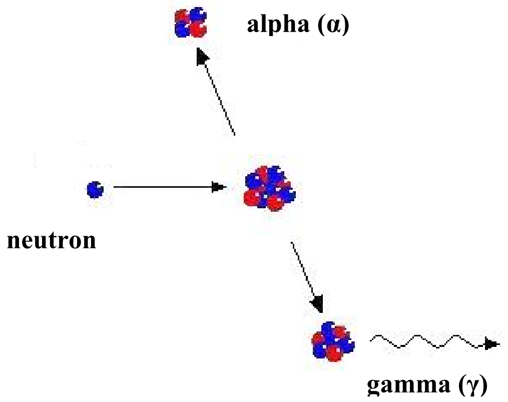
Version 2.1

RADIATION BASICS

FOR HOSPITAL EMERGENCY ROOM FIRST RECEIVERS



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This document contains the first phase of the training required to use the **Ludlum Responder Kit** to survey patients that may have been exposed to ionizing radiation.

- Within this document are *text boxes* that give extra or interesting information.

- Wording in underlined, bold **blue** and especially **red** text are important to the understanding of radiation and the proper safety responses.

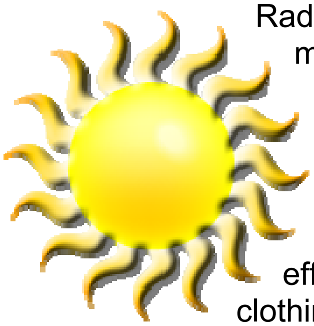
There are questions at the end of each unit and a final exam at the end of the document. The unit questions designed are to emphasize important information and prepare the student for the final exam.

Training Content

Unit quiz answers are located at the back of this document.

INTRODUCTION

What is Radiation?



Radiation is energy traveling through space. Sunshine is one of the most familiar forms of radiation. It delivers light and heat and with exposure over time it can cause our skin to tan and eventually burn. We have increasingly recognized that too much exposure to sunshine is not a good thing. Sunshine's radiation consists of a range of wavelengths (long-wave infra-red to short-wave ultraviolet). We control our exposure to this form of radiation and its effect on us with sunglasses, shade, air conditioning, hats, protective clothing and sunscreen.

Beyond the sun there are other sources of radiation such as the earth, gases in the air, high voltage equipment, and the stars. Collectively we refer the several types of particles and rays given off by such radioactive material as *ionizing radiation* .

- Living things have evolved in an environment of ionizing radiation
- All Organisms are continuously exposed to ionizing radiation
- Most ionizing radiation occurs naturally and some of it is manufactured artificially
- Many of us owe our lives and health to such radiation manufactured artificially
- Radiation is used to diagnose ailments, and some people are treated with radiation to cure disease.
- Ionizing radiation particles and rays can knock electrons out of atoms and molecules - such as water, protein, and DNA which can cause damage to living tissue.
- Ionizing radiation at high levels or prolonged exposure can be dangerous, so it is necessary for us to "control our exposure."

We can help control exposure and the effects of ionizing radiation, by understanding the nature of radiation, its effects, and how to protect ourselves and others from unnecessary exposure.

UNIT 1
RADIATION BASICS

Background radiation

We evolved in a world that has some radiation, and we have adaptations to heal the damage from background levels. More than healing, there is growing evidence that at least some radiation is actually needed for proper functioning of the body, especially the immune system. It's possible that slight increases above background may even be beneficial. However, this is still unproven, so we go with the current preponderance of evidence: any additional exposures beyond background may cause some degree of harm, and this risk is proportional to the exposure. It is very clear from the available evidence that large exposures are harmful.

- Naturally and inevitably present in our environment (sunlight, air, ground).
- Exposure levels vary (i.e. People living in areas with granite or mineralized sand receive more terrestrial radiation than others, while people living or working at high altitudes receive more cosmic radiation).
- Most of our exposure is due to radon, a gas which seeps from the earth's crust and is present in the air we breathe.

In the United States, the average dose of background radiation an individual receives per year is estimated to be 3.6 milliSieverts (mSv), 80% of which is from natural sources and 20% of which is from man-made sources.

- The full effects of low-dose background radiation are not known, but high doses have been shown to be carcinogenic.
- Very high-dose exposures over a short period of time, can result in immediate and lethal health effects.

IONIZING RADIATION

Ionizing Radiation is made up of several types of high energy particles and waves.

- ***Fast moving particles given off of a radioactive atom when it changes to another state – the flying piece acts like atomic shrapnel***

- ***High Energy electromagnetic waves carrying enough energy to disrupt everything in its path – acts like a severe atomic aftershock***

Ionizing Radiation loses energy with each atom it hits until the energy is gone (the energy is transferred bit by bit to what ever it crashes into).

Radioactive decay **is the process in which unstable atomic nuclei assume a more stable configuration by emitting particles with kinetic energy (alpha or beta particles) or electromagnetic waves (gamma rays).** If a person is exposed to these high-energy particles or electromagnetic waves, energy is deposited into the tissues and can cause injury.

When ever radioactive material enters the environment it behaves like the substance it is in (all the while giving off fast moving particles and high energy waves = radiation). Radioactive material can get into the air, water, soil, plants, animals and people making the host and everyone around them toxic.

Exposure to Ionizing Radiation can be Toxic.

The toxicity caused by ionizing radiation directly relates to how much of it gets into the body and what gets disrupts.

> Low-level exposure from accidental contact with radioactive isotopes in laboratory research may lead to relatively minor toxicity. On the other hand, inappropriate handling of high-level radioactive material such as cobalt-60 from radiographic or radiotherapy machinery can lead to acute sickness and even death.
>
> In a terrorism context, a conventional bomb has a radiological dispersal device (RDD), “dirty bomb,” laced with significant amounts of radioactive material, the conventional blast and thermal injuries is just part of the risk – radioactive material can get into the air, soil, water, plants, and victims. The risk of finely-divided radioactive material may be ingested, inhaled, or absorbed through the skin would exist for both bomb victims and rescue workers.
>
> In addition a detonation of a nuclear weapon or improvised nuclear devices would lead not only to a catastrophic blast and thermal injuries but also lethal radiation – the subsequent consequences would be far-reaching.
>
> Currently, relatively few medical treatments are available to counter radiological and nuclear threats, and most of those in development will need extensive preclinical testing before they can be evaluated for licensure.
>
> Notably, only a small number of radiation countermeasures have been entered into the Strategic National Stockpile (SNS). More such agents are needed, based on the range of options *(there aren’t THAT many)*.

HALF-LIVES AND IMPLICATIONS FOR DECONTAMINATION

In many cases, contaminated items will simply decontaminate themselves if they are left alone for periods of time. After ten half-lives, the amount of radioactive material left is less than one tenth of one percent of what was there to begin with. Even a fairly dangerous amount of [32 P] (half-life of 14.3 days) that could

reasonably be dispersed is almost certainly harmless six months after an event. Even an enormous contamination would be clean a year after the event (levels would be less than 1/4,000,000th of what was there to begin with.) Most daughter products of a true nuclear blast (or fizzled bomb) have even shorter half-lives, and articles with potentially lethal contamination at the incident will probably be safe within a few weeks. Victims may be more inclined to give up contaminated personal effects or evacuate contaminated areas if this is made clear to them in appropriate circumstances, they have a good chance of getting their property back in good condition after not too long. That may not be the case in a dirty bomb scenario with a longer-lived isotope.

You can't see….smell…..taste….feel…Radiation.

Radiation can only be detected by radiation detection instruments.

This characteristic makes radiological emergencies unique from other types of emergencies (such as floods, explosions or chemical releases). **Radiation exposure can cause considerable widespread fear.**

IONIZING VERSUS NONIONIZING RADIATION

Radiation can be broken down into 2 categories:

- ionizing radiation
- nonionizing radiation

The term ***ionizing radiation*** *refers to either high-energy particles or electromagnetic waves that have the ability to deposit enough energy to break chemical bonds and produce an ion pair.* Ionization occurs when the process of energy transfer liberates an orbital electron from an atom or molecule producing this ion pair. If living cells receive this energy, cellular function becomes compromised by DNA damage and mutation.

Nonionizing radiation refers to radiation that lacks the energy to liberate orbital electrons. All radiation from the electromagnetic spectrum except x-rays and gamma rays are included in this category. Examples of nonionizing radiation include microwaves, visible light, and infrared light. Because nonionizing radiation is lower energy radiation, injury is usually related to local heat production and is generally less severe. Ionizing radiation is consequently the focus of radiation-induced injury.

IONIZING RADIATION TYPES

Gamma Radiation (γ) is not a particle…..but a photon

Gamma radiation, emitted during the nuclear detonation or later in fallout, is highly energetic and is so penetrating that a significant part will pass through the human body without interaction. About 75% of the photons will interact with and lose energy to the atoms of the target tissue. This energy deposition may occur anywhere along a given photon's path, and therefore, anywhere in the body. If the gamma photon flux is high and the whole body is exposed, a fairly homogeneous deposition of energy will occur. This is in marked contrast to the highly localized energy deposition patterns of alpha and beta radiations. High-energy gamma emitters deposited within the body can result in total body irradiation just as effectively as external sources, if the quantities deposited are large enough and despite the fact that the emitters may not be distributed uniformly throughout the body.

Energy can travel through space in the form of electromagnetic radiation. Electromagnetic radiation is composed of massless waves of oscillating electric and magnetic fields. In a vacuum, these waves move at a constant speed, the speed of light (3×10^8 m/s). All electromagnetic waves propagate with characteristic wavelength and frequency, with the wave's energy being directly proportional to frequency and inversely proportional to wavelength. Within the electromagnetic spectrum, only x-rays and gamma rays have enough energy to produce ion pairs. The remaining waves within the spectrum, such as microwaves and radiowaves, are nonionizing.

IONIZING RADIATION: PARTICULATE RADIATION (IN ORDER OF HAZARD)

Ionizing radiation can also be in the form of particulate radiation, which includes small charged or neutral particles traveling with high energy. These particles may be alpha particles, electrons (beta particles), neutrons, or protons.

Neutron Radiation (n) A neutron is an electrically neutral particle found within the nucleus of an atom. Neutrons are slightly greater in mass than protons. High-energy neutrons rarely occur naturally but can be produced in a particle accelerator or in nuclear reactor as part of the fission process. Neutron exposure is most consequential in a nuclear reactor accident or during nuclear weapons detonation.

Since neutrons are uncharged particles and can react only with the nuclei of target atoms, the probability of interaction of neutrons in the energy range characteristic of the fission spectrum detonation during their path through the human body is roughly comparable to that of low-energy gamma photons. *Think of neutrons as “Teflon Coated” as they don’t stick to matter, they just slide through it.*

Neutron radiation can result in whole-body irradiation. The energy deposition will not be uniform, and the side of the body which faces the detonation will absorb more energy than the opposite side.

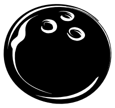
The major effect of this non-uniform deposition of energy will be to cause a wide variation in the typical radiation doses causing radiation sickness rather than significant variation in the overall clinical effects.

Beta Particles (β) Beta particles are another type of particulate radiation. These particles are *high-energy electrons* emitted from decaying isotopes such as strontium-90. Beta particles have a mass about 8000 times smaller than an alpha particle and travel at speeds near the speed of light. As a result of these properties, beta particles travel approximately 6 to 12 feet in air.

These high-energy electrons are also easily produced in linear accelerators and are commonly used to generate x-rays and in cancer radiotherapy. As in alpha radiation, the main hazard with beta particles lies with internal exposures. With significant skin exposure, however, beta particles have sufficient energy to cause cutaneous burns, "beta burns."

High speed electrons in the form of beta radiation lose most of their energy after penetrating only a few millimeters of tissue. *If the beta emitting material is on the surface of the skin, the resulting beta irradiation causes damage to the basal stratum of the skin. The lesion is similar to a superficial thermal burn.* However, if the beta material is incorporated internally, the beta radiation can cause much more significant damage. The damage will be in spheres of tissue around each fragment or source of radioactive material. The total damage is a function of the number of sources and their distribution in the body. The distribution is determined by the chemical nature of the material.

Alpha Particles (α) Alpha particles are charged particles made up of 2 protons and 2 neutrons with zero electrons—*essentially the nucleus of a helium atom*. In air, alpha particles only travel a distance of up to eight inches, and are unable to penetrate the skin or any solid substance to a significant depth. *Think of alpha particles as the bowling balls of atomic particles, they're big, heavy and don't go very far.*



If Alpha particles are essentially helium nuclei and Beta particles are basically high energy electrons………..*then???*

Why can't we put a bunch of alpha and beta emitters in a box shake it up and make helium???

Unfortunately nuclear physics isn't quite that simple.

However, it sounded like a pretty good idea at the time ☺

In the body, however, alpha particles can cause significant damage to soft internal tissue because they deposit all their energy in a very short distance. These particles are only a concern when alpha-emitting isotopes are ingested or inhaled.

Internal deposition of alpha particles are of importance on a long term basis in terms of causing radiation injury which is of greater significance than from beta particles.

It should be noted that many alpha emitting materials also emit gamma radiation.

A well-recognized source of alpha radiation involves the decay of radium into radon gas. Radium is an alkaline earth metal and a decay product of uranium and is found in uranium-bearing rocks or ores. Radium decays into radon gas, which can accumulate in poorly ventilated areas such as basements. Inhalation of radon on dust particles can lead to substantial doses of alpha radiation to the bronchi or lungs. The US Environmental Protection Agency attributes 10,000-20,000 cases of lung cancer per year to radon exposure.

Protons (p): A proton is a *positively charged* particle that is more than 1800 times the size of an electron. Protons make up a major component of cosmic radiation originating from the sun. All but a small amount of the sun's proton radiation is deflected by the earth's magnetic field.

Radioisotopes

Radioisotopes are atoms that contain **an unstable combination of neutrons and protons. The combination can occur naturally, as in radium-226, or can be produced artificially by altering the atoms**, in some cases using a cyclotron and in others, a nuclear reactor. Atoms containing this unstable combination regain stability by shedding radioactive energy, hence the term radioisotope. Nuclear medicine uses small amounts of radiation to provide information about a person’s body and the functioning of specific organs. The information received is used by physicians to make an accurate diagnosis of the patient’s illness. In certain cases radiation can be used to treat diseased organs or tumors.

Radioisotopes emit different types of radiation (gamma radiation, alpha radiation, and beta radiation). Modern industry uses radioisotopes in a variety of ways to improve productivity and, in some cases to gain information that cannot be obtained in any other way. Selected radioactive sources are used in industrial radiography, gauging applications and mineral analysis. Short-lived radionuclides are used in flow tracing and mixing measurements. Gamma sterilization is used for medical supplies, some bulk commodities and increasingly for food preservation and sterilization. The half life of most of the industrial radioisotopes is longer, than the nuclear medicine radioisotopes therefore making them a little more useful in designing a RDD.

Table 1-1. Fundamental properties of radiation

Properties	Alpha (α)	Beta (β)	Gamma (X –Ray) (γ)	Neutron (n)
Mass	Large mass 2 protons and 2 neutrons (4 amu)(helium nucleus)	Solid mass (about 1/1838 of 1 amu)	No mass electromagnetic wave or photon	Mass of 1 amu
Electrical Charge	+ 2 positive	-1 negative	None	None
Range in the air	Short range ¼ to 2 inches (4cm) in dry air,	up to about 10 feet (3 meters) in dry air	Very far several hundred feet. Very high penetrating power since it has no mass or charge	Very far. Several hundred feet. High penetrating power due to lack of charge (difficult to stop)
Shielding	2 inches of air, A sheet of paper, dead layer of skin	Plastic, aluminum foil, clothing safety glasses	Inches of Lead, Concrete, Water, Steel	Materials with high hydrogen content, water, concrete, plastic, polyethylene, boron cadmium
External Hazard	Does not represent external hazard.	Externally for unprotected skin and eyes.	Whole body exposure. Can penetrate through the body.	Whole body exposure. Can penetrate through the body.
Biological Hazard	Internal hazard if the source is inside the body (inhaled, ingested, or injected in wound.) Can deposit large amounts of energy in a small area internally	Internal hazard if the source is inside the body (inhaled, ingested, or injected in wound.) Can deposit large amounts of energy in a small area internally	Hazard may be internal or external. This depends on whether the source is outside or inside the body.	Hazard may be internal or external. This depends on whether the source is outside or inside the body.
Sources	Usually emitted by transuranic elements: Uranium, Plutonium, Americium, Radon and Radium	Fissionable products such as Cesium 137, Tritium, Carbon-14, and iodine 132	Fission Products. Many natural emitters in soil, industrial and medical sources. Cesium 137, Cobalt 60, depleted Uranium	Few natural sources. Fission and nuclear reactors. Cosmic radiation entering atmosphere creates neutrons. Plutonium, Californium 252.

