Radiological Transportation Emergency Training

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Robert Steelhammer, P.E.

CED engineering.com
PDH FOR THE PROFESSIONAL

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.com

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Introduction

Sometimes as engineers we are required to go to a customer's facility. Certain testing methods like radiography and positive material identification (PMI) require the use of radiological devices. Certain training is sometimes required by state or local regulations to transport your device to another location to test a customer's part.

The reliance upon, and use of, radioactive material in agriculture, industry, and medicine continues to increase. As the manufacture, use, and disposal of radioactive material has increased, so has the need to transport it. Consequently, the potential for the first responder to encounter an incident involving some type of radioactive material has increased. Having knowledge of radiological hazards, and the terminology used to describe them, will increase your ability to quickly recognize, safely respond, and accurately relay information during an incident involving radioactive material. I am relying heavily on the Transportation Emergency Preparedness Program presented by FEMA (IS-302) for emergency responders and adapting to engineers that actually use the devices or have a need to understand how they are used.

In 1980, there were 75 nuclear power plants in the United States. The number of shipments at that time was growing rapidly. Today we have many industrial uses, like positive material identification that was in its infancy at that time, as well as other industrial uses of radiation sources.

Licensing and Certification

Radiological devices require extra care and training. They also require registration or a license depending on the device and the state. For example, if you have a PMI gun that operates by x-ray there is a legal requirement. In the state of Texas, you would be required to have it registered. You would also be required to use a dosimeter for a year, while using the device. If your PMI gun had a source (i.e. Am-241), the requirements are different. In that case, it would need to be licensed. It would also require a leak test every six months and a shutter check every six months. The Department of State Health Services sends an inspector out to check your paperwork and unit. This is usually an unannounced visit. The State is usually the entity that you will communicate with after an incident/accident.

Problems in communication after an accident can be illustrated by the March 1977 case of a North Carolina rail accident. The train was carrying uranium hexafluoride, as well as other hazardous materials. It derailed near Rockingham, North Carolina. The response to this accident has become a case of inadequate emergency preparedness, mostly due to ineffective communication. There were 17 agencies that responded, but nobody assumed control until the arrival of a state radiological team.

Background on Radiation

Radiation is all around us and has been present since the birth of this planet. Today, both man-made and natural radioactive material are part of our daily lives. We use radioactive material for beneficial purposes, such as generating electricity and diagnosing and treating medical conditions. Radiation is used in many ways to improve our health and the quality of our lives.

In 1895, while working in his laboratory, Wilhelm Roentgen discovered a previously unknown phenomenon: rays that could penetrate solid objects. Roentgen called these rays “X-rays.” The practical uses of X-rays were quickly recognized, and, within a few months, a medical X-ray picture was used to locate shotgun pellets in a man’s hand.

In 1896, Henri Becquerel reported observing a similar radiological phenomenon caused by uranium ore. Later that year, Pierre and Marie Curie identified the source of the radiation as a small concentration of radium, a radioactive material, in the ore.

These discoveries set the stage for using radiation in medicine, industry, and research. Since that time, scientist have developed a detailed understanding of the hazards and benefits of radiation. In fact, scientists understand radiological hazards better than hazards associated with most other physical and chemical agents.

Basic Radiological Concepts

Atomic Structure

All matter is made up of atoms. Atoms are invisible to the naked eye. The three basic components of the atom are protons, neutrons, and electrons. The central portion of the atom is the nucleus. The nucleus contains protons and neutrons, which are very close to each other. Electrons orbit the nucleus. Figure 1 shows a typical atom.

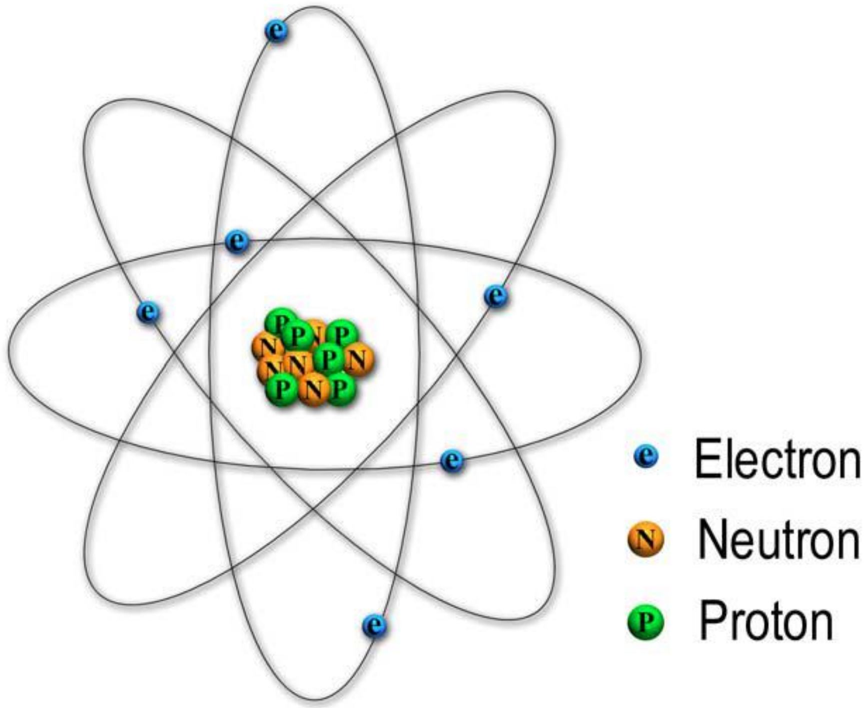


Figure 1. A typical atom (DOE)

Protons are located in the nucleus of the atom and have a positive electrical charge. The number of protons determines the identity of the element.

Neutrons are located in the nucleus of the atom and have a neutral electrical charge. The number of neutrons determines the nuclear properties of the atom.

Electrons orbit the nucleus and have a negative electrical charge. The number of electrons determine the chemical properties of the atom.

There are cases where atoms of a particular element have the same number of protons but a different number of neutrons. These are called isotopes. Isotopes of the same element have identical chemical properties regardless of the number of neutrons it has, but the nuclear properties can be quite different. An example is hydrogen, as shown in Figure 2.

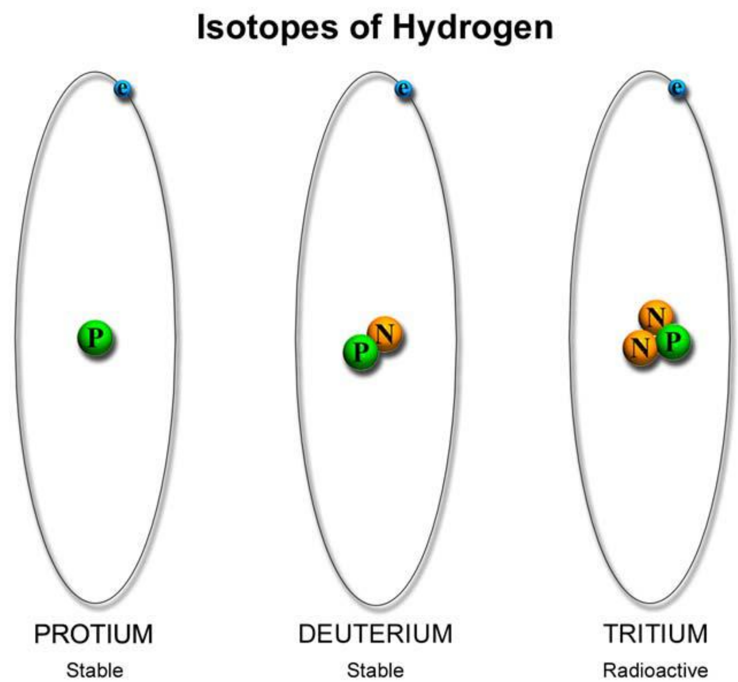


Figure 2. Isotopes of hydrogen (DOE)

There are three isotopes of hydrogen shown in Figure 2, with tritium being a radioactive isotope (radioisotope).

Stable or Unstable Atoms

Only certain combinations of protons and neutrons will result in a stable atom. If there are too many or too few neutrons for the given number of protons, the resulting nucleus will have too much energy, and it will be an unstable atom. An unstable atom will become stable by giving off excess energy in the form of radiation. Unstable atoms are also known as radioactive atoms.

Ionizing Radiation

You may be familiar from some of the radiation terminology from a previous engineering or physics course. There are many kinds of radiation. Examples include heat, visible light, radio waves, and microwaves. They are all electromagnetic radiation. Non-ionizing radiation such as radio waves and microwaves and much lower in energy than ionizing radiation such as x-rays and cosmic rays.

Ionizing radiation has energy sufficient to remove electrons from atoms. Ionization is the process of removing electrons from atoms. It is this ability to remove electrons from atoms that make ionizing radiation potentially dangerous. Radiation in this course, is ionizing radiation. The ionization process is shown in Figure 3.

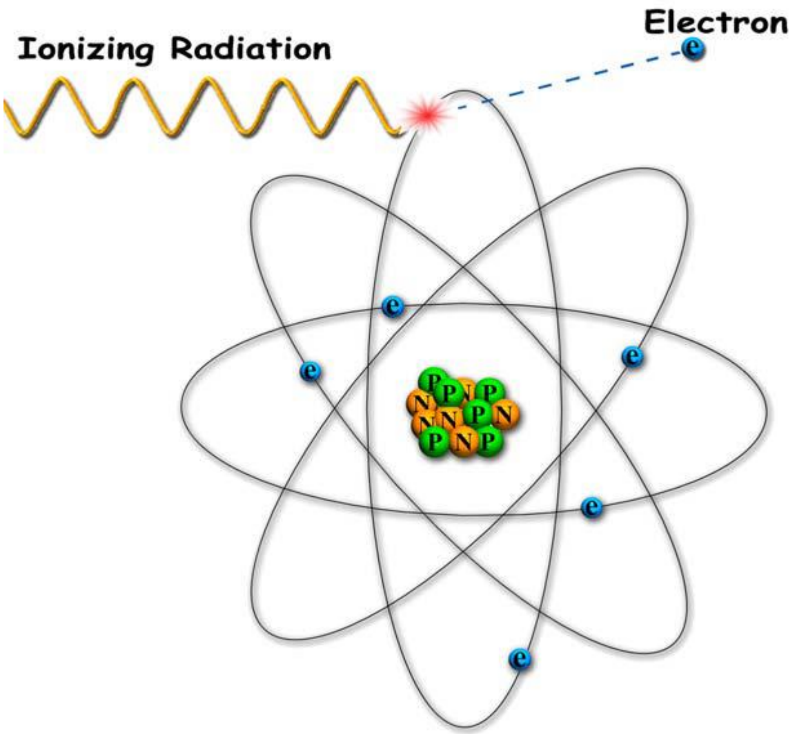


Figure 3. The ionization process (DOE)

Radioactive Material and Radioactivity

Radioactive material is any material that emits ionizing radiation. Radioactivity is the process by which an unstable atom emits radiation. Radioactive atoms can be created by a nuclear process, but can also exist naturally, like uranium ore, thorium rock, and forms of potassium. When an atom undergoes the process of radioactivity, it is called radioactive decay. Radioactive decay will change it into another type of atom, maybe another element. An example is uranium (unstable) decays to lead (stable). The time of the decay process varies depending on the isotope and can vary from fractions of a second to billions of years.

The rate of radioactive decay is measured and quantified in terms of half-life. Each radioactive material has a different half-life. Regardless of the material, radioactivity is constantly decreasing. The activity is down to less than one percent after seven half-lives. Table 1 shows some of the common radioactive materials and their approximate half-life.

Radioisotope	**Half-Life**	**Atomic Number**
Nitrogen-16	7 seconds	7
Technetium-99m	6 hours	43
Thallium-201	73 hours	81
Cobalt-60	5 years	27
Caesium-137	30 years	55
Americium-247	432 years	95
Uranium-238	4.5 billion years	92

Table 1. Common radioisotopes, their half-life, and atomic number.

Radioactive Terminology and Units

There are four (4) basic types of ionizing radiation. Most of the commonly transported radioactive materials emit one or more forms of ionizing radiation. The four basic types are alpha radiation, beta radiation, gamma radiation, and neutron radiation. They differ in their penetrating power and the manner in which they affect human tissue. A general understanding of each type is discussed.

Alpha Radiation

Alpha radiation is high-energy particles that are relatively large, heavy, and only travel a short distance. Because they are so large and heavy, they lose their energy very rapidly, have a low penetrating ability, and a short range of travel (i.e. a few inches in air). Because of the alpha particles short range and limited penetrating ability, external shielding is not required. Alpha particles are easily stopped by a few inches of air, a sheet of paper, or the dead (outer) layer of skin that surrounds our bodies and easily stops alpha particles. Alpha radiation poses a minimal biological risk outside the human body. The greatest hazard from alpha-emitting material occurs when the material is inhaled or ingested. Once inside the body, the alpha radiation can cause harm to individual cells or organs.

