This product is a part of the Radiological Education Monitoring and Outreach Project (REMOP) conducted by the University of Georgia Savannah River Ecology Laboratory in Burke County, Georgia with assistance from Georgia Women's Actions for New Directions. This project is supported by grants from the Department of Energy Savannah River Site.

3. Radiation in Our Lives

Concepts

- What the types of radiation in the environment are.
- The sources of radiation exposure to humans.
- The pathways of radionuclides in the environment and human bodies.
- How radiation is measured and what that is measuring (radioactive decay).

Skills: critical thinking, decision-making, observation

Materials

- Easel and poster board with large markers
- Handouts
- PowerPoint if not using easel and poster board

Time Consideration: Preparation 10-15 minutes, one 40-minute period

Objectives

- Participants will describe where radiation comes from in their community.
- Participants will understand how humans can be exposed to radiation.
- Participants will be able to describe the difference between ionizing radiation and non-ionizing radiation.

Key terms: radiation, radionuclides, background radiation, concentration, ionizing radiation, non-ionizing radiation, dose, pathways, alpha particles, beta particles, gamma radiation, frequency, atom, proton, electron, neutron, molecule, element

Background

Radiation and radionuclides are present in our day-to-day lives through multiple sources. It is important first to understand the foundation of radiation, which are elements. Elements are the building blocks of all matter and can be found in 3 basic forms, as solids, liquids, and gases. Elements make up our air, water, soil, clothes, bodies, computers, plants, etc. Examples of elements include oxygen, helium, uranium, lead, mercury, copper, and many more. On Handout 2, you'll see the Periodic Table of Elements, which is how all the known elements are organized. Today, we'll discuss the components of elements and the properties of elements and how those relate to the radiation we experience in our lives and environment.

The two sources of radiation are natural radiation and human-made radiation (Figure 1; 1,2). Natural radiation is also commonly called background radiation. Background radiation is radiation that comes from the sun, the ground, and outer space. Common sources of human-made radiation are medical x-rays, medical treatments, consumer products (like tobacco and televisions), nuclear weapons, and nuclear power (3). There are two types of radiation, non-ionizing radiation and ionizing radiation. Non-ionizing radiation includes radio waves, microwaves, infrared radiation and visible light that has a relatively low-energy output. Ionizing radiation has a higher frequency (or energy) than ionizing radiation and includes sources like ultraviolet (UV) radiation, x-rays, and gamma rays.

Radiation can pose health risks through burns and tissue damage (non-ionizing) as well as damage to DNA and cells (non-ionizing). About 79% of human-made radiation in the United States is from medical x-rays and nuclear medicine (like cancer treatments). Consumer products, like tobacco, domestic water supply, smoke detectors, computer screens, and televisions, make up about 16% of human-made radiation. The final 5% of human-made radiation is from occupational exposure, fallout, and the nuclear fuel cycle (1). As you increase your distance from a radiation source, your potential exposure also decreases (Figure 2). In November and December, we'll be discussing what risk means and what the risks from radiation are, but today we're focusing on how radiation is measured.

Radioactive elements lose energy over time, and this energy loss is called "decay." As elements decay, the energy emitted decreases over time and therefore any potential exposure risk to humans' decreases over time. Each element has a half-life (or the time it takes for one-half of a radioactive sample to decay) and can range from 5 days (bismuth-210) to over 4 billion years (uranium-238). An example of how scientists use half-life for scientific discoveries is the use of carbon-dating. Carbon-14 is a radioactive isotope that is naturally found in living organisms. When the organism dies, the carbon-14 is no longer replaced, so it decays. The amount of carbon-14 loss from the dead organism can be compared to living organisms' levels of carbon-14 to determine the time of death (4). The three main types of decay are alpha radiation, beta radiation, and gamma radiation. We'll discuss what each of these types of radiation does and how they can potentially affect us.

Tritium is one of the primary ionizing radiation sources of concern for Burke County residents from the Savannah River Site (SRS) and Georgia Power's Plant Vogtle and one of the radioactive elements monitored for by environmental monitoring programs in the area. In Burke County, tritium falls under regulation from the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), and the Department of Energy (DOE). Tritium molecules easily bind to water because of the similar molecular makeup. Tritium can be potentially hazardous when it decays, emitting ionizing radiation through the form of a beta particle (6). This beta particle from decaying tritium has relatively low energy, unable to penetrate the skin and moves only about 6 mm through the air before losing their energy (6). However, the most significant source of radioactive contamination is the aboveground testing of nuclear weapons in the 1950s and 1960s (2). Even though weapons testing and disasters like Chernobyl occur hundreds or thousands of miles away, radioactive contamination can be deposited through the atmosphere throughout the world (2, 5). Handout 4 from the CDC is a great illustration of the difference between radiation exposure to radiation contamination. In October, we'll be discussing how environmental monitoring programs in the area sample and monitor elements like tritium and then we'll discuss risk in November and December. Today we are going to focus on how radiation from elements like tritium is measured and what those measurements mean about one another.

We'll discuss in future Community Talks how environmental monitoring of radioactive elements is regulated by the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC). Today's Community Talk is going to focus on the basics of radiation and how we are and can be exposed to it. In the end, we'll discuss additional resources for learning more about radiation.