Unit 1 Study Questions

1. Nonionizing radiation refers to radiation that lacks the energy to liberate orbital electrons. All radiation from the electromagnetic spectrum except _______ are included in this category.

    a. X-rays
    b. Microwaves
    c. Infrared light
    d. Visual light

2. All the sources of radiation listed below are particles except:

    a. Neutron
    b. Alpha
    c. Beta
    d. Gamma

3. What is background radiation?

    a. The radiation level in the Hot Zone
    b. The radiation level determined by experts
    c. The radiation level that is natural and inevitably present in our environment.
    d. The radiation level used for X-rays.

4. A radioisotope:

    a. Are atoms that contain an unstable combination of neutrons and protons.
    b. Occur naturally.
    c. Can be produced artificially.
    d. All of the above.

5. Radioisotopes only emit one type of radiation.

    a. True b. False

6. Radioactive decay:

    a. is the process in which unstable atomic nuclei assume a more stable configuration.
    b. may emit particles with kinetic energy (alpha or beta) or electromagnetic waves (gamma rays)
    c. is caused by too many dental x-rays
    d. a, b, and c
    e. a and b only

7. Which characteristic(s) make radiological emergencies different from other types of emergencies such as floods, chemical releases or explosions.

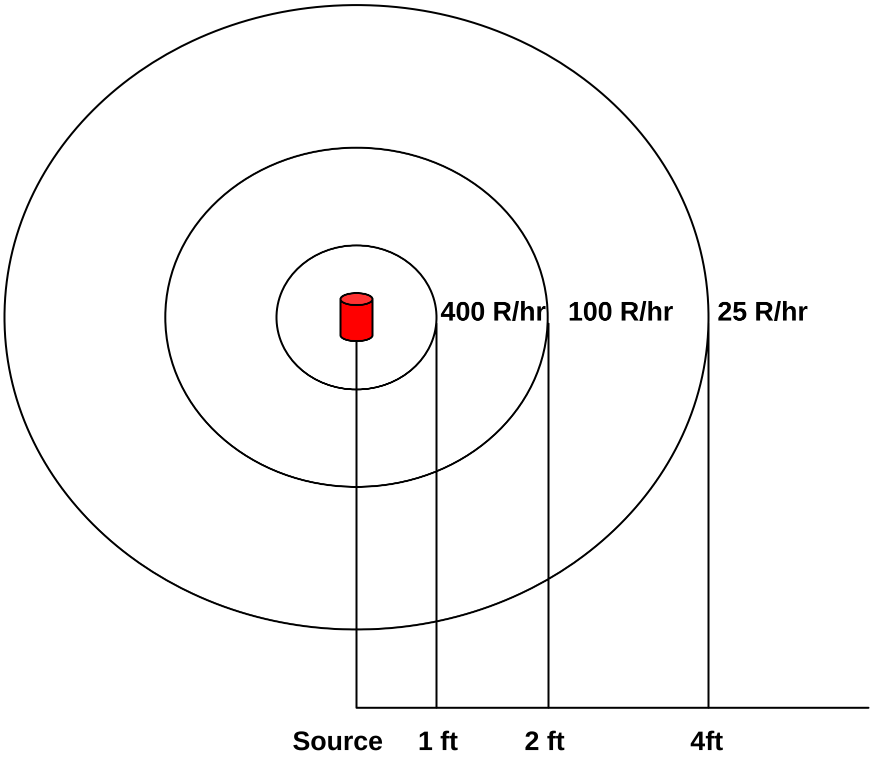
   a. You can not see, smell, feel or taste radiation
   b. Radiation can only be detected by radiation detection instruments
   c. Most people have a great fear of radiation
   d. all of the above

UNIT 2
DOSE LIMITS AND EXPOSURE GUIDANCE

ALARA as low as reasonably achievable means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical.

The dose limits below, apply to the doses incurred over the duration of the emergency. The dose to workers performing emergency services may be treated as an "once-in-a-lifetime" exposure, and not added to the occupational exposure accumulated under normal, nonemengency conditions for the purpose of determining conformance with the normal occupational limits. (EPA Manual of Protective Action Guides and Protective Actions for Nuclear Incidents (EPA 400 R-92-001)).

INVERSE SQUARE LAW



Point source considerations are important because of the dramatic increase in dose that occurs as responders approach the source. The formula used to calculate the change in exposure as the distance from a point source varies is:

R_1 is the initial rate	D_1 is the initial distance
R_2 is the new rate	D_2 is the new distance

$R_1D_1 = R_2D_2$ therefore 400 R/hr $(1^2) = R_2 (2^2)$ 400/4 =100 as shown above

<u>Double the distance</u>	***<u>1/4 the dose rate</u>***
<u>Halve the distance</u>	***<u>4 times the dose rate.</u>***

*Sum of the doses from the external dos e and internal dose (from the intake of radioactive material) to nonpregnant, adult emergency ;workers. Responders performing services during emergencies should limit the dose to the lens of the eye to 3 the listed values and limit the doses to any other organ (including the skin and extremities to 10 times the listed value µ.

Table 2-1 EPA Guidance for Dose Limits for Workers Performing Emergency Services

Dose Limit * (Whole Body)	**Emergency Activity Performed**	**Condition**
5 rem	**All activities**	
10 rem	**Protecting valuable property, Hazard control/mitigation**	**Where lower dose not practicable**
25 rem	**Lifesaving or protection of large populations**	**Where lower dose not practicable**
More than 25 rem	**Lifesaving or protection of large populations**	**Only on a volunteer basis to persons fully aware of risks involved.**

Table 2-2. Dose Work Rate Comparisons

Dose Rate Recommendations	**Actual Values**	**Exercise Values**
Contaminated (Persons)	2 X Background Reading (cpm or µR/hr or mR/hr)	2 X Background Reading (cpm or µR/hr or mR/hr)
Hot Line	**1 – 5 mR/hr (0.001 – 0.005 R/hr)**	**100 µR/hr (0.1 mR/hr)**
Work in Hot Zone	**1 mR/hr - 10 R/hr (0.001 – 10 R/hr)**	**100 µR/hr – 1000µR/hr (0.1 mR/hr – 1 mR/hr)**
Turn Back Dose Rate (Except Lifesaving)	**10 R/hr**	**1mR/hr**
Turn Back Dose Rate (Even for Lifesaving)	**200 R/hr**	**4 mR/hr**

1 µR = 0.001 mR = 0.000001 R
1 R/hr = 1,000 mR/hr = 1,000,000 µR/hr

Natural Background: Approximately 10 µR/hr = 0.01 mR/hr = 0.25 mR/day

NOTE: Gamma-ray survey meters usually read values in R/hr (not rem/hr), but the dose limits are given in rem (not R). For gamma radiation, you can consider R/hr and rem/hr to be the same.

The green-yellow-red doses of the *Stay Timetable* correspond to the 5-10-25 rem guidelines form the Dose Guidelines Table. The gray columns represent lethal doses. A 300 to 350 rem dose is considered the LD_{50} for humans within 60 days without hospital care. A 450 to 500 rem dose is considered the LD_{50} for humans within 60 days even with hospital care.

The *Calculation for exposure time* is: $\text{Time} = \frac{\text{Dose}}{\text{Dose Rate}}$

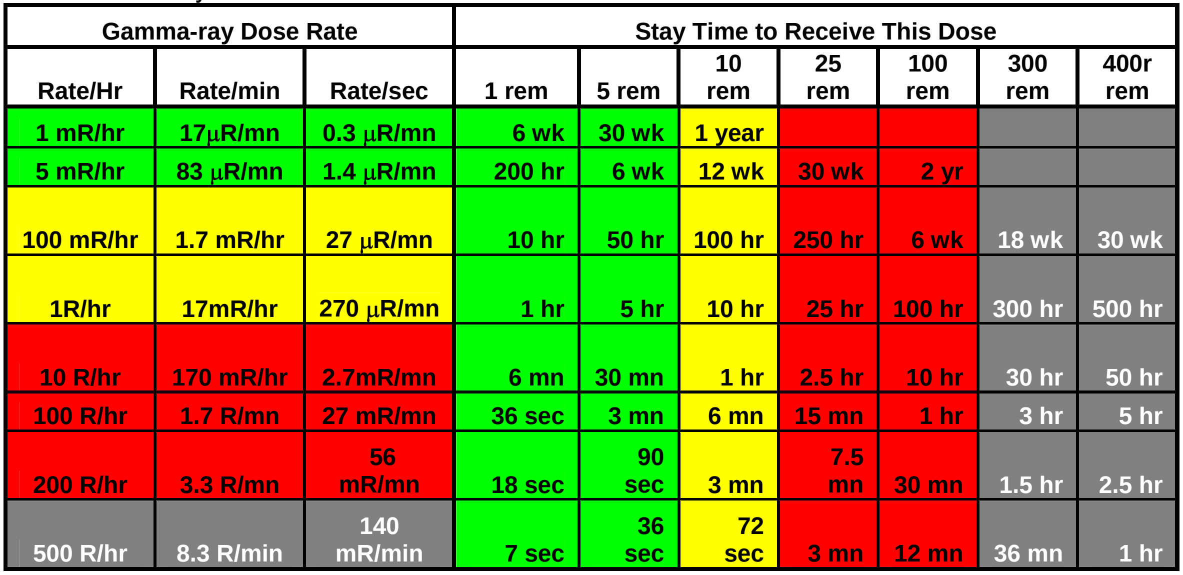
If a responder was in a field of 10 R/hr, how log would it take to receive a lethal dose of 500 rem?

In this case it would be $\frac{\text{Dose}}{\text{Dose Rate}} = \text{Time (hours)}$

500/10 = 50 hours

Or it would take approximately 2 days to receive a lethal dose of radiation at the given dose of 10R/hr.

Table 2-3. Stay Timetable



Gamma-ray Dose Rate			Stay Time to Receive This Dose						
Rate/Hr	Rate/min	Rate/sec	1 rem	5 rem	10 rem	25 rem	100 rem	300 rem	400r rem
1 mR/hr	17μR/mn	0.3 μR/mn	6 wk	30 wk	1 year				
5 mR/hr	83 μR/mn	1.4 μR/mn	200 hr	6 wk	12 wk	30 wk	2 yr		
100 mR/hr	1.7 mR/hr	27 μR/mn	10 hr	50 hr	100 hr	250 hr	6 wk	18 wk	30 wk
1R/hr	17mR/hr	270 μR/mn	1 hr	5 hr	10 hr	25 hr	100 hr	300 hr	500 hr
10 R/hr	170 mR/hr	2.7mR/mn	6 mn	30 mn	1 hr	2.5 hr	10 hr	30 hr	50 hr
100 R/hr	1.7 R/mn	27 mR/mn	36 sec	3 mn	6 mn	15 mn	1 hr	3 hr	5 hr
200 R/hr	3.3 R/mn	56 mR/mn	18 sec	90 sec	3 mn	7.5 mn	30 mn	1.5 hr	2.5 hr
500 R/hr	8.3 R/min	140 mR/min	7 sec	36 sec	72 sec	3 mn	12 mn	36 mn	1 hr

PROTECTION

The Three Fundamental Strategies: TIME, DISTANCE & SHEILDING

Unsealed radionuclides, sealed sources, X-ray machines, irradiators, and other sources of ionizing radiation may present a hazard of external exposure.

Protection from these sources is based on applying three fundamental strategies (***Time, Distance, Shielding***)

- ***Minimize the time*** spent near sources (a linear reduction).

- ***Maximize the distance*** from sources (an inverse square reduction).

- ***Use shielding*** of appropriate type (an exponential reduction).

Time Simply reducing the amount of time spent near or in contact with any source results in a proportionate reduction in dose. Minimize the time and you will minimize the dose. [15,16]

$$\frac{\text{sieverts}}{\text{hour}} \times \text{hour} = \text{sieverts}$$

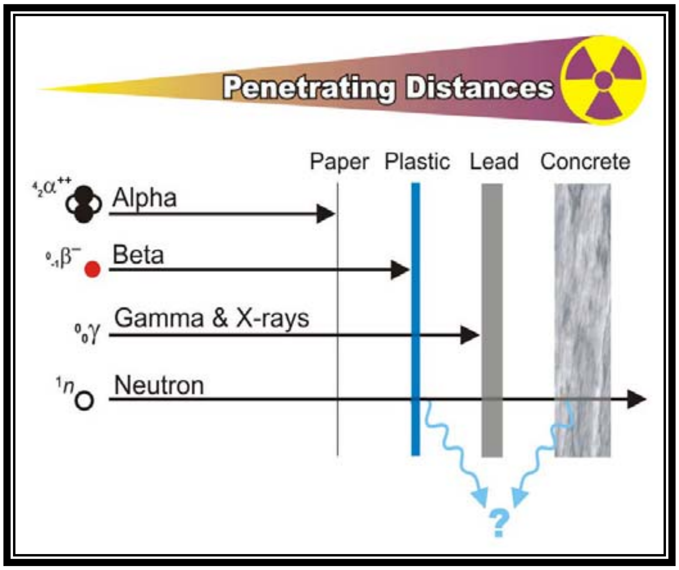
Distance Exposure decreases with distance according to the ***inverse square law***, by which the radiation intensity varies inversely with the square of the distance from a source. Increasing the distance from a source by a factor of two reduces the intensity to one quarter. Increasing the distance from a source by a factor of three reduces the intensity to one ninth.

$1/2^2 = 1/4$

$1/3^2 = 1/9$

This rule has important practical applications. A source with an exposure rate of 100 mR/hr at 10 centimeters from the surface has an exposure rate of 1 mR/hr at 100 centimeters from the surface, *or little more than an arm's length away*.

Shielding Proper shielding can result in an exponential reduction of dose for gamma emitters and a near-total reduction for beta emitters. Select appropriate shielding materials during the planning stages of any experiment or clinical procedure. Shielding design may be simple--no more complex or costly than sheets of plywood or plastic--or may involve complex calculations that depend on the type of radiation, the energy and frequency of emission, the configurations of source and room, and the occupancy factors.



The amount of shielding required depends on the type of radiation being shielded, the activity of the source, and on the dose rate which is acceptable outside of the shielding material. In choosing a shielding material, the first consideration must be personnel protection. An effective shield will cause a large energy loss in a small penetration distance without emission of more hazardous radiation. However, other factors may also influence the choice of shielding materials such as, cost of the material, weight of the material, and how much space is available for the material. The effectiveness of the shielding material is determined by the interactions between the incident radiation and the atoms of the absorbing medium. The interactions which take place depend mainly upon the type of radiation (alpha, beta, gamma, and neutron), the energy of the radiation, and the atomic number of the absorbing medium.

Absorbed Dose

- Amount of energy of any type of ionizing radiation that is deposited in any type of material.
- Unit: rad (or Gray)
- 100 rad = 1 Gy

Exposure:

- Defined as 3.336 x 10-10 Coulombs per cm3 of air.
- Only defined for photons in air.
- Unit: R (used in honor of physicist *Wilhelm Roentgen* who discovered the X-rays).
- 1R to biological material ~ 1 rad

Unit 2 Study Questions

1. Which source of radiation has the greatest penetration requiring the greatest amount of shielding

   a. Neutron
   d. Alpha
   e. Beta
   f. Gamma

2. Which source of radiation has the least penetration requiring the least amount of shielding?

   a. Neutron
   b. Alpha
   c. Beta
   d. Gamma

3. What method of protection should be the last resort?

   a. Time
   b. Distance
   c. Shielding
   d. Personal Protection Equipment

4. Simply speaking the Inverse Square Law States:

   a. Double the distance – quarter the exposure
   b. Half the distance – four times the exposure
   c. a and b
   d. none of the above. The inverse square law only applies to sound.

5. Unsealed radionuclides, sealed sources, X-ray machines, irradiators, and other sources of ionizing radiation may present a hazard of external exposure. Protection from these sources is based on applying the following fundamental strategies:

   a. Minimize the time spent near sources (a linear reduction)
   b. Maximize the distance from sources (an inverse square reduction)
   c. Use shielding of appropriate type (an exponential reduction).
   d. All of the above

UNIT 3
PERSONAL PROTECTION EQUIPMENT

RESPIRATORY PROTECTION

Personal Protection Equipment (PPE) protection levels are classified as Level A, Level B, Level C, and Level D.

