

Tritium

WHAT IS TRITIUM?

Tritium is an isotope of hydrogen that occurs naturally in very small quantities. Hydrogen has three isotopes:

- **Protium** Ordinary hydrogen with one proton and one electron in the atom. When two atoms of protium are combined with one atom of oxygen, water is created. Ordinary hydrogen comprises over 99.9 percent of all naturally occurring hydrogen.
- **Deuterium** Sometimes called “heavy hydrogen,” a non-radioactive isotope that has a neutron in the atom, in addition to the proton and electron. Water made with this isotope is called “heavy water.” Deuterium comprises about 0.015 percent of all hydrogen.
- **Tritium** A radioactive isotope of hydrogen that has two neutrons in addition to the proton and the electron. Tritium is the only one of the three hydrogen isotopes that is radioactive. Tritium makes up only 1×10^{-18} percent of natural hydrogen.

Radioactive elements such as tritium will spontaneously change into a different atom in a process referred to as radioactive decay. When tritium decays, it changes into an isotope known as helium-3. This decay process changes about 5.5 percent of the tritium into helium-3 every year. The time that it takes a radioactive isotope to decay to half the original amount is called the **half-life**. Tritium has a half-life of 12.3 years. When tritium decays, it emits a form of radiation known as a beta particle, a negatively charged particle similar to an electron. This is a very weak form of radiation and can be stopped by a thin sheet of metal or a few sheets of paper.

WHY IS TRITIUM IMPORTANT TO DOE/NNSA?

The National Nuclear Security Administration (NNSA) is responsible for supplying nuclear materials for national security needs and ensuring that the nuclear weapons stockpile remains safe and reliable. Tritium is an essential component of every weapon in the U.S. nuclear weapons stockpile. Because tritium decays at a rate of 5.5 percent per year, as long as the Nation relies on a nuclear deterrent, the tritium in each nuclear weapon must be replenished periodically. Because tritium is so rare in nature, useful quantities of tritium must be produced.

HOW IS TRITIUM PRODUCED IN A NUCLEAR REACTOR?

All nuclear reactors produce tritium as a normal by-product of their operations. A nuclear reactor can also be designed to produce additional tritium. That process uses tritium producing burnable absorber rods (TPBARs), which are specially fabricated rods that replace nonmoveable burnable absorber rods in the reactor core. TPBARs are long, thin tubes that contain lithium-6. When neutrons in the reactor core strike a lithium-6 nucleus, the nuclear reaction produces tritium. During the reactor’s normal fuel cycle (about 18 months), TPBARs are irradiated and the tritium gas is captured. At the end of the fuel cycle, some fuel rods are depleted, which means they no longer contain enough uranium-235 to power the reactor as designed and must be replaced. During the refueling period, depleted fuel assemblies, as well as fuel assemblies that contain TPBARs, are removed from the reactor core and transferred to the spent fuel pool. TPBAR assemblies are then removed from the fuel assemblies,

mechanically separated from the base plate, and placed in a consolidation container. The consolidation container with the TPBARs is placed in a shipping cask, sealed, placed on a truck, and transported to the Tritium Extraction Facility at the Savannah River Site for extraction and purification.

WHAT IS PERMEATION?

During irradiation of TPBARs in a reactor, a small amount of tritium diffuses through the TPBAR cladding into the reactor coolant; this is called permeation. Permeation of small amounts of tritium through the TPBAR cladding into the reactor coolant systems is expected. Permeation of tritium from TPBARs increases the quantity of tritium in the reactor's coolant water system in comparison with a reactor that is not being used to produce tritium.

The 1999 EIS estimated that the permeation rate of tritium through the TPBAR cladding into the reactor coolant system would be less than or equal to 1 curie per TPBAR per year. Based on tritium production experience at Watts Bar 1, NNSA has determined that tritium permeation through the cladding is about three to four times higher than this estimate; nevertheless, tritium releases to the environment have been below regulatory limits.

HOW DOES TRITIUM ENTER THE ENVIRONMENT?

Because tritium is an isotope, or type, of the hydrogen atom, it can combine with oxygen in the coolant water to become part of a water molecule (tritiated water). Tritiated water in the reactor coolant can reach the environment via several mechanisms, including (1) operations that refresh the reactor coolant to maintain the correct system parameters, (2) refueling operations, and (3) normal leakage and diffusion from the primary system into secondary systems. Tritium is released to the environment through the normal operations of the radioactive waste system or in steam system blowdown or condensing cooling water.

WHAT ARE THE REGULATORY LIMITS FOR TRITIUM IN THE ENVIRONMENT?

Although there are no specific regulatory limits on tritium releases, there are regulatory limits to which tritium releases are *applicable*. For example, regulations implemented under the *Safe Drinking Water Act* require the tritium concentration at any drinking water intake to be below 20,000 picocuries per liter. Another example concerns doses from radiation. The most stringent regulatory limits for doses from normal operations are 10 millirem per year from all pathways, 3 millirem per year from the liquid pathway, and 5 millirem per year from the air pathway.

WHAT ARE THE EFFECTS OF RADIATION ON HUMANS?

Radiation, such as that from tritium, can cause a variety of damaging health effects in people. The most significant effects are induced cancer fatalities. These effects are referred to as "latent" cancer fatalities because the cancer might take many years to develop. The average American receives about 620 millirem per year from all sources of radiation, both natural and manmade, of which about 300 millirem per year are from natural sources.

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