Beta Radiation

Beta radiation consists of particles that are smaller, lighter, and travel farther than alpha radiation. Beta radiation is more penetrating than alpha radiation because beta particles are smaller and lighter. The depth of penetration in human tissue is less than ¼ inch. In air, beta radiation can travel several feet. Beta radiation may be blocked or shielded by plastic (i.e. SCBA face shield), aluminum, thick cardboard, several layers of clothing, or the walls of a building.

Outside the human body, beta radiation constitutes only a slight hazard. Because beta radiation penetrates only a fraction of an inch into living skin tissue, it does not reach the major organs of the body. Exposure to high levels of beta radiation can cause damage to the eyes and skin. Internally, beta radiation is less hazardous than alpha radiation because beta particles travel farther than alpha particles, thus the energy deposited by the beta radiation is spread out over a larger area, causing less harm to individual cells or organs.

Gamma Radiation
Gamma radiation is electromagnetic radiation, similar to x-rays. It does not consist of particles like alpha and beta radiation, but waves of energy that have no mass or electrical charge. Because they have no mass or electrical charge, gamma radiation is able to travel great distances and penetrate almost anything. It requires dense material as shielding (i.e. lead, steel, or concrete) and can easily penetrate human tissue. Gamma radiation poses a hazard to the entire body because it can penetrate tissue.

Neutron Radiation
Neutron radiation consists of neutron particles ejected from an atoms nucleus. Neutron radiation can travel long distances and penetrates like gamma radiation. It is best shielded with high hydrogen content material like water, graphite, or plastic. It would not commonly be found in a transportation situation, but would be in a nuclear reactor.

Fissile Material
Fissile material is material with atoms capable of nuclear fission (splitting of the atom). DOT regulations define fissile material as plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination thereof. This material is typically transported with additional shipping controls that limit the quantity of material in a shipment. Packages used for fissile material are designed and tested to prevent a fission reaction from occurring during normal transport conditions as well as hypothetical accident conditions.

Criticality Safety Index (CSI)
The Criticality Safety Index (CSI) is a number used to provide control over the accumulation of packages, over packs, or freight containers containing fissile material. The CSI is assigned by the shipper and is displayed on the fissile label. Under normal conditions, the aggregate criticality safety indices of all fissile material packages on a shipment will not exceed 50.

Low Specific Activity (LSA)
LSA is an acronym that means low specific activity. This means that the material has a limited amount of radioactivity in comparison to the total amount of material present. Material such as uranium and thorium ores, mill tailings, and contaminated earth are often transported as LSA. Radioactive waste is often transported as LSA material.

Special Form Radioactive Material
Radioactive material that is either a single solid piece of a sealed capsule that can be opened only by destroying the capsule. In accident conditions, special form radioactive material would be non-dispersible, and thus would not present a contamination hazard. Though not a contamination hazard, special form sources would pose a significant radiation hazard. A sealed radioactive source used in radiography or in positive material identification is an example of special form radioactive material.

Surface Contaminated Objects (SCO)
A Surface Contaminated Object (SCO) is a solid object that is not itself radioactive, but has radioactive material deposited on its surface (contamination). An example of SCO material would be contaminated protective clothing or equipment used in decommissioning activities.

Transport Index (TI)
The transport index (TI) is a single number that is used to provide control over radiation exposure and establish transport controls. It is a dimensionless number determined by the shipper. The TI appears on Radioactive Yellow II and III labels and on the shipping papers associated with the material. The transport index can be used as a starting point in determining whether there has been damage to a package. The TI is equal to the maximum radiation level in mrem/hr at one meter from an undamaged package. The carrier uses the transport index to control the total number of packages allowed on a vehicle. Under normal transport conditions, the sum of all transport indices cannot exceed 50. An example of a label with the TI is shown below.

The above example is a package with a Radioactive Yellow-III label attached and a TI marked on the label of 2.5. It should read between 50 and 200 mrem/hr on contact with the package and 2.5 mrem/hr at one meter from the package. A reading of 5 mrem/hr at one meter from the package indicates potential damage.

Shipping Labels
After checking the radiation labels at a package's surface and at one meter, shippers will attach a radiation warning label to the package. Radiation warning labels are attached to opposite sides of each package. There are three different warning labels, and they are applied based on the contact and one meter radiation labels: Radioactive White-I, Radioactive Yellow-II, and Radioactive Yellow-III.

Radiation warning labels specify the contents and the activity of the material inside the package. In addition, Radioactive Yellow-II and Radioactive Yellow-III specify the TI.

Common Radioactive Material Shipping Names

Title 49 of the Code of Federal Regulations (CFR) is where the regulations for the transport of radioactive material are found. Title 49 contains the Hazardous Material Table (HMT), that categorizes the materials that the DOT has designated as hazardous material for transportation purposes. For each of the materials listed, the HMT provides information on the hazard class , the UN ID, the Proper Shipping Name (PSN), and other information for preparing hazardous material shipments. The PSNs for radioactive material is listed in the blue pages of the ERG. Note that the words “radioactive material” appear as part of the PSN.

Measuring Radiation

The Roentgen (R) and Rem (Roentgen Equivalent Man)

The exposure to radiation is measured in units of roentgen and rem. For most purposes, one roentgen is equal to one rem. Because one roentgen (or one rem) is a large amount of radiation, the prefix term milli is often used. Milli means one one-thousandth in the SI system, therefore there are 1,000 mrem in one rem or 1,000 mR in one roentgen.

One of the traditional units for radiation measurement is the Sievert. One Sievert is 100 rem.

According to the National Council on Radiation Protection and Measurements (NCRP) in NCRP Report No. 93, the average person is exposed to an annual dosage of approximately 360 mrem per year from both man-made and natural sources.

Measuring Radioactivity

Radioactivity is measured as the number of nuclear transformations or disintegrations that occur in a sample during a specific time. This is known as the activity of a sample. Activity is required to be listed on radiation warning labels and shipping papers in SI units. An example is shown below.

The SI unit for activity is the Becquerel (Bq). This is equal to one disintegration per second (dps). The conventional unit of activity is the curie (Ci), which is 3.7 X 10^{10} or 37 billion disintegrations per second. Both the curie and Becquerel measure activity. The activity in curies is sometimes shown on shipping labels after the activity in Becquerels. One curie is considered to be a large amount of activity and one Becquerel is considered to be a small amount of activity. The conversion is multiply curies by 3.7 X 10^{10} to obtain Becquerels.

Activity can also be expressed as a measure of its concentration or specific activity. Common terms for measuring specific activity are curies per gram (Ci/g) or becquerels per kilogram (Bq/kg). It is important to note that there is no direct relationship between activity and the physical amount of material. Very high activity can come in very small packages. For example, one gram of cobalt-60 has an activity of approximately 42 TBq, or 42 trillion disintegrations per second. On the other hand, one gram of thorium-232 has an activity of approximately 4kBq or 4,000 disintegrations per second. You would need to have 10 billion grams (23,000 pounds) of thorium-232 to equal the activity in one gram of cobalt-60.

Radioactive Contamination

A material that spontaneously emits ionizing radiation is a radioactive material. When deposited in places where we don't want it, it is called radioactive contamination. Radioactive contamination can be spillage on the ground, on the skin, or inhaled dust, to name a few.

A person can be exposed to radiation and not become contaminated. Radioactive contamination emits radiation. If a person is contaminated with radioactive material, they will be exposed until the contamination is removed. The Transport Index is determined by taking the maximum radiation level (as measured in mrem/hr) at one meter (3.3 feet) from an undamaged package.

Types of Radioactive Contamination

There are two basic types of radioactive contamination, internal and external. Radioactive contamination is serious. This is because, as long as the material is on you, your clothing, or inside your body, you are being exposed. A short exposure to these materials may be safe, but prolonged or very close exposure may not be. The possibility of internal contamination is a special concern. Once inside the body, contamination can be difficult to remove.

Radioactive material that is not dangerous outside the body may be dangerous if it is allowed to enter the body. This is the reason that the use of personal protective equipment (PPE) is important. It is also important to not eat, drink, smoke or chew while on the scene of a radioactive material incident.

There is also a concern that individuals contaminated externally will contaminate others, known as secondary contamination. Secondary contamination is when a contaminated person or object touches something and that is touches by another person, and that person becomes contaminated. An example of spreading contamination can be given by imagining chalk on a blackboard. Think of the chalk as radioactive material. You are considered to be contaminated if the chalk dust is transferred to your hands. The dust can be transferred from your hands to your shirt. The transfer to your shirt is called secondary or cross contamination.

Sources of Radioactive Material

There are naturally occurring sources of ionizing radiation that expose us to background radiation. These sources include the Earth's crust, water, air, cosmic rays and particles. There are also man-made sources of ionizing radiation such as x-rays in a medical procedure. The body even contains naturally occurring radioactive material.

Radioactive material can be a solid, liquid, or a gas. Common radioactive materials include radiopharmaceuticals, consumer products, industrial sources, and radioactive waste.

Radiopharmaceuticals are radioactive drugs that are used for medical diagnoses or radiation therapy to treat an illness. They are the most commonly transported radioactive material in the United States. Most have short half-lives and are typically transported by air and express delivery services and take the form liquid, gas, solid, or powder.

Consumer products can take many forms. The most common example is the smoke detector. The amount of radioactivity in the smoke detector is below the regulatory limits and is not marked as radioactive material during transport.

Industrial sources are sealed sources of radiation used in construction and manufacturing for checking welds and metals for flaws (i.e. radiography). They are also used to check concrete and asphalt and to test the density of soil (i.e. soil density gauges). They are also used to test the composition of metal (i.e. Positive Material Identification). These industrial instruments can contain a source of cesium-137 or americium-241, as an example for things like PMI. They typically have small amounts of radioactive material. Radiography sources often contain high level sources that could pose a high exposure risk, if it were outside its protective packaging. These usually contain iridium-192 or cobalt-60.

Nuclear fuels are another source of radioactive material. This can be new fuel being transported to a nuclear power plant or spent fuel being transported for storage or disposal. These are solids that are transported in specifically designed packages called shipping casks.

Radioactive waste is waste material from nuclear power plants, nuclear processing plants, research institutions, and medical facilities. It is commonly transported by rail or highway.

Radioactive material is among the most regulated hazardous materials transported. The regulations for shipping radioactive materials are developed by the EPA and the NRC.

Dose and Dose Rate

We receive radiation doses every day from cosmic rays, from outer space, from radon gas, and other radioactive elements in the Earth. This radiation is known as natural background radiation. It includes radiation from plants, animals, and from within our bodies.

We are also exposed to man-made sources of radiation from medical and dental treatments (mostly from x-rays), television sets, and from coal fired power plants. The radiation received from man-made sources are dwarfed by the radiation received from natural sources.

Radiation dose is the amount of radiation energy that is deposited in the body. The radiation dose rate is the rate at which radiation energy is deposited in the body. The dose rate is measured in exposure per unit of time. This can be likened to the speedometer and odometer in your car. The speedometer measures the rate (speed), like the dose rate. The odometer measures the total distance traveled, like the total dose received.

Dosage is typically measured in millirem and the dose rate in terms of millirem per hour. The average annual radiation dose per person in the US from all sources is approximately 360 millirem. Many people though will receive far more than that in a given year (mostly due to medical procedures). Workers at nuclear facilities are allowed up to 5,000 millirem of radiation exposure per year.

Radiation Risk

There are detrimental effects associated with exposure to radiation. Understanding the risks will allow you to evaluate them and help you minimize the risks. A risk assessment in a sense.

Radiation can damage living cells causing modification of the cell DNA or the death of a cell. Most organs and tissues are in the body are not affected by the loss of even a considerable number of cells. If the number lost is large enough, there can be observable harm to organs which may lead to outward observable effects, or death in some cases. This type of harm occurs in individuals exposed to large doses of radiation in a short period of time. Damaged cells that do not die as a result of the radiation exposure often repair the damage, leaving no adverse health consequences. If the damage is not repaired, the resulting modification to the DNA may be transmitted to future cells and can lead to cancer. These effects may take years to show.

After the discovery of ionizing radiation, scientists began to collect and analyze information about its biological effects. Scientists have continued studies of the effects of radiation on cells, plants, animals, and humans since that time. There is no concrete data on the effects of low doses of radiation, although scientists have predicted effects of large doses based on studies of groups and individuals receiving large doses of ionizing radiation. Knowledge of the effects from large exposures on humans was obtained from studies of the following groups:

- Early radiation workers receiving large doses of radiation before scientists understood the biological effects and consequences of exposure to ionizing radiation. Standards have been since developed to protect workers as well as the public.
- Survivors of the atomic bombs dropped on Hiroshima and Nagasaki. There were more than 80,000 survivors. This is the group that gave the most information on the effects of ionizing radiation.
- Cancer patients were another group that give us is information on radiation effects. Some cancer patients receive large doses of radiation on a specific portion of the body to destroy cancerous cells. Doctors try to minimize the exposure of healthy tissue adjacent to a tumor site.
- Radiation accident victims are another source that information has been gathered. Often there are detailed medical records in this group.

