# Basics of Radiation – Field [Transcript]

Hello and welcome to the Minnesota Homeland Security and Emergency Management’s online training course – The Basics of Radiation.

Please type your name, both first and last, and press enter

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## Introduction

In today’s popular culture we are surrounded by misinformation about the nuclear power industry and radioactivity. This misinformation plays on our fears and imaginations. We find it in the TV shows that we watch, the books that we read, the games that we play, the movies that we go to, and occasionally sensationalized stories will even make the news.

Many times, however, the information in these popular culture sources are – at best – one sided and misleading. And – at worst – completely false.

As a result of this influence, we all have various preconceptions when it comes to radioactivity. Unfortunately, not all of our preconceptions may be correct. It is, therefore, the purpose of this course to present you with the facts about radioactivity and hopefully clear up some of the possible misconceptions people may have about what radioactivity is, what it does, and how we can use it effectively and manage it safely.

## Overview:

For the duration of this course, we will discuss the principle aspects of radiation including what it is, it’s health effects and how we can protect ourselves from radiation. As we go through this training we will try to put it into context as to what it means for emergency workers that would be doing various jobs in the wake of an accident at a nuclear power plant.

## Background

Radioactivity is all around us. It can be easily measured. In fact [beeping] if a survey meter is turned on in an empty room, you can record the background radiation [beeping continues]

Actually, everything we encounter in our daily lives contains some radioactive material – some naturally occurring and some manmade.

It’s in the air we breathe, the water we drink, the food we eat, the ground we walk upon, and even in the consumer products we purchase and use. As a matter-of-fact, most residential smoked detectors contain a low-activity Americium- 241 source. And light-saving light bulbs contain a low level of Promethium-147. And while less common than it once was, some brands of lantern mantels incorporate Thorium-232. Such mantels are sufficiently radioactive that they are often used as a check-source for survey meters. Also some antique pottery, such as the orange or red Fiestaware, are radioactive due to the presence of uranium in the glaze.

And finally, food contains a variety of different types and amounts of naturally-occurring radioactive materials. For example, low-sodium salt substitutes contains enough potassium-40 to double the background rate for a survey meter.

Because we are surrounded by radioactivity at all times, the average person receives a dose of approximately 360 millirem to 620 millirem every year. Most of this comes from Radon, the colorless and odorless gas that can seep into our basements. Fifteen percent comes from external background and another fifteen percent comes from various medical applications.

Eleven percent of our annual dose actually comes from inside the body. While four percent comes from various consumer products and all other sources.

So, why is there a range in the dose from 360 to 620 millirem? The reason is due to the increased reliance on medical applications that use radiation, especially CT scans. For example, an average chest x-ray can range from about ten to 39 millirem. While an average CT scan varies from approximately 150 to 1300 millirem.

So, depending on your exposure to the medical applications that use radiation, your average dose may be closer to 360 millirem or 620 millirem.

## Radiation

So, what is radiation?

Well, its energy transported away from the nucleus of an unstable atom in the form of either particles or waves.

There are many different forms of radiation, ranging from very high energy to very low energy.

From the standpoint of radiation protection, radiation is usually separated into two categories – ionizing and non-ionizing – to denote the level of danger posed to humans.

Ionization is the process of removing electrons from atoms, leaving two electrically-charged particles behind.

It is these electrically charged particles that have the potential to cause damage to living tissue.

Extremely low-frequency, radio, microwave, infrared, visible, and ultraviolet radiation are all considered non-ionizing or low-energy. Whereas, x-ray, gamma and cosmic radiation are considered high-energy.

In this presentation we will examine the four types of ionizing radiation that we should be aware of in the context of a release at a nuclear power plant: alpha particles, beta particles, gamma rays and neutrons.

In this figure we have a radioactive source and four different shielding materials: a piece of paper, some metal foil, a brick wall and a glass of water.

Alpha radiation is a positively-charged helium nucleus that is emitted from a larger, unstable nucleus. It is a relatively massive particle, but it only has a short range in air, about one to two centemeters and can be absorbed completely by paper or skin. It is therefore considered to be not much of an external hazard. Alpha radiation can, however, be hazardous if it enters the body through inhalation or ingestion.

As a matter-of-fact, radon gas is an alpha emitter and it is for this reason that a radon is such an important and harmful internal hazard.

