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.

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5. Tritium in Our Lives

Concepts

- How tritium is created and exists in our atmosphere.
- The potential exposure pathways for tritium
- The Drinking Water Standard and how it protects our health

Skills: critical thinking, decision-making, observation

Materials

- Clear 2-liter bottle
- Food coloring
- Poster board
- Poster markers
- Optional: computer with internet connection to show pertinent web pages

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

Objectives

- Participants will be able to explain what tritium is and the sources of tritium.
- Participants will be able to describe tritium exposure pathways in our environment.
- Participants will understand what the Drinking Water Standard is.

Key terms: tritium, radiation, contaminant, concentration

Background

We often hear contaminants discussed in Burke County, but it can be difficult to remember what each contaminant specifically does. Tritium is a contaminant that is a by-product of missions on the Department of Energy Savannah River Site (DOE-SR) and Georgia Power's Plant Vogtle. Tritium is a radioactive isotope of hydrogen, instead of having one neutron, it has 2 (1,2,3). Tritium can be a gas, but it is most commonly found as a liquid because it easily bonds with oxygen (2). Tritium has a half-life of 12.3 years in the environment but due to the replenishment of tritium from human-made sources it is still measurable in the environment (2).

Tritium has three main sources in the environment: natural tritium, nuclear weapons testing, and releases from the nuclear industry (5). Human-made tritium is in the environment from widespread above-ground testing of nuclear bombs in the 1950s and 1960s, peaking in 1963 (3), and continues to be in the environment from nuclear power plants and continued remediation of nuclear weapons. Tritium is also used in everyday items like the glow in wristwatches and rifle sites, as well as exit signs to cause a luminescence that doesn't require batteries or electricity (4).

The most likely way a human will come into contact with tritium is through radioactive tritiated water (1). Tritiated water acts very similarly to water but with an additional hydrogen atom. There is no way to chemically or mechanically remove tritium from water, so remediation techniques include dilution with water and respiration, or the process by which oxygen moves through cells, in this case, plants (8). However, because of the shared properties of water, tritium is excreted from the human body in less than a month based on studies on accidentally exposed males (9). Tritium most commonly moves through the environment in the water cycle, due to sharing properties with water (2). When tritiated water is in its gaseous stage, it is eliminated almost immediately through respiration (8). Remediation of tritium can include heat (in soil and concrete), use of respiration in trees (ion exchange), and dilution with other mixtures, including water (12). However, there are no large-scale populations studies on the effects of tritium due to the difficulty of long-term studies and tritium's short half-life.

Two governmental agencies regulate tritium, the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA). The NRC regulates the manufacturers of tritium, like governmental agencies (DOE-SR) and nuclear power plants (Plant Vogtle). The releases of tritium from these sources are closely monitored and reported to the NRC where the data is made publicly available. We discussed this process in October and November at the Community Talks, and this information can be found on the REMOP webpage. The NRC is also in charge of regulating dose limits for radiation workers in the United States. In the Radiation Community Talk, we discussed the creation of dose estimations and to whom the regulations apply. This information can also be found on our REMOP webpage. The drinking water standard set by the EPA in Chapter 40 of the Code of Federal Regulations for tritium is 20,000 picocuries (pCi/l) or about four millirems (mrem) per year to the public (6). We will discuss in February and March in our Community Talks on Risk, and how these regulatory values are studied and set with the goal to protect environmental and human health.

Tritium is naturally present in low levels across the globe because it naturally occurs in the upper levels of our atmosphere. However, tritium is also a by-product of operations on the Department of Energy Savannah River Site (DOE-SR) and Georgia Power's Plant Vogtle. In the DOE-SR annual site environmental report (7), tritium levels in Burke County groundwater are at 0.00 pCi/mL in 2016 (Figure 1). In 1999, tritium was recorded in Burke County at 0.41 pCi/mL in groundwater wells. That is about 0.000002% of the drinking water standard.

On the NRC website (www.nrc.gov), you can find information regarding Plant Vogtle, including daily status reports, reactor event notifications, and safety reports. According to environmental monitoring reports from Georgia Power, in 2016 Plant Vogtle measured 283 pCi/l in raw, untreated drinking water. This is about 1.4% of the drinking water standard.