- Level A (Totally-encapsulated, with SCUBA gear and chemical-protective suit) – to be used when the greatest level of skin, respiratory, and eye protection is required.
- Level B (Hooded chemical-resistant clothing, with SCUBA gear) maintains the highest level of respiratory protection with a lesser level of skin protection – to be used when there is a lesser risk of splash contamination.
- Level C (Hooded chemical-resistant clothes with air purifying respirators either full or half-faced) – to be used when the concentration(s) and type(s) of airborne substance(s) is known and it is safe to use an air purifying respirator.
- Level D (work uniform with minimal protection) – used for nuisance contamination only.

RDD events, by their nature, disperse radioactive material. There is a risk that finely-divided material may be ingested, inhaled, or absorbed through the skin, for such an incident ***Level C protection is generally sufficient.***

There are several approaches to respiratory protection. Fit-tested full or half face Respirator with P-100 high efficiency particulate air (HEPA) cartridge-filtered respirators should be used when available. Powered-air purifying respirators (PAPRs) with P-100 HEPA cartridges are also useful. Any respiratory protection that is designed to protect responders against chemical or biological agents will likely offer benefits in an RDD event. In fact, concerns for the presence of chemical contaminants at a terrorist event will normally drive the selection of respiratory protection as they may require a higher level of PPE.

SKIN PROTECTION

Current weather conditions, as well as the environment at the event, will drive the selection of anti-contamination clothing. Normal chemical or particulate barrier clothing and gloves give excellent personal protection against airborne particles. The choice of clothing will often be driven by other more immediate hazards, such as fire, heat, or chemicals. Protection for these hazards covers any additional threat that radioactive material could pose.

Transport of the severely injured to available acute care medical facilities should not be delayed due to suspected or confirmed radiological contamination on the

patient. If a critically injured but contaminated patient must be transferred immediately, make preparations for limitation of contamination at the destination facility. [17]

SHELTERING

- Sheltering will normally be the preferred protective action until an orderly evacuation of the contaminated area can be made. Monitoring for contamination and applying decontaminating techniques should be performed prior to releasing people.
- Sheltering should be directed if the projected effective dose. Recommendation is, or has the potential to be, greater than 10 mSv (1 rem).
- Sheltering need not be implemented if the projected effective dose is less than 1 mSv (100 mrem).

Evacuation of most population groups should be directed if it is more protective than sheltering, but not if the projected dose is less than 50 mSv (5 rem), with the following exception: For special groups for which evacuation puts them or the public at a greater risk (e.g., persons on medical life support, institutionalized criminals, etc.), evacuation should not be directed if the projected effective dose is less than 100 mSv (10 rem).[18]

Unit 3 Study Questions

1. Transport of the severely injured to available acute care medical facilities should not be delayed due to suspected or confirmed radiological contamination on the patient.

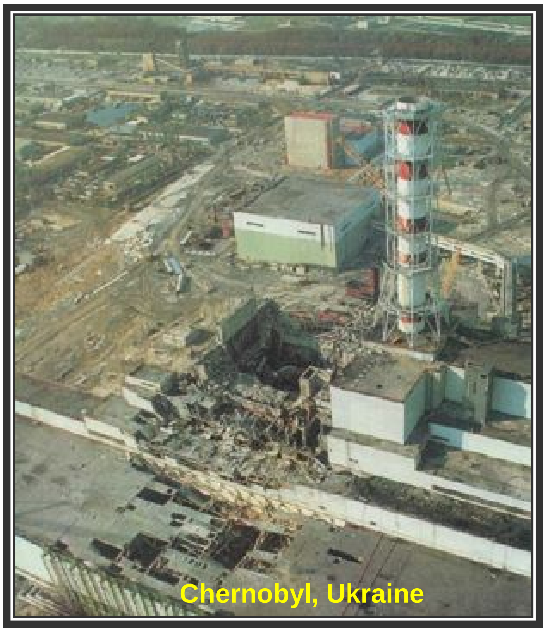
    a. True b. False

2. Which level of personal protection equipment is generally sufficient when working around radiation.

    a. Level A
    b. Level B
    c. Level C
    d. Level D

UNIT 4
SOURCES OF LARGE SCALE IONIZING RADIATION RELEASE

NUCLEAR POWER PLANTS



Although construction and operation of nuclear power plants are closely monitored and regulated by the Nuclear Regulatory Commission, accidents, though unlikely, are possible. The most immediate danger from an accident at a nuclear power plant is exposure to high levels of radiation. A nuclear power plant accident would not cause the same widespread destruction as a nuclear weapon. Although radioactive materials could be released in a cloud or plume, no fallout is produced to endanger people.

There may be a radiation hazard in the surrounding areas, depending on the type of accident, amount of radiation released, and weather factors. At the onset of an accidental release, radiation would be monitored by authorities to determine potential danger and warn the public. Because it is a known event, local citizens would be evacuated or instructed on how to avoid radiation hazards. Local municipalities train and practice release accident scenarios with a full range of emergency response organizations, and residents are familiar with responses.

To predict radionuclide contamination/emission from a power plant one can look at the previous accidents and releases involved. Among other accidents, one can list the Windscale accident of 1957, the Oak Ridge Pu release of 1959, the explosion of an Army low power reactor in 1961, the 1974 Browns Ferry fire, the Three Mile Island 1979 accident, and the 1986 Chernobyl accidents. Possible accidents are continuously being studied in the industry to assure safety of power plants and compliance with today's regulations.

Table 4-1, Release of Radioactive Material From Nuclear Power Plants.

Facility	**Radioisotopes**	**Release**	**Comments**
Windscale (now called Sellafield)	^{131}I, ^{137}Cs, ^{89}Sr, ^{90}Sr	30,000 Ci, 20,000 of which was from ^{133}I	There were no acute health effects as result of this accident. However, for 2 weeks, all milk produced on farms within a few kilometers of the plant was collected and withdrawn from consumption due to Sr-90 and radioactive iodine uptake by dairy cattle.
Oak Ridge	^{133}I	10 Ci of ^{133}I	The explosion resulted in plutonium contamination of the pilot-plant building, nearby streets, and building surfaces. The adjacent air-cooled graphite reactor building became contaminated when plutonium was drawn into the ventilation system.

U.S. Army Low Power Reactor	^{239}Pu, 95Zr, 95Nd	Unknown	Although there were three casualties related with this accident, all of the radioactive material, with the exception of ^{131}I, was contained within a three-acre plot.
Three Mile Island	^{85}Kr,	15 Ci	Average dose to people was about 1 millirem. Exposure from a full set of chest x-rays is about 6 millirem. The maximum potential off-site radiation dose was 83 mrem at the site boundary.
Hanford	^{131}I, ^{103}Ru, ^{106}Ru, ^{239}Pu, ^{90}Sr, and ^{144}Cs	740,000 Ci	Major radioactive releases occurred between 1944 and 1957. estimations of release in Curies is ^{131}I, 739,000; ^{103}Ru, 1,600; ^{106}Ru 388; ^{90}Sr, 64.3, ^{239}Pu, 1.87, ^{144}Ce, 3,770. Epidemiologic studies have not found conclusive evidence of effects in the downwind populations.
Chernobyl	^{131}I, ^{137}Cs,	7,300,000 Curies (1,000,000 Ci /24 hours first 7 days)	Caused the deaths, within a few weeks, of 30 power plant employees and firemen responders, 28 with acute radiation syndrome, evacuation of about 116,000 people.

Potassium Iodide (KI) only works if there is an exposure to ^{131} Iodine. Other radioisotopes require other decorporating drugs.

What About Iodine allergies???

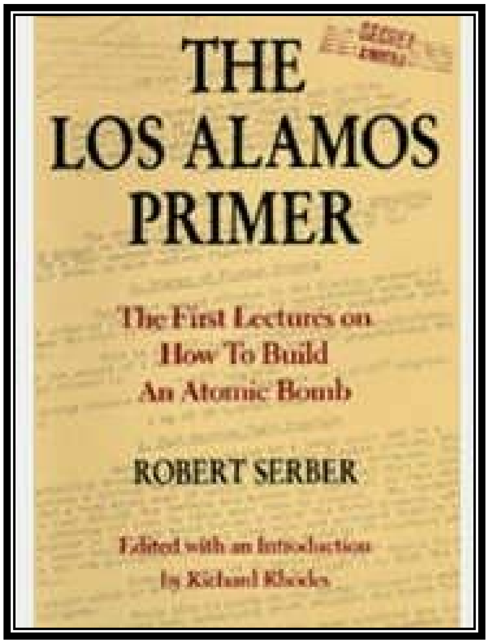
According to Scott H. Sicherer, MD, FAAAAI, on behalf of the Adverse Reactions to Foods Committee and the Adverse Reactions to Drugs and Biologicals Committee New York, NY in their article: Risk of Severe Allergic Reactions from the Use of Potassium Iodide for Radiation Emergencies:

"Potassium iodide (KI) may be prescribed for widespread use in the event of a radiation emergency to prevent the uptake of radioactive iodide by the thyroid gland. The available literature was reviewed and expert opinion sought among members of the Adverse Reactions to Foods and the Adverse Reactions to Drugs and Biologicals Committees of the Academy to assemble evidenced-based conclusions regarding the risks of an allergic reaction to this therapy.

- **Anaphylactoid reactions to radiocontrast media (RCM) should *not* be considered evidence of KI allergy.**
- **Allergic contact dermatitis from iodine-containing antibacterial preparations should *not* be considered evidence of IgE antibody–mediated KI allergy or sensitivity.**
- **IgE antibody–mediated allergy to seafood should *not* be considered evidence of KI allergy or sensitivity.**
- **Physicians should *ensure* that persons are *not* allergic to inactive ingredients or components of the KI formulation prescribed."**

IMPROVISED NUCLEAR DEVICE (IND)

An IND is made when terrorists acquire fissile material by purchase, diversion, or force for the purpose of fabricating a crude nuclear bomb. Two types of fissile material could be used for this purpose, highly enriched uranium (HEU) or plutonium. HEU would be far easier to make into a successful IND. It is generally assumed that successful INDs would have yields in the 10-20 kiloton range (the equivalent to 10,000-20,000 tons of TNT). A twenty-kiloton yield would be the equivalent of the yield of the bomb that destroyed Nagasaki and could devastate the heart of a medium-sized U.S. city, while causing fire and radiation damage over a considerably wider area.



THE
LOS ALAMOS
PRIMER

The First Lectures on
How To Build
An Atomic Bomb

ROBERT SERBER

Edited with an Introduction
by Richard Rhodes

If an INDs that fizzled – that is, did not detonate fully, it might still produce a nuclear yield, which though far less powerful, could still cause very significant damage. *The Los Alamos Primer and other “how to” books are available on Amazon.com.*

Two types of fissile material could be used for this purpose, highly enriched uranium (HEU) or plutonium, but the former would be far easier to make into a successful IND.

According to the conservative figures used by the International Atomic Energy Agency, only 25 kilograms of HEU or 8 kilograms of plutonium would be needed to manufacture a weapon. It is more difficult to maintain strict control over fissile materials than over nuclear weapons.

The Chain of Causation for an IND

The principal elements that would have to combine for a terrorist group to detonate an IND at a high-value target, such as an American city, include the following steps:

1. A terrorist group with extreme objectives and the necessary technical and financial resources to execute this scheme must organize and begin operations.
2. The group must then choose to engage in an act of nuclear terrorism at the highest level of violence.
3. These terrorists must then acquire sufficient fissile material to fabricate an IND, through gift, purchase, theft, or diversion.
4. They must next fabricate the weapon.
5. The group must transport the intact IND (or its components) to a high-value target.
6. Finally, the terrorists must detonate the IND to complete their plan.

Although variants of this chain of causation can be imagined, this outline can serve as a means to determine where to apply risk reduction measures to lessen the probability that such an act of nuclear terror might occur. All of these elements must be realized for a terrorist IND attack to succeed, and intervention at any stage can be sufficient to avert catastrophe.

NUCLEAR DETONATION

The immediate physical devastation could appear similar to that of the World Trade Center following the events of September 11, 2001. The two major injury and death producing forces in a nuclear detonation are blast forces and thermal radiation, both of which will cause injuries at much greater distances much greater than radiation injuries.

However, the dust and debris from this event will be highly radioactive. There would be thousands of people both contaminated and injured at the scene. In addition, there may be thousands of people in a large area potentially extending many miles outward from the initial point of attack with serious radiation exposures, due to radioactive fallout, although they may have no obvious physical injury or contamination. Radioactive fallout with potential for long-term health effects will extend over a large region far from ground zero. There would likely be many persons experiencing symptoms related to acute radiation syndrome.

Nuclear Detonation Effects Two basic types of blast forces occur simultaneously in a nuclear detonation blast wave. They are direct blast wave overpressure forces and indirect blast wind drag forces. Blast wind drag forces are the most important medical casualty-producing effects. Direct overpressure effects do not extend out as far from the point of detonation and are frequently masked by drag force effects as well as by thermal effects. The drag forces are proportional to the velocities and durations of the winds, which in turn vary with distance from the point of detonation, yield of the weapon, and altitude of the burst. These winds are relatively short in duration but are extremely severe. They can be much greater in velocity than the strongest hurricane winds. Considerable injury can result, due either to missiles (shrapnel) – particularly glass fragments or to casualties being blown against objects and structures in the environment (blunt trauma).

Thermal burns will be the most common and extensive injuries, subsequent to both the thermal pulse and the fires it ignites. The thermal radiation emitted by a nuclear detonation causes burns in two ways, by direct absorption of the thermal energy through exposed surfaces (flash burns) or by the indirect action of fires caused in the environment (flame burns). Since the thermal pulse is direct infrared, burn patterns will be dictated by location and clothing pattern. Exposed skin will absorb the infrared, and the victim will be burned on the side facing the explosion. Skin shaded from the direct light of the blast will be protected.

BURN CAVEATS
Hiroshima and Nagasaki Survivors

Hiroshima 20-day Burn Survivors: only 1.9% flame burns
Nagasaki 20-day Burn Survivors: only 3.4% flame burns

- **98% of burns involved head and/or limbs**
- **Hand burns involved back of hand**
- **Burns around eyes rare**

Majority of burns were 1st or 2nd degree and healed within 4 weeks
Nearly all 2nd and 3rd degree burns became infected
Treatment was limited largely to local applications and dressings
Greatest number and severity of burns occurred in 1500 – 2000 meter range

Low percentage of survivors within 1500 meters of hypocenter

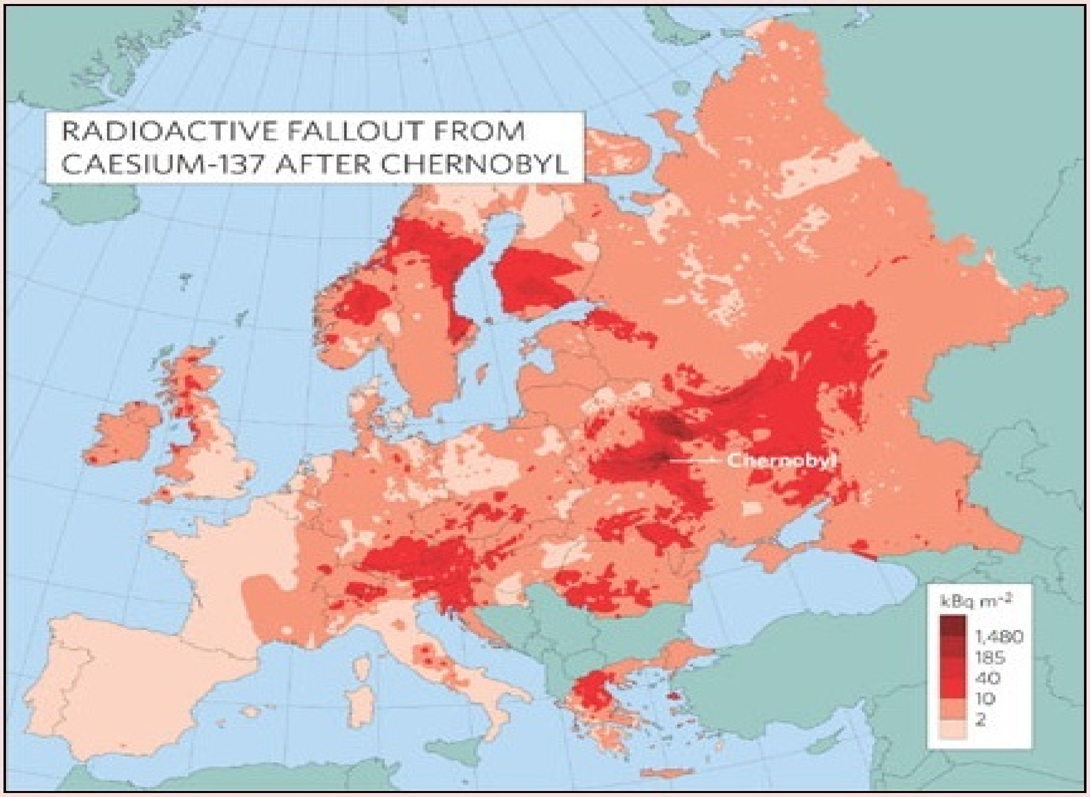
The longest-range effect from the nuclear blast is sudden exposures to high-intensity visible light and infrared radiation of a detonation that will cause eye injury specifically to the chorioretinal areas. Individuals looking directly at the flash will receive retinal burns. Flash blindness occurs with peripheral observation of a brilliant flash of intense light energy, for example, a fireball. This is a temporary condition that results from a depletion of photopigment from the retinal receptors. The duration of flash blindness can last several seconds when the exposure occurs during daylight. The blindness will then be followed by a darkened afterimage that lasts for several minutes. At night, flash blindness can last for up to 30 minutes.