Years of radiation related research have helped us determine how ionizing radiation can damage the human body and what levels of exposure can cause a certain type of damage. These studies have yielded more information about the biological effects of ionizing radiation than many other environmental hazards.

Ionizing Radiation's Effects on the Body

The effects of ionizing radiation occur at the cellular level. The human body is made up of many organs. Each of these organs are made up of specialized cells. Ionizing radiation can effect the normal operations of these specialized cells.

Damage to any material by ionizing radiation is from ionizing the atoms in that material, therefore, changing the atomic structure of that material. The chemical properties of those atoms are altered when its atoms are ionized. This is how ionizing radiation damages a cell; it ionizes the atoms and changes the resulting chemical behavior of the atoms and molecules of the cell. If a person receives a sufficiently high dose of radiation and a lot of cells are damaged, there may be noticeable health effects.

One factor in determining the biological effect is the amount of the body exposed to ionizing radiation. Cancer patients receive large doses of radiation to destroy tumors, but this radiation is concentrated on a specific portion of the body. Whole body exposure poses more risk of radiation-induced damage affecting a larger area.

Some parts of the body are more sensitive to radiation and thus more prone to radiation-induced damage. Radiation damage to cells in the body depends on how sensitive the cells are to ionizing radiation. Typically, the most sensitive cells are those that divide rapidly or those that are in the process of dividing. These cells are most vulnerable because it is impossible for them to repair any damage occurring during cell division. Examples of these rapidly dividing types of cells include blood forming cells, cells lining the intestinal tract, or cells in an embryo or fetus.

A special concern is a developing embryo or fetus. They are especially sensitive to ionizing radiation. The system of cells in the developing embryo or fetus are especially sensitive because they are unspecialized and dividing rapidly. We generally become less sensitive to ionizing radiation with increasing age. The exception to this is later in life we become more sensitive because of a less effective cellular repair mechanism. Health and genetics also play a role in effects of exposure to ionizing radiation.

Slower dividing cells are more specialized. They are not as easily damaged by ionizing radiation. Examples of these slower dividing cells include nerve cells, brain cells, and muscle cells.

The biological effects of ionizing radiation depend on the dosage and fast the radiation dose is received. Doses of radiation are divided into two categories: acute radiation doses and chronic radiation doses.

Acute Radiation Doses

An acute dose is a large dose of radiation received in a short period of time. The body cannot repair or replace cells fast enough after receiving an acute dose of radiation. Physical effects can be seen in these case. Some of the possible health effects from acute doses of radiation include reduced blood count, loss of hair, nausea, and fatigue. The physical reaction to an acute dose of radiation results from extensive cell damage over a short period of time.

Cancer patients receiving radiation therapy are treated using an acute dose. They receive high doses over a short period of time applied to a small portion of the body. Ionizing radiation is used to treat cancer because cancer cells divide rapidly and they are sensitive to ionizing radiation.

It takes a large acute dose of radiation before people experience any observable physical effects. These physical effects may take days to manifest themselves and may include nausea, vomiting and diarrhea. Survivors of the bombs dropped on Hiroshima and Nagasaki received acute doses of radiation. Acute doses were also received by the first responders and some plant personnel at Chernobyl.

Most radioactive material shipments are packages containing a small amount of radioactivity. Federal packaging regulations require the level of radiation be low enough that those that handle packages, or those who are exposed to the package, will not experience any adverse health effects. Highly radioactive material is shipped in in special packages that have been designed to withstand severe accident conditions without breaching or releasing their radioactive contents.

Chronic Radiation Doses

A small dose of radiation received over a long period of time is known as a chronic dose. The human body is better able to handle a chronic dose of radiation than an acute dose of radiation. The body can repair the damage received from chronic doses as fewer cells will need repair at any given time. The body has enough time to replace dead or damaged cells with healthy ones. Chronic doses do not have the detectable health effects seen with acute doses of ionizing radiation. Due to cell repair, even a sophisticated blood analysis will not reveal biological effects. Examples of chronic radiation doses are natural background radiation and doses received by employees of nuclear or medical facilities.

Risks of Exposure

Studies have shown that large non-lethal acute radiation doses (greater than 10,000 millirem) can increase the risk of cancer. We don't know if this is true for low does delivered over an extended period of time. The current radiation protection philosophy is based on the assumption that any dose of radiation may result in human health effects such as cancer or genetic damage. Numerous epidemiological studies conducted to date indicate that the health risks at doses below 10,000 millirem are either zero or too low to be measured.

Pathways of Entry

There are several ways that radiation can enter the body. Internal contamination results when radioactive material enters the body. The skin, mouth, and nose are the most obvious routes to introduce internal contamination. Radioactive material can enter the body through the same pathways as any other material. These biological pathways include:

Inhalation – smoke particles and other airborne particulates may enter the body through the lungs as you breathe.

Ingestion – this includes eating, drinking, smoking, or chewing contaminated items may cause internal radiological contamination.

Absorption – radioactive material can be absorbed through the skin or mucous membranes the same way as other things are absorbed.

Injection – radioactive material can be introduced to the body through cuts, wounds, direct medical injections, or punctures in the skin.

Safe Packaging

Prior to transporting a package, regulations require that radioactive materials be properly packaged, sealed, surveyed for external radiation, and then checked for external contamination. The package is then marked and labeled as required to communicate specific information about the contents.

Package Markings

The makings on a package are designed to inform transportation workers and emergency response personnel about the radioactive contents of the package. The package markings are marked clearly on the outside of the package. Some of the package markings may include:

Proper shipping name and UN identification number (i.e. Radioactive material, Type A package, UN 2915)
"Radioactive LSA" or "Radioactive SCO" as applicable
"Type IP-1, IP-2, IP-3, or Type A" or "Type B" as applicable
Gross weight on packages weighing more than 110 lbs
Orientation arrows: This indicate that the package may contain liquids
"USA"
"RQ" if the package contains a reportable quantity of material

Radiation Warning Labels

Radioactive material packages may require special labels. This is in addition to the required markings. The radioactive labels alert personnel (particularly handlers) that the package contains radioactive material and may require special handling and storage controls. Bulk packages that contain large volumes of low-level radioactive material may not require labels, but vehicle placards may be required.

When labels are required, they must be applied to opposite sides of the package. Labels contain specific information about the quantity and type of radioactive material being shipped. The type of label used depends on the external radiation level, or the package contents. The shipper must measure the radiation level to determine the required label.

The following labels are typical on packages used to transport radioactive materials:

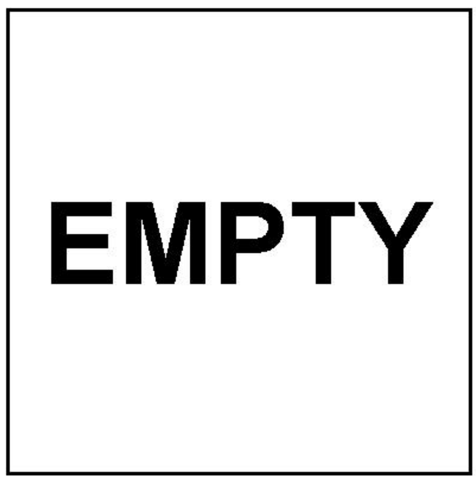
Radioactive White-I: Minimal radiation levels detectable outside the package. Maximum contact radiation level 0.5 mrem/hr.

Radioactive Yellow-II: Medium-level radiation detectable outside the package. External contact radiation levels ranging from greater than 0.5 mrem/hr to a maximum of 50 mrem/hr. Maximum allowable transport index is 1.

Radioactive Yellow-III: Highest radiation levels detectable outside the package. External contact radiation levels ranging from greater than 50 mrem/hr to a maximum of 200 mrem/hr. Maximum allowable transport index is 10.

Fissile Label: applied to packages that contain fissile materials. The Criticality Safety Index (CSI) for each package will be noted on the label. The CSI is displayed on the label to assist the shipper in controlling how many fissile packages can be grouped together in shipping. When applicable, the fissile label will appear adjacent to the radioactive material label.

EMPTY: Applied to packages that have been emptied of their contents as far as practical, but may contain regulated amounts of internal contamination and minimal radiation levels detectable outside the package.



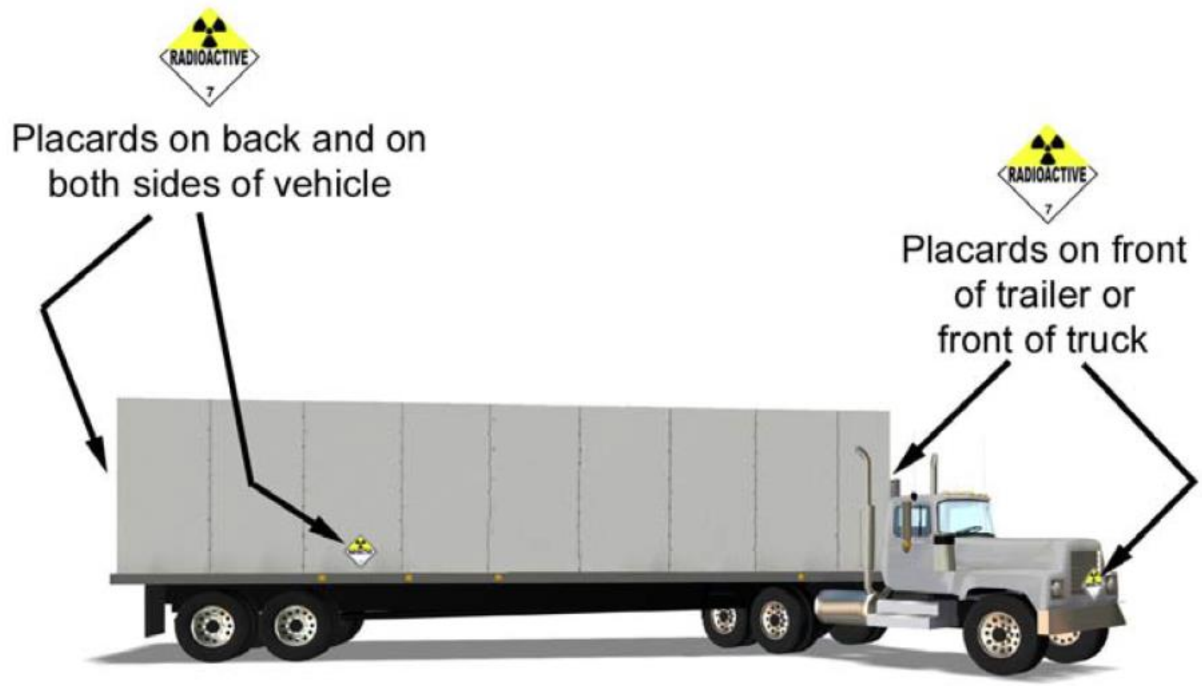
If a package is encountered in a response situation and it has a radiation warning label, note carefully the specific label. Note any other information or markings on the package. Write all of the information down and check for accuracy.

Placarding Requirements

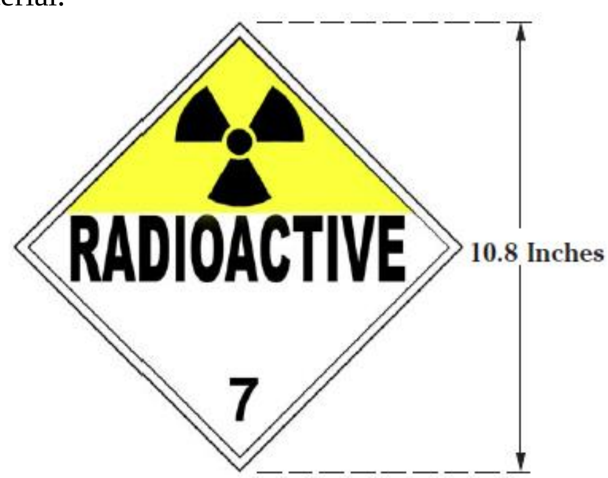
Not all radioactive material shipments require the transport vehicle be placarded. Highway and rail shipments that contain excepted quantities and packages with the EMPTY, Radioactive White-I, and Radioactive Yellow-II labels do not require placarding of the vehicle. The following require placarding:

Packages with the Yellow-III label
Exclusive Use LSA/SCO shipments in excepted packages
Highway Route Controlled Quantities of material

When placards are required, they must be in plain view and displayed on all four sides of the transport vehicle as shown below.



The standard placard for radioactive material is square-on-point and is yellow on top and white on the bottom, with black lettering and a black radiation symbol in the yellow portion. The standard size is approximately 11 by 11 inches. In the bottom corner, the DOT hazard class "7" denotes radioactive material.