Beta radiation is an electron emitted from an unstable nucleus. Beta particles are much smaller than alpha particles and can penetrate further into materials or tissues. Beta radiation can be absorbed completely by sheets of plastic, glass, or metal, and it does not normally penetrate beyond the top layer of skin.

However, large exposures to high-energy beta emitters can cause skin burns and such emitters can also be hazardous if inhaled or ingested.

Gamma radiation is a very high-energy photon or a form of electromagnetic radiation like light that is emitted from an unstable nucleus that is often emitting a beta particle at the same time. It can be very penetrating and only a substantial thickness of dense materials such as concrete and steel or lead can provide good shielding. Gamma radiation can, therefore, deliver significant doses to internal organs without inhalation or ingestion.

And, finally, neutron radiation is a neutron emitted by an unstable nucleus. In particular, during atomic fission and nuclear fusion. And so, therefore, plays an important role in the generation of electricity at a nuclear power plant. Because they are electrically neutral, they can be very penetrating and require heavy shielding, rich in hydrogens, such as water, which reduce exposures. However, because neutrons are usually produced artificially in the reactor core, they would not be a concern in the unlikely event of a release at a nuclear power plant.

## Half-life

Unlike a biological hazard that can potentially replicate and increase as the emergency progresses, one of the fortunate aspects concerning an emergency involving radioactive materials is that it decreases or decays over time, so that the amount that we have at the beginning of the incident is the most that we will ever have to deal with.

The manner in which radioactive materials decay is also very predictable. It decays in terms of half-lives. So, at time zero we have a certain amount of radioactive material, here represented by these eight balls stacked on top of one another.

After one half-life, half of the materials have decayed, leaving – in this case – only four balls of radioactive material.

During the next half-life, it doesn’t mean that the rest of it will decay, but again half of the radioactive material will decay away, leaving two balls of radioactive material.

As this process progresses, half of the material will decay away by the end of each subsequent half-life.

It is important to note here, that the amount of radioactive materials never actually reaches zero. It only approaches closer and closer to zero as time progresses.

## Radiation and us – health effects

Within the general population, different people have varying sensitivities to radioactivity. The youngest in the population are the most sensitive and as we age our sensitivity to radioactivity decreases.

However, even as an adult, some cells in our more sensitive to the damaging effects of radioactivity than others.

It all has to do with how fast our cells our dividing. Those cells that replicate the fastest are the most sensitive, such as cells found in bone marrow.

While those cells that replicate very slowly, or not at all, such as nerve cells are the least sensitive to the effects of radioactivity.

There are four possible affects to cells when exposed to ionizing radiation. First, the ionizing radiation can pass through the cell without damaging. This would obviously be the best-case scenario.

Second, the radiation can damage the cell, but the cell will repair itself.

Third, radiation can damage the cell and the cell attempts to repair itself, but does so incorrectly. This could lead to division errors and ultimately to an increase risk of cancer in the long term.

And fourth, it may kill the cell outright. We have a lot of cells and can afford to lose a few. However, the problem comes if too many cells are killed too quickly. If this happens, acute health problems can be the result.

Now let’s explore scenarios three and four in a little more detail. First, scenario three: This is a result of a low amount of radiation exposure over a long period of time, which can lead to a cumulative build-up of errors in the DNA and an increase risk of cancer in the long term. This low level exposure over a long period of time is known as chronic exposure.

In scenario four, the death of cells can result an acute exposure to iodizing radiation or a high dose over a short period of time. Under extreme conditions, this can result in nausea, skin damage, loss of appetite, fatigue, and even death under a worse-case scenario.

While it is important not to down-play the seriousness of these acute effects, it is equally important to understand that the likelihood of experiencing these symptoms after an exposure to radiation is extremely low.

As a matter-of-fact, this is one of the misconceptions that this training seeks to correct.

Before we take a look at actual numbers, we need to first understand the units that are used to measure radiation: the CPM, the Roentgen, and the Rem.

The CPM, or counts per minute, is used as a measurement of radioactivity and contamination and is a common setting on many survey meters.

The Roentgen is a measurement of radiation in dry air and can tell you what your exposure is.

Survey meters in dosimetry can measure radiation in Roentgen. And because our cells are not made of dry air we need something that is an expression of dose in human tissue and that is where the term the Rem comes in.

Because gamma radiation can damage regardless of whether or not it has been ingested, the conversion between roentgen and rem with gamma is one to one.