<u>Nuclear Detonation Radiation Exposure Injuries</u> The effects of a surface or of a shallow subsurface burst will not be greatly different from those accompanying a low air burst. However, as increasing amounts of contaminated earth and debris are sucked up into the active cloud the hazard from the residual nuclear radiation in the early fallout increases. The only direct information concerning human casualties resulting from a nuclear explosion is that obtained following the air bursts over Japan. The exposure injuries relate to the particular heights of the burst and yields of the weapons exploded over

Hiroshima and Nagasaki, the weather, the terrain, and other conditions existing at the times and locations of the explosions. A wide variety of ionizing radiation can interact with biological systems, but there are only four types of radiation associated with atmospheric and underground nuclear detonations of biological significance. In order of importance, they are **gamma, neutron, beta, and alpha**.

Blast Effects Blast radiations, which are quite different from thermal radiation, and consist of gamma rays, neutrons, beta particles, and a small proportion of alpha particles. Most of the neutrons and part of the gamma rays are emitted in the fission and fusion reactions, (simultaneously) with the explosion. Even when the fireball touches the ground, the alpha and beta particles are not very important. The initial nuclear radiation may thus be regarded as consisting only of the gamma rays and neutrons produced during a period of 1 minute after the nuclear explosion. Both of these nuclear radiations, although different in character, can travel considerable distances through the air. Both gamma rays and neutrons can produce harmful effects in living organisms.

Radioactive Fallout In most circumstances, the whole-body dose from the gamma rays emitted by the early fallout will represent the major external hazard from the delayed nuclear radiation. The biological effects are then similar to those from equal acute doses of radiation. In addition, injury can arise in two general ways from external sources of beta particles. If the beta-particle emitters, e.g., fission products, come into actual contact with the skin and remain for an appreciable time, a form of



J. SMITH & N. A. BERESFORD CHERNOBYL: CATASTROPHE AND CONSEQUENCES (PRAXIS, CHICHESTER, 2005) radiation injury, sometimes referred to as "beta burn," will result. In addition, in an area of extensive early fallout, the whole surface of the body may be exposed to beta particles coming from many directions. Information concerning the development and healing of beta burns mostly was obtained from observations of the Marshall Islanders who were exposed to fallout in March 1954 (for detailed on external beta effects see “The Effects of Nuclear Weapons, Chapter XII-Biological Effects”).

Unit 4 Study Questions

1. A nuclear power plant accident would <u>not</u> cause the same widespread destruction as a nuclear weapon.

   a. True   b. False

2. Following a nuclear detonation which is true?

   a. Radioactive fallout only occurs for a ground blast. An air burst produces little fallout.
   b. Blunt trauma is the most common injury and is caused by the shockwave.
   c. Thermal burns will be the most common and extensive injuries, subsequent to both the thermal pulse and the fires it ignites.
   d. The gamma radiation only lasts for the first 24 hours.

3. In most circumstances, the whole-body dose from the ________ emitted by the early fallout will represent the major external hazard from the delayed nuclear radiation.

   a. Gamma rays
   b. Alpha Particles
   c. Beta Particles
   d. Photons

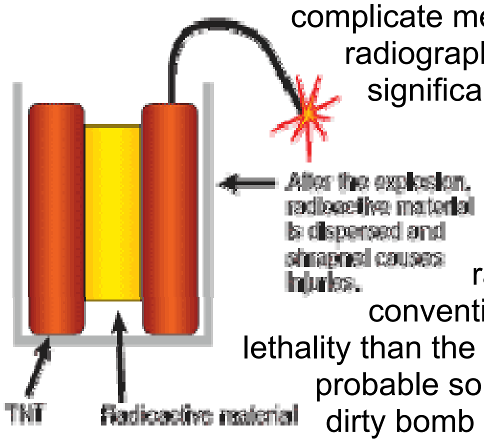
4. The “initial” nuclear radiation may be regarded as consisting only of ________ and __________ produced during a period of 1 minute after the nuclear explosion.

   a. Alpha and Beta particles
   b. Beta particles and Gamma rays
   c. Gamma rays and Neutron particles
   d. Neutron and Beta particles

UNIT 5
RADIOLOGICAL DISPERSION DEVICES, AND RADIOLOGICAL EXPOSURE DEVICES

RADIOLOGICAL DISPERSION DEVICES (RDD)

An RDD is any dispersal device causing purposeful dissemination of radioactive material across an area without a nuclear detonation. A terrorist or combatant with conventional weapons and access to radionuclides from sources such as a nuclear waste processor, nuclear power plant, university research facility, medical radiotherapy clinic or industrial complex can develop an RDD. This type of weapon causes conventional casualties to become contaminated with radionuclides and would complicate medical evacuation from the area. Damaged industrial radiography units and old reactor fuel rods can also cause significant local radiation hazards.



Basically, the principal type of dirty bomb, or Radiological Dispersal Device (RDD), combines a conventional explosive, such as dynamite, with radioactive material. In most instances, the conventional explosive itself would have more immediate lethality than the radioactive material. At the levels created by most probable sources, not enough radiation would be present in a dirty bomb to kill people or cause severe illness. For example, most radioactive material employed in hospitals for diagnosis or treatment of cancer is sufficiently benign that about 100,000 patients a day are released with this material in their bodies.

However, certain other radioactive materials, dispersed in the air, could contaminate up to several city blocks, creating fear and possibly panic and requiring potentially costly cleanup. Prompt, accurate, non-emotional public information might prevent the panic sought by terrorists .

A second type of RDD might involve a powerful radioactive source hidden in a public place, such as a trash receptacle in a busy train or subway station, where people passing close to the source might get a significant dose of radiation.

Impact of a RDD The extent of local contamination would depend on a number of factors, including the size of the explosive, the amount and type of radioactive material used, and weather conditions. Prompt detectability of the kind of radioactive material employed would greatly assist local authorities in advising the community on protective measures, such as quickly leaving the immediate area, or going inside until being further advised. Subsequent decontamination of the affected area could involve considerable time and expense.

What People Should Do Following an Explosion Move away from the immediate area--at least several blocks from the explosion--and go inside. This will reduce exposure to any radioactive airborne dust.

- Turn on local radio or TV channels for advisories from emergency response and health authorities.
- If facilities are available, remove clothes and place them in a sealed plastic bag. Saving contaminated clothing will allow testing for radiation exposure.
- Take a shower to wash off dust and dirt. This will reduce total radiation exposure, if the explosive device contained radioactive material.
- If radioactive material was released, local news broadcasts will advise people where to report for radiation monitoring and blood and other tests to determine whether they were in fact exposed and what steps to take to protect their health.

The Worst Case Scenario for a Radiological Dispersion Device (RDD)
In a couple of words……Powdered ^{137}Cs. It is a very fine powder and could be easily dispersed and would require a huge clean up effort.

A dirty bomb is in no way similar to a nuclear weapon. The presumed purpose of its use would be therefore not as a Weapon of Mass Destruction but rather as a Weapon of Mass Disruption.

RESPONSE TO A RDD

Unlike a nuclear detonation, RDDs are likely to affect relatively small areas **(several city bocks),** and the most effective protection is to leave the affected area. Do not shelter-in place. If there is a possibility that the suspected device has explosives attached, it should be treated as a bomb. Do not reenter the contaminated area. Individuals evacuating a contaminated area should be decontaminated immediately and seek medical attention. Decontamination is most easily achieved by simply taking a shower, washing effectively, and changing into clean clothing.

Do not use Potassium Iodide (KI). Use of potassium iodide: KI is an antidote almost exclusively used in the aftermath of reactor incidents. ***KI only counters the effects of radioactive iodine internally ingested or inhaled.***

Unfortunately radioactive materials can range from conventional weapons isotopes, to materials used in medical and industrial processes. KI should be administered only by health professionals and only if the radiation contamination is identified as being radioactive iodine. With the radioactive isotope unknown, KI administration is not recommended. Potassium iodide, without the presence of radioactive iodine, will cause negative health effects in certain groups of people. Radioactive iodine is very difficult to obtain, and is not considered a likely isotope to be used in an RDD incident.

The area impacted during the emergency phase by an explosive Radiological Dispersion Device (RDD) where acute health effects are possible, as well as lesser affected areas that have levels of contamination that meet or exceed the criteria of 10–50 mSv for evacuation (U.S. EPA 1992), can be assumed to be bounded within a 500 m radius (Harper et al. 2006) and might be considerably smaller, depending on the amount of radioactivity in the weapon and the kinetics of the explosive.

- If there is no knowledge of the size of the initial radiological source, or if it is known (from law enforcement intelligence sources earlier) that the device.
- contained a very large radiological source— greater than 370 Tbq (10,000 Ci)— establish a high zone boundary at 500 m in all directions from ground zero. Do not decide anything based on the perceived wind direction, especially in an urban setting where the wind field can be very complex. This boundary definition is consistent for both alpha and beta-gamma emitters;
- Evacuate the high zone to control the dose to the population therein. Control access to the high zone to limit the number of non-contaminated persons entering the most contaminated area and exclude nonessential people;
- Confirm the outer boundary of the high zone when the actual 10 mSv h_1 line is determined from instrument readings. In most cases, this will be much closer to the source than 500 m;
- Define the outer boundary of the high zone at 10 mSv hr_1 because this has the advantage of establishing the point where emergency personnel can stay, unrestricted, for 4–5 h without exceeding 50 mSv from external exposure, unless a more pragmatic location further away reduces the dose rate to As Low As Reasonably Achievable (ALARA). But, for saving lives and protecting critical infrastructure, 10 mSv h_1 is an acceptable radiation level if occupancy near this boundary is necessary for the first few hours of the crisis. (Note: Even though the outer boundary of the high zone is recommended at the 10 mSv h_1 boundary, ballistic fragments or isolated high spots that greatly exceed 10 mSv h_1 could be located inside or outside the zone. For example, 60Co in metallic form tends to fracture into large pieces and partially aerosolize (Harper et al. 2006);
- If it is known (from prior law-enforcement intelligence) that the source is smaller than 370 Tbq (10,000 Ci), establish the initial high zone boundary at 250 m without waiting for measurements from instrumentation;
- Once the high zone is defined, establish the outer boundary of the medium zone where the radiation level is in the range of 0.01- 0.1 mSv h^{-1}. Definition of this boundary with this range gives first responders flexibility to set up the outer boundary of the medium zone at the most pragmatic locations, rather than being tied to an explicit exposure rate, i.e., 0.02 mSv h^{-1}. The inner boundary of the medium zone, <10 mSv h^{-1}, is the outer boundary of the high zone. The low zone is defined outside of the outer boundary of the medium zone such that occupancy time is unrestricted for the first responders;

Radiological Dispersion Device (RDD) Triage and Decontamination. Triage and decontamination strategies should be developed separately from those used for chemical and biological agents. For the more probable scenarios, expect that the victims' clothes or bodies will not be dangerously contaminated, nor will they have inhaled enough radioactivity to cause acute health effects. *This is in contrast to chemical or biological agents where the material still present on the victims could be immediately dangerous to them or others with whom they will subsequently have contact upon returning home or elsewhere*.

> **Herat, Afghanistan**—Based on evidence uncovered in Herat, including detailed diagrams and documents stored on computers, British intelligence agents and weapons researchers conclude that Al Qaeda has succeeded in constructing a small dirty bomb, though the device has not been found. Officials do not know how much radiation the dirty bomb could spread, but they suspect that Afghanistan's Taliban regime helped Al Qaeda build the device by providing radioactive sources from medical devices. Furthermore, Abu Zubaydah, the captured Al Qaeda lieutenant now in American custody, told interrogators that such a device existed. In Kabul, in April 2002, IAEA experts secured several powerful unguarded radiation sources, mainly cobalt, once used in medical and research applications.

While medically significant levels of contamination are not expected in the general population of uninjured contaminated persons, a small subgroup of high zone evacuees or some of the injured/contaminated victims possibly will need prompt decontamination due to potential acute effects from high skin contamination, and/or medical intervention to mitigate an inhalation exposure that could lead to acute health effects, i.e., acute pneumonitis may result from an alpha emitter, or hematopoietic syndrome from 137Cs:

- If possible, pre-plan to triage those who need decontamination at exits as far away from contaminated areas as practical;
- Pre-position radiological monitors at exits; and
- Assure that exit points are in areas of relatively low background, less than or equal to twice background, or at most, approximately 0.5 _Sv h^{-1}. First, separate those people who need medical consideration from those who do not (as practical).
- Assume that a person is not likely to have received a significant dose from inhalation without presenting gross external contamination at triage.
- Separate from all others those persons with upper body contamination, particularly of the shoulder, head, and hair.
- Assume that individuals with contamination only on lower portion of the body
- crossed the contaminated zone but were not exposed to the passing plume and did not inhale high airborne radioactivity concentrations. People with significant upper body contamination may require evaluation for follow-up medical treatment because they may have inhaled excess amounts of radioactive material.

- With help from the media, the responders can seek those persons who were outdoors in the high zone, determined by its actual radiological footprint, but were not seen at a triage station. These two subgroups of people need to be evaluated promptly; they probably do not pose an urgent medical emergency, but should be treated as a medical emergency.

Radiological Dispersion Device (RDD) Personal Protective Equipment (PPE) For First Responders because the initial plume will pass beyond the high zone in 10–15 min, most first responders will not be exposed to high airborne concentrations of particulates because they will arrive after it has passed or first encounter the plume downstream when concentrations have become diluted. Therefore, because the remaining levels of airborne radioactivity along with any additional contribution from re-suspension will be relatively low, the PPE requirements, as a minimum, are as follows:

- Uniform;
- Goggles;
- Gloves of any type; and
- Half-face air purifying respirator (APR) (most responders typically use a full-face one that affords more protection).

Supplied air respirators (Level A and B) are excessive for this level of hazard.

