 rad or 50 mSv)	16 mg daily

People with nodular thyroid with heart disease should not take KI. Individuals with multinodular goiter, Graves' disease, and autoimmune thyroiditis should be treated with caution – especially if dosing extends beyond a few days. If you are not sure if you should take KI, consult your healthcare professional. For more information visit: **www.fda.gov/drugs/bioterrorism-and-drug-preparedness/frequently-asked-questions-potassium-iodide-ki**

Decontamination Techniques

Packaging Stable Patients for Transport

Patients can be packaged with a wrapping method to mitigate the spread of contamination. The three sheet or "Burrito" method encloses the contamination in a wrap that is pre-made.

The wrap is three plastic sheets that are approximately the same size as a queen size sheet (90x102 inches/244x267 cm). These sheets should be rolled up toward the middle of the long side. This method may be used with a long spine board or other appropriate devices.

This method is used for stable externally contaminated patients that are injured and cannot perform self-decontamination.

- The contaminated victim is placed on the top sheet. A spine board or movement device can be placed in between the second and third sheets.
- Remove the clothing by cutting it. Wrap the clothing in the top sheet to remove it.
- The top sheet is removed and left on scene.
- The victim is wrapped and secured in the middle sheet, leaving access for medical care.
- The victim is removed from the contaminated area, leaving the third bottom sheet and the sheet-wrapped clothing on the scene.

Safety of Healthcare Personnel

Radiologically contaminated patients generally pose no danger to healthcare personnel. Implementation of universal precautions is an effective action for protection against contamination. The radiation exposure hazard from a radiologically contaminated casualty does not prevent lifesaving medical and trauma treatments.

Steps for External Decontamination:

1. Perform lifesaving medical and trauma care.
2. Confirm radiological incident/survey for gross contamination.
3. Move to controlled area, if possible.
4. Remove clothing in a controlled manner.
5. Conduct radiological survey.
6. Continue all medical and trauma care.
7. Identify isotope(s).
   - Alpha, beta, gamma, neutron
   - Identify specific radioisotope
8. Collect samples.
   - Nasal, mouth, and wound
9. Remove contamination.
   - Disposable wipes, soap, and water
   - Wounds
   - Orifices
   - Intact skin
10. Conduct radiological survey after decontamination.
11. Repeat decontamination as necessary.

Contact REAC/TS at **865-576-1005** (OROC).

Radionuclides			
Alpha (dpm/cm²)	**Beta/ Gamma (dpm/cm²)**	**Beta/ Gamma (μR/hr)**	**Actions**
<600	<6,000	Non-detectable	• None required
600-6,000	6,000-60,000	Non-detectable	**Intervention Optional** • Decontaminate or advise to shower and wash clothing • No significant health risk
6,000-60,000	60,000-6000,000	20-30	**Intervention Advisable** • Prevent inadvertent ingestion and inhalation • Limit spread of contamination from contaminated person • Decontaminate
>60,000	>600,000	200-300	**Intervention Required** • Prevent inadvertent ingestion and inhalation • Limit spread of contamination from contaminated person • Decontaminate • Continued health physics and medical evaluation

Initial Management for Contaminated Victims

The initial management of a patient contaminated by radioactive materials is to perform all immediate life-/limb-saving actions. Contaminated casualties should not be barred entry to a medical facility if necessary for life-saving care.

Note: In a mass casualty incident, divert casualties with life-threatening injuries to a controlled area in emergency department while other casualties undergo mass decontamination (removal of outer clothing will enable dry decontamination of patients). When a smaller numbers of casualties enters a medical unit after a radiological incident, they should be considered contaminated unless verified as non-contaminated. A quick head-to-toe radiological survey should provide sufficient evidence of the presence or absence of gross contamination. Surveys can usually be done while medical personnel are assessing the medical stability of the patient.

Decontamination Techniques

1. Ensure all life-threatening conditions are stabilized
2. Admit to a contamination control area
3. Remove the clothing carefully and protect the victim's airway from contamination
4. Treat all medical and trauma conditions
5. Initial survey checking for contamination in wounds, body orifices, and intact skin
6. Determine what radionuclide is involved, if unknown, determine if it is alpha or beta particles, or gamma rays
7. Obtain samples including blood for laboratory, nasal swabs, and mouth swabs
8. Decontaminate wound using good contamination control. Priorities are wounds, orifices, and intact skin
9. After cleaning, resurvey until criteria for decontamination are met, or after discussion with on-site radiation control/protection/health physics and/or REAC/TS

Gross radioactive contamination is typically detected via a quick scan of the patient with appropriate survey instrumentation. Radiological decontamination is performed in a similar manner to chemical decontamination.

Note: Chemical decontamination may be a lifesaving priority.

Radiological decontamination is not an emergency but is an urgency. Decontamination should follow basic common sense. Unlike chemicals, radioactive materials cannot be "neutralized". They can only be moved from one point to another. The challenge is to remove the radioactive material from one area and transfer it to where you want it to be without spreading it to points in between.

Critical medical procedures including intravenous access, intubation, and other lifesaving techniques should be performed prior to gross radiological decontamination.

Clothing Removal

Once the patient has been medically stabilized, remove their clothing. Some call this "dry decontamination" as removing outer clothing can decrease contamination from 80% to 90%. The patient's airway can be protected with a surgical mask, oxygen mask, or splash shield. This reduces the risk of inhalation of radioactive particles.

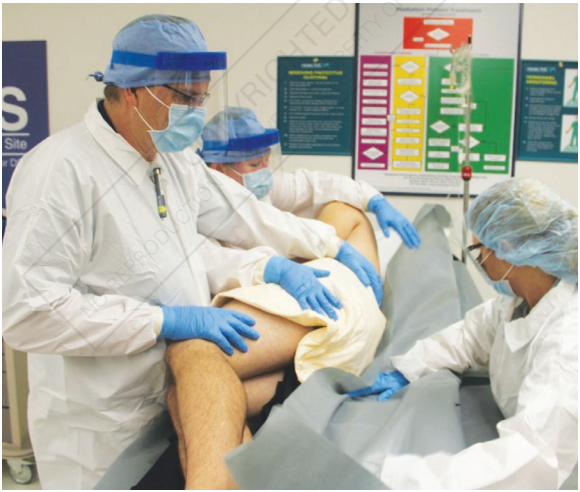
Garments should be removed by careful cutting, not tearing, and removing the clothing in a direction away from the patient's airway. Roll the clothes outward and away from the patient's skin to trap the radioactive material in the clothing.