However, because alpha emitters are only considered to be a hazard when inhaled or ingested, the conversion is not one to one. Keeping this in mind for the purpose of this training, one rem will be considered the same as one roentgen. However, it is important to remember that is not always the case.

In addition, because these terms use the metric system, one roentgen, or one R, is the same as a thousand miliroentgen or milli-R and one REM is the same as 1000 millirem.

## Acute Effects of Radiation

Now let’s put this into context and look at some actual numbers – this chart gives details about the clinical symptoms that result from various doses of ionizing radiation for an untreated individual. The first column shows that from 0 to 100 rem there are essentially no clinic symptoms, no incidents of vomiting, no affected organs. The therapy is to let people know they will be fine because the prognosis is excellent and nobody dies.

Now remember back to earlier in this training when we said the dose for an average chest x-ray is 10 to 39 millirem, if we use the high end of this range and round it up to 40 millirem to make the numbers easier to work with we will see that 40 milirem is the same as 0.04 rem, therefore in order to reach the equivalent of one hundred rem it would require a minimum of 2 thousand five hundred chest xrays all at once. And still there would be no clinical symptoms. Even if the full body dose were doubled to 200 rem and clinical symptoms started to appear , without any treatment at all the prognosis is still excellent and the dose is not lethal. Between 200 and 600 rem everyone would begin to have clinical symptoms and without treatment from 600 to 1000 rem the prognosis becomes guarded and the lethal range begins at one thousand rem.

So even though no clinical symptoms would be expected until doses of about 100 to 200 rem are reached, you may be asking yourself what’s happening at the cellular level at these lower doses. Well below 10 rem there are no noticeable effects of radiation that can be detected even with the most sensitive biological assays. That is the reason for the three dotted lines below the 10 rem mark on this graph. Since no changes can be detected the exposure risks below 10 rem are unknown. Above 10 rem however, small changes can be detected in the DNA and these changes become more detectable as the dose increases.

## Exposure Limits

So what do these numbers mean in relation to a possible accident at a nuclear power plant. Exposure limits have been set at both the federal and state levels to ensure the safety of emergency workers. In the state of Minnesota the emergency worker exposure limit is 3R for the entire incident. This includes all emergency workers, even those who would be out tracking the plume. These levels can be increased to 10 or 25R for special situations on a strictly voluntary basis for the protection of valuable property or in order to save lives but for all intents and purposes once an emergency worker reaches 3R they’re done for the incident. To increase the safety of emergency workers additional exposure limits have also been set. These include a turnback limit of 1R meaning that if this level is reached emergency workers must exit the area and reassess their situation. And there is an exposure rate limit meaning they must leave an area if their exposure instruments are reading 100 mR/hr or 0.1 R/hr.

Let’s put this into the context of a real event. This slide shows data from the actual release at the Fukushima plant in Japan. The data lets us see exposure rates on the ground at various time points following the incident from March 17 to April 17 2011. As time progresses we can see evidence of the radioactive decay as the area colored in red quickly disappears and the area colored in orange gets smaller. The top left panel is from March 17 through March 19th when the exposure rates were the highest. Even at this time point the highest exposure rate was only about 12.5 mR/hr meaning that if an emergency worker were to stay in that area of highest radiation exposure until they received the Minnesota administrative limit of 3R they would need to remain there for a total of 240 hours or ten days and still there would be no noticeable changes that could be detected.

To sum up, radiation does not cause immediate death, sudden incapacitation or those horrifying burns and wounds that you may have seen pictures of on the Internet except at extremely high doses. Also, the doses received at a nuclear power plant incident would be far too low to cause any acute health effects from radiation.

## Questions

Question:

Multiple choice

At what does will a person begin to show clinical symptoms of radiation sickness?

0-100 mRem

100-200 Rem

500-600 Rem

900-1000 Rem

Question

True or false. An ACUTE radiation dose is one where a person receives a large does in a short amount of time.

Question:

At what dose do cellular changes begin to be noticed

5 mRem

10 mRem

5 Rem

10 Rem

The administrative General Exposure Limit for emergency workers in minnesota is (fill in the blank0 R

Choices:

1, 3,5 or 25

The Turnback Limit for emergency workers in Minnesota is (fill in the blank) R

Choices

1,3,5 or 25

The Turnback Exposure rate limit is (fill in the blank ) mR/hr

Choices

10, 50, 100, 500

True or False, The dose received by an emergency worker would be far below levels that would result in any acute effects of radiation.

