Tritium, Radiation Protection Limits, and Drinking Water Standards

Background

The Nuclear Regulatory Commission evaluates abnormal releases of tritium-contaminated water from nuclear power plants, particularly those that result in groundwater contamination. The NRC has repeatedly determined these releases either remain on power plant property or involve such low offsite levels of tritium that they do not affect public health and safety. The NRC takes these abnormal releases very seriously and continues to review them to ensure that nuclear plant operators take appropriate action.

What is the NRC doing about the tritium leaks and spills at nuclear power plants?

The NRC's inspections evaluate a nuclear power plant's programs to inspect, assess and repair equipment and structures that could potentially leak. The NRC has also focused on evaluating a plant's ability to analyze how spills or leaks could affect groundwater. The agency's resident inspectors at every operating U.S. nuclear plant regularly monitor all these activities. Any shortfalls can trigger more intensive NRC oversight of a plant.

In 2006, the NRC's "lessons learned" task force examined previous abnormal liquid releases of radioactivity from U.S. commercial nuclear plants. The task force's findings and the NRC's response, as well as a 2010 senior management review of the recommendations, are available on the NRC website's page on groundwater contamination. The staff updated the information again in a 2012 paper to the Commission. In 2016, the staff recommended, and the Commission agreed, that current regulatory requirements were adequate to protect public health and safety, and did not warrant additional requirements or guidance.

As with any industrial facility, a nuclear power plant may inadvertently spill or leak liquid material. However, the plant design and the NRC's inspection program both help ensure safety limits will be met – even in abnormal situations. This backgrounder provides a general overview of the health effects of tritium and the technical bases for the NRC's standards to protect public health and safety, as well as the drinking water standards established by the U.S. Environmental Protection Agency.

Tritium

- Tritium is a naturally occurring radioactive form of hydrogen that is produced in the atmosphere when cosmic rays collide with air molecules. As a result, tritium is found in very small or trace amounts in groundwater throughout the world. It is also a byproduct of the production of electricity by nuclear power plants. Tritium emits a weak form of radiation, a low-energy beta particle similar to an electron. The tritium radiation does not travel very far in air and cannot penetrate the skin.

Tritium from Nuclear Power Plants

- Nuclear power plants have reported abnormal releases of water containing tritium, resulting in groundwater contamination.
- Most of the tritium produced in nuclear power plants stems from a chemical, known as boron, absorbing neutrons from the plant's chain reaction. Nuclear reactors use boron, a good neutron absorber, to help control the chain reaction. Toward that end, boron either is added directly to the coolant water or is used in the control rods to control the chain reaction. Much smaller amounts of tritium can also be produced from the splitting of uranium-235 in the reactor core, or when other chemicals (e.g., lithium or heavy water) in the coolant water absorb neutrons (NAS, 1996; UNSCEAR 1988).
- Like normal hydrogen, tritium can bond with oxygen to form water. When this happens, the resulting "tritiated" water is radioactive. Tritiated water (not to be confused with heavy water) is chemically identical to normal water and the tritium cannot be filtered out of the water.
- Nuclear power plants routinely and safely release dilute concentrations of tritiated water. These authorized releases are closely monitored by the utility, reported to the NRC, and made available to the public on the NRC's website.

How do people become exposed to tritium?

- Tritium is almost always found as tritiated water and primarily enters the body when people eat or drink food or water containing tritium or absorb it through their skin. People can also inhale tritium as a gas in the air.
- Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the soft tissues. Half of the tritium is excreted within approximately 10 days after exposure. About 10 percent of the dose from any tritium exposure comes from the small fraction of the exposure that the body retains as organically bound tritium (ICRP-30, 1979).
- Everyone is exposed to small amounts of tritium every day, because it occurs naturally in the environment and the foods we eat. Workers in federal weapons facilities; medical, biomedical, or university research facilities; or nuclear fuel cycle facilities may receive increased exposures to tritium.

How does the radiation dose from nuclear power-related tritium compare to the dose a person receives from natural background radioactivity or from medical procedures?

- Tritium is present naturally in the environment and the radiation produced by natural tritium is identical to the radiation produced by tritium from nuclear power plants.
- The tritium dose from nuclear power plants is much lower than the exposures attributable to natural background radiation and medical administrations.
- Humans receive approximately 50 percent of their annual radiation dose from natural background radiation, 48 percent from medical procedures (e.g., x-rays), and 2 percent from consumer products. Doses from tritium and nuclear power plant releases account for less than 0.1 percent of the total background dose (NCRP, 2009) As an example, drinking water for a year

from a well with 1,600 picocuries per liter of tritium (comparable to levels identified in a drinking water well after a significant tritiated water spill at a nuclear facility) would lead to a radiation dose (using EPA assumptions) of 0.3 millirem (mrem). That dose is:

- at least 2,000 to 5,000 times lower than the dose from a medical procedure involving a full-body CT scan (e.g., 500 to 1,500 mrem from a CT scan)
- 1,000 times lower than the approximate 300 mrem dose from natural background radiation
- 50 times lower than the dose from natural radioactivity (potassium) in your body (e.g., 15 mrem from potassium)
- 12 times lower than the dose from a round-trip cross-country airplane flight (e.g., 4 mrem from Washington, D.C. to Los Angeles and back)

What are the possible health risks from tritium radiation exposure?

> **ALARA (as low as reasonably achievable)** is a radiation safety principle for minimizing doses and releases of radioactive material by using all reasonable methods. In principle, no dose should be acceptable if it can be avoided or is without benefit. [See Title 10, Section 20.1003, of the *Code of Federal Regulations* (10 CFR 20.1003).]