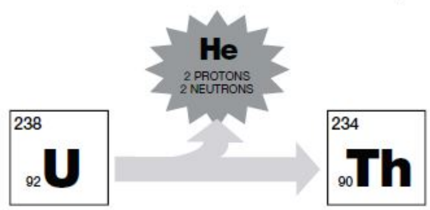
Preparation

1. Prepare easel and ensure that markers are working.
2. Ensure all participants have a handout and writing utensil available.
3. Review the Contaminant In Our Lives Lesson Plan (August). Summarize the sources, environmental pathways, and human pathways of exposure before beginning this lesson.

Lesson

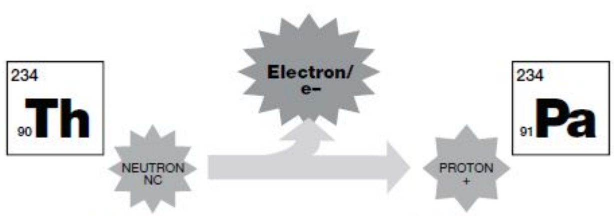
1. Describe what an element is. Elements are the building blocks of matter and can be found in 3 forms. Explain that everything we see is made of elements, as well as the air that we breathe and the liquids that

we drink. Our bodies are made of elements – the certain vitamins we take (like calcium and potassium). Elements are found in 3 forms, solids, liquids, and gases. Explain that element can be very stable, like carbon or copper, and can be very unstable, such as uranium and other radioactive elements.
2. Briefly describe the 3 basic components of an atom – protons, electrons, and neutrons – and refer to the first image in Handout 1. Describe how these components build each of the elements, and that each element has different properties that allow it to bind to other elements and molecules in the environment.
3. As we discussed earlier, there are a couple of sources of radiation exposure, which is exposure to radioactive decay processes – background and human-made radiation. Does anyone remember an example of background radiation? Wait for an answer (see below for examples). Does anyone remember an example of human-made (see below for examples)? Refer back to Handout 1, where Figure 5 will be present.
    a. Background: the sun, the ground, outer space
    b. Human-made: microwaves, medical x-rays, medical treatments, tobacco, smoke detectors, televisions, nuclear weapons, and nuclear power
4. The process of an element losing energy is called "decay." Radioactive decay is the emission of energy in the form of ionizing radiation. Ionizing radiation is a high-energy form of radiation that can pose health risks by damaging tissues and DNA in cells. Non-ionizing radiation has much lower energy and includes radiowaves and visible light.
5. Radioactive elements' decay time is typically discussed using the term "half-life." The second image illustrates the iodine-131 and its half-life.
6. There are three types of decay: alpha, beta, and gamma. You'll see on Handout 1 in the third image, an example of an element emitting three types of radiation. The arrows pointing out of the element are the types of decay we're discussing.
    a. Label each type of decay and describe. Draw the example below each type of decay on the Flipboard. Encourage students to label the diagram on their handout as you label yours.
        i. Alpha decay is the emission of helium (the element) nucleus or more simply, 2 protons. Protection from alpha decay can be prevented by a piece of paper or a few inches of air due to the low energy output.



NOTE: In the above example of an alpha decay, it is intuitive to note that the emission of 2 protons will decrease the atomic number by 2, because of the emission of 2 protons. Less obvious or simply overlooked is the decrease in the mass number by 4 nucleons (2 protons and 2 neutrons in total)!

        ii. Beta decay is the emission of a charged particle or electrons. Beta decay can be prevented by aluminum, brass, or plastic.



NOTE: Another perhaps obvious observation is that there is an increase by 1 of the number of protons in the new nuclide. Not so intuitive is that the mass number does not change. The total number of nucleons remains the same.

   iii. Gamma decay is the emission of ultra-high energy, non-visible light. It requires stronger preventative measures, like lead.

   b. Refer to the fourth image on Handout 1, of the relative energy output and protective layers from each type of decay discussed. Use the example of the x-ray: x-rays penetrate the soft tissue, but the reason we can see our bones is that the x-rays do not penetrate our bone. We also wear the lead vest or blanket to isolate the area of our body that needs to be x-rayed. This is to reduce our exposure to a high energy source of radiation.
      i. Think of this of measuring the difference between throwing a ping pong ball at a piece of paper (alpha) versus throwing a baseball at a piece of paper.

7. Discuss the second image on Handout 2. An example of two elements is decaying. Explain how this can be a complicated process and a very long process for certain radioactive elements.
8. Now that we know where radiation comes from, it's important to understand the ways radiation is measured. Encourage students to use the space on the back of their handout to write out these equations with you and explain that the equations are also at the top of the Personal Radiation Dose Estimate handout.
   a. There are multiple ways that radiation is measured and what those units of measurement mean (Figure 6, Handout 1). We're going to focus first on what a rad is and how a rad relates to a mrem. Typically, mrem is how we will see the biological risk of a radioactive source translated to us.
   b. A unit of radiation exposure is a "rad" – write this on the Flipboard. Each following lettered step will be added to the Flipboard.
   c. A rad equals .01 joule of radiant energy / 1 kilogram of tissue. A joule is a measure of energy. This equation translates to energy/2.2 pounds for us.
   d. The radiation dosage that will cause the same amount of biological injury is given in "rem."
   e. Rem = rad x factor
      i. Factor – the factor by which the absorbed dose (rad) must be multiplied to obtain a quantity that expresses the biological damage (rem) to the exposed tissue. It is used because some types of radiation (like alpha radiation) are more damaging to live tissue than other types of radiation when the dose is equal (Health Physics Society).
   f. Table 1