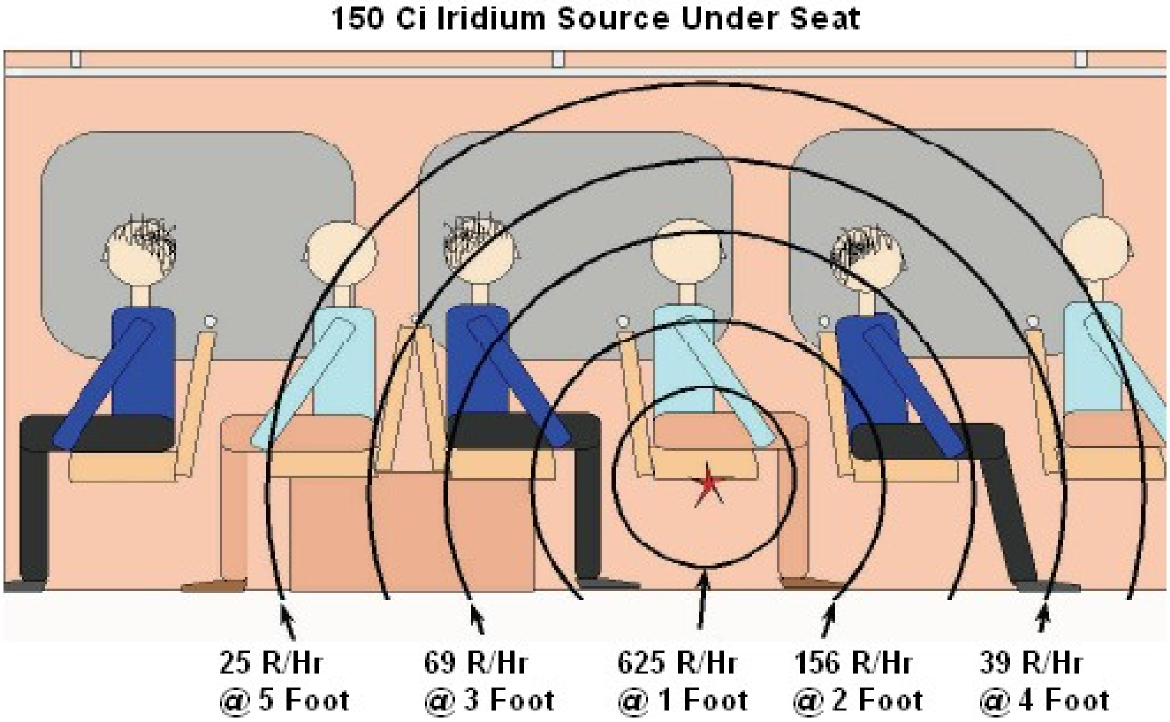
Argun, Chechnya— December 1998 The head of the Russian-backed Chechen Security Service, Ibragim Khultygov, announces that a Security Service team has found a container filled with radioactive materials and attached to an explosive mine hidden near a railway line. They safely defuse the bomb but do not identify the radioactive substances involved. The location of the discovery—in a suburban area 10 miles east of the Chechen capital of Grozny, where a Chechen rebel group is known to operate an explosives workshop—leads nuclear specialists to suspect Chechen rebels' involvement in the incident. Shamil Basayev, the rebel leader who phoned in the dirty-bomb threat in Moscow three years earlier, is the known chief of the explosives workshop near Argun

RADIOLOGICAL EXPOSURE DEVICE (RED)

terrorists could choose to use radiological exposure device could employ radioactive sources that are stolen from industrial facilities or from hospitals. These devices could have the potential to expose people to lethal doses of radiation by hiding the source in a public place, or in a mass transit system, on a sports arena or on board a luxury liner. Tens to hundreds of people could present with symptoms of acute radiation syndrome. Thousands more could require medical or exposure monitoring. This scenario actually happened an accidental incident in Goiânia, Brazil, in 1987.

An RED causes exposure but NOT contamination. The exposure dose and specific effect on people would depend on:

- Source properties: isotope, activity, amount
- Proximity of each person to the source
- Length of time people were in proximity to the source
- Whether a person's whole body or only a portion of the body received exposure



Goiania, Brazil, Sept 13, 1987, is the best characterized of radiation accidents giving a clear picture of medical and public health response. A private radiotherapy institute moved to new premises, leaving behind a teletherapy unit containing a Cs-137 source, without notifying authorities and without securing the site. During site demolition, the unit was partly demolished. Two people entered the premises to search for scrap metal and removed the source assembly, taking it home to try to dismantle it. In the attempt, the source capsule ruptured. Public health authorities became aware that a radiation accident may have occurred when one of the victims, making a connection between the illnesses and the source capsule, took the source remnants to the municipal public health department; this action set into play the medical response and remedial actions. Twenty people were identified by medical triage as needing hospitalization. Triage was performed in a soccer stadium in which 112,800 people were monitored from September 30 through December 21, 1987. 249 people were internally or externally contaminated (skin and/or clothing) and 2000 sq m of the environment was contaminated. Four people died within four weeks of hospital admission. Estimated dosages received ranged from 4.5-6.0 Gy (total body dose, independently estimated based on cytogenetics). Two people survived such a dosage.

Remedial actions: Authorities brought all potential sources of contamination under control, first, which took three days, then took actions to bring back normal living conditions, which took until March 1988. Radiation surveys on foot and by car and airplane were conducted to determine and monitor the areas of contamination. Sampling of air, food and fruit, soil, groundwater, sediment, river water, and drinking water took place. Environmental contamination necessitated evacuation of 41 residences, demolition of seven homes, and removal of large amounts of soil by heavy machinery. Waste was placed first into temporary planned waste storage then moved to permanent planned storage. The total volume of waste was 3500 cubic meters, more than 275 truckloads. Heavy rain that fell between Sept 21 and 28 complicated the response by dispersing cesium further into the environment rather than washing it away; radioactive materials were found to be deposited on roof tops after the rainfall.

Unit 5 Study Questions:

1. In most instances, detonation of an Radiological Dispersion Device (RDD) the

   a. conventional explosive itself would have more immediate lethality than the radioactive material,
   b. not enough radiation would be present to kill people or cause severe illness,
   c. could contaminate up to several city blocks, creating fear and possibly panic and requiring potentially costly cleanup
   d. a, b only
   e. a, b, and c

2. An Radiological Dispersion Device (RDD) is <u>any</u> dispersal device causing purposeful dissemination of radioactive material across an area without a nuclear detonation.

   a. True b. False

3. Following a dirty bomb detonation the extent of local contamination would depend on a number of factors, including:

   a. the size of the explosive,
   b. the amount and type of radioactive material used,
   c. weather conditions
   d. a and b only
   e. a, b, and c

4. Following a Radiological Dispersion Device (RDD) Explosion people should do all of the following <u>except</u>:

   A. Move away from the immediate area--at least several blocks from the explosion--and go inside. This will reduce exposure to any radioactive airborne dust.
   b. Turn on local radio or TV channels for advisories from emergency response and health authorities.
   c. Use of potassium iodide: KI is an antidote used to counter ingested radioactive iodine.
   d. If facilities are available, remove clothes and place them in a sealed plastic bag. Saving contaminated clothing will allow testing for radiation exposure.
   e. Take a shower to wash off dust and dirt. This will reduce total radiation exposure, if the explosive device contained radioactive material.

5. Which statement(s) concerning a Radiological Dispersion Device (RDD) and a Radiological Exposure Device (RED) are true?

   a. A RDD is dispersed by an explosion

b. RDD and RED both cause exposure
c. A RDD causes contamination
d. a, b, and c
e. a, and c only

6. Exposure-dose and toxic-effects of a Radiological Exposure Device (RED) would depend on all <u>except</u>:

   a. (Source properties) isotope, activity, amount
   b. (Area) how large of an area the “blast” dispersed the source.
   c. (Time) Length of time people were in proximity to the source
   d. (Distance) Proximity of each person to the source
   e. (shielding) Whether a person's whole body or only a portion of the body received exposure.

UNIT 6
MONITORING EQUIPMENT

PORTAL MONITORS

Portal monitors can detect gamma contamination on an individual or any item passing through it. They are better suited for detecting higher energy gamma emitters, and is not well suited for detection of beta emitters, especially low energy ones. Most alpha emitting radionuclides cannot be detected with portal monitors. The requirements in "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in support of Nuclear Power Plants" NUREG-0645 FEMA-REP-1 Rev 11 (REP-1) should be used for establishing criteria for MDA for these instruments. [30]

Using REP-1 a portal monitor (stand-alone whole-body personal contamination monitor) used to monitor individuals exposed or potentially exposed to a plume of radioactive material must have the capability to detect one microcurie (µCi) of radionuclides that emits beta and gamma radiation (radionuclides such as those that may be released following a reactor accident) in the form of surface contamination with a widespread non-uniform distribution over an individual.

This current detection limit guidance is based on a 1 µCi of Cs-137. This criterion assumes a release involving fresh fission products from a reactor accident; however, more restrictive criteria could be considered to account for radiological event involving a mixture of beta-gamma emitters without the more easily detectable gamma emitters. [30]

PORTABLE INSTRUMENTS

The primary purpose for performing radiological surveys is to determine the extent of any existing health hazards, establish protective control boundaries, and provide data on which to base decontamination requirements.

Portable instruments are designed for detecting beta and alpha emitters. Consideration should be given to instruments with both alpha and beta detection capabilities for releases involving both types of radiation.

radiological surveys The types of radiological surveys that can be performed on-scene are "area surveys," "personnel surveys," and "equipment surveys." Each of these surveys have a different purposes, and is performed for different reasons. The differences between the survey types are:

> ***Area surveys* may involve the determination of fallout patterns on the ground, levels of airborne activity, or contamination patterns to establish hazard control zones.** Area surveys are normally done once the HazMat technician has gathered information from the appropriate agency/agencies about what is happening

---

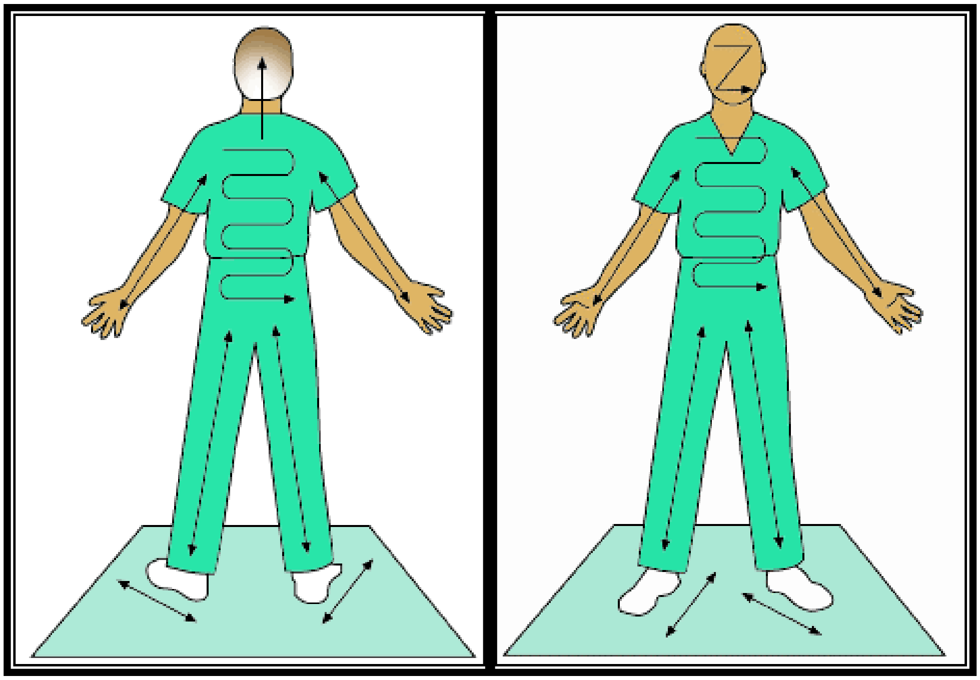
on-scene, and spoken with those at the command center about any information they have regarding the incident.[30]


A terrified child confronts a radiation survey meter in Goiânia, Brazil.

***Personnel surveys* are performed to detect the presence of contaminated material on the body's surface, in body openings (e.g., nose and ears), or, in the case of casualties with traumatic injury, contamination in wounds.** The results of personnel surveys are used to evaluate health hazards, to establish decontamination requirements, and determine the level of medical treatment. Equipment/material surveys are conducted primarily to ascertain requirements for decontamination.

Personnel Contamination Survey Procedures

In performing a "personnel survey" the individual to be monitored stands with legs spread and arms extended. The responder should begin the survey at the head, subsequently surveying the upper trunk, arms, lower trunk, and legs. The individual being surveyed is asked to turn to the back, and the procedure is repeated. As in equipment and area surveys, care must be taken not to permit the detector probe to touch any potentially contaminated surfaces.


Personal Contamination Survey Procedure. (Public Monitoring Needs Guidelines, Bechtel Remote Sensing Laboratory, DOE, NNSA)

Personnel Contamination Survey Procedures (continued):

It is not necessary to perform the personnel contamination survey in exactly the order shown in the Sample Personnel Contamination Survey Procedure, but a consistent procedure should be followed to help prevent accidentally skipping an area of the body. Tell the person to stand erect, with feet spread slightly, and arms extended with palms up and fingers straight out. Pause the probe for about five seconds at locations most likely to be contaminated.

- Top and sides of head, face (pause at mouth and nose for approximately five seconds; this may indicate internal contamination)
- Front of the neck and shoulders
- Arms (pause at each elbow)
- Hands (pause at palms for approximately five-seconds)
- Chest and front abdomen
- Front of the legs (pause at each knee)
- Shoe tops
- Have the person being surveyed turn around
- Back of the head and neck
- Back of Arms (pause at each elbow)
- Back of Hands (pause at palms for approximately five-seconds)
- Back and rear of abdomen (pause at the seat of pants)
- Back of the legs (pause at the knees)
- Shoe bottoms (pause at sole and heel)

Return the probe to its holder on the meter when finished. **Do not** set the probe down on the ground. **The probe should be placed in the holder with the sensitive side of the probe facing to the side or facing up so that the next person to use the meter can monitor his/her hands before handling the probe.**

The most common mistakes made during the survey are:
- Holding the probe too far away from the surface (should be about ½ inch or less)
- Moving the probe too fast (should be about one-probe diameter per second or 1 to 2 inches per second)

Potential Portable Instrument Problems for Responders When instruments have not been used for an extended period of time, a battery check should be performed. Additionally, a check of the overall condition of the instrument is warranted. The only way to be confident that an instrument is performing correctly is to response check the instrument to a known source of radiation (e.g., a small radiation check source provided by the instrument manufacturer). If the instrument responds within ±20% of a previously performed response check, then a certain degree of confidence can be placed with the performance of the instrument.

Radiation meters should be checked and calibrated annually by a certified calibration lab to ensure the equipment is operational and giving correct readings. As radiation detectors age, some of the components deteriorate. If an instrument has been on a shelf, untouched, for ten years, do not rely on those meters. They may not work at all, or they may read twice or half the actual radiation levels, etc.

Vehicle or Portal Monitoring Vehicle monitoring systems for beta/gamma radiation is available in a configuration similar to that of personal portal monitors. In fact, some personal portal monitors can be configured to monitor vehicles (with less sensitivity). Vehicle monitoring could be a large part of a response if the public uses their own vehicles to evacuate or if major roadways are affected. Additional sets of vehicle monitors should be obtained, with portable instruments used as backups. Four sets should be considered, as this would allow monitoring of two roadways (one monitoring system on each end).

> ***Beta-gamma monitoring*** Portal monitors may be used when the gamma component of the contamination is adequate for easy detection. For aged fission products, release surveys can only be performed using hand-held contamination monitors and require long monitoring times. During an emergency, surveying a vehicle will take lower priority than addressing other contamination issues such as contaminated personnel.
>
> ***Alpha monitoring*** The range of alpha radiation prohibits the use of portal monitoring. Portable instruments will be required for alpha radiation monitoring. Vehicles will have to be held until later stages of the event when resources can be devoted to this effort. If the contamination includes known gamma emitters, the alpha contamination level can be inferred from the gamma monitoring results provided by portal monitors.

Monitoring of Personal Property Though people are encouraged to minimize personal possessions brought out during evacuation, some personal effects monitoring will be required. Current technology will require portable survey of these effects. However, technology exists which could allow automation with minimal effort (similar to inspection conveyors at airports). This type of system should be developed for beta/gamma radiation monitoring. The range of alpha radiation would make a similar system for alpha monitoring much more challenging.

> ***Clothing*** Contaminated clothing should be removed and replaced with clean clothing. This requires supplies of clean clothing to be available or easily purchased. Replacement of outer clothing may be adequate for removing most of the contamination in all but the most severe cases. Plans should be made before the event regarding the procurement of replacement clothing for persons exiting a contaminated area. One method of providing replacement clothing would be to request assistance from department stores, sporting goods distributors, hospitals, and other organizations that may have abundant supplies of clothing for outfitting large numbers of people.

Glasses/dentures/prostheses/jewelry, etc. Glasses, contact lenses, dentures, prostheses, jewelry and other essential personal items can be monitored using a small article monitor or tool monitor relying on scintillation detectors for detection of gamma emitters. The return of some personal items to individuals may be essential, after an initial decontamination procedure.