Preparation

1. Review materials from the Radiation 101 lesson.
2. Gather materials for the activity

Lesson

1. Review the vocabulary of an atom.
    a. Atom is a building block of all matter.
    b. The center of an atom is called the nucleus and contains the neutron and the proton.
    c. Around the nucleus of an atom, are very energetic particles called electrons.
2. Draw/describe tritium structure and explain what each piece is and its properties.
    a. Hydrogens bond to oxygen, just like the two hydrogens in water. However, there is an extra hydrogen atom, which means the molecule has a positive charge.
    b. You can also draw a water molecule to illustrate the similarities between the two molecules.
3. Review the vocabulary and concepts of alpha, beta, and gamma radiation.
    a. Alpha radiation – low energy emitter, cannot travel through a piece of paper
    b. Beta radiation – low energy emitter, cannot travel through skin
    c. Gamma radiation – high energy emitter, cosmic rays
4. Explain that tritium is a type of beta emitter. Because tritium is a beta emitter, it means that the radiation cannot penetrate our outer skin layer.

5. Tritium comes from a few processes, but at a nuclear energy facility, it happens when a neutron absorber, the element boron, is added to the coolant. This addition of boron absorbs excess radioactivity and helps control the nuclear energy process. This amounts to about 2 grams of tritium per year from nuclear power plants (20,000 Curies). Tritium is also produced as a part of the nuclear weapons process, about one atom of tritium per 10,000 fission reactions.
6. Describe the process of dilution and proceed with the below activity.
7. At the end of the activity, make sure to remind participants of the resources available about tritium – the additional handouts and the environmental reports.

Activity

The goal of this activity is to illustrate how contaminants can be emitted from power plants and industrial facilities below and above regulatory limits and the effects it can have on the environment and human health. You can either demonstrate the activity to the group or provide multiple set-ups so that participants can follow along on the action with you.

1. In a clear, plastic 2-liter jug, fill it with water.
2. Ask participants to use their imagination, and imagine that the water is air. This demonstration will illustrate what dispersion of contaminants into the environment look like, even though we can barely see it happening.
3. When preparing to add the food coloring, explain that the food coloring is going to represent the contaminant (any contaminant, in this case, tritium). Drop 1-2 drops of food coloring into the 2-liter.
4. Ask the participants to observe what happens to the food coloring. Ask them to compare the distribution of the food coloring to something – help participants in getting at comparing the food coloring to smoke out of a smokestack.
5. Describe that this food coloring, directly out of the stack, is concentrated. When the food coloring mixes when the water (in our case, contaminant mixes with the air), it is evenly distributed and diluted, and the water is still almost completely clear.
6. Explain that this is when an environmental monitoring program would take a sample and receive a result to compare to health regulations set by the government. Other measurements are also taken directly from the stack.
7. Begin explaining that the problem occurs when there is too much of a contaminant emitted. Take the food coloring and drop 7-10 drops into the 2-liter. Shake the 2-liter to mix the food coloring in completely. Continue to explain that this represents a higher concentration of the emitted contaminant. Higher concentration emitted means that there will be a higher concentration distributed and diluted into the atmosphere.
8. Ask the participants what they think the results of a sample taken for an environmental monitoring program would be now. The result would be higher than in the previous bottle.
9. Repeat steps 7-8, but this time, add more than 12 drops of food coloring. Explain that this is likely when the contaminant would exceed limits and regulations. There is too much of the contaminant added into the system for the system to cope with it. Think of this as someplace with a lot of smog issues.
10. Ask participants what they've learned or if this has helped them visualize how contaminants are emitted and regulated. Also ask what participants think would happen when more than one contaminant is in the system? Potentially, you can go back through this activity with a second color of food coloring. Discuss what this means for regulations and environmental monitoring programs (regulations are often for one contaminant, often mixtures of contaminants are not studied, and environmental monitoring programs often test for many contaminants but cannot easily study them as a mixture).

Figures

Figure 1. Figure from SRS's 2016 Site Environmental Report with the tritium levels in groundwater from Burke County and Screven County from 1999 – 2016.