Particle	Dosage	Factor	Health effect
Alpha	1 rad	10	10 rem
Beta	10 rad	1	10 rem

   g. 1 rem = 1000 millirems (mrem)
   h. So, when you consider all the sources of radiation, the average annual exposure per person in the U. S. is about 620 mrem/year according to the Nuclear Regulatory Commission and the Environmental Protection Agency (about half is due to human-made sources, 310 mrem)
   i. Radioactivity can also be measured in becquerels, Curies, grays, and Sieverts. The definitions of all of these radiation measures are on Handout 1, Figure 6 and a comparison of two similar images in different units of measurement.
9. Leave plenty of time for answering questions about the above discussion.
10. Proceed to the Activity Below if time allows. If not, encourage participants to do the activity at home.

Activity

This activity allows students to calculate their exposure to radiation. Print out copies of the Personal Annual Radiation Dose sheet to work through with each participant.

1. Let's look at the Personal Annual Radiation Dose handout.
2. Walk through each section as a group. Discuss any differences in exposures (people who smoke and people who don't, people receiving medical treatment, people that live outside of Burke County).

3. Help all participants add up their scores. Discuss how this score relates to the average annual exposure of a U. S. citizen (620 mrem). Is it higher or lower?

Figures

Figure 1. The graph is representing the half-life of iodine-131.
Figure 2. Alpha, beta, and gamma definitions.
Figure 3. Alpha, beta, and gamma energy and preventative materials.
Figure 1. Pie chart revised from BEIR VII (1). This graph shows the relative contributions of both natural background radiation and human-made radiation to citizens in the United States of America.

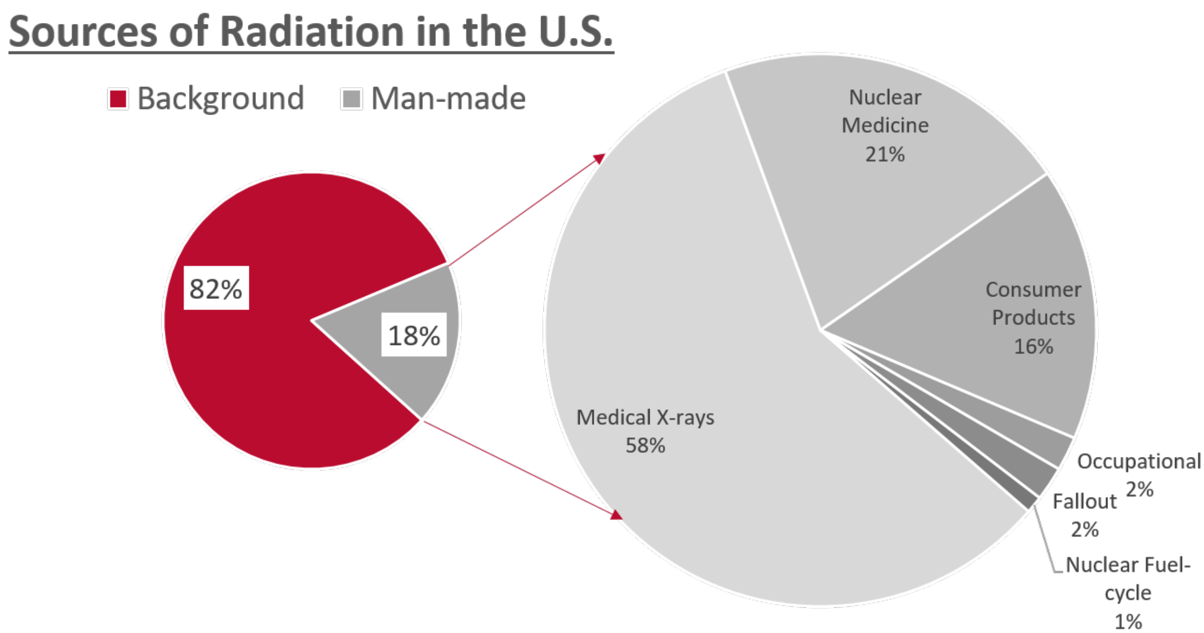
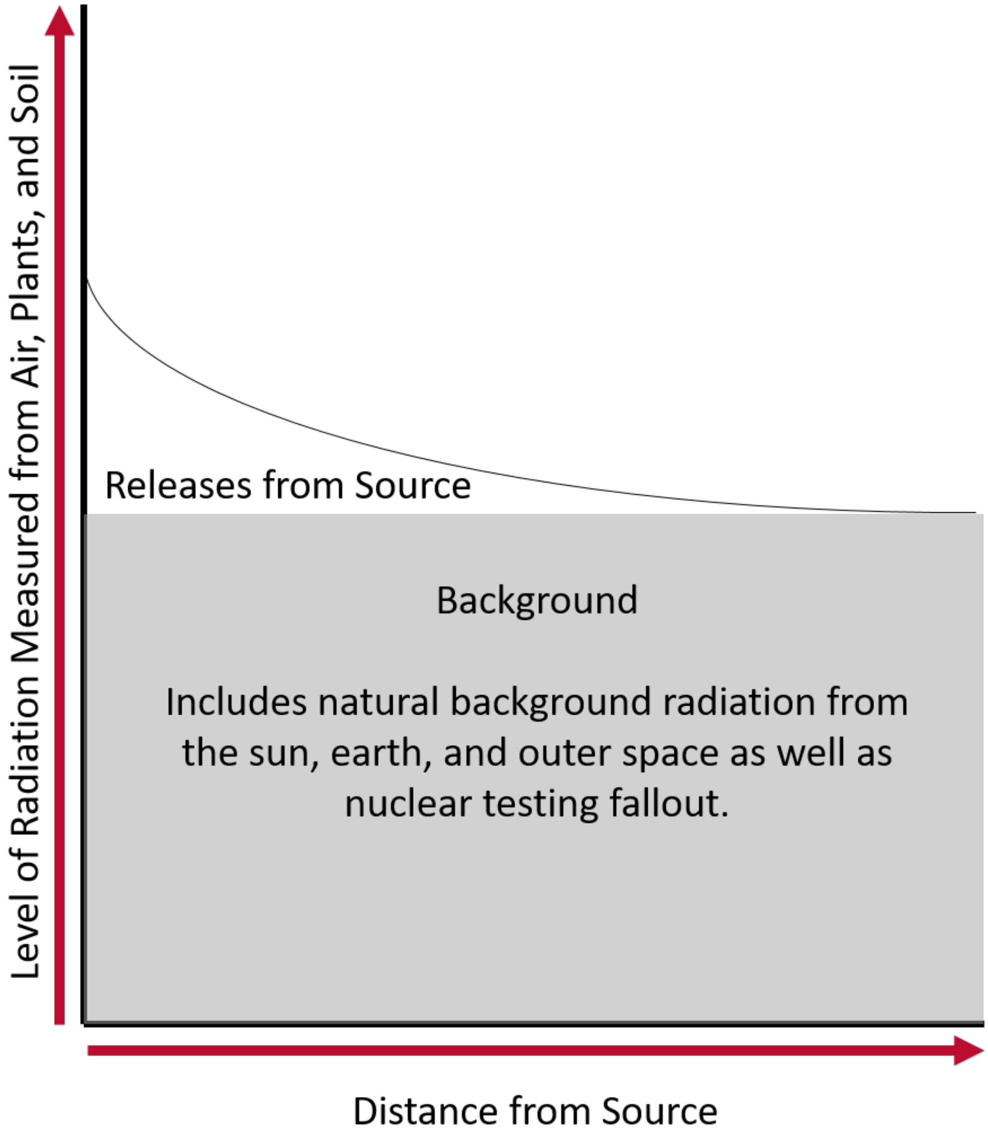