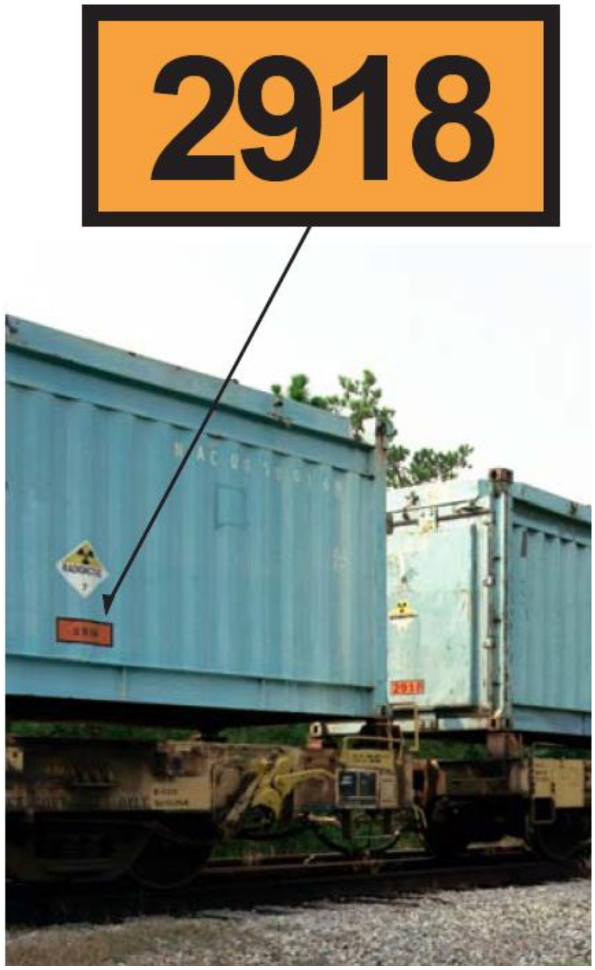


Another type of radioactive placard that may be encountered on highway shipments, looks like the standard placard except it has a white square background and a black border. This type of placard represents a "Highway Route Controlled Quantity" (HRCQ) shipment. These shipments contain higher quantities of radioactive materials and require special controls during transport. Special controls include operating vehicles over "preferred routes."

A preferred route is the Interstate Highway system or a state designated alternate route selected by a state agency. The driver of a HRCQ vehicle must be provided with a written route plan, must have received DOT mandated training within two years prior to the shipment, and must have a certificate of the training his possession during the shipment.

United Nations Identification Number

The vehicle may have a United Nations Identification Number (UN ID) located close to the placard. The UN ID will appear on either an orange panel or on a plain white square-on-point configuration similar to a placard. The orange panel is orange with black lettering and has a four-digit identification number that identifies the radioactive material. This four-digit number is the UN identification number of the material being transported. The orange panel and square on point configuration is used because UN identification numbers may not be displayed on a Class 7 placard. The UN ID can be used to locate the name of the material and the response guide in the Emergency Response Guidebook (ERG).



Secondary Hazards

Emergency responders should always be alert for the presence of secondary hazards at an incident site. Secondary hazards can come from hazardous material carried on the vehicle or from external factors such as downed power lines or spilled fuel. If you see a radioactive placard, do not be distracted from looking for additional placards that may be on the vehicle. Radioactive material may have other hazardous properties, such as compressed gas or corrosive. Don't get "tunnel vision" about radiation. It is important to look for spilled fuel, downed power lines, or any other hazard that may be present. The radioactive material may be less of a hazard than other hazards that may be present at the accident scene.

Initial Response Actions

Government officials at the state, tribal, or local level are responsible for emergency response to an incident within their jurisdiction. This includes incidents that involve radioactive material. They should develop a response plan to successfully handle transportation incidents that involve radioactive material. The US Department of Energy has a TEPP Model Initial Response Procedure available.

Safety, Isolation, and Notification (SIN)

In order to effectively carry out duties as a responder, they must remember that their safety and protection is foremost. A useful acronym to help remember initial response actions is "SIN." SIN stands for:

Safety first and always
Isolate and deny entry
Notifications

Approaching an incident involving radioactive material is similar to approaching an incident involving other hazardous material. To ensure safety, the incident scene should be approached from upwind and upslope. The hazard should be identified from as far away as possible, with the use of binoculars, if they are available. Initial isolation distances can be found using the ERG. After assuring their own safety, the priorities for the responder are rescue, lifesaving, first aid, and fire control. These priorities are higher than for taking radiation measurements. All of the guides in the ERG indicate that radiation presents minimal risk during transportation accidents.

If entering the area to perform rescue operations, the radiation exposure can be minimized by following a few guidelines:

Minimize your **time** in the incident area. The less time you spend in a radiation field, the less of a radiation dose you will receive.

Maintain a safe **distance** from radioactive material packages. Do not touch damaged packages or spilled material.

Use other available material for **shielding** whenever possible. For example, a vehicle between you and the radiation source can reduce your radiation exposure.

When responding to a transportation incident involving radioactive material, isolate the scene. This will help reduce the potential for spreading radioactive contamination and to minimize the possibility of radiation exposure. Guides 161 through 166 in the ERG can be used to determine initial isolation distances. These guides recommend an initial isolation distance of 75 feet in all directions. Emergency responders at any hazardous material scene should keep unauthorized persons away from the area and position themselves uphill, upwind, and upstream of the incident. If lifesaving, first aid, firefighting is not necessary at a scene, there is no reason for a responder to enter the area. They should avoid the urge to go in to have a look. Once the area is isolated, attempts to identify the material involved in the incident by consulting the ERG.

When a hazardous material incident of any kind occurs, the proper agencies and personnel should be notified as soon as possible. Most states have a radiological health agency. In the State of Texas, it is the Texas Department of State Health Services. The state radiological health agency may be able to provide assistance or resources for a radioactive material incident. The local notification procedure may be similar to this:

Call Dispatch/911

Ask dispatch to make other necessary contacts, to include:

Other local personnel that may be needed
State radiological agency
Neighboring jurisdiction potentially affected
Include the following in the dispatch notification:
Your name, agency, and contact information
Radioactive materials involved and type of packaging
Severity of the incident (injuries and/or breached packages)
Location of the incident
Actions taken
On-scene contact (Incident Commander) and contact information
How incident occurred
Shipping information from the shipping packages or papers
Contact the emergency response phone number listed on the shipping papers
Other notifications that may be necessary

Shipping Papers

A valuable source of information about the nature of the material being transported is the driver of the transport vehicle. The driver can assist in retrieving the shipping papers, as they contain valuable information about the material being transported. They include the name, address, and phone number for the shipper and the receiver, as well as contain specific information on the nature of the radioactive material.

The shipping papers must include an emergency response phone number, including the area code (or international access code) for use in the event of an emergency involving the material. The person answering must be knowledgeable (or have immediate access) of the material and the mitigation actions to be taken.

Shipping papers are required for all modes of transport. The driver of a motor vehicle transporting hazardous material are required to have shipping papers readily available to response personnel. A vehicle's shipping papers can usually be found in a holder mounted on the inside of the driver's side door, or within an arm's reach of the driver. The driver is supposed to place the shipping papers in the driver's seat when not in the vehicle. Shipping papers are important, but they should not be retrieved at the expense of safety.

If the shipping papers can be retrieved, information found on them specific to radioactive materials includes:

Identity of each material/radionuclide (i.e. Mo-99, Ti-201, I-123, Am-241)
Physical and chemical form of each material (salt/solid)
The amount of radioactivity contained in each package
Category of label applied to each package (i.e. Radioactive Yellow-II)
Assigned transport index for each package (applies to Yellow-II and Yellow-III labels)
Fissile controls information, when applicable

The location of the shipping papers may vary, depending on the mode of transportation. The papers may be located in the following places:

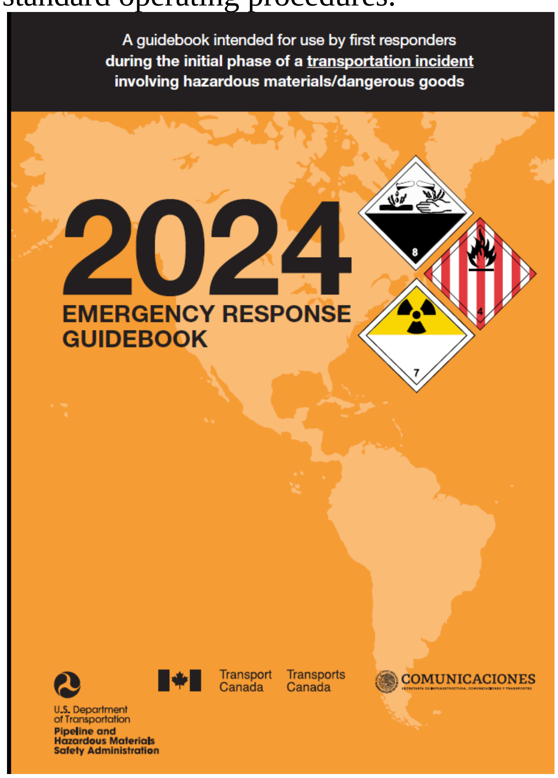
In the cab of a motor vehicle
In the possession of a crew member of a train
In a holder on the bridge of a vessel (ship)
In the possession of a pilot on an aircraft

If the shipping papers are potentially contaminated, the following steps can be taken to help prevent the spread of contamination when removing shipping papers from the hot zone:

Separate each page
Carefully wipe off any liquid or other material from the shipping papers' surfaces
Pass bags through the contamination line and decontaminate the outside of each bag by wiping it off
In the clean zone, place another plastic bag over the outside of the original bag
Handle the documents carefully until they can be checked for contamination. If it is possible, make photocopies of the documents through the bags and place the originals in a safe location.

Emergency Response Guidebook (ERG) Overview

The ERG provides guidelines for responders to use for commonly transported hazardous material. This includes radioactive material. The guides for radioactive material are numbered 161-166. The most current is the ERG 2024. The ERG is only a guidebook and should not override local established standard operating procedures.



The purpose of the ERG is to assist a responder in making informed decisions about the type of hazards involved and initial precautions to take at an incident.

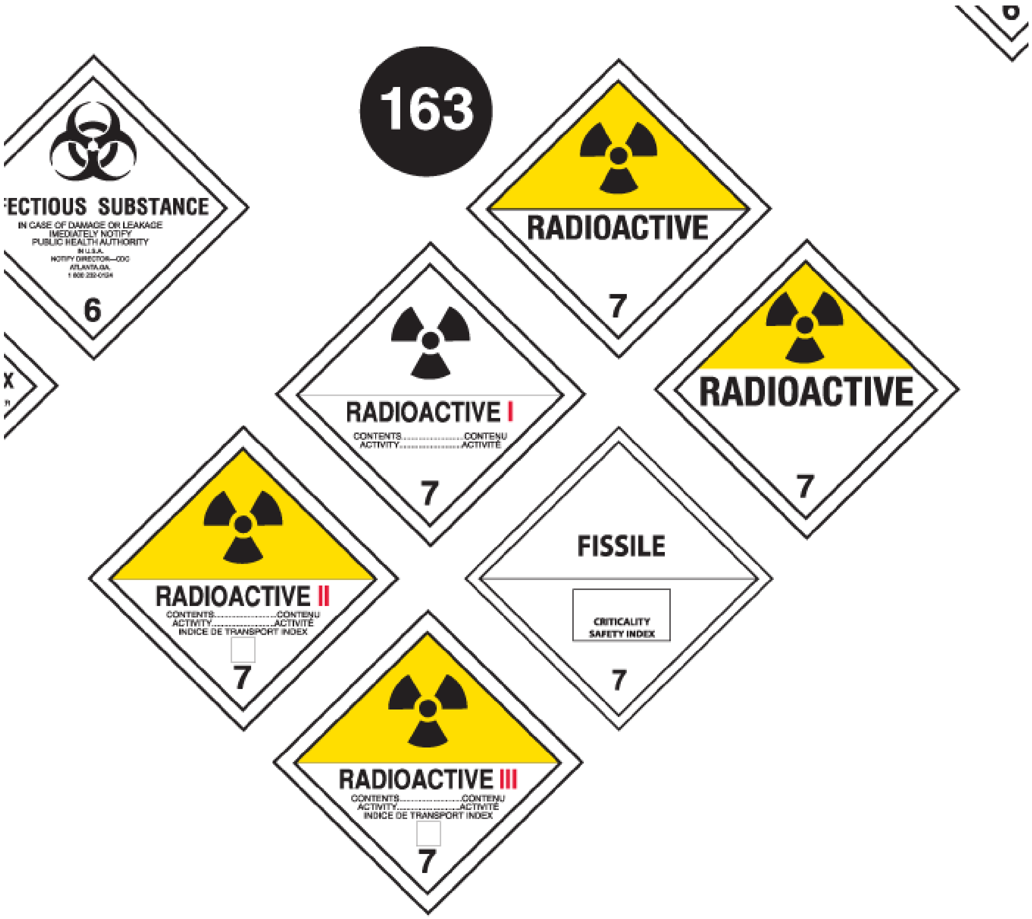
The ERG lists the four-digit UN ID used on shipping papers, package markings and some placards, as well as the Proper Shipping Names of hazardous material. Each hazard has a guide and precautions to help protect responders from harm. It also lists common placards used in the transportation of hazardous material.