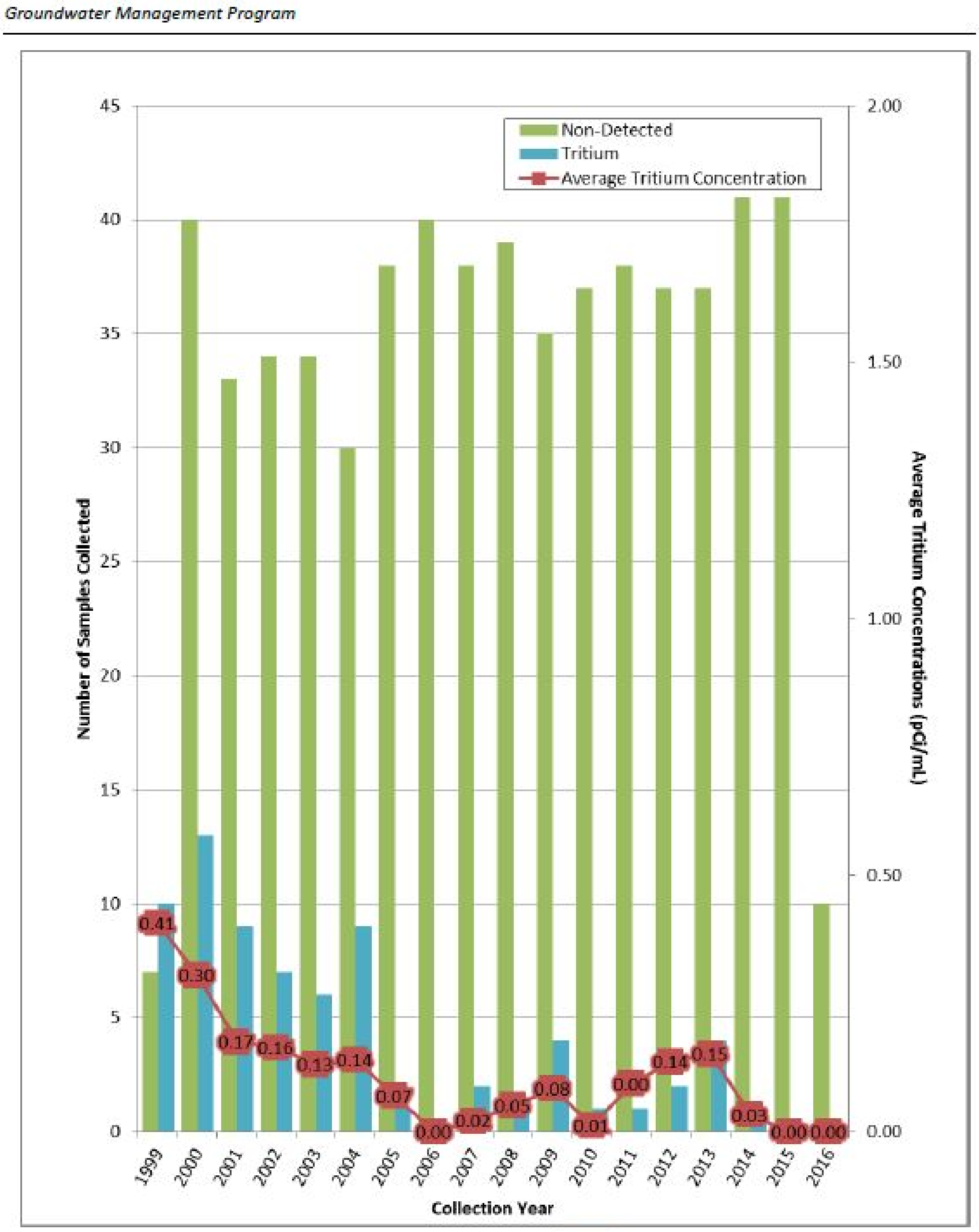
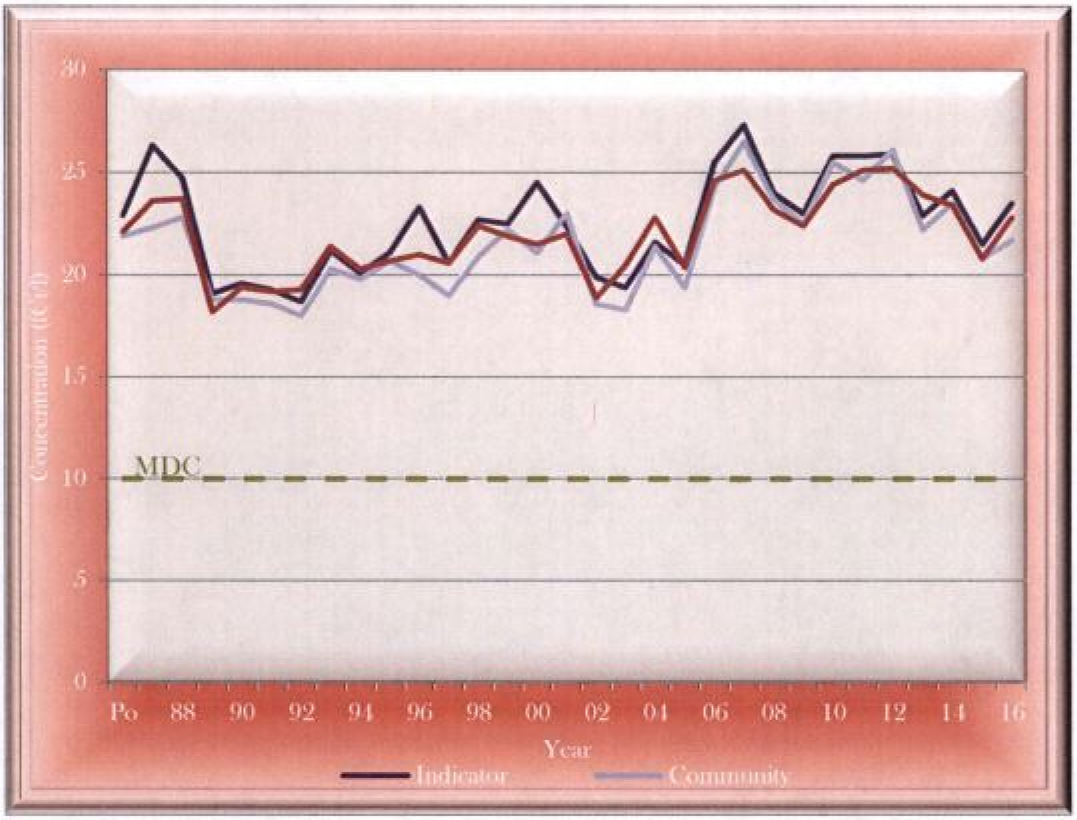