## Radiation Protection

When working around radioactive materials there are a couple of concepts we need to keep in mind in order to adequately protect ourselves from the effects of ionizing radiation.

Those concepts are exposure and contamination.

Exposure. Radiation exposure occurs when a person is close enough to the source of radiation to be hit by the energetic particles and waves given off by the radioactive material.

Radioactive contamination occurs when radioactive material is deposited in or on an object or person.

(slide showing man standing by a fire)

To illustrate the difference between contamination and exposure, we have placed a person next to this campfire. As he stands there he feels its warmth and therefore is exposed to the heat being released by the fire just as someone close to a radioactive source would be exposed to the radiation emitted from that source. But when that person moves away from the fire, they no longer feel its warmth and are therefore no longer exposed to its heat, just as someone who moves away from a radioactive source would no longer be exposed to the radiation it emits. However, unlike the fire analogy such a person would not feel any heat from the radioactive source. With an actual campfire and an open flame, there will also be smoke that is emitted. The smoke can get on your clothes and can be detected even when the fire is no longer present. This situation is analogous to radioactive contamination. Radioactive contamination stays with you and can be detected and spread even after the person leaves the area.

## Sources of contamination and exposure

If there were a release at a nuclear power, there would be various sources of contamination and exposures that we would need to be aware of. Inhalation can occur if someone is immersed in the plume and breathes in the radioactive material contained within it resulting in contamination.

Cloud Shine can be a source of exposure even if the person is not immersed in the plume. If a plume containing Gamma emitters, is high above the Gamma rays can still shine down due to their ability to travel great distances. Similarly, Ground Shine can occur If the plume is deposited on the ground resulting in exposure from the radiation it emits. And, finally the food supply. Deposited radioactive material could potentially get into our water and even be ingested by animals that we use as a source of food and food products. Because of this possibility we have plans and procedures that address this type of scenario.

These plans and procedures are reviewed and renewed annual by the federal emergency management agency or FEMA and are exercised regularly to ensure the protection of the public and our food supply.

## Contamination and exposure

There are two types of contamination – internal and external.

External contamination can be found on the skin or clothing and can be removed by washing with lukewarm soap and water. Then there is internal contamination which is inhaled or ingested. As such it cannot be removed by simply washing with soap and water. While this makes it more troublesome, it can be removed by normal body processes and there are medical ways of removing it that are available to health care providers.

Here we have an unmarked barrel sitting in an empty room emitting these yellow wavy lines.

What type of radiation is this?

If you answered Gamma you are correct. We know that it’s Gamma not just because of the yellow, wavy lines which we wouldn’t be able to see in an actual situation, but because the radiation is able to penetrate the metal barrel. Let’s now put a responder in the room with this radioactive source.

Is this responder contaminated, exposed, or both to the radiation emitted from this barrel?

If you answered exposed then you are correct. The radioactive material is enclosed within the barrel so if this responder were to leave the area, he would no longer be exposed to the radiation. Now let’s take the scenario a step farther and see what happens if we remove the lid (slide shows green dots now in the air around the responder) and release the radioactive material contained within.

In this situation, is the responder now contaminated, exposed or both.

If you answered both you are correct.

He is contaminated due to all the radioactive material that has landed on him. He will take it with him when he leaves the area and can spread it to anything he comes into contact with. He is also exposed due to all the radiation material he is not in contact with. We can remove the external contact that he has (slide shows responder under shower) by removing his clothes and washing with soap and water.

However, if we are able to look inside (slide shows chest xray) we may notice he has internal contamination caused by inhaling the airborne radioactive material.

## ALARA Principle

To keep our dose as low as is reasonably achievable when we are working with and around radioactivity we need to use the principles of time, distance and shielding.

Time. In order to minimize our dose we must spend the least amount of time in a radiation area and be sure we clean up any contamination as quickly as possible.

Distance. The further we are away from a radioactive source the lower our exposure rate will be.

More on this in the next slide.

Shielding is placing an object or shielding material between yourself and the radioactive source.

In this training we have already discussed how various radioactive particles are shielded by different materials.