Tools and other hand-carried items Laptop computers, family keepsakes, and photographs may be carried by individuals evacuating an event site. Items exhibiting extensive contamination with alpha or beta emitters will probably have to be bagged and set aside until resources are allocated for monitoring these items. During the evacuation, these items will be collected for later survey. Some means of identifying the items should be implemented to facilitate getting them back to the owner after being surveyed. Cell phones, laptop computers, and other small items may be monitored with portable instruments or small article monitors and/or decontaminated by sanitary wipes if the contamination levels permit.

Medications Persons on prescription medication such as insulin, heart medication, blood pressure medication and other critical medications would be expected to bring their medications with them. In cases where the event site cannot be reentered and the medicine is needed, the local public safety agency will need the ability to quickly procure and distribute critical medications. For medications, which are not readily available, the medication taken from the event site may be decontaminated as long as it was contained within the sealed prescription bottle during the time of the release.

Monitoring and Decontamination of Pets and Animals Evacuees are typically instructed to leave their pet with a three-day supply of food and water. It is anticipated that many people will want to take these “member of their family” with them. Even if they do not, there will be a significant re-entry demand after three days.

Monitoring for gamma emitters can be accomplished using portal monitors or hand-held portable survey instruments. Beta and alpha emitters may require the use of hand-held portable instruments. Surveys times for animals may have to be delayed due to other priorities (citizen treatment) and the difficulty of keeping the animals still and the possibility of contamination being hidden within the hair.

In addition, farm animals may also need to be surveyed at some point. These animals may not cooperate in using standard portal monitors or handheld survey methods.

DOCUMENTATION

A means of documenting the individual and property surveys and results will need to be implemented. When surveying large numbers of people, vehicles, pets and or personnel property the task of documenting survey results will undoubtedly become burdensome. Preplanning needs to occur to determine how surveyed individuals will be tracked. One suggestion would be to use driver's license numbers, student ID numbers, or in the case of children, a number associated with the parent or guardian for each child. For individuals without readily available identifiers, other means of tracking the people will have to be implemented. In these cases, taking the individual's name, date of birth, place of birth, address, and phone number should be adequate for uniquely identifying that individual. This will be necessary if follow-up or verification needs to be performed.

Unit 6 Study Questions

1. Portal monitors are best suited for which of the following radiation exposure measurements.

    a. Gamma emitters
    b. Beta emitters
    c. Alpha emitters
    d. Neutron emitters

2. The primary purpose for performing radiological surveys is to:

    a. determine the extent of any existing health hazards,
    b. establish protective control boundaries,
    c. provide data on which to base decontamination requirements
    d. all of the above

3. *“Area surveys”* may involve the determination of:
    a. fallout patterns on the ground
    b. levels of airborne activity
    c. contamination patterns
    d. all of the above

4. “*Personnel surveys”* are performed to detect the presence of contaminated material on the body’s surface, in body openings (e.g., nose and ears), or, in the case of casualties with traumatic injury, contamination in wounds.

    a. True
    b. False

UNIT 7
HEALTH EFFECTS OF IONIZING RADIATION

Medical providers must be prepared to adequately treat injuries complicated by ionizing radiation exposure and radioactive contamination. Nuclear detonation and other high-dose radiation situations are the most critical (but less likely) events as they result in acute high-dose radiation.

Acute high-dose radiation occurs in three principal situations:

1. **A nuclear detonation** which produces extremely high dose rates from radiation during the initial 60 seconds (prompt radiation) and then from the fission products in the fallout area near ground zero.
2. **A nuclear reaction** which results if high-grade nuclear material were allowed to form a critical mass (“criticality”) and release large amounts of gamma and neutron radiation without a nuclear explosion.
3. **A radioactive release** from a radiation dispersal device (RDD) made from highly radioactive material such as ^{60}Co or ^{137}Cs which can result in a dose sufficient to cause acute radiation injury.

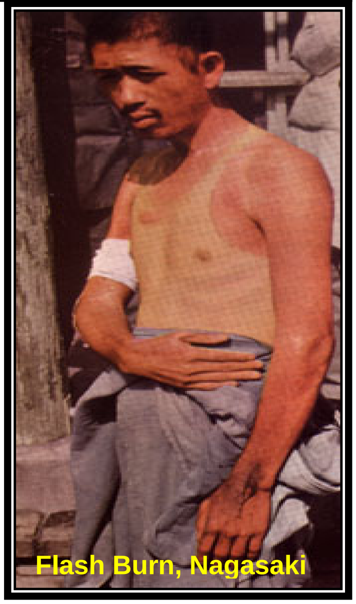
In a nuclear disaster, triage decisions cannot be made on the evidence or probability of conventional injury alone. When significant radiation exposure is combined with conventional injuries, there may be a dramatic shift of patients to the expectant category (Table III-1). In order to make an appropriate decision, the triage officer must recognize the symptoms of ARS and understand the difficulties in estimating radiation exposure from clinical findings.

Cutaneous Phenomena. Information about the cutaneous changes after ionizing radiation exposure comes mainly from accidental or therapeutic high-dose local radiation exposures and, to a lesser extent, from studies of the victims of the 1986 nuclear reactor accident in Chernobyl, USSR, and the 1987 cesium-137 accident in Goiânia, Brazil. Skin injury in those events resulted from very intense local irradiation or direct contact of the skin with radioactive material. Burns among casualties at Hiroshima and Nagasaki in 1945 were caused by heat rather than radiation exposure.

Gastrointestinal Phenomena. A sense of fatigue and malaise associated with nausea and loss of appetite is characteristic even of relatively low-dose radiation exposure (1-2 Gy). The abrupt onset of nausea and vomiting occurs with acute high-dose radiation in the range of 5-10 Gy. These initial symptoms may be followed by a short latent period of 1-2 days. The severity of initial symptoms, including diarrhea, serves as a useful index of probable outcome, as does the rapidity of onset or a delay in the appearance of symptoms. Following the latent period, an increase in vomiting, diarrhea, and anorexia, as well as dehydration and signs of infection, can be expected. An abrupt onset of bloody diarrhea after acute high-dose radiation indicates lethal exposure. If less-acute doses are received, diarrhea may not appear for several days or a week after exposure. The onset of diarrhea within a week of exposure is usually associated with death.

Burn Injury. Burns are judged by the size of the burn in relation to the whole body and by the depth of the burn injury. Different methods exist to calculate the extent or size of a burn injury. The most common method, which provides a quick estimate of burn size, uses the "Rule of Nines," where the body is divided into areas equaling multiples of nine percent of the total body surface area. The palm of your hand, for example, is equal to about one percent of your body's surface area. The head and arms are each equal to nine percent of the body surface. The chest and back are each 18 percent (two X nine percent). Each leg is 18 percent (two X nine percent). This totals 11 nines, or 99 percent. The heads of infants and small children are in relatively larger proportion to the total body surface area, and the limbs are in smaller proportion than adults limbs. The total body surface area of a burn is referred to as TBSA. The TBSA and burn depth analysis are recorded on a hospital chart known as a "burn diagram." Determining the percent of body surface area burned is important for correct fluid replacement. A more severe hematopoietic subsyndrome is likely if partial- thickness burns involve more than 10% of the body surface.


Beta burns from radioactive fallout


Flash Burn, Nagasaki

Blast Injury. Dynamic overpressure from the explosion of a nuclear weapon will induce overt crush injuries and occult internal bleeding. The triage officer should suspect occult traumatic injuries, which will likely place the irradiated patient in the expectant category.

- Direct overpressure and Crushed building victims
- Air cavity injuries (e.g., ear, lung, gut)
  - ruptured viscera (organs)
  - alveolar hemorrhage

  - pulmonary edema
- Dynamic pressure (nuclear winds) Translational effects
  - Decelerative tumbling (fractures, lacerations)
  - Impact with a solid surface (blunt trauma)
- Missiling effects (e.g., projectiles, flying shards of glass)

Eye Injury. Eye injuries from a thermonuclear flash may be as minor as transient blindness (for a few seconds to minutes) or a permanent retinal scar in which peripheral vision is spared. These are minimal injuries. However, permanent foveal damage with 20/200 visual acuity may occur if the victim focuses directly on the nuclear fireball. A variety of eye injuries resulting primarily from protracted high-dose radiation exposure was observed among firefighters at the Chernobyl reactor accident. These injuries will most likely lead to permanently impaired vision.

TYPES OF RADIATION-INDUCED INJURY

Regardless of where or how an accident involving radiation happens, three types of radiation-induced injury can occur: external irradiation, contamination with radioactive materials, and incorporation of radioactive material into body cells, tissues, or organs.[13]

Irradiation is exposure to penetrating radiation. Irradiation occurs when all or part of the body is exposed to radiation from an unshielded source. *External irradiation does not make a person radioactive.*

External Irradiation External irradiation occurs when all or part of the body is exposed to penetrating radiation from an external source. During exposure this radiation can be absorbed by the body or it can pass completely through. A similar thing occurs during an ordinary chest x-ray. Following external exposure, an individual is not radioactive and can be treated like any other patient.

External irradiation can be divided into *whole-body exposures* or *local exposures*. In either case, the effective dose can be calculated, taking into account the attenuation of the body and the steep gradients of absorbed dose throughout the body.

Contamination The second type of radiation injury involves *contamination* with radioactive materials. Contamination means that radioactive materials in the form of gases, liquids, or solids are released into the environment and contaminate people externally, internally, or both. An external surface of the body, such as the skin, can become contaminated, and if radioactive materials get inside the body through the lungs, gut, or wounds, the contaminant can become deposited internally.

Incorporation The third type of radiation injury that can occur is *incorporation* of radioactive material. Incorporation refers to the uptake of radioactive materials by body cells, tissues, and target organs such as bone, liver, thyroid, or kidney. In general, radioactive materials are distributed throughout the body based upon their chemical properties. Incorporation cannot occur unless contamination has occurred.

These three types of exposures can happen in combination and can be complicated by physical injury or illness. In such a case, serious medical problems always have priority over concerns about radiation, such as radiation monitoring, contamination control, and decontamination.

Deterministic effects: effects that can be related directly to the radiation dose received. The severity increases as the dose increases. A deterministic effect typically has a threshold below which the effect will not occur.

Stochastic effect: effect that occurs on a random basis independent of the size of dose. The effect typically has no threshold and is based on probabilities, with the chances of seeing the effect increasing with dose. If it occurs, the severity of a stochastic effect is independent of the dose received. Cancer is a stochastic effect.

ACUTE RADIATION SYNDROME (ARS)

Radiation sickness, known as acute radiation syndrome (ARS), is a serious illness that occurs when the entire body (or most of it) receives a high dose of radiation, usually over a short period of time. Many survivors of the Hiroshima and Nagasaki atomic bombs in the 1940s and many of the firefighters who first responded after the Chernobyl Nuclear Power Plant accident in 1986 became ill with ARS.

People exposed to radiation will get ARS **only if**:

- The radiation dose was high (doses from medical procedures such as chest X-rays are too low to cause ARS; however, doses from radiation therapy to treat cancer may be high enough to cause some ARS symptoms),
- The radiation was penetrating (that is, able to reach internal organs),
- The person's entire body, or most of it, received the dose, and
- The radiation was received in a short time, usually within minutes.

The first symptoms of ARS typically are nausea, vomiting, and diarrhea. These symptoms will start within minutes to days after the exposure, will last for minutes up to several days, and may come and go. Then the person usually looks and feels healthy for a short time, after which he or she will become sick again with loss of appetite, fatigue, fever, nausea, vomiting, diarrhea, and possibly even seizures and coma. This seriously ill stage may last from a few hours up to several months.

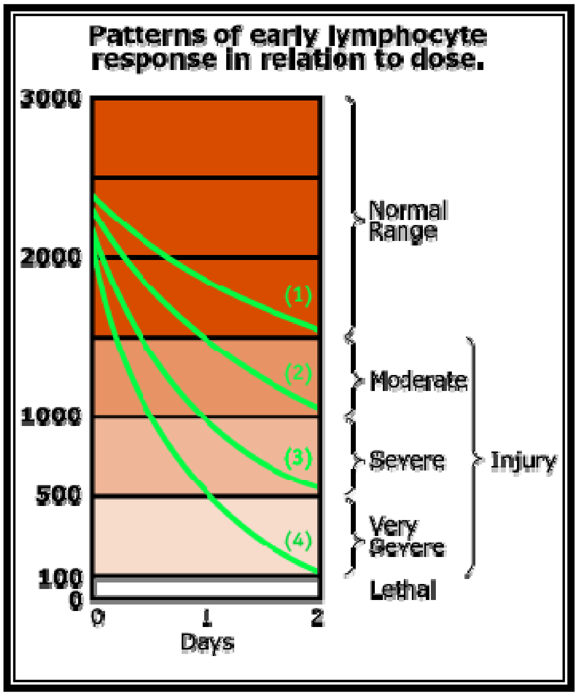
People with ARS typically also have some skin damage. This damage can start to show within a few hours after exposure and can include swelling, itching, and redness of the skin (like a bad sunburn). There also can be hair loss. As with the other symptoms, the skin may heal for a short time, followed by the return of swelling, itching, and redness days or weeks later. *Complete healing of the skin may take from several weeks up to a few years depending on the radiation dose the person's skin received.*

The chance of survival for people with ARS decreases with increasing radiation dose. Most people who do not recover from ARS will die within several months of exposure.

The cause of death in most cases is the destruction of the person’s bone marrow, which results in infections and internal bleeding. For the survivors, the recovery process may last from several weeks up to 2 years.

The ARS is characterized by four distinct phases: a prodromal period, a latent period, a period of illness, and one of recovery or death.

During the prodromal period patients might experience loss of appetite, nausea, vomiting, fatigue, and diarrhea; after extremely high doses, additional symptoms such as fever, prostration, respiratory distress, and hyperexcitability can occur. However, all of these symptoms usually disappear in a day or two, and a symptom-free, latent period follows, varying in length depending upon the size of the radiation dose. A period of overt illness follows, and can be characterized by infection, electrolyte imbalance, diarrhea, bleeding, cardiovascular collapse, and sometimes short periods of unconsciousness. Death or a period of recovery follows the period of overt illness.
In general, the higher the dose the greater the severity of early effects and the greater the possibility of late effects.



According to the data presented in the paper, "Early Dose Assessment Following Severe Radiation Accidents," curve 1-4 correspond roughly to the following whole-body doses:

- curve 1 - 3.1 Gy;
- curve 2 - 4.4 Gy;
- curve 3 - 5.6 Gy;
- curve 4 - 7.1 Gy.

Nausea and vomiting due to radiation are seldom experienced unless the exposure has been at least 0.75 to 1 Gy (75-100 rads) of penetrating gamma or X-rays and it has occurred within a matter of a few hours or less. The prospective patient who has been asymptomatic within the past 24 hours will most certainly have had less than 0.75 Gy of whole-body exposure. Hospitalization generally will be unnecessary if the dose has been less than 2 Gy (200 rads).

Depending on dose, the following syndromes can be manifest:

- ***Hematopoietic syndrome*** - characterized by deficiencies of WBC, lymphocytes and platelets, with immunodeficiency, increased infectious complications, bleeding, anemia, and impaired wound healing.

- ***Gastrointestinal syndrome*** - characterized by loss of cells lining intestinal crypts and loss of mucosal barrier, with alterations in intestinal motility, fluid and electrolyte loss with vomiting and diarrhea, loss of normal intestinal bacteria, sepsis, and damage to the intestinal microcirculation, along with the hematopoietic syndrome.
- ***Cerebrovascular/Central Nervous System syndrome*** - primarily associated with effects on the vasculature and resultant fluid shifts. Signs and symptoms include vomiting and diarrhea within minutes of exposure, confusion, disorientation, cerebral edema, hypotension, and hyperpyrexia. Fatal in short time.
- ***Skin syndrome*** - can occur with other syndromes; characterized by loss of epidermis (and possibly dermis) with "radiation burns."

10 RESPONSE TASKS
for Hospital Emergency Room First Responders

Preparing for response to a radiological incident, healthcare facilities will most likely be required to carry out the following "10 basics of response." (as referenced in *Radiation and Life by, Eric J Hall*)

1. FIRST TREAT AND STABLEIZE

Assure medical staff that when an incident combines radiation exposure with physical injury, initial actions must focus on treating the injuries and stabilizing the patient.

2. BE READY TO MANAGE A CROWD

You or your hospital must be prepared to manage large numbers of frightened, concerned people who may overwhelm your treatment facility.