If the patient is unable to stand, the clothing can be removed using a logroll procedure. Before the patient is moved to the stretcher, multiple sheets should be placed on the bed. After the clothing is cut away from the patient, the top sheet is folded over the clothing, trapping the contamination in the clothes and the sheet.

The sheet can be removed by rolling it away from the airway. This creates a clean surface after removal of the clothing and top sheet. This is similar to changing sheets on an immobile person. AFTER the sheet is removed and while still on their side, a quick radiological survey using a survey meter on the back is performed, looking for any obvious areas of contamination.

The clothing should be secured in a plastic bag and removed from the area. The control line should double bag the clothing, and label the bag with a radiation symbol and the patient's identification. Valuables may be secured in another impermeable container.

If the radioisotope is unknown, the clothing can be sent to resources used to identify radioisotopes. This may be local industries, labs, hazardous materials teams, or other prearranged facilities that can perform gamma spectroscopy can aid in identification.



Wound Decontamination

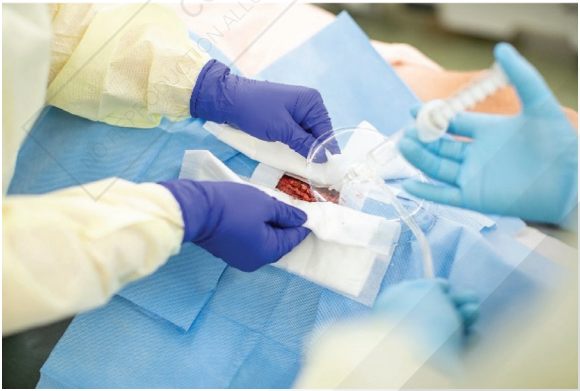
Wounds are a priority for decontamination. A contaminated wound is a direct route to internalized contamination.

Prior to decontaminating a wound, perform a detailed survey to document baseline counts per minute. This survey should take 20 seconds and be consistent with the same meter and same person surveying, if possible.

Intact skin immediately adjacent to the wound can be decontaminated using disposable wipes. Use the wipes to wipe dirt and contamination away from the wound. A new wipe should be used for each swipe.

Drapes may be applied to the area to prevent the spread of contamination. Drapes are most effective when they are impermeable, but anything that prevents the spread of radioactive material can be used.

Gently irrigate the wound using sterile saline or wound wash. Initial decontamination does not require any special chemicals or soaps, and grease and oil-based contamination can be removed with mild soaps and detergents.



The purpose of the initial irrigation is to attempt to remove the bulk of the contamination, so do not be too aggressive in order to prevent splashing and potential contamination spread. The runoff should be directed into a receptacle – a lined garbage can is acceptable.

Absorbent pads can shield splashing at the wound site. After the initial decontamination the wound should be covered with a dressing while the drapes are removed and a clean, barrier pad placed under the affected area prior to resurvey.

Note: All generated radioactive waste should be kept in a pre-arranged location for later collection and disposal.

Radiological Surveys

Repeat radiological surveys to determine the effectiveness of the decontamination attempts. The wound should be covered as the drapes are removed and a clean, absorbent pad placed under the affected area prior to resurvey.

If the wound is still contaminated, the process should be repeated until the guidelines for stopping contamination are met. Should the contamination levels continue to be elevated and decontamination progress be overly slow or nonexistent, the wound can be gently examined for foreign bodies.

Minor debridement may be necessary. 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.

Decontamination of Body Orifices

Decontamination of body orifices poses a challenge in that easily applied methods are limited. Many times, the nares can be decontaminated simply by having the patient blow their nose. Irrigation of the nares should be avoided due to the risk of forcing more radioactive material into the body via the oropharynx. One exception to this is with newer saline mist sprays, but again, these should only be used if one can avoid any accumulation of mist ending up in the oropharynx. Routine methods used to irrigate the eyes are acceptable, but care should be taken to ensure the run-off is directed away from the nose/mouth and to prevent it from entering the ears.

Decontamination of Intact Skin

When decontaminating the skin avoid creating irritation. Abrading the skin may create an entry point for radioactive materials to enter the body. Always start with the simplest method. One good option is the use of moistened wipes (baby wipes), disposing of each wipe after each area is cleaned. If baby wipes are not effective, take more aggressive steps. One should take care to maintain the integrity of the skin. Gently scrub the skin with a soft cloth, tepid water, and soap.

The cleaning motion should go from the outside of the contamination to the inside, much like cleaning up a paint spill. The goal is to minimize the area of contamination, not to spread it outwardly. It may be helpful to drape the area and set up a collection basin if large amounts of fluids are used for irrigation during decontamination.

In a large incident, individuals may need to self-decontaminate by wiping off hair, exposed skin, and clothing by using dry or moistened cloths.

Contaminated hair can be washed with mild shampoos. Do not let the wash/rinse water run onto the face or into the ears. Do not use conditioner or combination shampoo/conditioner. This can adhere the contamination to the hair and make removing it challenging. Body hair may be clipped away. Do not shave the area since this may lead to skin abrasions. The patient may be averse to having their hair cut and estimation of potential external dose and determination of risk will aid in this decision. Bare skin and hair should be thoroughly washed. If practical, the wastewater should be disposed of appropriately.

Excision of wounds is appropriate when surgically and medically indicated and/or if the wound is significantly contaminated with an easily shielded alpha emitter.

Guidelines for Stopping Decontamination

Decontamination efforts may be stopped when the following conditions are met:

- The victim becomes medically unstable
- The area of contamination is clean
- Counts per minute are two times background or less (unless this is an alpha emitter in a wound)
- Consultation with health physics experts and/or REAC/TS
- Counts do not drop with the best efforts (Consult with health physics and REAC/TS)
- Increasing redness or abrasions begin to occur

Biodosimetry

Biodosimetry is the measurement of a biological response as a surrogate for absorbed radiation dose in exposed humans. Dicentric chromosome assay is considered the "gold standard" for estimating an individual's whole-body absorbed radiation dose.