The NRC agrees with national and international radiation protection regulatory agencies that any exposure to radiation could pose some health risk. This risk increases with exposure in a linear, no-threshold manner. Lower levels of radiation therefore have lower risks. The health risks include increased occurrence of cancer. Since it is assumed that any exposure to radiation could pose some health risk, it makes sense to keep radiation doses as low as reasonably achievable-known as ALARA. The NRC's radiation dose limits and ALARA requirements minimize the health risk and ensure that no individual exceeds federal health and safety standards.

> A **millirem** (mrem) is a term use to describe how much radiation the body absorbs. For example, scientists estimate that we receive a dose of 620 mrem every year from natural (e.g., radon) and human-made (e.g., medical) radiation sources.

The NRC sets dose limits for radiation workers and the general public well below the levels of radiation exposure that cause health effects in humans – including a developing embryo or fetus. The effects of high doses and high dose rates are well understood. Public health research, however, has not established health risks at low doses and low dose rates – below about 10,000 mrem.

The NRC calculated a maximum annual dose of less than 0.1 mrem to a member of the public from a significant tritiated water spill at the Braidwood Station nuclear power plant in Illinois. This dose is well below the NRC's 500 mrem dose limit for declared pregnant workers at nuclear facilities and the 100 mrem annual dose limit for members of the general public.

For additional comparison, the average U.S. citizen receives about 310 mrem annually from natural sources, mostly radon gas (NCRP, 2009). No adverse health effects have been discerned from doses arising from these levels of natural radiation exposure. Man-made sources of radiation from medical, commercial, and industrial activities contribute about another 310 mrem to our annual radiation exposure.

Radiation Protection Limits

The NRC evaluates radiation protection recommendations from international and national scientific bodies to ensure our standards are appropriate. Among those standards, the NRC and EPA have established three layers of radiation protection limits to protect the public against potential health risks from nuclear power plant spills or leaks of radioactive liquid. The NRC's analysis shows doses to the general public from abnormal tritium releases at nuclear power plants are well below the strictest protective limits and, therefore, do not pose a measurable risk to public health and safety.

Layer 1: 3 mrem per year ALARA objective – Appendix I to 10 CFR Part 50

The NRC requires that nuclear plant operators must keep offsite radiation doses from gas and liquid releases as low as reasonably achievable. For liquid releases, such as diluted tritium, the ALARA annual offsite dose objective is 3 mrem to the whole body and 10 mrem to any organ of someone living close to the plant boundary. This ALARA objective is 3 percent of the annual public radiation dose limit of 100 mrem and a small fraction of the natural background radiation dose.

If a nuclear power plant exceeds half of these radiation dose levels in a calendar quarter, the plant operator must investigate the cause(s), initiate appropriate corrective action(s), and report the action(s) to the NRC within 30 days from the end of the quarter.

Layer 2: 25 mrem per year standard – 10 CFR 20.1301(e)

EPA radiation dose limits related to nuclear power are 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of an individual member of the public. NRC regulations incorporated these EPA standards in 1981, and all nuclear power plants must now meet these requirements. These standards apply to nuclear power plants and facilities that mill and manufacture nuclear fuel. The NRC's ALARA objectives are lower than these EPA standards (NRC, 1980).

Layer 3: 100 mrem per year limit – 10 CFR 20.1301(a)(1)

The NRC's final layer of protection of public health and safety limits radiation doses to 100 mrem per year for individual members of the public. This limit applies to every civilian facility that uses radioactive material.

The NRC's 100 mrem per year dose limit is related to the 1990 recommendations of the International Commission on Radiological Protection. The ICRP's scientists provide recommendations regarding radiation protection, including dose limits. These dose limits are often implemented by governments worldwide as legally enforceable regulations. The ICRP recommended the 100 mrem per year limit after concluding a lifetime of exposure at this level would result in a very small health risk and is roughly equivalent to background radiation from natural sources (excluding radon) (ICRP, 1991). The U.S. National Council on Radiological Protection and Measurements also recommends the dose limit of 100 mrem per year (NCRP, 1993).

Drinking Water Standards

The EPA's authority under the Safe Drinking Water Act sets federal limits for drinking water contaminants. Water suppliers must provide water that meets these standards, called maximum contaminant levels. Some states have adopted the EPA's drinking water standards as legally enforceable groundwater protection standards. These standards are often used in assessing laboratory test results of water from private wells.

The EPA's dose-based drinking water standard of 4 mrem per year is based on a maximum contaminant level of 20,000 picocuries per liter for tritium. If other similar radioactive materials are also present in the drinking water, the annual dose from all the materials combined shall not exceed 4 mrem per year. This standard was expected to be exceeded only in extraordinary circumstances (EPA, 1975; EPA, 1976b).

Picocurie (pCi) is a term used to describe how much radiation and, therefore, how much tritium, is in the water. A pCi is a unit that can be measured by laboratory tests.

In 1991, EPA used improved calculations to conclude a tritium concentration of 60,900 pCi/L would yield a 4 mrem per year dose. However, EPA kept the 20,000 pCi/L value for tritium in its latest regulations.

Additional Tritium Resources

- U.S. NRC: https://www.nrc.gov/reactors/operating/ops-experience/tritium/faqs.html
- U.S. EPA: https://www.epa.gov/radiation/radionuclide-basics-tritium
- California EPA: https://oehha.ca.gov/media/downloads/water/chemicals/phg/phgtritium030306.pdf

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