3. HAVE A PLAN TO ROUTE PATIENTS OFF SITE

You or your hospital must have a plan for distinguishing between patients needing hospital care and those who can go to an off-site facility.

4. SET-UP A RADIATION TREATEMENT AREA

You or your hospital must know how to set up an area for treating radiation incident victims in an ER.

5. DECONTAMINATE

You or your hospital should be aware that a good way to approach decontaminating a radioactively contaminated individual is to act as if he or she had been contaminated with raw sewage.

6. TAKE PRECAUTIONS

You or your hospital must know how to avoid spreading radioactive contamination by using a double sheet and stretcher method for transporting contaminated patients from the ambulance to the emergency treatment area.

7. HAVE A TREATMENT PLAN

You must know how to recognize and treat a patient who has been exposed to significant levels of radiation.

8. KNOW THE SIGNS AND SYMPTOMS

You should recognize the radiological findings of illness/injury caused by biological or chemical terrorist agents.

9. KNOW WHO TO CALL FOR SUPPORT

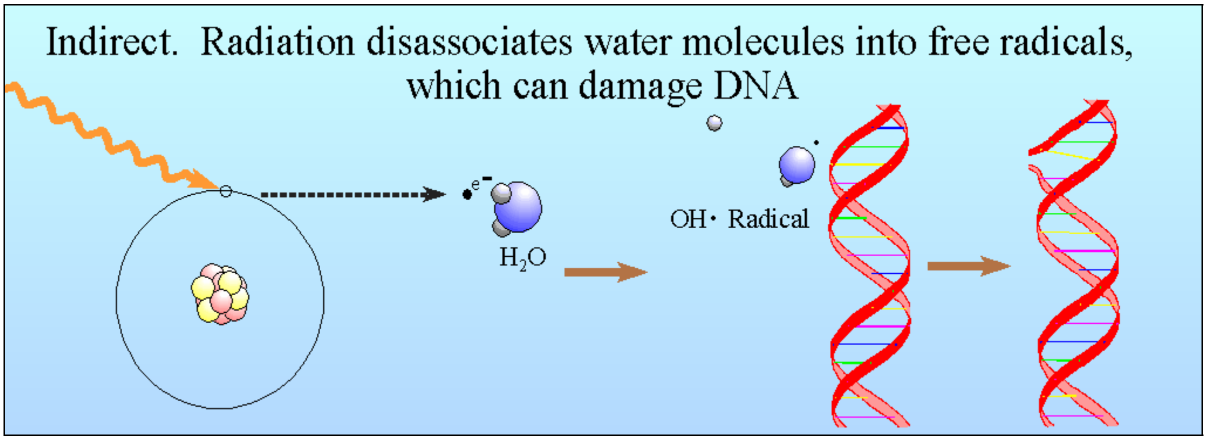
You should know what agencies or organizations to contact in the event of a radiation emergency and how to reach them.

10. PLAN FOR OFF SITE TRIAGE

You or your hospital must have a plan to evaluate and counsel non-injured patients exposed to radiation at a location outside of the hospital.

Table 7-1 Health Effects and Emergency Medical Conditions of Exposure to Radiation

	Pre Clinical	Clinical			Lethal	
Radiation Dose Range	25,000 to 100,000 mrem	100,000 to 200,000 mrem	200,000 to 600,000 mrem	600,000 to 1,000,000 mrem	1,000,000 to 35,000,000 mrem	over 35,000,000 mrem
Vomiting Incidents	None	5 to 50 %	50 to 100 %	100 %	100 %	100 %
Vomiting Delay Time	N/A	3 to 6 hours	2 to 3 hours	15 to 30 min	5 to 20 min	less than 3 min
Leading Organ	None	Bone Marrow, Blood System, Stomach and Intestinal System			Tiny Blood Vessels, Stomach and Intestinal System	Brain, Spinal Cord (Central Nervous System)
Signs	Mild Weakness	Reduced White Blood Cells	Destroyed White Blood Cells		Diarrhea, Fever	Convulsions, Tremors
Therapy	Reassurance	Blood System Restoration	Blood Transfusion Drubs, (Cytokines)	Bone Marrow Transplant	Maintain Electrolytes	Sedatives
Prognosis	Excellent	Excellent	Good	Poor	Death	Death
incidence of Death	None	0 to 5 %	15 to 80 %	80 to 90 %	Almost 100 %	100 %



Mammalian Cells Radio sensitivity

"Most" sensitive
- Spermatogonia
- Lymphocytes
- Hematopoietic stem cells
- Intestinal crypt cells

"Less" sensitive
- Myelocytes (e.g. RBC precursors)
- Epithelial cells (e.g. skin cells)

"Least" Sensitive
- Nerve Cells
- Muscle Cells

TREATMENT OF THE COMBINED INJURY PATIENT

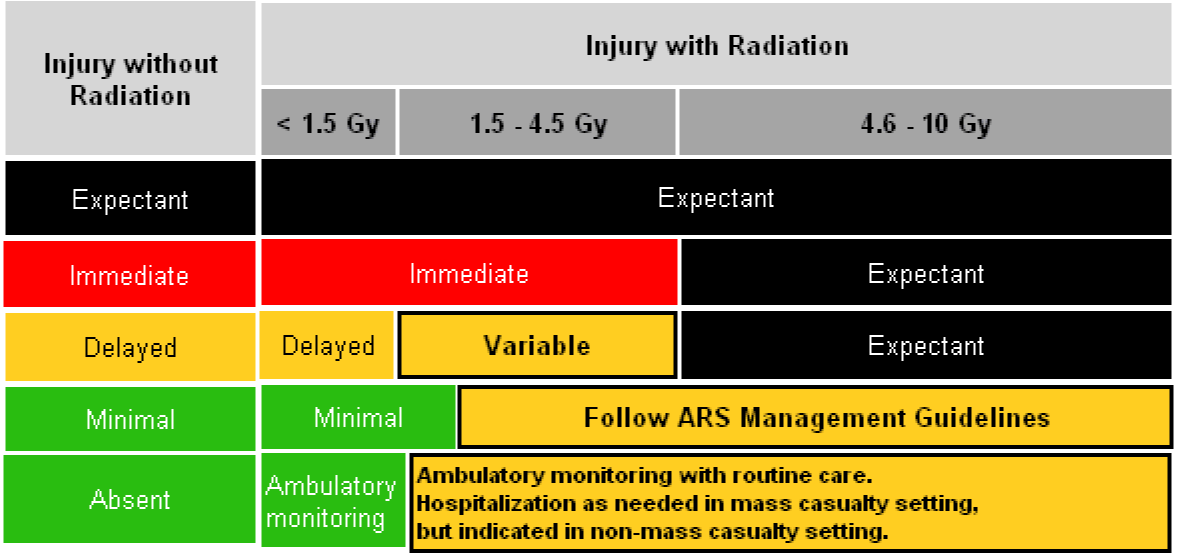
Combined injury is physical, thermal, and/or chemical trauma combined with radiation exposure at a dose sufficient to diminish the likelihood of overall survival or functional recovery.

Combined injury will be common in a radiation mass casualty event and the patients have a worse overall prognosis than do patients with trauma alone or radiation exposure alone

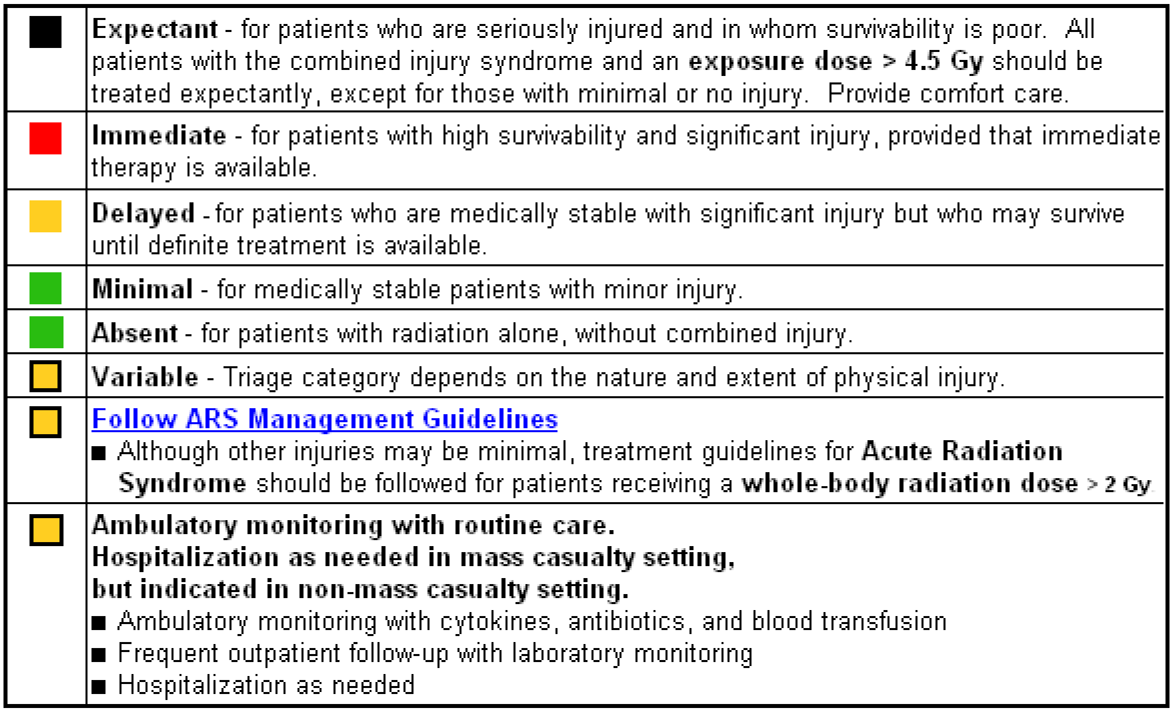
Treatment priorities in order are:
- Ensure the safety of the responders
- Evaluate and treat patients with life-threatening injuries
- Manage radiation issues, including internal and external contamination and exposure

There may be only a 24- to 36-hour window when surgery can be performed prior to the onset of cytopenias in the ARS combined injury patient. Use of hematopoietic growth factors (cytokines) may alter this time window. Close hematologic monitoring is required before and after surgery.

The Triage Categories with and without Combined Injury charts were adapted from Medical management of the acute radiation syndrome: “Recommendations of the Strategic National Stockpile Radiation Working Group” and “Medical Consequences of Nuclear Warfare” by HHS.

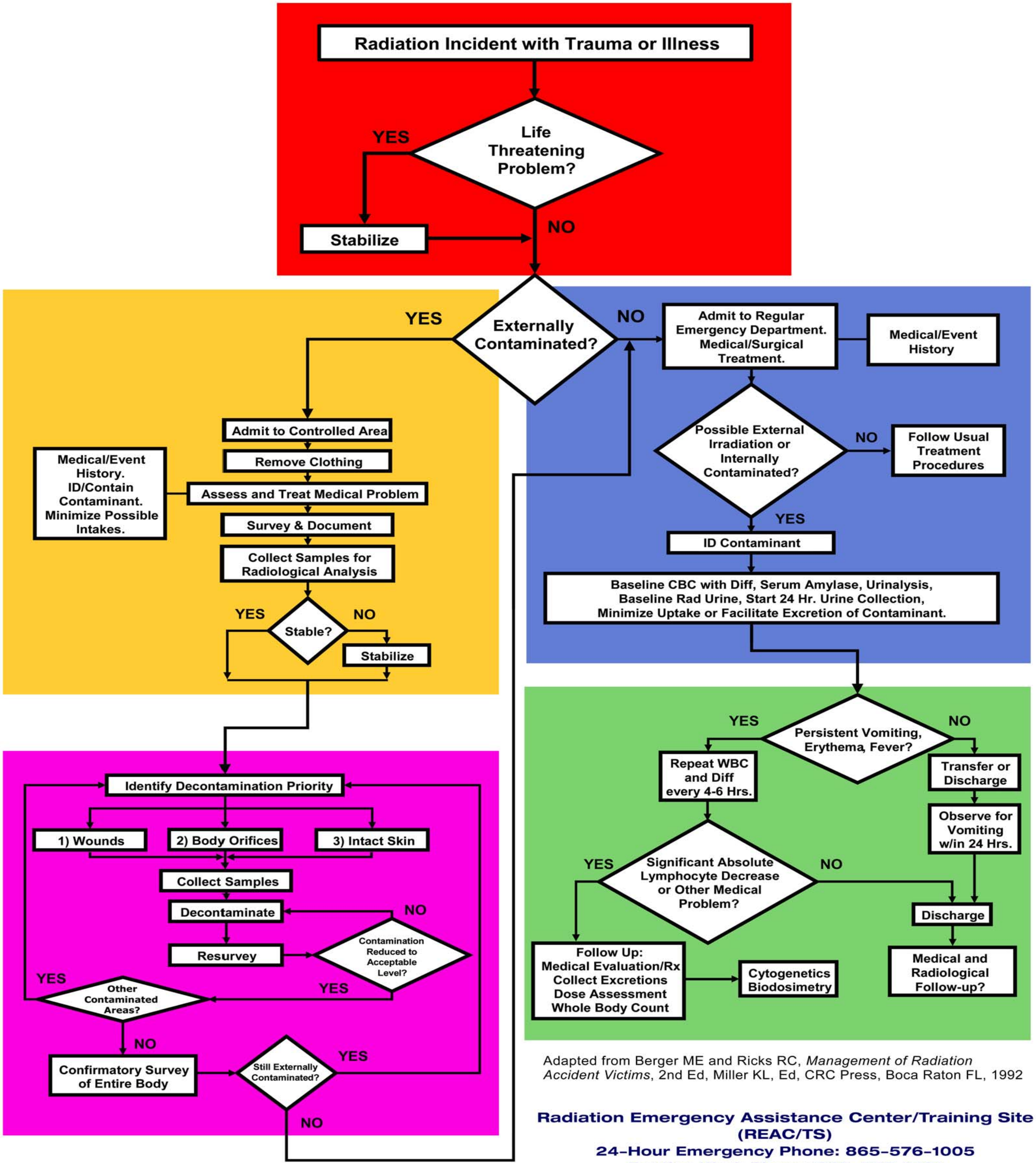


Injury without Radiation	**Injury with Radiation**		
	< 1.5 Gy	**1.5 - 4.5 Gy**	**4.6 - 10 Gy**
Expectant	Expectant		
Immediate	Immediate		Expectant
Delayed	Delayed	**Variable**	Expectant
Minimal	Minimal	**Follow ARS Management Guidelines**	
Absent	Ambulatory monitoring	**Ambulatory monitoring with routine care.** **Hospitalization as needed in mass casualty setting, but indicated in non-mass casualty setting.**	



⬛	**Expectant** - for patients who are seriously injured and in whom survivability is poor. All patients with the combined injury syndrome and an **exposure dose > 4.5 Gy** should be treated expectantly, except for those with minimal or no injury. Provide comfort care.
🟥	**Immediate** - for patients with high survivability and significant injury, provided that immediate therapy is available.
🟨	**Delayed** - for patients who are medically stable with significant injury but who may survive until definite treatment is available.
🟩	**Minimal** - for medically stable patients with minor injury.
🟩	**Absent** - for patients with radiation alone, without combined injury.
🟨	**Variable** - Triage category depends on the nature and extent of physical injury.
🟨	**Follow ARS Management Guidelines** ■ Although other injuries may be minimal, treatment guidelines for **Acute Radiation Syndrome** should be followed for patients receiving a **whole-body radiation dose** > 2 Gy
🟨	**Ambulatory monitoring with routine care.** **Hospitalization as needed in mass casualty setting,** **but indicated in non-mass casualty setting.** ■ Ambulatory monitoring with cytokines, antibiotics, and blood transfusion ■ Frequent outpatient follow-up with laboratory monitoring ■ Hospitalization as needed

Radiation Victim Treatment



Adapted from Berger ME and Ricks RC, *Management of Radiation Accident Victims*, 2nd Ed, Miller KL, Ed, CRC Press, Boca Raton FL, 1992

Radiation Emergency Assistance Center/Training Site (REAC/TS)
24-Hour Emergency Phone: 865-576-1005
Routine Work Phone: 865-576-3131
On the Web: www.orau.gov/reacts

RADIATION EMERGENCY AREA

The patient who is both contaminated and injured must be treated in the emergency department's Radiation Emergency Treatment Area where the patient can receive adequate medical care while the contamination is controlled. The Radiation Emergency Area is not necessarily a fixed location in the emergency department. It can be set up anywhere in the hospital, e.g., in the OR. It must always have an entrance, a treatment area, a buffer zone and an exit. The entire complex *must* be controlled. The flow of personnel, equipment and supplies is in one direction, from the clean part of the hospital into the controlled area. NOTHING and NO ONE leaves this area until properly surveyed for contamination. This includes blood samples, X-rays, etc.. Contamination that is not visible to the naked eye – dirt, liquid, etc. – will not have enough radioactivity to cause early or visible radiation injury to the patient or attendant, and late effects are likely to be negligible. An unhurried approach to decontamination also is influenced by the fact that radiation intensity decreases with the passage of time (Linnemann, 2001). With a survey meter, levels of contamination are measured in the following units:

MEDIAL STATISTICS FROM HIROSHIMA

- Hospitals: 3 out of 45 were functional (6.7%).
- Physicians: 59 out of 298 were functional; only 28 without significant injury (9.4%).
- Nurses: 1654 out of 1780 were casualties (92.9%).
- 10,000 injured patients went on their own or with assistance within 12 hours to the Red Cross Hospital (600 beds).
- In the biggest hospital, the Red Cross Hospital, only 6 out of 30 physicians were able to function. And only 10 out of 200 nurses were able to provide patient care.
- 70% of patients with combined injury.