Color-Coded Sections (Overview)

The initial section is **white** and contains general guidelines for any hazardous material situation. It addresses safety precautions and who to call when assistance is needed. The initial white section contains the "table of placards and initial response guides." The table of placards displays the placards used on transport vehicles carrying hazardous materials.

Refer to the table of placards and initial response guides if responding to an incident and you are unsure of the material on the placard. Match the vehicle placard(s) with one of the placards displayed on the table of placards. There is a numbered guide located next to each placard on the table. This guide number is shown as a circles number next to the placard. This guide number should be used until the hazardous material can be further identified.

For radioactive materials, package labels and placards are used on shipments are shown in the table of placards as shown below. If you see a radioactive label or placard pictured and have no other information, you can determine that Guide 163 should be used by looking at the circled number next to the radioactive label and placard on the table.



The **yellow** section shows the four digit UN ID in numerical order. By looking up the UN ID number, the guide number and name of the hazardous material can be found. For example, if you were looking up UN ID 2977, you would find that the name of the material is Uranium hexafluoride, fissile and the guide number is 166.

ID No.	Guide No.	Name of Material
2930	**134**	Poisonous solid, flammable, organic, n.o.s.
2930	**134**	Toxic solid, flammable, organic, n.o.s.
2931	**151**	Vanadyl sulfate
2931	**151**	Vanadyl sulphate
2933	**129**	Methyl 2-chloropropionate
2934	**129**	Isopropyl 2-chloropropionate
2935	**129**	Ethyl 2-chloropropionate
2936	**153**	Thiolactic acid
2937	**153**	alpha-Methylbenzyl alcohol, liquid
2937	**153**	Methylbenzyl (alpha) alcohol, liquid
2940	**135**	Cyclooctadiene phosphines
2940	**135**	9-Phosphabicyclononanes
2941	**153**	Fluoroanilines
2942	**153**	2-Trifluoromethylaniline
2943	**129**	Tetrahydrofurfurylamine
2945	**132**	N-Methylbutylamine
2946	**153**	2-Amino-5-diethylaminopentane
2947	**127**	Isopropyl chloroacetate
2948	**153**	3-Trifluoromethylaniline
2949	**154**	Sodium hydrosulfide, hydrated, with not less than 25% water of crystallization
2949	**154**	Sodium hydrosulfide, with not less than 25% water of crystallization
2949	**154**	Sodium hydrosulphide, hydrated, with not less than 25% water of crystallization
2949	**154**	Sodium hydrosulphide, with not less than 25% water of crystallization
2950	**138**	Magnesium granules, coated
2956	**149**	5-tert-Butyl-2,4,6-trinitro-m-xylene
2956	**149**	Musk xylene
2965	**139**	Boron trifluoride dimethyl etherate
2966	**153**	Thioglycol
2967	**154**	Sulfamic acid
2967	**154**	Sulphamic acid
2968	**135**	Maneb, stabilized
2968	**135**	Maneb preparation, stabilized
2969	**171**	Castor beans, meal, pomace or flake
2977	**166**	Radioactive material, uranium hexafluoride, fissile
2977	**166**	Uranium hexafluoride, radioactive material, fissile
2978	**166**	Radioactive material, uranium hexafluoride, non fissile or fissile-excepted
2978	**166**	Uranium hexafluoride, radioactive material, non fissile or fissile-excepted
2983	**131P**	Ethylene oxide and propylene oxide mixture, with not more than 30% ethylene oxide
2984	**140**	Hydrogen peroxide, aqueous solution, with not less than 8% but less than 20% hydrogen peroxide
2985	**155**	Chlorosilanes, flammable, corrosive, n.o.s.
2986	**155**	Chlorosilanes, corrosive, flammable, n.o.s.
2987	**156**	Chlorosilanes, corrosive, n.o.s.
2988	**139**	Chlorosilanes, water-reactive, flammable, corrosive, n.o.s.
2989	**133**	Lead phosphite, dibasic
2990	**171**	Life-saving appliances, self-inflating

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The **blue** section lists each hazardous material by proper shipping name. Looking up the name of the hazardous material in this section gives the guide number. Using the previous example, if we look up "Radioactive material, Uranium hexafluoride, fissile" we find the guide number 166 and the UN ID 2977.

Name of Material	Guide No.	ID No.
Radioactive material, surface contaminated objects (SCO-I or SCO-II), fissile	**165**	3326
Radioactive material, surface contaminated objects (SCO-I, SCO-II or SCO-III), non fissile or fissile-excepted	**162**	2913
Radioactive material, transported under special arrangement, fissile	**165**	3331
Radioactive material, transported under special arrangement, non fissile or fissile-excepted	**163**	2919
Radioactive material, Type A package, fissile, non-special form	**165**	3327
Radioactive material, Type A package, non-special form, non fissile or fissile-excepted	**163**	2915
Radioactive material, Type A package, special form, fissile	**165**	3333
Radioactive material, Type A package, special form, non fissile or fissile-excepted	**164**	3332
Radioactive material, Type B(M) package, fissile	**165**	3329
Radioactive material, Type B(M) package, non fissile or fissile-excepted	**163**	2917
Radioactive material, Type B(U) package, fissile	**165**	3328
Radioactive material, Type B(U) package, non fissile or fissile-excepted	**163**	2916
Radioactive material, Type C package, fissile	**165**	3330
Radioactive material, Type C package, non fissile or fissile excepted	**163**	3323
Radioactive material, uranium hexafluoride, fissile	**166**	2977
Radioactive material, uranium hexafluoride, non fissile or fissile-excepted	**166**	2978
Rags, oily	**133**	1856
Receptacles, small, containing gas	**115**	2037
Red phosphorus	**133**	1338
Refrigerant gas, n.o.s.	**126**	1078
Refrigerant gases, n.o.s. (flammable)	**115**	1954
Refrigerant gas R-12	**126**	1028
Refrigerant gas R-12B1	**126**	1974
Refrigerant gas R-12B2	**171**	1941
Refrigerant gas R-13	**126**	1022
Refrigerant gas R-13B1	**126**	1009
Refrigerant gas R-14	**126**	1982
Refrigerant gas R-21	**126**	1029
Refrigerant gas R-22	**126**	1018
Refrigerant gas R-23	**126**	1984
Refrigerant gas R-32	**115**	3252
Refrigerant gas R-40	**115**	1063
Refrigerant gas R-41	**115**	2454
Refrigerant gas R-114	**126**	1958
Refrigerant gas R-115	**126**	1020
Refrigerant gas R-116	**126**	2193
Refrigerant gas R-124	**126**	1021
Refrigerant gas R-125	**126**	3220
Refrigerant gas R-133a	**126**	1983
Refrigerant gas R-134a	**126**	3159
Refrigerant gas R-142b	**115**	2517
Refrigerant gas R-143a	**115**	2035
Refrigerant gas R-152a	**115**	1030

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The **orange** section contains the guides to use for each material. These guides contain the precautions to take for each hazardous material. These guides identify potential hazards (health, fire, or explosion) and emergency actions (initial, spill, leak, and first aid). Each guide has two pages. Guide 166 is shown below:

GUIDE 166 RADIOACTIVE MATERIALS - CORROSIVE (URANIUM HEXAFLUORIDE/WATER-REACTIVE)

POTENTIAL HAZARDS

HEALTH

- Radiation presents minimal risk to transport workers, emergency response personnel and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases.
- Low radiation hazard to people. **Chemical hazard greatly exceeds radiation hazard**.
- Substance reacts with water and water vapor in air to form **toxic and corrosive hydrogen fluoride gas, hydrofluoric acid**, and an extremely irritating and corrosive, white-colored, water-soluble residue.
- **Toxic; may be fatal if inhaled, ingested, or absorbed through skin.**
- Direct contact with substance and gas may cause burns to skin, eyes, or respiratory tract.
- Runoff from control of cargo fire may cause low-level pollution.

FIRE OR EXPLOSION

- Substance does not burn.
- The material may react violently with fuels.
- Product will decompose to produce toxic and/or corrosive fumes.
- Containers in protective overpacks (horizontal cylindrical shape with short legs for tie-downs), are identified with AF, B(U)F or H(U) on shipping papers or by markings on the overpacks. They are designed and evaluated to withstand severe conditions including total engulfment in flames at temperatures of 800°C (1475°F) for a period of 30 minutes.
- Bare filled cylinders, identified with UN2978 as part of the marking (may also be marked H(U) or H(M)), may rupture in heat of engulfing fire; bare empty (except for residue) cylinders will not rupture in fires.
- Radioactivity does not change flammability or other properties of materials.

PUBLIC SAFETY

- **CALL 911. Then call emergency response telephone number on shipping paper.** If shipping paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.
- **Priorities for rescue, life-saving, first aid, fire control and other hazards are higher than the priority for measuring radiation levels.**
- Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.
- Stay upwind, uphill and/or upstream.
- Keep unauthorized personnel away.
- Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

PROTECTIVE CLOTHING

- Wear positive pressure self-contained breathing apparatus (SCBA).
- Wear chemical protective clothing that is specifically recommended by the manufacturer **when there is NO RISK OF FIRE**.
- Structural firefighters' protective clothing provides thermal protection **but only limited chemical protection**.

EVACUATION

Immediate precautionary measure

- Isolate spill or leak area for at least 25 meters (75 feet) in all directions.

Spill

- See Table 1 - Initial Isolation and Protective Action Distances.

Fire

- When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

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Page 2 of the guide lists the emergency actions for fire, spill or leak, and first aid for that material.

RADIOACTIVE MATERIALS - CORROSIVE (URANIUM HEXAFLUORIDE/WATER-REACTIVE)

GUIDE 166

EMERGENCY RESPONSE

FIRE

- DO NOT USE WATER OR FOAM ON MATERIAL ITSELF.
- If it can be done safely, move undamaged containers away from the area around the fire.

Small Fire

- Dry chemical or CO_2.

Large Fire

- Dry chemical, CO_2, or withdraw from area and let fire burn.
- Only use water if the package is intact.
- DO NOT GET WATER on spilled substance or inside containers.
- ALWAYS stay away from tanks in direct contact with flames.
- Fight fire from maximum distance or use unmanned master stream devices or monitor nozzles.

SPILL OR LEAK

- Do not touch damaged packages or spilled material.
- **DO NOT GET WATER** on spilled substance or inside containers.
- Without fire or smoke, leak will be evident by visible and irritating vapors and residue forming at the point of release.
- Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material.
- Residue buildup may self-seal small leaks.
- Dike far ahead of spill to collect runoff water.

FIRST AID

Refer to the "General First Aid" section.

Specific First Aid:

- Medical problems take priority over radiological concerns.
- Use first aid treatment according to the nature of the injury.
- **In case of skin contact with hydrogen fluoride gas and/or Hydrofluoric acid**, if calcium gluconate gel is available, rinse 5 minutes, then apply gel. Otherwise, continue rinsing until medical treatment is available.
- Do not delay care and transport of a seriously injured person.

In Canada, an Emergency Response Assistance Plan (ERAP) may be required for this product. Please consult the shipping paper and/or the "ERAP" section.

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The **green** section of the ERG contains the table of initial isolation and protective action distances. These distances are useful for protecting people from vapors resulting from spills considered poisonous of toxic if inhaled. If you find an index entry is highlighted in the yellow or blue sections, look for the UN ID number and name of the material in the table of initial isolation and protective action distances. Contains the table of initial isolation and protective action distances. These distances are useful for protecting people from vapors that result from spills considered poisonous or toxic, if inhaled. If you find an index entry is highlighted in the yellow or blue sections, look for the UN ID number and name of the material in the table of initial isolation and protective action distances. Begin necessary protective actions.

2977 2977	166 166	Radioactive material, uranium hexafluoride, fissile **(when spilled in water)** Uranium hexafluoride, radioactive material, fissile **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	30 m (100 ft)	0.4 km (0.2 mi)	1.6 km (1.0 mi)
2978 2978	166 166	Radioactive material, uranium hexafluoride, non fissile or fissile-excepted **(when spilled in water)** Uranium hexafluoride, radioactive material, non fissile or fissile-excepted **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	30 m (100 ft)	0.4 km (0.2 mi)	1.6 km (1.0 mi)
2985	155	Chlorosilanes, flammable, corrosive, n.o.s. **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	60 m (200 ft)	0.5 km (0.3 mi)	1.6 km (1.0 mi)
2986	155	Chlorosilanes, corrosive, flammable, n.o.s. **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	60 m (200 ft)	0.5 km (0.3 mi)	1.6 km (1.0 mi)
2987	156	Chlorosilanes, corrosive, n.o.s. **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	60 m (200 ft)	0.5 km (0.3 mi)	1.6 km (1.0 mi)
2988	139	Chlorosilanes, water-reactive, flammable, corrosive, n.o.s. **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	60 m (200 ft)	0.5 km (0.3 mi)	1.6 km (1.0 mi)
3023	131	2-Methyl-2-heptanethiol	30 m (100 ft)	0.2 km (0.1 mi)	0.2 km (0.1 mi)	60 m (200 ft)	0.6 km (0.4 mi)	0.8 km (0.5 mi)
3048	157	Aluminum phosphide pesticide **(when spilled in water)**	30 m (100 ft)	0.1 km (0.1 mi)	0.7 km (0.4 mi)	400 m (1250 ft)	1.6 km (1.0 mi)	4.5 km (2.8 mi)
3057	125	Trifluoroacetyl chloride	30 m (100 ft)	0.2 km (0.1 mi)	0.9 km (0.6 mi)	800 m (2500 ft)	4.9 km (3.1 mi)	11.0+ km (7.0+ mi)

"+" means distance can be larger in certain atmospheric conditions

TABLE 1

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If the words "when spilled in water" also appear in conjunction with the listed material, the material is indicated to be water reactive and may produce a toxic gas. There is a table of water reactive materials at the end of the **green** section. Our example of Uranium hexafluoride produces hydrogen fluoride.