For inquiries regarding cytogenetic biodosimetry, call REAC/TS at: **865-576-3131**

Multi-Parametric Biodosimetry Based on Early Response

Techniques used:

- Time to vomiting
- Lymphocyte depletion
- Signs and symptoms/vital signs
- Early dose estimation
- Medical and trauma labs
- History of incident
- Radiological surveys
- Spot urine
- Bioassays

Management of mass casualties and diagnosis for early medical treatment cannot be addressed by a single biodosimetry assay for all the potential radiation exposure scenarios.

The U.S. National Council for Radiation Protection and Measurements (NCRP) Commentary No. 19 (2005) recommends a multi-parameter-based triage (i.e., time to vomiting, lymphocyte depletion kinetics, and other bioindicators/biodosimeters) as the best method for the early assessment of a patient's absorbed radiation dose.

Biodosimetry is not intended to replace physical dose estimation, but to provide additional information on an individual's biological dose that may aid in appropriate medical intervention.

It is widely accepted that vomiting within 1-2 hours and a decline in lymphocyte counts to 1/2 or 1/3 of the baseline values within 24 hours can be serious, indicating a potentially lethal radiation exposure dose.

Based on time-to-emesis data, if there is no vomiting within 8-10 hours, then the exposure dose is likely to be less than 1 Gy and such individuals can be moved to outpatient facilities.

The guidelines recommended by REAC/TS for biodosimetry include the following documentation:

- Clinical signs and symptoms
- Radioactive dose evaluation
- CBC and differential
- Personal survey for contamination and area dosimetry
- Cytogenetic biodosimetry

Cytogenetic Biodosimetry Assay-Dicentric Chromosome Assay

Dicentric Chromosome Assay (DCA) is the "gold standard" for measuring the absorbed radiation dose in humans after incidental, accidental, and intentional external exposures.

REAC/TS Cytogenetic Biodosimetry Laboratory (CBL) is one of the two reference laboratories funded by the U.S. Government that has the expertise to carry out DCA-based radiation dose estimation in the aftermath of radiological/ nuclear emergencies.

Note: DCA does not assist in determining or confirming regulatory dose. It is only done for physicians to aid in making medical decisions.

Basic information pertaining to the performance of DCA and its potential applications as well as limitations are described below:

Basic Information

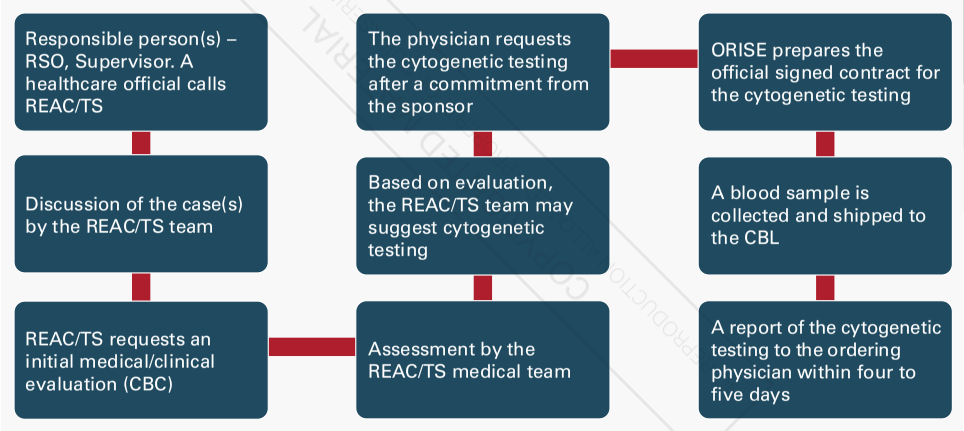
- Dicentric chromosome results from the mis-rejoining of two broken chromosomes after radiation exposure and the dicentric chromosome formation is dependent on radiation quality (photons or alpha particles), dose, dose rate, and total volume of body exposed (whole-body or partial).
- The baseline frequency of dicentric chromosomes is 1 in 1000 lymphocytes (0.001/cell) without any dependence on age and gender.
- DCA can detect as low as 0.1 Gy of exposure (with statistical certainties) to photons with a clear dose dependency up to 5 Gy.
- DCA is performed using the blood samples collected from the exposed victims. Blood samples (5-10 ml) are usually collected in vacutainers with green tops containing sodium or lithium heparin as an anticoagulant. REAC/TS CBL staff can be contacted if further information is needed for collection and shipment of samples.

Continued on next page...

- Blood samples can be collected at or around 24 hours or up to 4-6 weeks after radiation exposure. Dose estimation for exposures longer than 6 weeks may require a correction factor to account for the half-life of lymphocytes.
- REAC/TS must be contacted before shipping the blood samples. The prescribing healthcare provider should discuss the appropriateness of the test before ordering.
- **Results are for clinical decision-making and not for regulatory purposes.**
- Blood samples after collection can be shipped at ambient temperature to *REAC/TS Cytogenetic Biodosimetry Laboratory* located at **1299 Bethel Valley Road, Oak Ridge, TN 37830**. Blood samples should not be frozen or stored at 4˚C after collection.
- DCA involves the *in-vitro* culture of lymphocytes for 48 hours in growth medium supplemented with serum, cytokines, antibiotics, and a mitogenic factor (PHA-Phytohemagglutinin). The total assay time for dose estimation is around 4-5 working days.
- For the dose estimation, a minimum of 500 cells are scored for detecting the yield of dicentric chromosomes. The observed dicentric chromosome frequency per cell is converted to whole-body absorbed radiation dose using standard calibration curve(s) generated using *ex-vivo* samples irradiated with known radiation doses.
- In the case of radiological/nuclear mass casualty incidents, scoring will be performed on 50 cells to facilitate a rapid dose estimation for a medical triage.
- The absorbed dose is reported at 95% confidence interval with lower and upper dose limits.