Figure 2. Graph revised from CDC (2). This graph illustrates background radiation exposure from potential local sources in Burke County.



Resources

1. "Beir VII: Health Risks from Exposure to Low Levels of Ionizing Radiation" Report in Brief. The National Academies.
2. Center for Disease Control. "The Savannah River Site Does Reconstruction Project."
3. http://hps.org/documents/background_radiation_fact_sheet.pdf
4. http://www.nuclearscienceweek.org/wp-content/uploads/2014/09/Atomic_Nucleus.pdf
5. https://www.cdc.gov/nceh/radiation/fallout/rf-gwt_home.htm
6. http://hps.org/documents/tritium_fact_sheet.pdf
7. https://emergency.cdc.gov/radiation/glossary.asp
8. Additional resources on radiation:
    a. https://www.cdc.gov/nceh/radiation/
    b. https://www.cdc.gov/nceh/radiation/links.htm
    c. https://emergency.cdc.gov/radiation/
    d. https://www.cdc.gov/nceh/radiation/health.html
9. Additional resources for understanding contaminants in the environment:
    a. Ewg.org – water quality analysis on the local, state, and national levels

Disclaimer

Definitions
All definitions are taken from the CDC website (7).

alpha particles - the nucleus of a helium atom, made up of two neutrons and two protons with a charge of +2. Certain radioactive nuclei emit alpha particles. Alpha particles carry more energy than gamma or beta particles and deposit that energy very quickly while passing through tissue. Alpha particles can be stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body. When alpha-emitting atoms are inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells.

Atom - the smallest particle of an element that can enter into a chemical reaction.

background radiation - ionizing radiation from natural sources, such as terrestrial radiation due to radionuclides in the soil or cosmic radiation originating in outer space.

Becquerels - the amount of a radioactive material that will undergo one decay (disintegration) per second.

beta particles - electrons ejected from the nucleus of a decaying atom. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received. They also pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled.

Biological half-life - the time required for one-half of the amount of a substance, such as a radionuclide, to be expelled from the body by natural metabolic processes, not counting radioactive decay, once it has been taken in through inhalation, ingestion, or absorption.