TABLE 2 - WATER-REACTIVE MATERIALS WHICH PRODUCE TOXIC GASES

Materials Which Produce Large Amounts of Toxic-by-Inhalation (TIH) (PIH in the US) Gas(es) When Spilled in Water

ID No.	Guide No.	Name of Material	TIH Gas(es) Produced
1931	**171**	Zinc dithionite	H_2S SO_2
1931	**171**	Zinc hydrosulfite	H_2S SO_2
1931	**171**	Zinc hydrosulphite	H_2S SO_2
2004	**135**	Magnesium diamide	NH_3
2011	**139**	Magnesium phosphide	PH_3
2012	**139**	Potassium phosphide	PH_3
2013	**139**	Strontium phosphide	PH_3
2308	**157**	Nitrosylsulfuric acid, liquid	NO_2
2308	**157**	Nitrosylsulphuric acid, liquid	NO_2
2353	**155**	Butyryl chloride	HCl
2395	**155**	Isobutyryl chloride	HCl
2434	**156**	Dibenzyldichlorosilane	HCl
2435	**156**	Ethylphenyldichlorosilane	HCl
2437	**156**	Methylphenyldichlorosilane	HCl
2495	**144**	Iodine pentafluoride	HF
2691	**137**	Phosphorus pentabromide	HBr
2692	**157**	Boron tribromide	HBr
2806	**139**	Lithium nitride	NH_3
2965	**139**	Boron trifluoride dimethyl etherate	HF
2977	**166**	Radioactive material, uranium hexafluoride, fissile	HF
2977	**166**	Uranium hexafluoride, radioactive material, fissile	HF
2978	**166**	Radioactive material, uranium hexafluoride, non fissile or fissile-excepted	HF

Chemical Symbols for TIH (PIH in the US) Gases:

Br_2	Bromine	HF	Hydrogen fluoride	NO_2	Nitrogen dioxide
Cl_2	Chlorine	HI	Hydrogen iodide	PH_3	Phosphine
HBr	Hydrogen bromide	H_2S	Hydrogen sulfide	SO_2	Sulfur dioxide
HCl	Hydrogen chloride	H_2S	Hydrogen sulphide	SO_2	Sulphur dioxide
HCN	Hydrogen cyanide	NH_3	Ammonia		

Page 338 **Use this list only when material is spilled in water.**

The final white section contains information about protective clothing, and fire and spill control methods. Criminal/Terrorist use of chemical/biological/radiological agents including the differences between a chemical and a biological agent. Indicators of the types of incidents are also listed. Personal safety considerations and decontamination measures are listed. The final white section contains a glossary of terms.

Transporting Radioactive Material

Radioactive material is an essential part of our modern society. Doctors use radioactive materials to diagnose and treat many diseases. Smoke detectors use them to give early warnings of fires in our homes and offices. Products such as plastic wrap, radial tires, and coffee filters are manufactures in factories that use radioactive materials.

Radioactive material is transported every day by roads, air, rail, and water. It is shipped from where it is produced to where it is used. The use of radioactive material sometimes produces radioactive waste that must then be shipped for disposal. Radioactive materials are shipped using strict federal regulations. These regulations are intended to protect the public and the environment from the risks associated with radioactive material during normal and accident conditions.

Radioactive material is generally shipped in its most stable form and most often that is solid. When shipped as a liquid or as a gas, additional precautions are required by federal regulations. A lot of research and design goes into packaging radioactive materials. The program has never resulted in a radiologically related death or injury from a transportation accident. The program includes emergency planning, driver training, and strict government inspections.

Hazard Evaluation

Federal regulations place strict administrative controls on the transportation of radioactive material. The worldwide philosophy of radioactive material transport is:

Safety should be primarily focused on the package, which is considered the first line of defense.

The package integrity should be directly related to the degree of hazard of the material it contains.

Radioactive Material Packaging

Radioactive material is packaged to ensure that radiation levels at the package surface do not exceed federal regulations. This ensures that shippers, the public, and the environment are not exposed to radiation levels that exceed recognized safe limits.

Different packaging types are required for various types, forms, quantities, and levels of radioactivity. There are four packaging types we will discuss:

Excepted Packaging
Industrial Packaging
Type A Packaging
Type B Packaging

Excepted Packaging

Excepted Packaging is used to transport materials with extremely low levels of radioactivity. Excepted Packaging is authorized for limited quantities of radioactive material that would pose a very low hazard if released in an accident. A smoke detector would be an example of a consumer good that would be shipped using this method. Excepted packaging is excepted (excluded) from specific packaging, labeling, and shipping paper requirements. They are required to have the letters "UN" and the four digit identification number for the radioactive material marked on the outside of the package. Excepted packaging is addressed in 49 CFR 173.421.

Industrial Packaging

Industrial Packaging is used for certain shipments of low activity material, as well as contaminated objects usually categorized as radioactive waste. Most low-level radioactive waste is shipped in these packages. Department of Transportation (DOT) regulations require that these packages allow no identifiable release of the material to the environment during normal transportation and handling. There are three types of industrial packaging: IP-1, IP-2, and IP-3. The category of package will be marked on the exterior of the package. The requirements for industrial packaging are addressed in 49 CFR 173.411.

Type A Packaging

Type A packaging is used to transport small quantities of radioactive material with higher concentrations of radioactivity than those shipped in industrial packaging. They are typically made of wood, steel, or fiberboard, and have an inner containment vessel made of glass, plastic, or metal surrounded by packing material made of polyethylene, rubber, or vermiculite. Examples of material shipped in Type A Packages include radiopharmaceuticals, radioactive waste, and radioactive sources used in industrial applications. Type A packaging and its radioactive contents must meet standard testing requirements to ensure that the package retains its containment integrity and shielding under normal transport conditions. The requirements for Type A packaging are addresses in 49 CFR 173.412.

Type A Packages must be able to withstand moderate degrees of heat, cold, vibration, reduced air pressure, impact, water spray, drop, penetration, and stacking tests. They are not designed to withstand the forces in an accident. The consequences of a material release from one of these packages would not be significant, since the quantity of material in this package is limited. Type A packages are only used to transport non life-endangering amounts of radioactive material.

Type B Packaging

Type B Packaging is designed to transport materials with high levels of radioactivity. Type B packaging can range from a small hand-held radiography camera to heavily shielded steel casks that weigh up to 125 tons. Examples of material shipped in Type B packaging include spent nuclear fuel, high level radioactive waste, and high concentrations of other radioactive material such as cesium and cobalt. These packages must withstand all Type A tests, as well as a series of tests that simulate severe or "worst case" accident conditions. The accident conditions are simulated by performance testing and engineering analysis. Life-endangering amounts of radioactive material are required to be transported in Type B Packages. The requirements for Type B packaging are addressed in 49 CFR 173.411, 49 CFR 174.413, and 10 CFR 71.

Risks Associated with Shipping Packages

Radioactive material in transport has additional information about potential risks to the responder, unlike other hazard classes. Some of this information may be found by identifying the packaging type for the material shipped. Excepted, Industrial, and Type A Packages contain non life-threatening amounts of radioactive material and pose minimal risk if contents are released in an accident. Type B Packages, may contain life-threatening amounts of radioactive material that could pose a significant risk if released in an accident.

The philosophy behind radioactive material transportation is where safety is primarily focused on packaging and package integrity and that it be appropriate to the material hazard. This dictates that Type B Packages be designed to withstand severe accident conditions.

In the DOE's fifty-year history of transporting radioactive material, there has never been a release from a Type B Package. There have, however, been accidents involving damage to the package. There were two of these between 1971 and 1991. One of these occurred on December 8, 1971. A truck of spent nuclear fuel left the road and the cask was thrown off and embedded in the ground. This accident occurred on U.S. 25 in Tennessee. The other accident occurred on February 13, 1985 where a steel drum with Ir-192 was involved in an accident where the vehicle overturned.

Radioactive Material Package Testing

The testing of radioactive material package designs are regulated by two agencies in the United States. These are the Department of Transportation (DOT) and the US Nuclear Regulatory Commission (NRC). There regulations are based on IAEA regulations.

The DOT is responsible for specifying the required test conditions for most packages. The NRC certifies that packages designed for materials with higher levels of radioactivity (Type B Packages) such as spent fuel meet NRC testing requirements. Package designs are tested using different methods, such as computer simulation, scale model testing, and/or full scale testing.

Type A Tests

Type A Packages must be able to withstand a series of tests that simulate normal transport conditions. These tests include:

Water – Water spray for 1 hour to simulate rainfall of 2 inches per hour

Drop – Free Drop test onto a flat, hard surface.

Stacking – Stacking test of at least 5 times the weight of the package. This test is conducted for at least 24 hours.

Penetration – Penetration test by dropping a 13 pound 1.25 inch diameter round bar vertically onto the package from a height of 3.3 feet.

Type B Tests

In addition to the requirements for Type A Packages, the NRC requires that Type B Packages be able to withstand a series of tests that simulate severe accident conditions. These tests include:

Free Drop – A 30-foot free drop onto a flat, essentially unyielding surface so that the package's weakest point is struck.
Puncture – A40-inch free drop onto a 6-inch diameter steel rod at least 8 inches long, striking the package at its most vulnerable spot.
Thermal – Exposure of the entire package to 1475 deg F for 30 minutes.
Immersion of the package under 50 feet of water for at least 8 hours.

Radiation Limits on Packages in Non-exclusive Use Shipments

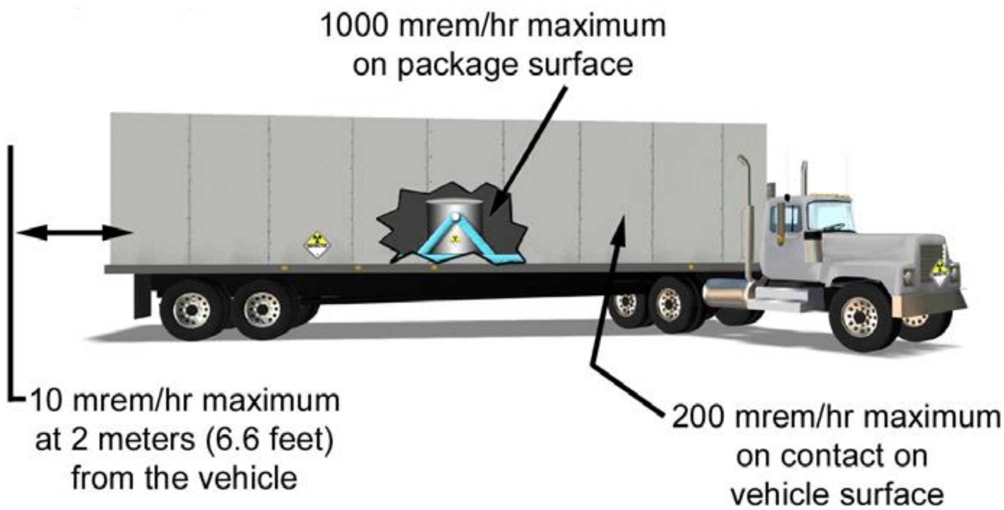
When radioactive material is transported under normal conditions (non-exclusive use), each package must be prepared for shipment so the maximum radiation level does not exceed 200 mrem/hour at any point on the external surface of the package and the transport index does not exceed 10. When assessing a package's integrity, you can use this information as a baseline for determining if damage has occurred to the package. For example, a dose rate reading of 250 mrem/hour on contact with the exterior of a package indicates possible damage.

In addition, you should not expect to see radiation dose rates on the surface of the vehicle that transports the material that are greater than the limits allowed for the packages inside the vehicle. An exception would be if several packages with dose rates close to 200 mrem/hr were located near the exterior surface of a vehicle where you may see a dose rate reading on the exterior of the vehicle above 200 mrem/hr.

Radiation Limits for Exclusive Use Vehicles

Packages that exceed certain radiation limits must be shipped by exclusive use. Packages shipped in exclusive use vehicles may have radiation levels up to 1,000 mrem/hr on the vehicle's exterior surface, provided:

The shipment is made in a Closed Transport Vehicle
The package is secured within the vehicle so that its position is fixed during transportation.
There are no loading or unloading operations between the beginning and end of the transportation



No point on the outer surfaces of the vehicle may exceed 200 mrem/hr. Drivers of exclusive shipments are required to have specific written instructions for the shipment included with the shipping papers.