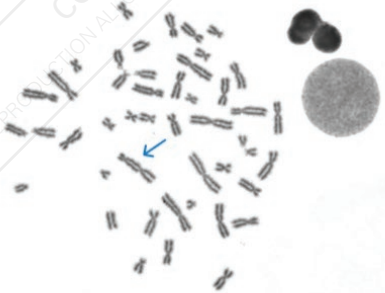
The flow chart below describes the sequence of steps to follow for requesting a cytogenetic biodosimetry test (DCA) for dose estimation at the REAC/TS CBL:

Flow Chart for Cytogenetic Biodosimetry at the REAC/TS CBL



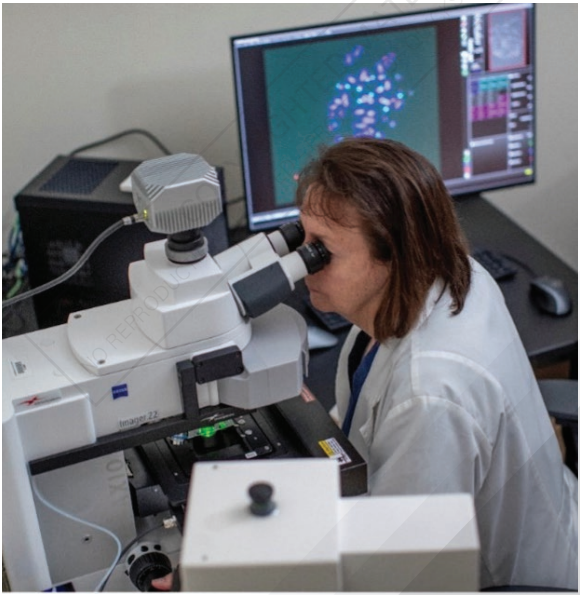
Advantages of DCA

- Dicentric formation is highly specific for radiation exposure.
- Its wide range of detection (0.1 Gy-5 Gy) can assist with emergency triage management of individuals with acute radiation syndrome (ARS).
- DCA can detect both partial and whole-body exposures.
- DCA is more sensitive than any of the available hematological assays (lymphocyte depletion kinetics, neutrophil to lymphocyte ratio, etc.) for detecting photons exposures less than 1 Gy.
- DCA is useful for estimating the absorbed radiation dose in those individuals who are asymptomatic for some of the prodromal signs/symptoms such as nausea and vomiting following low-dose exposures (< 1 Gy).



Potential Limitations of DCA

- Laborious and time-consuming attributes of DCA make its utility limited for mass casualty incidents.
- DCA is time-sensitive, and the absorbed dose prediction accuracy may not be precise if a substantial time has elapsed.
- DCA may not be useful for acute high radiation exposures exceeding 5 Gy due to extensive death of lymphocytes.
- DCA may not distinguish between partial and whole-body exposures if the exposure doses are less than 2 Gy.



Other Cytogenetic Biodosimetry Assays

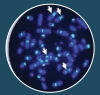
Translocations

- Translocations are exchange events between two or more chromosomes (arrow).
- Translocations are stable for decades and therefore useful for retrospective biodosimetry.
- Translocations are detectable by Fluorescence In Situ Hybridization (FISH) using DNA probes for specific chromosomes or all the 46 human chromosomes (multicolor FISH).
- Unlike DCA, the baseline frequency of translocations is modulated by age, lifestyle, and disease status.
- Turnaround time for dose estimation is like DCA 9 (4-5 days).

PCC (G0 phase)

- Premature Chromosome Condensation (PCC) in G0/G1 phase is performed by fusing human lymphocytes with mitotic cells of Chinese Hamster Ovary (CHO) using Polyethylene Glycol (PEG).
- PCC assay can be used for radiation doses higher than 5 Gy.
- Absorbed dose is estimated based on the yields of any of the aberrations (rings, dicentrics, translocations, and excess chromosome fragments) using appropriate calibration curves.
- Turnaround time for dose estimation is approximately 8 hrs.

PCC (G2 phase)



- PCC can be performed in G2 phase using a protein phosphatase inhibitor, Calyculin A, or Okadaic acid.
- G2 PCC can be used for detecting high radiation exposures ranging from 5 Gy to 25 Gy of photons.
- Useful for partial-body exposures of higher than 5 Gy.
- FISH using centromeric and telomeric probes is required for dicentric detection (arrows).
- Turnaround time for dose estimation is like DCA (4-5 days).

CBMN

- In the Cytokinesis Block Micronucleus (CBMN) assay, binucleated cells are generated by blocking the cytoplasmic division by Cytochalasin B.
- The CBMN assay measures the micronucleus (arrow) resulting from broken chromosome fragments or whole chromosomes.
- Unlike DCA, CBMN assay is not specific to radiation exposure.
- The lower detection limit is about 0.3 Gy of photons.
- Turnaround time for dose estimation is 5-6 days.

Guidance on Choice of Biodosimetry Methods

Dose Range in Gray (Gy)	Recommended Dosimetry Method	Clinical Signs
0.1-1	Dicentric Chromosome Assay (DCA), bioassays if internal contamination suspected.	None, slight decrease in lymphocyte count. Not medically significant.
1.0-3.5	DCA Lymphocyte depletion, repeated complete blood counts, bioassays if internalized	Decreased blood cells, lymphocytes early, other blood cells late. Dicentrics evident. Bioassays positive for internal contamination. Mild to moderate bone marrow damage.
3.5-7.5	DCA (up to 5 Gy). Lymphocyte depletion, repeated complete blood counts, premature chromosome condensation (PCC) bioassays and whole-body count if internalized.	Pancytopenia, lymphocytes early, other blood cells late. Dicentrics evident. Bioassays positive for internal contamination. Serious signs and symptoms of acute radiation syndrome, GI syndrome.
7.5-10	Lymphocyte depletion/PCC/bioassay	Pancytopenia, severe bone marrow depletion, GI syndrome, potential neurovascular syndrome. Severe signs and symptoms.
Above 10	PCC	Critical signs and symptoms. Total depletion of bone marrow. Neurovascular syndrome, death expected.

Physical Dosimetry and Molecular Biodosimetry Techniques

Electron Paramagnetic Resonance

Electron Paramagnetic Resonance (EPR) is sometimes called electron spin resonance (ESR), not to be confused with erythrocyte sedimentation rate. EPR is based on the capability of the technique to provide specific and sensitive measurements of unpaired electrons in solid tissue, which are created in proportion to the absorbed dose. This technique is usually performed on tooth enamel, hair, fingernails, and toenails. Reliable dose detection sensitivity is above 1 Gy of photons.