Figure 7-6 Tritium Concentration in Wells Sampled in Burke and Screven Counties, Georgia

Figure 2. Taken from the 2016 Georgia Power Environmental Report. MDC is the minimum detectable concentration of an analyte measured. In this case, the MDC for gross beta in air concentration is 10

Figure 3-1. Average Weekly Gross Beta Air Concentration



Resources

1. https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html
2. http://hps.org/documents/tritium_fact_sheet.pdf
3. https://www.epa.gov/radiation/radionuclide-basics-tritium
4. https://www.ccpa.net/DocumentCenter/Home/View/3173
5. Boyer, C., L. Vichot, M. Fromm, Y. Losset, F. Tatin-Froux, P. Tuetat, P.M. Badot. 2009. Tritium in plants: A review of current knowledge. *Environmental and Experimental Botany* 67 (1):34-51.
6. https://www.nrc.gov/docs/ML1029/ML102990104.pdf
7. https://www.srs.gov/general/pubs/ERsum/er16/docs/chapter7-2016.pdf
8. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3057633/
   Dingwall, S., C. E. Mills, N. Phan, and K. Taylor. 2011. Human Health and the Biological Effects of Tritium in Drinking Water: Prudent Policy Through Science – Addressing the ODWAC New Recommendation. *Dose Response* 9(1):6-31.
9. Snyder, W. S., B. R. Fish, S. R. Bernard, M. R. Ford, and J. R. Muir. 1968. Urinary Excretion of Tritium following exposure of man to HTO – a two-exponential model. *Phys. Med. Biol.* 13 (4):547-559.
10. https://www.scientificamerican.com/article/is-radioactive-hydrogen-in-drinking-water-a-cancer-threat/
11. https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bg-analys-cancer-risk-study.html
12. https://www.eolss.net/sample-chapters/C06/E6-13-04-08.pdf

Disclaimer

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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 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.

Tritium - (chemical symbol H-3) a radioactive isotope of the element hydrogen (chemical symbol H).

Handout 1

We will provide additional handouts about tritium:

1. http://hps.org/documents/tritium_fact_sheet.pdf
2. https://www.ccpa.net/DocumentCenter/Home/View/3173
3. Definitions sheet

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Radiological Education, Monitoring, and Outreach Project

Talk 5: WHAT IS TRITIUM?

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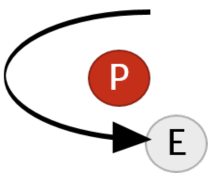
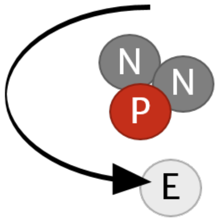
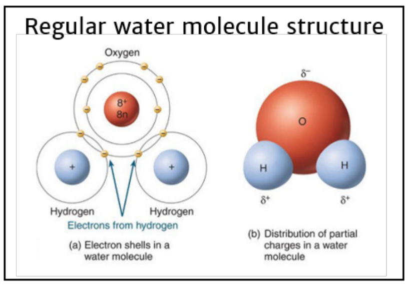