RADIOLOGICAL DECONTAMINATION SHOULD NEVER INTERFERE WITH MEDICAL CARE.

Triage and disposition is challenging. For example, in the 1987 ^{137}Cs accident in Goiânia, Brazil, 8.3% of the first 60,000 people screened, presented with signs and symptoms consistent with acute radiation sickness: skin reddening, vomiting, diarrhea, etc. although they had not been exposed.

Mental Health professionals, ideally psychiatrists due to their background as physicians, should be an integral part of the teams that perform initial screening and triage. Referral to a mental health specialist is usually experienced as stigmatizing. The patient may feel that the physician has missed some important clue of contamination and is dismissing him prematurely.

WHY IT IS SAFE TO TREAT CONTAMINATED PATIENTS

The radioactive substance has been on the patient the whole time from the incident up through transport to the hospital. It is right on them, and maybe in them. There is nothing between their cells and the radioactive material. In contrast, responders and medical personnel will not be exposed to the contaminated patient for very long, will usually have most of their bodies at least at some distance from the patient, and will be shielded by substances between the patient and themselves, including the patient's own body, blankets, etc. It's essentially impossible for a patient to make it to the hospital alive if they are emitting enough radiation to be an immediate danger to the people treating them. That's why the radiation emitted by a contaminated patient poses no acute risks.

The radioactive materials on them can be harmful, but only if you absorb the materials into or onto yourself. The important things are to avoid contaminating yourself by practicing the same basic precautions you would for any other contaminant like blood, and to decontaminate the patients as soon as their condition allows it to be done safely.

DECONTAMINATION OF PERSONNEL AND CONTAMINATION MONITORING

Decontamination Line Setup Considerations The decon line should be established **uphill and upwind** from the event. The decon corridor should be established prior to the first responder being sent into the "hot" or contaminated area. What this means, essentially, is that there needs to be some forethought or preplanning about what should occur. The area should be surveyed, and the responder needs to focus on establishing a safe or uncontaminated area for the decon line. The next step that should occur is assembly of the decontamination crew and donning the necessary protective clothing.

Decon is simply the process of removing contamination from a victim. During the course of personnel (either ambulatory or nonambulatory) going through the decon line, the first responder must note the personnel readings on a Personnel Contamination Survey Sheet such as the one provided in the Documentation section. If the person has an injury that is life threatening, the injury is addressed before decon.

In a radiological event, there is a good chance that a significant number of the public will be exposed to low levels of radiation. It is unlikely that this exposure/contamination will lead to acute/immediate health effect. As such, the decontamination procedures should be commensurate with the hazards. For example, the victims' modesty should be considered; therefore, there is no need to remove the persons' clothing in an open, unprotected area.
If a radiological incident did occur, the responder must determine if his organization can handle the number of contaminated personnel. If it is a radiological incident and

it is greater than the organization capacity can handle, you have to know who to call for help.[30]

Contamination Control All trash and waste generated or collected inside of a controlled area needs to be segregated labeled and held until the time that enough qualified personnel and time is available to survey the waste to determine the proper disposal methods needed.

Where practical, wastewater contaminated with radioactivity should be labeled and controlled as radioactive waste. However, due to the expected large-scale impact that exists during a large-scale emergency, limited controls such as earthen berms to collect the wastewater or restricting the flow from drinking water sources may be the best reasonable method. Once the decon operation is done, the contaminated water will be disposed of in a manner described by local and state laws. For smaller events a locked approved Resource Conservation and Recovery Act (RCRA)-type storage area should be identified and designated for this purpose. Spillage to the soil or water supply should be minimized.

Scene Control Scene control may involve a larger area. A control problem will almost instantly be created by: decontamination line set up with numerous volunteers who all want to "help," a huge press corps seeking information about the incident, and the public in general wanting to see what is happening. While the actual incident site may only be a city block in size, the area that will need to be controlled may be an area the size of several blocks. First responders should work closely with other support personnel such as HazMat technicians to make sure that the decontamination area is properly secured and controlled to prevent unwanted visitors.

For large-scale events, the decontamination/hotline facility needs to accommodate large numbers of people, have shower facilities, and large parking lots, if possible. Good candidates include stadiums, high schools, fitness centers, etc.

Decontamination
lines in the city where the winds come from different directions or where dust is easily stirred up are more ideal if set up in an area providing indoor shelter, preferably with two big doors on the sides to serve as entrances and exits. This will help to protect personnel and responders from alpha and beta particles flying around or from gamma rays. An indoor casualty collection point would also be ideal.

DECONTAMINATION

The statement below was initially under Half-Lives And Implications For Decontamination, on page 7. It is extremely important that people understand that if the half-life is short then victims may get their property back so it is being stated again.

> **“Victims may be more inclined to give up contaminated personal effects or evacuate contaminated areas if this is made clear to them in appropriate circumstances, they have a good chance of getting their property back in good condition after not too long. That may not be the case in a dirty bomb scenario with a longer-lived isotope.”**

Decontamination is usually performed during the care of such patients by the emergency service and, ideally, prior to arrival at medical facilities. As this will not always be possible, decontamination procedures should be part of the operational plans and guides of all divisions and departments. This ensures flexibility of response and action and will prevent delay in needed medical treatment. The simple removal of outer clothing and shoes, in most instances, will effect a 90% reduction in the patient’s contamination.

UPTAKE AND CLEARANCE USING DECORPORATING DRUGS

Internal contamination occurs by three main routes (listed in order of importance): inhalation, ingestion, and wound contamination. A fourth and infrequent route is percutaneous absorption, which applies almost exclusively to the radioisotope tritium and its association with water.

The uptake and retention of a radionuclide are influenced by its portal of entry, chemistry, solubility, metabolism, and particle size. Clearance time (time required for particles to be removed from the lungs) depends on which respiratory compartment receives the deposit,1-3 and time will be an important factor in treatment decisions. Times for respiratory clearance into the next higher compartment are as follows: trachea, 0.1 hour; bronchi, 1 hour; bronchioles, 4 hours; and alveoli, 100-1,500 or more days.

Soluble particles that are deposited into the alveoli may be systemically absorbed at the alveolar-blood interface, and may thereby become incorporated into target organs. Insoluble particles also pose a threat, especially if plutonium from unspent fuel or industrial accidents is present. Prolonged exposure of the alveolar epithelium to high-LET alpha emitters, like plutonium, has been related to increased incidence of malignancy.

In 1955, the International Commission on Radiological Protection adopted a model for evaluating the hazards of inhaled radioactive particles. According to this model, 25% of inhaled radioactive particles are immediately exhaled, and the remaining 75% are deposited along the respiratory tree. About half of the particles are deposited in the upper bronchial tree, where they are moved by the ciliary epithelium to the nasopharynx. In the nasopharynx, they are propelled by the mucociliary swallowing reflex into the digestive tract, where they enter the gastrointestinal path. Ingestion is usually secondary to inhalation and the mucociliary swallowing response. However, direct ingestion from contaminated foodstuffs is also probable. The degree of intraluminal gastrointestinal exposure depends on transit time through the gut, which will vary widely from person to person. The mean clearance times of the human digestive tract are stomach, 1hour; small intestine, 4 hours; upper large intestine, 13-20 hours; and lower large intestine, 24 hours, resulting in a total mean emptying time of 42 hours. The much slower rate of movement in the large intestine places its luminal lining at higher risk for damage from nonabsorbable radionuclides. Gastrointestinal transit time may be shortened by use of emetic and/or purgative agents.

Some relatively soluble radionuclides may not be absorbed due to acidic or caustic properties that fix them to tissue proteins. Systemic absorption through the intestine varies widely, depending on the radioisotope and its chemical form. Clear differences exist between radioiodine, which is rapidly and completely absorbed, and plutonium, which is almost nonabsorbed (0.003%). Furthermore, nonabsorbable alpha emitters apparently do not cause gastrointestinal injury, even in large amounts. Nevertheless, the gastrointestinal tract is the critical target organ for the many insoluble radionuclides that travel its length almost unabsorbed. Decorporation drugs are drugs that will remove radionuclides from the body in various ways. These drugs work in several ways and are listed as:

Ion Exchange Resins limit gastrointestinal uptake of ingested or inhaled radionuclides. Prussian blue and alginates have been used in humans to accelerate fecal excretion of cesium-137.

Blocking Agents, such as, oral potassium iodide (KI) must be given as soon as possible after the exposure to radioiodine. When administered prior to exposure to radioiodine, 130 mg daily of oral KI will normally suffice.

Mobilizing Agents are more effective the sooner they are given after the exposure to the isotope. For example, increasing oral fluids increases tritium excretion.

Chelation Agents may be used to remove many metals from the body. The chelates are water soluble and excreted in urine.

Some of the decorporation drugs, such as KI, Prussian Blue, and DPTA are maintained by the State of Arizona in a stockpile and in the Strategic National Stockpile. Palo Verde Nuclear Generating Plant also maintains KI in case there is an accidental release of radiation from the facility.

What is the Strategic National Stockpile?

Not only does the SNS stockpile radiation decorporation drugs, CDC's Strategic National Stockpile (SNS) has large quantities of medicine and medical supplies to protect the American public if there is a public health emergency (terrorist attack, flu outbreak, earthquake) severe enough to cause local supplies to run out. Once Federal and local authorities agree that the SNS is needed, medicines will be delivered to any state in the U.S. within 12 hours. Arizona and it’s Counties have plans coordinated with the CDC to receive and distribute SNS medicine and medical supplies to local communities as quickly as possible.

The SNS is a national repository of:
- antibiotics,
- chemical antidotes,
- radiation decorporating drugs
- antitoxins,
- life-support medications,
- IV administration,
- airway maintenance supplies,
- and medical/surgical items.

The SNS is designed to supplement and re-supply state and local public health agencies in the event of a national emergency anywhere and at anytime within the U.S. or its territories.

The SNS is organized for flexible response

The first line of support lies within the immediate response 12-hour Push Packages. These are caches of pharmaceuticals, antidotes, and medical supplies designed to provide rapid delivery of a broad spectrum of assets for an ill defined threat in the early hours of an event. These Push Packages are positioned in strategically located, secure warehouses ready for immediate deployment to a designated site within 12 hours of the federal decision to deploy SNS assets.

VENDOR MANAGED INVENTORY (VMI)

If the incident requires additional pharmaceuticals and/or medical supplies, follow-on vendor managed inventory (VMI) supplies will be shipped to arrive as determined necessary by Public Health and the CDC. If the agent is well defined, VMI can be tailored to provide pharmaceuticals, supplies and/or products specific to the suspected or confirmed agent(s). In this case, the VMI could act as the first option for immediate response from the SNS.

MEDICATIONS USED TO TREAT AND/OR REMOVE INTERNAL RADIATION:

Table 5. Medications used to treat and/or remove internal radiation.[18]

Radioactive Material	Drug	Administestration	Comments
Americium	Ca-DTPA, Zn-DTPA	Parenteral	Zn-DTPA is initially 10 times less effective than Ca-DTPA for initial chelation of transuranics. After 24 hours efficiency of both agents is about the same.

Cesium	Prussian blue	Oral	Acts by ion-exchange, adsorption, and mechanical trapping within crystal structure. Not absorbed through intact GI wall. Clearance depends on GI transit time.
Cobalt	Unknown try penicillamine	Oral	Nothing too good
Iodine	Potassium Iodide (KI)	Oral	Within about first 4 hours, used to block uptake of radioactive iodine.
Iridium	Unknown try penicillamine	Oral	Nothing too good
Palladium	Unknown try penicillamine	Oral	Nothing too good
Phosphorus	Na phosphate or K phosphate.	Oral	Used to block uptake of radioactive phosphate
Plutonium	Ca-DTPA, Zn-DTPA	Parenteral	Zn-DTPA is initially 10 times less effective than Ca-DTPA for initial chelation of transuranics. After 24 hours efficiency of both agents is about the same.
Radium	calcium	Oral	Alginates are also useful to reduce GI absorption oral to reduce GI absorption and increase urinary excretion.
Rubidium	Prussian blue		Acts by ion-exchange, adsorption, and mechanical trapping within crystal structure. Not absorbed through intact GI wall. Clearance depends on GI transit time.
Stronium	Calcium Gluconate and Ammonium Chloride	Intravenous	Oral ammonium chloride for acidification. Alginates are useful to reduce gastrointestinal absorption.
Thallium	Prussian blue		Acts by ion-exchange, adsorption, and mechanical trapping within crystal structure. Not absorbed through intact GI wall. Clearance depends on GI transit time.
Tritium	Water	Oral	Force water to promote diuresis
Uranium	Ca-DTPA, Zn-DTPA	Parenteral	Na bicarbonate to alkalinize urine - see comments by Americium
Yttrium	Ca-DTPA, Zn-DTPA	Parenteral	Within *4 hours only. - see comments by Americium*

Unit 7 Study Questions

1. Acute high-dose radiation occurs in principal situations with the exception of:

   a. A nuclear detonation which produces extremely high dose rates from radiation during the initial 60 seconds (prompt radiation) and then from the fission products in the fallout area near ground zero.
   b. A nuclear reaction which results if high-grade nuclear material were allowed to form a critical mass ("criticality") and release large amounts of gamma and neutron radiation without a nuclear explosion.
   c. Radioactive exposure from a ^{60}Co Radiological Exposure Device (RED) placed in proximity of a large gathering of people,
   d. A radioactive release from a Radiological Dispersion Device (RDD) made from highly radioactive material such as ^{60}Co or ^{137}Cs which can result in a dose sufficient to cause acute radiation injury.

   Match the correct definition with the correct term:

2. Irradiation

3. Deterministic Effects

4. Incorporation

5. Combined Injury

6. Stochastic Effect

   a. Related directly to the radiation dose received. The severity increases as the dose increases and typically has a threshold below which the effect will not occur.

   b. A random basis independent of the size of dose and typically has no threshold. Based on probabilities, increasing with dose, but is independent of the dose received. The cause of radiation induced cancer.

   c. Exposure to penetrating radiation.

   d. The uptake of radioactive materials by body cells, tissues, and target organs such as bone, liver, thyroid, or kidney. In general, radioactive materials are distributed throughout the body based upon their chemical properties.

   e. physical, thermal, and/or chemical trauma combined with radiation exposure at a dose sufficient to diminish the likelihood of overall survival or functional recovery.

7. Where practical, wastewater contaminated with radioactivity should be labeled and controlled as radioactive waste. However, due to the expected large-scale impact that exists during a large-scale emergency, limited controls such as using “earthen berm” barriers to collect the wastewater or restricting the flow from drinking water sources may be the best method.

    a. true b. False

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UNIT STUDY QUESTION ANSWERS

UNIT 1

1. a
2. d
3. c
4. d
5. b
6. e
7. d

UNIT 2

1. a
2. b
3. d
4. c
5. d

UNIT 3

1. a
2. c

UNIT 4

1. a
2. c
3. a
4. c

UNIT 5

1. e
2. a
3. e
4. c
5. d
6. b

UNIT 6

1. a
2. d
3. d
4. a

UNIT 7

1. c
2. c
3. a
4. d
5. e
6. b
7. a