Like translocations, EPR and ESR can be useful for retrospective dosimetry due to long lived signal of unpaired electrons and these techniques have been found useful for radiation dose reconstruction in radiation-exposed populations of Japan and the former Soviet Union. Research in this field continues and like the DCA and the "omics" described below, will be available at very specialized labs and centers.

Molecular Markers in Body Fluids and Tissues

Molecular markers (biomarkers) reflect underlying changes in physiology arising from physical damage (e.g., cell lysis and the release of intracellular proteins into the circulation, oxidation by-products, or DNA breakage), underlying changes in biochemistry (e.g., the presence of new metabolites or changes in levels of key gene products), and/or changes in cellular composition of tissues. These markers include molecules as diverse as DNA, RNA, proteins, and small molecule metabolites. All these markers are collectively known as "omics" markers representing transcriptomics, genomics, proteomics, and metabolomics. Research in the field of "omics" opens new avenues for the discovery of novel organ specific biomarkers for predicting organ dysfunction and recovery after radiation exposure.

Long-Term Effects

Long-term effects of ionizing radiation include radiation-induced carcinogenesis, intellectual disability after in-utero exposure, and late organ effects (e.g., vascular changes, fibrosis, atrophy, and thyroid dysfunction/cancer). Cataracts and infertility are common.

Statistically significant evidence is noted for radiation-induced leukemia of all varieties except chronic lymphocytic leukemia (CLL). In addition, radiation-induced carcinoma has been reported for the breast, thyroid, colon, stomach, lung, and ovary. Borderline or inconsistent results are noted for radiation-induced carcinoma of the esophagus, liver, skin, bladder, CNS system, multiple myeloma, and lymphoma. The leukemias generally manifest with a latency period of 2-5 years, while the latency is longer for the solid cancers.

The Biological Effects of Ionizing Radiation (BEIR) VII Committee of the National Academy of Sciences, in its report (BEIR VII, 2006), extensively considered the mathematical risk-dose models currently in use. The BEIR VII Committee concluded that the best model for the risk of delayed effects is still the linear non-threshold model (LNT). The LNT model implies that the risk of a given delayed effect is none at zero dose and increases linearly with increasing dose.

Based on 2015-2017 data from the National Cancer Institute (NCI), approximately 39.5% of men and women will be diagnosed with cancer. Using estimates from the International Commission for Radiation Protection (ICRP) and the U.S. National Council for Radiation Protection and Measurements (NCRP), it is usual to put the increased risk of radiation-induced cancer at 5.6 % per Gy for a working population (20-64 years) and 7.3% per Gy for the entire population (0-90 years). So, if a worker receives a dose of 1 Gy, their increase in cancer risk would be 39.5% + 5.6% = 45.1 %.

In most occupational exposures, cancer risk is minimal but may be modulated by exposure dose, dose rate, radiation quality, and inter-individual variation in radiation sensitivity/susceptibility.

Understanding excess risk of fatal cancer requires general knowledge of baseline risk of fatal cancer. From above, in a population of 100 million people, 17.5 million people are expected to die from cancer. According to NCRP Report No. 115 (1993), the lifetime excess risk of fatal cancer is 4% per Sv (0.04% per rem) for a worker population and 5% per Sv (0.05% per rem) for the general population. If this same population received an excess total dose of 10 rem (0.1 Sv) over their life span, there would be an excess risk of 50,000 cancer deaths (calculated from [10,000,000 people] [0.0005 deaths per person per rem] [10 rem] = 50,000 excess cancer deaths). Therefore, the total revised burden of fatal cancers in a population of 10 million individuals from a 0.1 Sv (10 rem) exposure is increased from 2.31 million to 2.36 million.

A similar magnitude of increase in overall cancer risk demands an understanding of baseline cancer risk. The excess lifetime risk of developing cancer from radiation is extremely small. According to estimates from the American Cancer Society, one out of every two men and one out of every three women will develop cancer. This equates to about 42% of the whole population developing cancer within their lifetime. BEIR VII estimates that 43 out of every 100 people in the U.S. will be diagnosed with cancer in their lifetime.

It additionally estimates that approximately one cancer per 100 people (~1%) may result from a single exposure to 10 rem (0.1 Sv) above background, implying that the radiation-induced cancer rate is about 10% per Sv.

The reader should note that although risk estimates among various Federal agencies, advisory groups, and international committees vary (BEIR V and VII, IAEA, NCRP, EPA, UNSCEAR, etc.), they are all in this general range.

Resources that may be helpful in medical consultation with irradiated patients include:

- The Health Physics Society website: Ask the Experts **www.hps.org/publicinformation/ate**
- BEIR V, VII, and UNSCEAR 1988, 2000 reports
- Various reports of the NCRP and ICRP (e.g., NCRP Report No. 115 and ICRP Publications 60 and 103)
- The American Cancer Society website: **www.cancer.org/research**

Non-Cancer Effects

Radiation can cause late effects other than cancer. These include cataracts, hyperparathyroidism, and a decrease in both T-cell mediated immunity and the B-cell humoral response. Survivors of in-utero exposure have also experienced infant microcephaly, intellectual disability, growth and development delay, and lower IQ and poor school performance.

Radiation-induced cataracts are well documented, most notably present as posterior subcapsular cataracts. Neutrons are particularly effective in causing cataract formation. The threshold dose for cataract formation is approximately 0.5 Gy (greater with fractionated doses). At 40 Gy dose to the eye, approximately 100% will form cataracts. The latency period ranges from 2 months to 35 years. With an increased dose to the eye, the latency period decreases.

Care of the Deceased

Reference: Centers for Disease Control and Prevention Guidelines for Handling Decedents Contaminated with Radioactive Materials-2021
www.cdc.gov/nceh/radiation/emergencies/pdf/radiation-decedent-guidelines.pdf

Casualties of a radiological incident are rare; the most common occurrence will be a person that dies shortly after a nuclear medicine or other treatment involving radiological materials. Standard precautions and body fluid isolation will protect from radiological contamination. REAC/TS recommends reviewing the document above before attempting to care for deceased victims of a radiological event.