Hydrogen atom



Tritium atom



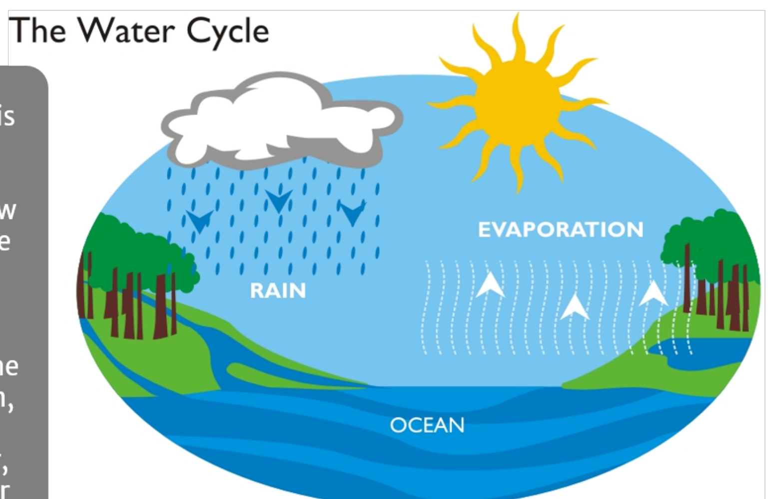
Tritium is a hydrogen atom with 2 additional neutrons (N).

Tritiated water is when a tritium atom replaces hydrogen atoms in a water molecule. Tritiated water has an additional neutron and acts very similarly to water. It also has the same structure as regular water (picture on the left).

Pictured on the right is the Water Cycle.

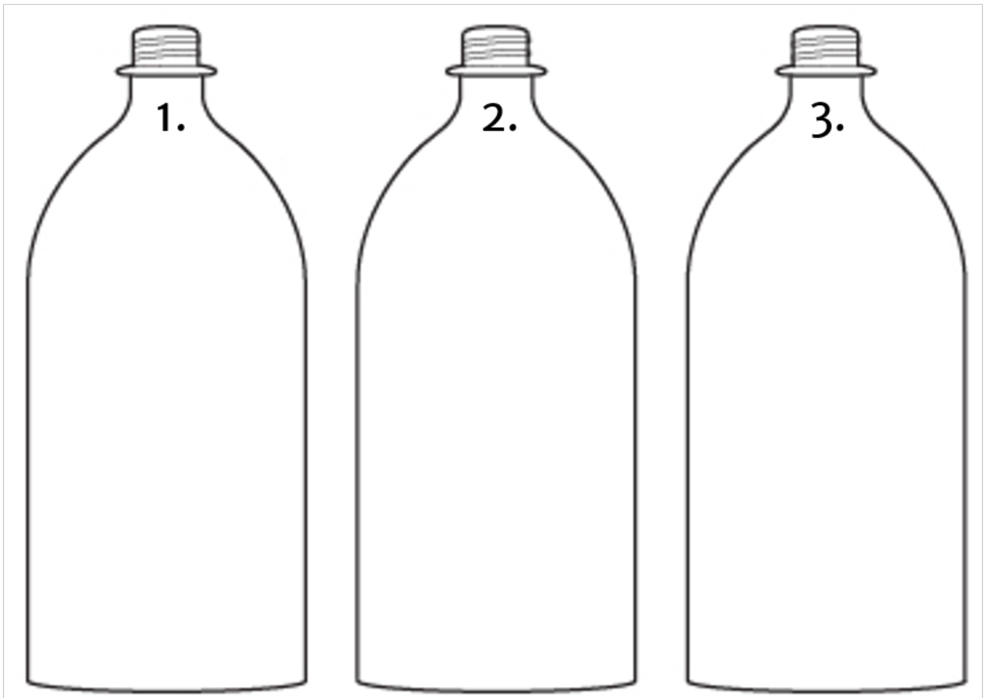
The Water Cycle is how water molecules move through our environment.

These pathways are the same way that tritium, due to it's shared properties with water, can move through our environment.



Back

This activity is easy to do at home with your friends and family. Below are instructions and a worksheet to write down your own observations and conclusions.



Make sure you have equal amounts of water in each clear 2-Liter bottle. Make observations about how the food coloring is distributed in the water and how that affects the color of the water. Write your observations on the lines below and talk about the questions afterwards.

1. In Bottle 1, add 1-2 drops of food coloring.

   ____

   ____

2. In Bottle 2, add 5-10 drops of food coloring.

   ____

   ____

3. In Bottle 3, add more than 10 drops of food coloring.

   ____

   ____

What do you think would happen if we took a sample of the water and measured the food coloring concentration in each bottle? Which bottle would have the most? The least?