Checking Packages for External Contamination

If you suspect a package may be breached, or it appears to be breached, you can check for the presence of removable contamination by taking a smear of the package. Removable contamination is defined as the radioactive material that can be transferred from a surface by rubbing with moderate pressure. The wipe/swipe (or smear) test is the universal method of assessing removable contamination. A small cloth, filter paper, or fiberglass disk is used to "wipe" an area or object suspected of being contaminated. A smear should cover a minimum surface area of 100 square centimeters. Smears should be dry and taken using moderate pressure. Protective clothing should be worn when taking smear samples to minimize the chances of personnel contamination.

Individual smear samples should be kept separate to avoid cross contamination. If pieces of cloth or paper towel are used, the samples can be kept spate by using plastic storage bags. Records should be maintained indicating date and location of each smear sample. They can be surveyed in the field with a contamination survey meter. The smear should be counted in a low background radiation area. The smears should be counted by holding the probe approximately ½ inch from the surface of the smear. Pausing for 5-10 seconds over the area provides adequate time for instrument response. When an object is considered contaminated depends on the state or local jurisdiction. Some jurisdictions, for example, use twice background or 100 CPM above background as a positive indication of contamination. Field counting techniques can be used to check for removable contamination, but may not be suitable for releasing material as clean. Release surveys are conducted under state or local radiation authority.

Handling of Exposed Individuals

When at the site of a radiological transportation incident, you must ensure your own safety as well as to ensure the safety of anyone exposed at the scene (patients). Approach the incident site with caution and look for hazards. Isolate the area and keep non-essential people away from the scene.

Emergency Medical Procedures

Medical issues take priority over radiological concerns. The use of universal precautions will help to reduce the spread of radiological contamination. Radiation exposure or contamination that results from a radioactive material shipment will not cause unconsciousness or immediate visible signs of injury.

Some radioactive materials are corrosive, such as uranium hexafluoride. Contact with corrosives can result in chemical burns or respiratory injury. Chemical burns from corrosive radioactive material are managed like any other corrosive injury. Patients should be treated according to the nature of their injuries. The presence of radiation does not interfere with rescue or extrication equipment used and will not influence the extinguishing properties of firefighting agents.

Do not delay treatment because of a lack of protective clothing nor survey meters, unless you standard operating procedures state otherwise. Emergency lifesaving assistance is always a higher priority than measuring radiation levels. Take precautions to avoid spreading contamination. A calm demeanor can be the most important for of treatment you can provide when handling a potentially contaminated person.

Radiation exposure is different from contamination. Contamination is a material that can get on you or in you. Exposure is energy that passes through you and exposure alone does not contaminate you.

The Department of Energy offers a Transportation Emergency Preparedness Program (TEPP) model procedure for the handling of contaminated patients and human remains.

Exposure Types

Three classes of patients may be encountered in a radiation incident. They are classified according to the following:

1. Patient exposed to radiation from an external source – A patient that was exposed to radiation alone will not pose a contamination problem. The degree of radiation-induced injury depends on the radiation dose received by the patient. Following external exposure, the patient is not radioactive or contaminated and can be handled without fear or concern of spreading contamination to you of the environment.

   Treat a patient exposed to external radiation the same as any other patient, as it would be like receiving radiation therapy. If the level of exposure was high, the patient may require further treatment at a specialized hospital. Not that no one has ever received a medically significant exposure to radiation during a transportation incident involving radioactive material.

2. Externally contaminated patient – Coming into contact with radioactive material (gas, liquid, or solid) that has been released into the environment can contaminate a patient. Externally contaminated patients may have more radioactive material on portions of their bodies or clothing. This contamination represents a potential hazard to other people. If external contamination is suspected and the patient is seriously injured, lifesaving assistance should be given immediately. Contaminated patents should be handled with protocols similar to those used for bloodborne pathogens.

   Protective clothing (coveralls, gloves, turnout gear, etc.) should be worn while handling an externally contaminated patient to limit the spread of contamination. The patient should be wrapped in a blanket or sheet during movement, and all related clothing and bedding should be saved in plastic bags. Identify the bags as "RADIOACTIVE – DO NOT DISCARD." The outer clothing of response personnel attending to the patient needs to be saved and surveyed for contamination by qualified personnel. Contaminated items will needs to be handled and disposed of in accordance with state and federal regulations.

   Contamination could be in or near a wound. In this case, the primary objective must be to treat the wound and prevent further contamination into the wound. An open cut or wound could allow contamination to enter the body. This could cause internal contamination.
3. Internally contaminated patient – The internally contaminated patient presents little risk to response personnel. The patient can become internally contaminated if radioactive material is inhaled, ingested, or introduced into the body through a cut or wound.

   The internally contaminated patient may also be externally contaminated and must be treated using external contamination procedures. The internally contaminated patient will require specialized treatment at a hospital to prevent further uptake of the contaminant and promote its removal from the patient's body.

Gross Decontamination

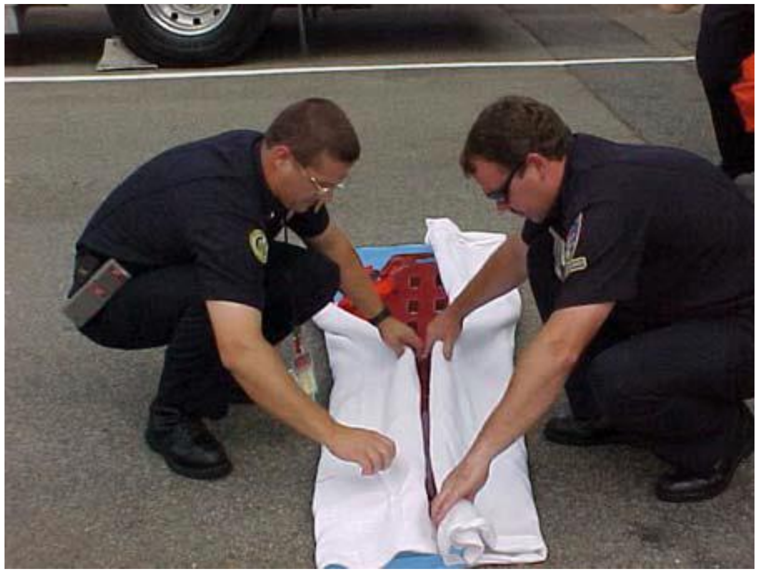
If contamination is suspected (presence of damaged or leaking packages), remove all of the patients outer clothing. This is called gross decontamination (decon). It can dramatically reduce the amount of contaminants on the body. The best technique is the cut the patient's outer clothing up the middle and carefully lay the cut clothing open away from the patient. This should minimize the spread of contamination. A gross decontamination should only be considered if radioactive material packages appear to be breached and it is suspected that contamination has been released.

If you suspect contamination and have performed a gross decontamination, the patient's clothing should be left inside the hot zone. This clothing will need to be bagged and identified as radioactive. Minimizing the amount of radioactive material in the treatment area will help keep radiation dose rates low. Wipe any exposed surfaces, especially around the patient's mouth, if a respirator or oxygen mask is being applied. Additional decontamination, if time permits, should only be done by those trained in radiological decontamination.

The following step-by-step procedure is provided as an example or performing gross decontamination and packaging of a potentially contaminated patient.

1. Utilize the ERG and conduct a scene size-up. Establish contamination control zones, and determine essential equipment needed, without entering the hot zone.
2. Prior to entering the hot zone, prepare the backboard or other device that will be used to remove the patient from the hot zone as follows:
   A. Spread the protective barrier (blanket, sheet, ect).
   B. Spread a second protective barrier (blanket, sheet, ect) on top of the first one.
   C. Place the backboard or other device in the center of the protective barrier as shown.

   D. Roll the edges of the protective barrier until only the remaining unrolled portion can be placed on top of the backboard or other extrication device.



E. Place any essential medical response equipment on top of the backboard or other device. Avoid taking advanced life support equipment into the hot zone.

3. Put on the appropriate protective gear. Firefighting gear or Body Substance Isolation Clothing (BSIC) is recommended, including two pairs of latex gloves and respiratory protection, if available (i.e. Self-Contained Breathing Apparatus, Air Purifying Respirator, or N95 Particulate Mask).
4. Enter the hot zone and place the backboard or other device adjacent to the patient and unroll the protective barriers. Life threatening injuries such as severe hemorrhaging and airway control should be corrected immediately. Advanced life support should not be attempted in the hot zone. The patient should be promptly packaged and transferred to the clean area for further care.
5. Evaluate the need for reducing contamination on the patient.
6. Reduce contamination on the patient's by carefully cutting the patients clothing away from the body.
7. Emergency responders should carefully remove their outer pair of latex gloves.
8. Treat non-life-threatening injuries as necessary. If there is contamination suspected in or near a wound or injury, the primary duty is to treat the wound or injury and prevent the spread of contamination.
9. Load the patient on the backboard or other device using standard medical protocols, and wrap the inner protective barrier around the patient.
10. Emergency medical care personnel should hand carry the patient to the boundary of the hot zone.
11. A second team should have transportation device (gurney or stretcher) waiting at the boundary of the hot zone. The device should be covered with a protective barrier.

12. At the boundary of the hot zone, the patient should be passed from the first set responders to the second.
13. After transferring the patient to the clean area, emergency medical providers should cover the patient with the protective barrier that was placed over the transport device.
14. The patient should be loaded into an ambulance for transport to the hospital. EMS personnel inside the ambulance should wear appropriate protective clothing.
15. EMS providers transporting the patient should verify the receiving hospital has the capability to treat a potentially radiologically contaminated patient.
16. EMS workers should notify the receiving hospital of the patient status, radiological contamination concerns, estimated time of arrival, and the need for the monitoring of themselves and the ambulance. Ask about special procedures for the receipt of contaminated patients (i.e. special entrance).
17. EMS providers should follow the hospital's radiological control protocol, upon arrival. EMS personnel should remove the patient from the ambulance and establish a contamination control zone in and around the ambulance. The ambulance should not be returned to service until the vehicle, equipment, and crew have been surveyed for radiological contamination.
18. Do not eat, drink, smoke, or chew until being surveyed and released by the Radiation Safety Officer at the hospital.

Detecting Radiation
Radiation cannot be detected by our senses, so using radiological survey instruments is necessary in measuring radiation. There are instruments for measuring radiation and ones for measuring contamination. There are some designed to detect both.

Basic Theory
Radiological survey instruments convert radiation energy into a meter reading. Ionizing radiation interacts with material in the detector to produce ions. The ions are collected by the detector and sent to the instrument. The instrument produces and audible and/or visual response. Some radiological survey instruments have the detector and meter combined into one unit while others have the detector attached to the meter by cable.

Contamination Survey Instruments
Contamination survey instruments are very sensitive and measure the presence of radioactive material by using counts per minute (CPM). They are useful in detecting contamination on equipment and personnel. Contamination survey instruments should not be used to measure radiation exposure. Contamination surveys should always be reported in counts per minute.
The purpose of a contamination survey is to locate radioactive material in unwanted places. Contamination surveys are useful for:

Locating contamination on equipment and personnel

Determining the effectiveness of decontamination efforts
Verifying contamination control boundaries
Determining the extent and magnitude of a contaminated area

It is important to first the meter reading in the cold zone to account for background (naturally occurring) radiation. This should be determined before performing a survey. Contamination surveys should be performed in areas with low background radiation. Higher background radiation levels make it more difficult to determine levels of contamination.

Follow the manufacturer's recommendations or local procedures for pre-operational checks and calibration frequency. Follow the steps below as a general guideline:

Verify the instrument is on, set to the lowest scale, the audio can be heard , and that there is a visual response
The probe (or detector) should be held within ½ inch of the surface being surveyed
Move the probe slowly, approximately 1 to 2 inches per second
If the count increases while surveying, pause for 5-10 seconds over the area to provide adequate time for instrument response

Familiarize yourself with your jurisdiction's (usually the state) guidelines for when an individual or object is considered contaminated. For example, some jurisdictions use twice background (or 100 CPM above) as a positive indicator of contamination.

Radiation Exposure Survey Instruments

Exposure rate survey instruments typically measure radiation in terms of milliroentgen per hour (mR/hr) or roentgen per hour (R/hr). These effects are usually recorded in the biological equivalent of mrem/hour or rem/hour (micro or milli sieverts/hour in SI units). Instruments reading mR/hr or R/hr are the most useful for measuring radiation fields an accident scene. Radiation survey instruments are generally not as sensitive as contamination survey instruments and may not detect some types of contamination as well.