Concentration - the ratio of the amount of a specific substance in a given volume or mass of solution to the mass or volume of solvent.

Curies - the traditional measure of radioactivity based on the observed decay rate of 1 gram of radium. One curie of radioactive material will have 37 billion disintegrations in 1 second.

Dose - radiation absorbed by person’s body. Several different terms describe radiation dose.

Electron - an elementary particle with a negative electrical charge and a mass 1/1837 that of the proton. Electrons surround the nucleus of an atom because of the attraction between their negative charge and the positive charge of the nucleus. A stable atom will have as many electrons as it has protons.

Element - 1) all isotopes of an atom that contain the same number of protons. For example, the element uranium has 92 protons, and the different isotopes of this element may contain 134 to 148 neutrons. 2) In a reactor, a fuel element is a metal rod containing the fissile material.

Gamma radiation - high-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wavelength. All gamma rays emitted from a given isotope have the same energy, a characteristic that enables scientists to identify which gamma emitters are present in a sample. Gamma rays penetrate tissue further than do beta or alpha particles but leave a lower concentration of ions in their path to potentially cause cell damage. Gamma rays are very similar to x-rays.

Half-life - the time any substance takes to decay by half of its original amount.

Ion - an atom that has fewer or more electrons than it has protons causing it to have an electrical charge and, therefore, be chemically reactive.

Ionizing radiation - any radiation capable of displacing electrons from atoms, thereby producing ions. High doses of ionizing radiation may produce severe skin or tissue damage.

Molecule - a combination of two or more atoms that are chemically bonded. A molecule is the smallest unit of a compound that can exist by itself and retain all of its chemical properties.

Neutron - a small atomic particle is possessing no electrical charge typically found within an atom's nucleus. Neutrons are, as the name implies, neutral in their charge. That is, they have neither a positive nor a negative charge. A neutron has about the same mass as a proton.
non-ionizing radiation

Pathways - the routes by which people are exposed to radiation or other contaminants. The three basic pathways are inhalation, ingestion, and direct external exposure.

Proton - a small atomic particle, typically found within an atom's nucleus, that possesses a positive electrical charge. Even though protons and neutrons are about 2,000 times heavier than electrons, they are tiny. The number of protons is unique for each chemical element.

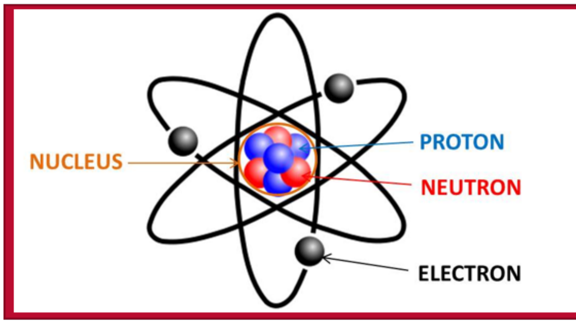
Rad (radiation absorbed dose) - a basic unit of absorbed radiation dose. It is a measure of the amount of energy absorbed by the body. The rad is the traditional unit of absorbed dose. It is being replaced by the unit gray (Gy), which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy per gram of material.

Radiation - energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves, and microwaves. Ionizing radiation is a very high-energy form of electromagnetic radiation.

Radioactivity - the rate of decay of radioactive material expressed as the number of atoms breaking down per second measured in units called becquerels or curies.
radionuclides