The objective for care of decedents is:

- Radiation dose to responders who handle and manage the deceased will be kept **as low as reasonably achievable**. The goal is to keep radiation exposures below the annual limit for radiation workers.
- Workers will minimize the spread of contamination. The goal is to manage retrieval, processing, and disposition of contaminated bodies to minimize or eliminate any further spread of contamination.
- Radiation exposures to the public will be kept **as low as reasonably achievable.** No one should receive a radiation exposure unless there is some benefit, such as respecting the religious or emotional needs of the bereaved family.
- Human remains will be treated with dignity and respect.

In the event of a casualty from a nuclear detonation, the casualties should not be disturbed until the short-term radioisotopes decay. In cases of radiation dispersal devices (RDD) or radiation exposure devices (RED) casualties can be recovered as needed.

In situations involving a criticality or critical assembly, the rescue personnel should confer with radiation safety before entering the area. Radiation doses in this area may be extremely high or have energy pulsations that can be dangerous to rescuers.

In the U.S., information about the Disaster Mortuary Operational Response Teams (DMORT) is available through the NDMS/HHS website:
https://aspr.hhs.gov/NDMS/Pages/dmort.aspx

Psychological Support and Risk

It is important to recognize signs of stress or other psychological issues early. Consider early involvement of mental health professionals, clergy, etc. Since risk is such a personal concept, it may be difficult to deal with the anxieties in a population associated with a real or imagined radiological incident. One has to keep in mind that many sources misrepresent the hazards associated with radiation.

To prevent serious mental health effects on healthcare providers and responders:

- Encourage the workers to talk about their stress (decompression). It may be eased through catharsis.
- Provide psychological first aid (PFA) to establish trust and facilitate coping with the situation.
- Pay attention to behavior changes and try to understand the underlying reasons.
- Provide assistance to team leaders to ensure the person assigned is right for the job and that the work (and radiation dose) is being equally distributed.
- Consider providing pre-assignment personality and psychological evaluation.

Nuclear Detonations

Nuclear detonations are world-changing events. REAC/TS recommends the following reading materials for responders while planning for these types of disasters.

United States Department of Homeland Security (DHS)/ Federal Emergency Management Agency (FEMA)

Planning Guidance for a Nuclear Detonation

www.fema.gov/sites/default/files/documents/fema_nuc-detonation-planning-guide.pdf

Radiological Dispersal Device (RDD) Response Guidance Planning for the First 100 Minutes

Nuclear/Radiological Incident Annex to the Response and Recovery Federal Interagency Operational Plans

www.fema.gov/sites/default/files/documents/fema_incident-annex_nuclear-radiological.pdf

Be Prepared for a Nuclear Explosion
International Atomic Energy Agency

Nuclear Safety Series/IAEA Publications

FEMA Guidance on Damage Zones

The first responder should be aware of the significance of the damage zones defined by the DHS publications.

Severe damage zone:

- Nearly all buildings destroyed
- Few survivors
- Hazardous radiation levels
- Survivors should shelter for 24 hours before evacuation
- Infrastructure is destroyed
- Fires mitigated by debris
- Flash burns
- Lethal doses of radiation even if in shelter

Moderate damage zone (Response should concentrate on this area):

- Significant building damage
  - Light buildings destroyed
  - Interiors blown out
- Winds of greater than 100 mph outbound, then returns to fill void
- Radiation fallout hazard may be variable
- Survivors are an evacuation priority
- Fires may be intense
  - Flame burns

Light Damage Zone:

- Windows shattered
- Commercial buildings damaged
- Flying glass and debris injuries
- Highly survivable area
- Survivors will self-evacuate
- Fallout may be heavy
- Shockwave damage from terrain reflection

Information for flash blinded or visually impaired victims will be needed.

All care of victims need triage (MARCH):

- Massive hemorrhage
- Airway
- Respirations
- Circulation
- Head injury/hypothermia

Fallout Concerns: Fallout will be of greatest concern in the first 24 hours after a detonation. Self-protection in a well-protected room is the best action. If a person has to be outside or is unprotected, fallout should be brushed off, clothing removed, and the person wiped off and/or washed.

Appendices

Appendix A-Obtaining Prussian Blue and DTPA

Obtain Prussian Blue and DTPA

REAC/TS has no financial or other interest in the above companies. This is for informational purposes only and is subject to change. We encourage anyone needing these medications to contact the above companies prior to an event.

United States: Individual patients by prescription only

Radiogardase cannot be sold directly to physicians, but only obtained via patient prescription. For stockpiles at institutional and government agencies, the purchaser must begin the order process by first contacting Heyltex.

McGuff Medical Products is a contracted 3rd party logistics provider for Heyltex.

Update: August 2023

Prussian Blue (Radiogardase)

McGuff Medical Products
3524 West Lake Center Drive
Santa Ana, CA 92704-6987

Phone: **800-854-8220** 7 a.m. to 5:30 p.m. Pacific time
Fax: **714-540-5614**

www.mcguffmedical.com/contactus

www.mcguffmedical.com/radiogardase-prussian-blue-05gram-36-capsulesbottle-physicians-must-order-via-prescription-from-mcguff-compounding-pharmacy-877-444-1133

Prussian Blue Stockpile

Heyltex Corporation
925 South Mason Rd., PMB #242
Katy, Texas 77450

Phone: **855-439-5839 (855-HEYLTEX)**
Fax: **855-937-9377**
Cell: **713-305-0873**

Lily Heyl: Available 4-12 weeks

Ca and Zn DTPA: Pentetate Calcium Trisodium Injectable/Pentetate Zinc Trisodium Injectable

Golden State Medical Supply
5187 Camino Ruiz
Camarillo, California, 93012

Phone: **805-477-9866**
8:30 a.m. -5:30 p.m. Pacific Time

International: Prussian Blue and Calcium and Zinc DTPA

Heyl Chemisch-pharmazeutische Fabrik GmbH & Co. KG
Kurfürstendamm 178 – 179
10707 Berlin | Deutschland

Phone: **+49 30 816 96 – 0**
Fax: **+49 30 817 40 49**
www.heyl-berlin.de/pharma/poisoning/zink-trinatrium-pentetat-zn-dtpa/?lang=en

Appendix B-Response Resources

Additional Response Resources

Department of Energy (DOE) — National Nuclear Security Administration (NNSA)

www.nnsa.energy.gov

The NNSA ensures that capabilities are in place to respond to any NNSA or DOE facility emergency. It is also the nation's premier responder to any nuclear or radiological incident within the U.S. or abroad and provides operational planning and training to counter both domestic and international nuclear terrorism.