Uses of Radiation Exposure Survey Instruments

The purpose of a radiation exposure survey is to locate and measure sources of radiation. Radiation exposure surveys are useful for the following:

Establishing control zone boundaries
Controlling the exposure of personnel
Assessing package integrity
Locating sources of radiation

Local procedures or manufacturers recommendations should be followed concerning pre-operational checks and calibration frequency of the instrument. Prior to performing a radiation survey, verify that the instrument is on, the range selector switch is on the lowest scale, the audio can be heard (if applicable), and a visual response registers on the meter.

Many radiation exposure survey instruments can detect both beta and gamma radiation. These instruments typically use a rotating or movable beta shield that can be opened to admit beta radiation as shown in the DOE photo below.

When the detector shield is closed , beta radiation is blocked out and only gamma radiation is detected. When the detector shield is open, both beta and gamma radiation is detected. The contribution of a beta dose to a measurement can be determined by subtracting the reading taken with the beta shield closed from the reading taken with it open (open window reading – closed window reading).

When you surveying beta and gamma radiation, measurements should be made by approaching the area or object to be surveyed with the detector extended in front of you and the beta shield in the open position. It will detect both gamma and beta radiation in the open position.

You should periodically monitor in a 360-degree circle to make sure you have not walked by a source of radiation. Monitor for radiation with the detector at waist level and periodically check above and below this level. When a source of radiation is discovered, survey to determine its approximate location.

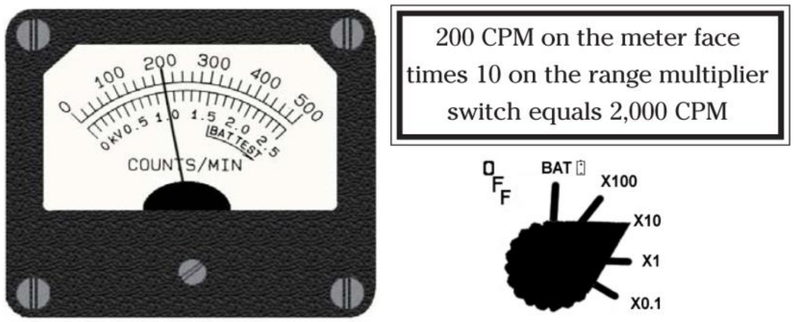
While performing a radiation survey, it is useful to listen to the audio response so that the response to a radiation field can be heard, even if you are temporarily distracted.

The following table can be used to assist in converting SI units to traditional units:

Reading in Sieverts	Equals	Reading in rem
1 microsieverts	=	0.1 millirem
1 millisievert	=	100 millirem
1 sievert	=	100 rem

Reading the Meter

Most of the newer survey instruments have digital displays and automatically adjust the range from microrem to millirem and rems per hour or from counts per minute (CPM) to kilo counts per minute. Analog instruments can be more difficult to read than digital instruments. It may require the user to multiply the reading displayed on the face by a multiplier, depending on the scale the range multiplier is set. This is much like the old analog multimeters. In the example below, the meter face shows a reading of 200 CPM. Since the range multiplier switch is set to X10, he reading of 200 is multiplied by 10, giving the actual reading as 2,000 CPM.



Contamination survey results are usually recoded in CPM and radiation survey results are usually recorded in mR/hr, as mentioned earlier. Some instruments display in both CPM and mR/hr. For those instruments, the user should determine which units to record their readings, based on the type of survey being performed (radiation or contamination). Contamination surveys are best performed using pancake style probes. Radiation surveys are best performed using hotdog style probes. The two styles are illustrated below.


Pancake Style Probe


Hotdog Style Probe

One such meter is the CD V-700 and its face reads in both CPM and mR/hr. This type of survey instrument should be used with the standard side window GM or hotdog probe for readings in mR/hr, when the probe window is closed and in CPM when the probe window is open.

Dosimetry Devices

Dosimetry devices are useful for keeping track of your total radiation dose. They are not required at an incident scene. They may be required by your state, however. The State of Texas requires a dosimeter for one year on registered x-ray devices used for Positive Material Identification (PMI). A dosimeter is like the odometer on your car. For example, where the odometer measures total miles traveled, the dosimeter measures the total dose you have received. There are several different types of dosimeters available.

Self Reading Dosimeters

A self-reading dosimeter (SRD) measures the radiation dose in roentgens (R) or milliroentgens (mR). They generally only measure gamma and x-ray radiation. The SRD can have many names, such as direct reading dosimeter (DRD), pockets ion chamber (PIC), and pencil dosimeter, to name a few.

To read the dosimeter, hold it up to a light source and look through the eyepiece. Record the reading before you enter a hot zone (radiation field). At 15 to 30 minute intervals, read your SRD while working in the hot zone, and read upon exit from the hot zone. If the reading is higher than expected or is reading off the scale, you should:

- Notify others in the hot zone
- Have the others check their SRDs
- Exit the hot zone immediately
- Follow your local reporting procedures

If you are using a low range (0 to 200mR) dosimeter, you should consider exiting the hot zone if the dosimeter reads greater than 75 percent of full scale, to prevent it from going off scale. If it goes off scale it no longer records the dose you received. A dosimeter can be recharged or zeroed after each use. Record the final reading when you leave the hot zone. Care should be exercised when using an SRD, since they are sensitive instruments. Rough handling, static electricity, or dropping a dosimeter can result in off-scale or erroneous readings.

Electronic Dosimeters

The electronic dosimeter serves the same function as the SRD, but has a digital readout to display the total dose received in milliroentgens (mR) or millirem (mrem). Many of them have an audible response to indicate the exposure rate using a series of chirping noises. The frequency increases or decreases in relation to the dose rate. The advantage of these is there is an audible warning when the dose rates increase.

Thermoluminescent Dosimeters

Thermoluminescent dosimeters (TLDs) do not give an instant reading of an accumulated dose as other dosimeters do. Specialized equipment id required to retrieve the exposure data. This type will be typically required when complying with the state requirements, as you receive a report.

Radioactive Contamination

Radioactive contamination is undesired radioactive material that has been deposited on the surfaces of or inside structures, areas, objects, or people. Radioactive material can be a solid, liquid, or a gas. If radioactive material is released from a package, anything that comes into contact with it can become contaminated. This includes personnel, personal protective equipment (PPE), vehicles, or tools, that can easily spread by cross contamination or secondary contamination to persons, surfaces, or equipment. Care should be taken to prevent cross contamination. The following practices will help avoid spreading contamination:

- Change gloves after handling contaminated equipment or accident victims
- Avoid unnecessary activity in the contaminated area
- Sleeve or wrap equipment before entering the area
- Do not eat, drink, smoke, or chew in the hot zone
- Avoid touching unprotected skin areas

Performing a thorough contamination survey on individuals and equipment exiting the hot zone can help minimize the spread of contamination.

Personnel can become internally contaminated, externally contaminated, or both. Internal contamination occurs when radioactive material is ingested, inhaled, or otherwise ingested into the body. External contamination occurs when radioactive material gets on you or your clothing.

Radioactive Decontamination

Radioactive decontamination involves removing radioactive material from locations where it is not wanted. Decontamination is performed in order to:

- Decrease radiation exposure by removing the radioactive material
- Prevent the further spread of radioactive material
- Prevent or decrease the risk of internal contamination

Field Decontamination

Field decontamination involves setting up a decontamination station near the accident scene and performing decontamination of equipment and personnel. If the equipment is not to be contaminated in the field, it will need to be bagged and labeled as “radioactive” and properly shipped to a facility where decontamination can be performed. When field decontamination is being considered, the advantages and disadvantages need to be considered.

One of the main advantages of field decontamination is that it removes the source of decontamination and limits the possibility of spreading contamination. Decontaminating equipment can free up that equipment for use outside the hot zone.

There are also limitations to field decontamination. It is time consuming. The process can be slowed by untrained personnel, so a lack of trained personnel is a limiting factor. They must also be surveyed by a properly trained radiation authority before they can be considered safe. Wet methods of field contamination can produce large amounts of water that needs to be properly disposed of.

Field Decontamination Setup

If field decontamination is found to be necessary, it is important to establish a decontamination area. The decontamination corridor is usually established inside the warm zone, running between the hot zone and cold zone. The Incident Commander and the Safety Officer will determine where the decontamination corridor should be established. The following factors should be considered:

- Wind direction in relation to the incident scene
- Background radiation levels
- The boundaries of the hot, warm, and cold zones
- Areas for best access to the incident scene

The decontamination corridor will need the following:

- Equipment drop area (inside the hot zone)
- Clothing removal station for protective clothing
- Radiological survey station for surveying personnel after removal of protective clothing
- Decontamination station where personnel decontamination is performed

Equipment Decontamination

Equipment decontamination involves the removal of radiological contamination from equipment. Not all equipment can be decontaminated. Preplanning before taking equipment into the hot zone can help prevent equipment from becoming contaminated. For example, it can be put into a clear poly bag before taking into the hot zone. The bag is removed and disposed of upon exit from the area. Radiological survey instruments are routinely bagged prior to entering a contaminated area to prevent them from becoming contaminated.

If equipment needs decontamination, the following methods should be considered:

- Critical hand-held equipment – trained personnel should attempt to decontaminate equipment by wiping it down with a damp, absorbent cloth
- Critical heavy equipment – trained personnel can attempt decontamination using a non-abrasive wash solution

All of the solid or liquid waste generated during decontamination will need to be controlled, properly packaged, and stored for eventual disposal in accordance with local procedures.

Personnel Decontamination

Consideration should be given to methods that will minimize the amount of waste generated. There are simpler methods available for decontamination that are less time consuming, require fewer resources, and generate less waste.

Gross decontamination (gross decon) by removing all clothing can dramatically reduce the contaminants on a person's body. After a gross decon, clothing should be left in the hot zone. This clothing should be contained and controlled until surveyed. Minimizing the accumulation of contaminated or radioactive material in the area will help keep area radiation dose rates low. Localized areas of dry or loose contamination on clothing can be removed using a tape press, like removing lint from clothing.

Decontamination of the skin of personnel may be accomplished by using conventional non-abrasive cleansing techniques on localized contaminated body surfaces. Mild soap and lukewarm water are preferred. Cold water can cause the skin pores to close and fix the contamination into the skin. Hot water can cause skin pores to open, allowing contamination to go deeper into the skin. Any water or material used for this process needs to be contained and considered as radioactive waste. For localized contamination, prepackaged and pre-moistened wipes may be used instead of water to minimize the amount of waste generated. Decontamination techniques beyond gross decon should only be performed by properly trained personnel and under the direction of the Radiation Authority.

Stopping Further Release of Radioactive Material

Minimizing the spread of radioactive material is important during the emergency phase of an incident. This is usually the responsibility of the hazardous material response team. Do not attempt to control the spread of radioactive material, if you are not trained in the methods. Some things you can do are:

- Contain any runoff water that may be contaminated

- Ensure that equipment inside the hot zone stays there until surveyed for contamination
- Ensure that all fires are out as soon as possible to limit the spread of radioactive material via smoke.

Waste Disposal

Waste disposal can be a problem at any hazardous material scene. For a radiological incident, processes should be put in place as soon as possible to ensure the radioactive waste is contained.

- Have plastic-lined waste containers at the entry/exit of the decontamination corridor for the disposal of potentially contaminated material. These containers are often the same as for other hazardous material contaminated waste.
- Seal the tops of full plastic bags and place them in a holding area inside the hot zone..
- Ensure that containers are clearly identified as radioactive and properly stored for later disposal.
- Ensure that the area is monitored, because as waste material accumulates, as increased radiation dose rates are possible when waste material accumulates.
- Let properly trained personnel (typically state response team) survey waste material for contamination. Contaminated waste will need to be disposed in accordance with the applicable laws and regulations.
- Survey all personnel and equipment prior to exit from the hot zone. Contaminated items should be decontaminated or properly packaged for future decontamination or disposal.

Other Considerations

Before making any decision about disposing of any material as waste, or decontaminating material or equipment, consider the following:

- Many radioactive materials have very short half-lives. Commonly shipped medical or research isotopes have half-lives of hours or days. Short-lived materials can be sealed in a container to await decay of the material to a stable isotope.
- When using large quantities of water for decontamination, remember that the water has to be handled as radioactive material. Contaminated water can be difficult to deal with and expensive to process.
- Do not generate unnecessary waste. Use only the material needed to complete a safe and effective response.

Documentation and Disposal Obligations

Once the initial response phase of the incident is done, the focus switches to cleanup and disposal of radioactive waste. The carrier is responsible for the costs associated with the cleanup of the accident scene and the disposal of the radioactive material/waste. Radioactive material carriers are required to provide financial protection in the unlikely event of an incident involving radioactive material. The required liability coverage for carriers of radioactive materials varies, depending on the mode of transport and the type and quantity of radioactive material being shipped. If the damages from a radiological transportation accident exceed the amount of the carrier's private insurance coverage, umbrella coverage is provided under the Price-Anderson Act.

Event documentation and reporting is important as a step in recovering costs associated with a transportation incident involving hazardous material. Time, resources, and property damage must be recorded for payment. Documentation will be needed as legal evidence in the future. Your documentation must include the who, what when, where, how, and why of accident investigation.

References

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