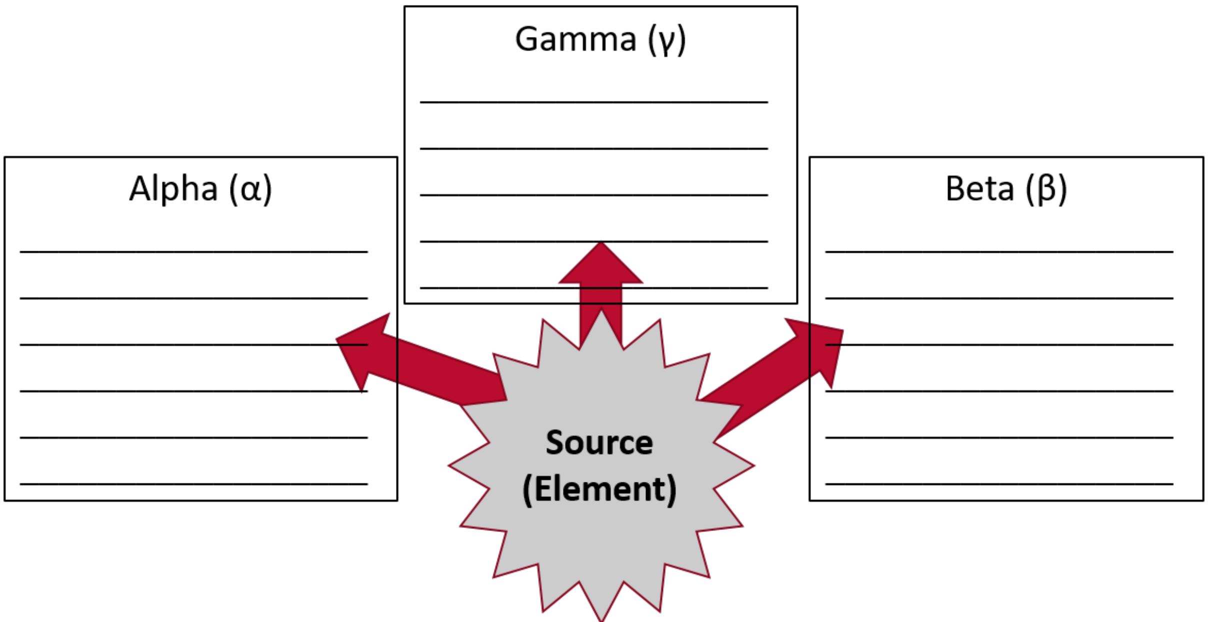
Handout 1

This handout is to follow along with the presentation, Radiation in Our Lives. If you have questions while participating, please let us know.

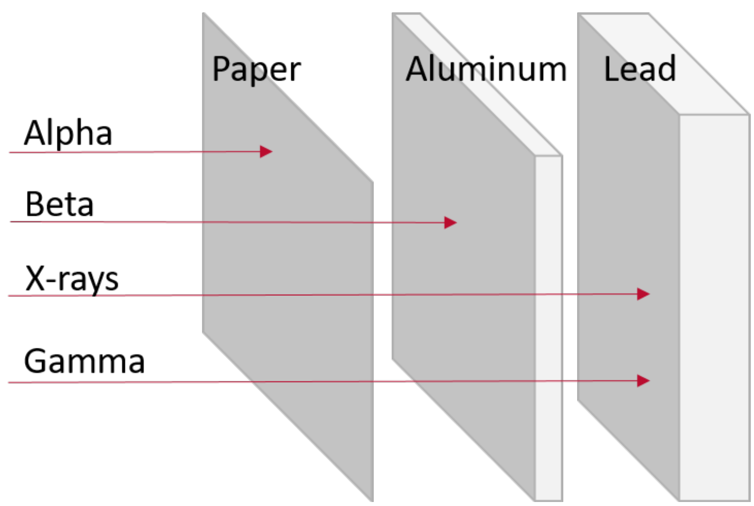


Elements are made up of 3 units: protons, neutrons, and electrons. These are the units that decay.

Elements can exists as a solid, liquid, or gas. Elements are found everywhere and are the building blocks of matter.

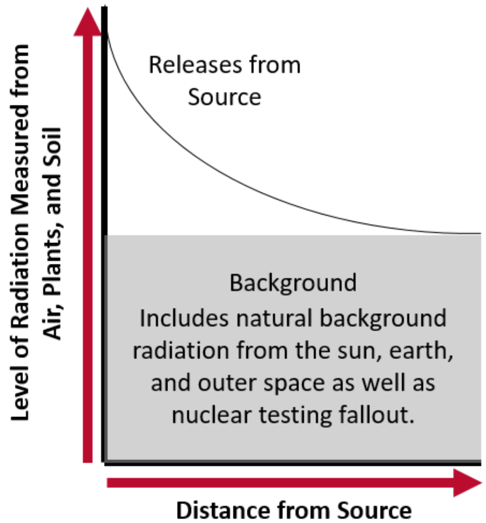


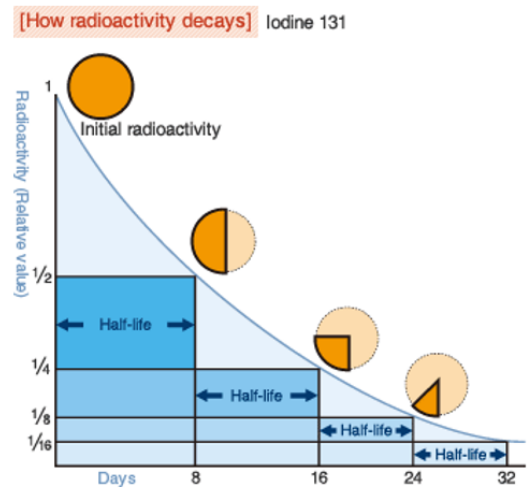
Alpha, beta, and gamma radiation can be prevented. Due to their energy levels, different thicknesses and preventative measures can be used. For example, alpha radiation can be prevented by putting a piece of paper between it and yourself.