Armed Forces Radiobiology Research Institute (AFRRI)

https://afrri.usuhs.edu

The AFRRI mission is to preserve the health and performance of U.S. military personnel and to protect humankind through research that advances the understanding of the effects of ionizing radiation.

To these ends, AFRRI collaborates with other government facilities, academic institutions, and civilian laboratories in the U.S. and other countries to research the biological effects of ionizing radiation. In addition, it provides medical training and emergency response to manage incidents related to radiation exposure. A similar pocket guide *(Medical Management of Radiological Casualties,* 3rd Edition, 2009) was produced by AFRRI to help guide military medical operations.

Radiation Emergency Medical Management (REMM)

https://remm.hhs.gov

The Radiation Emergency Medical Management (REMM) for Healthcare Providers is a United States Department of Health and Human Services website with resources for the medical management of radiation events. The REMM:

- Provides guidance for healthcare providers, primarily physicians, about clinical diagnosis and treatment of radiation injury during radiological and nuclear emergencies.
- Provides guidance for the wider healthcare community (see Other Audiences), including trainers, about issues related to planning for and responding to radiation mass casualty incidents.
- Provides just-in-time, evidence-based, usable information with sufficient background and context to make complex issues understandable to those without formal radiation medicine expertise.
- Provides web-based information that is also downloadable in advance, so that it would be available during an emergency if the internet is not accessible.

Radiation Injury Treatment Network (RITN)

https://ritn.net

RITN is a national network of medical centers with expertise in managing bone marrow failure. We work with partners from other medical specialties to assist with managing acute radiation syndrome and its health-related consequences.

- 74 network hospitals.
- RITN hospitals provide comprehensive evaluation and treatment in an inpatient and outpatient setting for victims.
- RITN helps to coordinate the response and shares critical information about the disaster between RITN hospitals and governmental agencies, including the Department of Health and Human Services, Administration for Strategic Preparedness and Response.

International Atomic Energy Agency (IAEA) – IAEA's Response System

www.iaea.org

The prime objectives of the IAEA's Response System are to facilitate the:

- Exchange of official real-time information among States/relevant international organizations.
- Provision of assistance/advice to States/relevant international organizations upon request.
- Provision of relevant, timely, truthful, consistent, and appropriate public information.

World Health Organization (WHO) – Radiation Emergency Medical Preparedness and Assistance Network (REMPAN)

www.who.int

- The network is designated to provide emergency medical and public health assistance to people over-exposed to radiation.
- Facilitates long-term care and follow-up of radiation accident victims and conducts research in radiation emergency medicine, radiotherapeutics, biodosimetry, and radiation epidemiology.

REAC/TS is a WHO/REMPAN collaboration center.

Centers for Disease Control and Prevention (CDC), Emergency Preparedness and Response

www.cdc.gov/index.htm

Agency to increase the United States, ability to prepare for and respond to public health emergencies, including radiological incidents.

Appendix C-Bibliography and Reference

- Radiation Emergency Assistance Center/Training Site **https://orise.orau.gov/reacts/index.html**
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Appendix D-Glossary of Terms and Acronyms

Acronym	Term
Absorbed Dose	Absorbed Dose is energy (joules) absorbed in matter per unit mass (kg) expressed as: SI units = 1 Gray (Gy) is 1 Joule/kilogram (J/kg) US units = 1 Rad = 0.01 Gray (10 mGy)
Adjudication	The operational process of resolving a radiation alarm. The typical process is Interdiction followed by Adjudication.
ALARA	As low as reasonably achievable
Alpha Particles	Alpha particles are low-energy radiation that can only travel 1 to 2 inches in air, cannot penetrate the dead layer of the skin, and can be shielded by a sheet of paper.
AMS	Aerial measuring system
APR	Air-purifying respirator
ARS	Acute radiation sickness
Atom	The basic unit of matter
Atomic Mass/ Weight	The mass of the combined number of protons and neutrons in a nucleus.
Atomic Number	The atomic number is the number of protons in an atom. **Note:** The number of neutrons (can vary) in an element also determines the isotope or isotopes of that element.
Bq	Becquerel (Bq) is a unit of radioactivity equal to 1 disintegration (or transformation) per second.

Acronym	Term
Beta Particles	Beta particles are radiation particles that behave like free electrons, can penetrate skin but not vital organs, and can be shielded by thick clothing or aluminum.
CBRNe	Chemical, biological, radiological, nuclear, and explosive – intended to replace "weapons of mass destruction."
Chronic Dose	A small radiation dose over a long time.
Civil Support Team	A U.S. National Guard Unit assigned to each state to assist with CBRNe events.
CMHT	Consequence Management Home Team
MILMED COE	NATO Military Medical Center of Excellence
Competent Authority	Designated by States to carry out specific functions with respect to issuing and receiving information relating to nuclear and radiological emergencies.
CONOPs	Concept of operations
Contamination	Contamination is radioactive material where you don't want it, and will require decontamination.
Cosmic Radiation	Radiation from outer space.
Count Time	The total time that data is collected during a measurement.
Criticality	A nuclear chain reaction. A nuclear reactor operates with a controlled criticality.
CST	Civil support team. A U.S. National Guard Unit assigned to each state to assist with CBRNe events.
CTCP	Counter Terrorism and Counter Proliferation

Ci	Curie (Ci) is a unit of radioactivity equal to 3.7×10^{10} disintegrations per second.
Dead Time	Dead time is the time in which a radiological detector's electronics cannot process the incoming data correctly.
DOE	Department of Energy
Dosimeter	A device that measures the integrated radiation dose and dose rate from an external source.
DOS	Department of State
Dose Limits and Equivalent Dose Limits	Dose limits are whole-body dose limits that are established to ensure no acute dose effects and minimize the probability of cancer.
Dose Rate	How fast radiation is delivered or absorbed.
DTPA	Medicine injected to remove plutonium, americium, and curium from the body.
DU	Depleted uranium
EOC	Emergency Operations Center
EMS	Emergency Medical Service
Equivalent Dose	Equivalent dose is the absorbed dose multiplied by a "radiation weighting factor" (or quality factor) dependent on radiation type. Equivalent dose is expressed as: SI Unit: Sievert (Sv) Sievert = Gray x w_R US Unit: 1 rem = 0.01 Sv (10 mSv)
ERO	Emergency Response Officer