## Inverse Square Law

Now let’s explore the concept of distance in a little more depth using the inverse square law. In this field we have a barrel that will act as our radioactive source, now if we place a person at a certain distance from this radioactive source he’ll be exposed to radiation emitted from the barrel. At this distance his exposure can be measured and recorded. Let’s mark his location with a red circle and move him further away. We can now mark his current distance to the radioactive source with a yellow circle. If we measure his current location we will see he is exactly twice the distance to the barrel as he was initially.

We can now calculate his new exposure using the inverse square law – the inverse square law tells us that when an individual has moved two times further away from the source of radioactivity their exposure will be one over two squared, or one quarter the intensity it was initially. Likewise if we move him even further away, marking his new location now with a green circle, we find that he is now three times further away from the barrel than we first placed him at the red circle. Again using the inverse square law we can calculate that when he has moved three times further away, his exposure will be one over three squared or one ninth of the intensity it was when he was standing at the red circle. The inverse square law demonstrates nicely the importance of increasing your distance from a radioactive source in order to maximize safety and minimize potentially harmful doses of radiation.

Question:

If this person were now moved 4 times away from his original position, what would be his relative radiation exposure?

Choices:

One fourth

One eighth

One sixteenth

One twenty-four

## Dosimetry

We have many different tools available to us to help keep us safe when we work around radioactive materials. One is the direct reading dosimeter or DRD, also known as the pencil dosimeter. Minnesota emergency workers have access to two different types of DRDs that are sensitive to different levels of radioactivity. One reads between zero and two hundred milliR or 0.2 R. the other reads from zero to twenty R. using these DRDs we can keep track of our exposure in real time. By holding them up to the light and looking through them we will see a scale with a needle telling us our current exposure. These dosimeters can be reused and rezeroed as necessary by using a charger to reset the needle. It is for these reasons that DRDs are so convenient to use. But, there is one drawback. And that is their accuracy. They are not extremely accurate. The needle can jump if they are bumped or dropped resulting in incorrect readings.

(HSEM Thermoluminescent Dosimeter)

Another dosimeter that would be used by Minnesota emergency workers is the thermoluminescent dosimeter or TLD. These dosimeters are extremely accurate and their readings would constitute the legal exposure received by emergency workers during an incident. Unfortunately, these dosimeters also have a drawback. And that is they are not able to be read in real time the way DRDs can be. To read a TLD they need to be collected and sent off to a lab to be analyzed. Therefore emergency workers would be required to carry both types of dosimeter during an incident, the DRD which can be read in real time as well as the TLD which is extremely accurate.

(Ticking of a Geiger counter machine)

Another instrument we can use is the Geiger counter or survey meter. These are used to detect the presence of ionizing radiation. Because radioactive contamination is invisible, we can use survey meters, such as the one pictured here, to find radioactive contamination wherever it might be.

Emergency workers use these or similar devices for tracking the plume, measuring exposure rates in contaminated areas and for deconing contaminated individuals.

 (graphic with KI)

And finally there is potassium iodide.

Also known as KI. Occasionally this pill is referred to as an anti-radiation pill. It’s not. Potassium Iodide only protects one organ. Your thyroid. From one radio nuclide and that’s radioactive iodine. Your thyroid requires iodine in order to function properly. But it can’t tell the difference between the radioactive and non-radioactive forms of iodine. As a result it takes up and uses whatever forms of iodine happen to be present at the time. The purpose of taking KI is to saturate your thyroid with the non radioactive form so if you encounter the radioactive form of iodine your thyroid will not be able to take it up.

## Dosimetry Questions

Pictures of drd and ltd with questions:

Click on picture of dosimeter that is most accurate

Click on picture of dosimeter that you can read in real time

Click on picture of dosimeter that can read the smallest level of exposure

Question:

What is the exposure that this dosimeter has measured?

15 mR

23 mR

23R

20R

On the following slide, you will receive your certificate listing your name, agency, the name of the course, today’s date and your score. If you would like a copy, click the printer button located at the bottom of the certificate, but be sure to adjust your printer preferences to print your certificate in landscape rather than portrait. Printing your certificate is for your own records and is not used to track your training. In order to receive credit, you MUST press the “POST RESULTS” button at the bottom of the following page. Once you do so you will be directed to enter your Adobe ID or e-mail address and password. If you do not have an Adobe ID and password, you can get one by clicking on the light blue text on this slide or by visiting Acrobat.com.