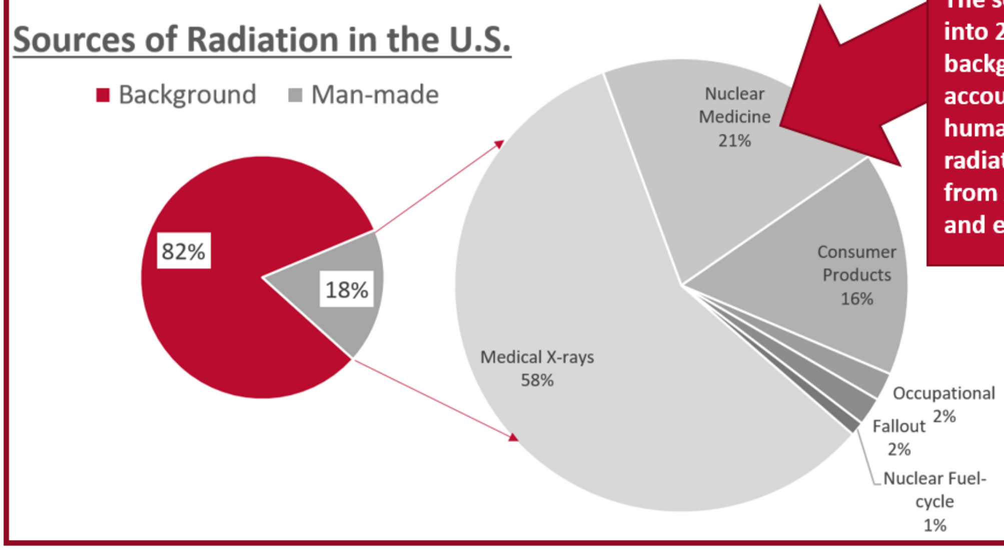


02: Radiation in Our Lives

Decay happens over time and distance. We use "half-life" to determine how a radioactive material weakens over time. Radiation also weakens as you increase your distance from the source.



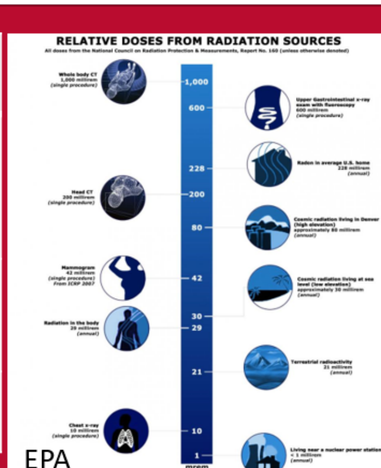




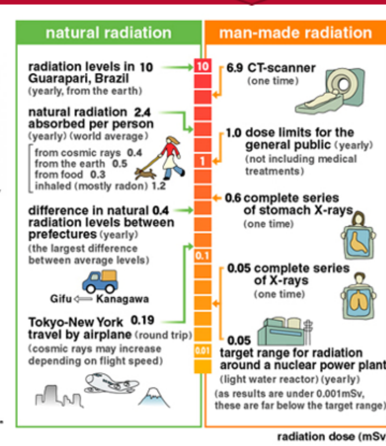
The source of radiation can be split into 2 categories, man-made and background. Background radiation accounts for most of the radiation humans experience. Man-made radiation accounts for radiation from x-rays, consumer products, and energy development.

Below are two examples of how mrem (left) and Sieverts (right) are used to measure the biological risk of radiation.

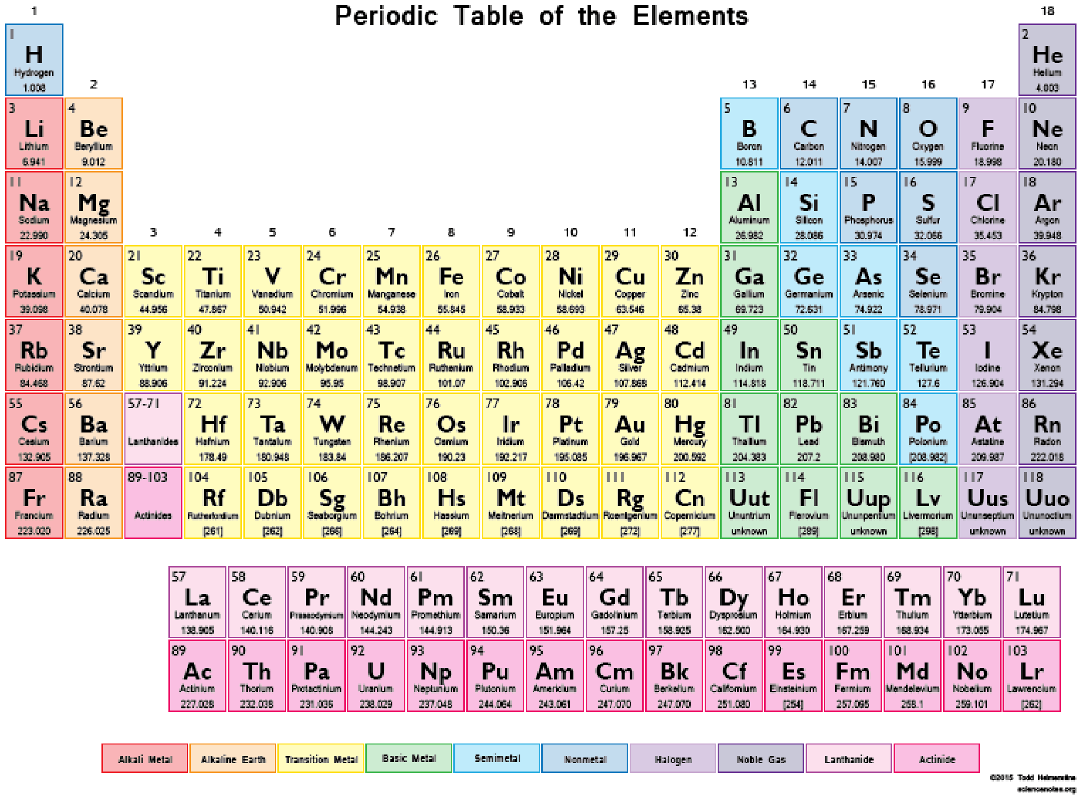
Conventional	Standard International	Definition
Curie (Ci)	becquerel (Bq)	amount of radiation given by a radioactive material
rad	gray	radiation absorbed by a person
rem/mrem	Sievert	measures biological risk