Acronym	Term
Erythema	Erythema is a superficial reddening of the skin, usually in patches, because of injury or irritation causing dilatation of the blood capillaries.
Free Radical	Molecule that may be ionized and is highly chemically reactive.
Gamma Rays	Ionizing radiation that has a high energy and short wavelength. These are produced from the nucleus of an atom.
Gamma Spectroscopy	Gamma-ray spectroscopy is the measurement in the form of a spectrum of the gamma ray energies for use in radioisotope identification.
GPS	Global positioning system
Gray (Gy)	The International unit of radiation exposure equal to 100 rem.
GSR	General safety requirement (IAEA)
Half-Life	Time required for a radioactive substance to lose half of its radioactivity. Half-lives range from a fraction of a second to millions of years.
HAZMAT	Hazardous material
Health Physics	The study of radiation protection and safety.
HPGe	High purity germanium
HVL	Half-value layer

IAEA	International Atomic Energy Agency
I3	Inhalation, ingestion, and immersion
ICP	Incident Command Post
ICS	Incident Command System
IED	Improvised explosive device
IND	Improvised nuclear device
INEL	Idaho National Engineering Laboratory
Ionization	Ionization is the process by which an electron is removed from the orbit of an atom.
Ionizing Radiation	Ionizing radiation is radiation that causes atoms to lose electrons (α, β, γ, x, n).
IA	Interagency
I-RAD	International Nuclear/Radiological Training for Emergency Response.
IXP	The International Exchange Program is a web-based tool that rapidly provides computer model predictions of concentrations, dose rates, and health effects caused by the atmospheric release of radioactive materials. This information is presented as a plume deposition plot over a street map or aerial photograph and can be developed for any country.
JIC	Joint Information Center
JOC	Joint Operations Center
LANL	Los Alamos National Laboratory
LD50	LD50 is the dose of radiation that causes a mortality rate of 50% of the group exposed within a specified time.
LEU/HEU	Low enriched uranium/high enriched uranium

Acronym	Term
Level A	Level A is a protection level that consists of a self-contained breathing apparatus (SCBA) and a totally encapsulating chemical-protective suit. Level A PPE provides the highest level of respiratory, eye, mucous membrane, and skin protection.
Level B	Level B is a protection level that consists of a positive-pressure respirator (supplied-air respirator such as SCBA) and non-encapsulated chemical-resistant garments, gloves, and boots (which guard against chemical splash exposures). Level B PPE provides the highest level of respiratory protection with a lower level of skin protection.
Level C	Level C is a protection level that consists of an air-purifying respirator (APR) and non-encapsulated chemical-resistant clothing, gloves, and boots. Level C protection provides the same level of skin protection as Level B, with a lower level of respiratory protection. This level of PPE is used when the type of airborne exposure can be adequately guarded against by an APR.
Level D	Level D is a protection level that consists of standard work clothes without a respirator. In hospitals, Level D consists of surgical gowns, masks, and latex gloves (universal precautions). Level D provides no respiratory protection and only minimal skin protection.

LRM	Linear radiation monitor
MCA	Multi-channel analyzer
MEST	Mobile Emergency Support Team
MOU	Memorandum of understanding
MORC	Material out of regulatory control (IAEA)
MPE	Major public event
NARAC	National Atmospheric Release Advisory Center
NEST	Nuclear Emergency Support Team
NIPC	Office of Nuclear Incident Policy and Cooperation, or DOE/NNSA/NA-81
NGO	Non-governmental organization
NORM	Naturally occurring radioactive material
NNSA	National Nuclear Security Administration (part of U.S. Department of Energy)
NRAT	Nuclear Radiological Advisory Team
OPSEC	Operational security
ORNL	Oak Ridge National Lab
PAPR	Powered air-purifying respirator
POC	Point of contact
PPE	Personal protective equipment
PRD	Personal radiation detector – a device a person can carry or wear that detects radioactivity.

Acronym	Term
PNNL	Pacific Northwest National Laboratory
Pu	Plutonium
Rad	A unit of absorbed radiation dose. 1 rad is the dose of radiation causing 100 ergs of energy to be absorbed by 1 gram of matter.
RANET	Radiological Assistance Network (IAEA)
RDD	Radiological dispersal device – an RDD (also known as a "dirty bomb") is a large amount of explosives coupled with radiological material that the explosion can disperse over a large area.
REAC/TS	Radiation Emergency Assistance Center/ Training Site is a 24/7 DOE assistance resource that provides medical advice, consultation, and assistance for radiation injuries and accidents.
RED	Radiological exposure device
REM	Roentgen equivalent man
RIID	Radiation isotope identification device
RPM	Radiation portal monitor
RSO	Radiation safety officer
RTG	Radioisotope thermal generator
SCBA	Self-contained breathing apparatus
Scintillator	Scintillators are detector materials that give off light when interacting with ionizing radiation.
Sievert	International unit for the absorbed dose in tissue.
SME	Subject matter expert

SNM	Special nuclear material
SPARCS	The Spectral Advanced Radiological Computer System
Specific Activity	Specific activity is the amount of radioactivity (Bq or Ci) per unit mass (usually grams) of a radionuclide.
Stay Time	The calculated time a responder can stay in the radiation field and not exceed a protective action recommendation.
TLD	Thermoluminescent dosimeter
TOC	Tactical Operations Center
TRIAGE	U.S. DOE online capability that provides support to responders during a radiation emergency.
TTX	Tabletop exercise
UN	United Nations
VBIED	Vehicle-borne improvised explosive device
WHO	World Health Organization
Whole-Body Counter	A specialized device to determine internal deposition of photon-emitting radionuclides.
WMD	Weapons of mass destruction
X-Ray	X-rays are radiation that originates from electron transitions between electron shells in an atom.

Note: Many of these terms and acronyms are not used in the document, but they are used by state, federal, and international response agencies.

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Radiation Emergency Assistance Center/Training Site
1299 Bethel Valley Road, MS-39
Oak Ridge, TN 37830

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