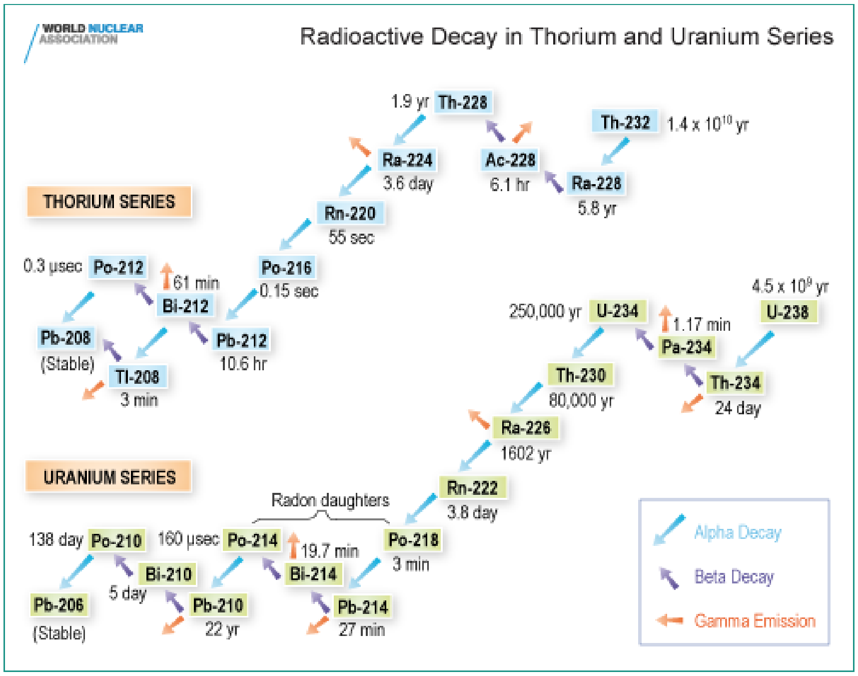


EPA



Handout 2
Periodic Table of Elements





Handout 3
Personal Radiation Dose Chart

Personal Radiation Dose Chart (adapted from the American Nuclear Society)

The average dosage of radiation per person in the United States is about 360 mrem/year, including estimated background radiation exposure. For individuals who work with and around radioactive materials (like on the SRS and Plant Votgle), national health standards allow up to a 5,000 mrem/year dose. However, SRS limit occupational dose to 100 mrem/year and monitors this using a dosimeter. This handout will help you estimate your personal average annual dose in mrem.

Remember:

$$rad = \frac{0.01\ joule\ of\ radiant\ engergy}{1\ kilogram\ of\ tissue}$$

$$rem = rad\ x\ factor$$
$$1\ rem = 1000\ mrem\ (millirems)$$

Particle	Dosage	Factor	Health effect
Alpha	1 rad	10	10 rem
Beta	10 rad	1	10 rem

RADIATION FROM:	**AVERAGE DOSE (mrem)**	
WHERE YOU LIVE		
Cosmic Radiation from Outer Space at 5,000 feet	+ 47	+______
Terrestrial Radiation from the Land		
States Bordering Gulf or Atlantic Coasts.	+ 23	+______
New Mexico, Utah, Colorado, or Wyoming	+ 90	+______
All other states	+ 46	+______
If you live in a stone, brick, concrete or adobe building	+ 7	+______
If you live within 50 miles of a nuclear power plant	+0.01	+______
If you live within 50 miles of a coal-fired power plant	+0.03	+______
WHAT YOU EAT, DRINK, AND BREATHE		
Internal radiation from food and water and your body	+ 40	+______
From radon in the air we breathe	+ 160	+______
HOW YOU LIVE AND CHOICES YOU MAKE		
Jet Plane travel for each 1,000 miles	+ 1	+______
The following are man made sources or radiation exposure		
Fallout from weapons testing (actually less than 1)	+ 1	+______
If you watch TV (true value less than 1)	+ 1	+______
Use a computer monitor	+ 1	+______
For smoke detectors in your home (0.008)	+ 1	+______
Transportation of Radioactive Materials (0.1)	+ 1	+______
Low Level Radioactive Waste Burial Site	+ 1	+______
Enhanced Sources (natural radiation increased by human activity)		
Consumer Products and enhanced sources such as radon in water and second-hand tobacco smoke)	+10	+______
Smoking 1 pack of cigarettes per day	+8000	+______
Medical Exposures		
Diagnostic X-rays (dental, broken arms, legs, etc.) Average	+40	+______
Nuclear Medical Procedures (thyroid scan)	+14	+______
Cancer Treatments (range from 40,000 to 70,000 mrem)		+______
TOTAL ANNUAL DOSE	______	mrem

Handout 4

Contamination versus Exposure – CDC