U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Fact Sheet

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Tritium, Radiation Protection Limits, and Drinking Water Standards

Background

The U.S. Nuclear Regulatory Commission (NRC) has recently evaluated several instances of abnormal releases of liquid tritium from several nuclear power plants, which resulted in groundwater contamination. The NRC determined that although the releases were unplanned, the levels of tritium were within radiation protection limits and did not pose a threat to public health and safety. Nonetheless, the NRC takes these unanticipated and unmonitored releases very seriously, and is currently reviewing these incidents to ensure that nuclear power plant operators have taken appropriate action.

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

The NRC has revised its inspection procedures for nuclear power plants to evaluate licensees' programs to inspect and assess the equipment and structures that have the potential to leak. The NRC has also placed additional emphasis on evaluating the licensees' abilities to analyze for additional discharge pathways, such as groundwater, as a result of a spill or leak.

The NRC has established a "lessons learned" task force to address inadvertent, unmonitored liquid releases of radioactivity from U.S. commercial nuclear power plants. This task force will review previous incidents, identify lessons learned from these events, and determine what, if any, changes are needed in the agency's regulatory program. The task force's findings are expected in the near future.

As with any industrial facility, a nuclear power plant may deviate from normal operation with a spill or leak of liquid material. However, the plant design and the NRC's inspection program both provide reasonable assurance that safety limits will be met — even in abnormal situations.

This fact sheet provides a general overview of the health effects of tritium and the technical bases for the regulatory standards that the NRC uses to protect public health and safety, as well as the drinking water standards established by the U.S. Environmental Protection Agency (EPA). Additional resources and references related to tritium are listed at the end of this fact sheet.

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. The radiation emitted from tritium is a low-energy beta particle that is similar to an electron. Moreover, the tritium beta particle does not travel very far in air and cannot penetrate the skin.

Tritium from Nuclear Power Plants

- Several nuclear power plants have recently reported abnormal releases of liquid tritium, which resulted in groundwater contamination (see http://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html).
- Many power plants (nuclear and otherwise) convert heat into electricity using steam. Non-nuclear power plants burn coal or oil to generate the heat to make steam. By contrast, nuclear power plants generate the heat to make steam through the process of atomic fission (atom splitting). Fission occurs when the nucleus of a heavy atom, such as uranium or plutonium, splits in two when struck by a neutron. This “fissioning” of the nucleus produces energy in the form of heat, and releases two or three new neutrons, which can then repeat the process to release even more neutrons — and more nuclear energy. The repetitive cycling of this process is called a “chain reaction.”
- Most of the tritium produced in a reactor is as a byproduct of the absorption of neutrons by a chemical known as boron. Boron is a good absorber of neutrons, which nuclear reactors use to help control the fission 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. Tritium can also be produced (to a lesser extent) from the fission process itself, or when neutrons are absorbed by other chemicals (e.g., lithium or heavy water) in the coolant water (NAS, 1996; UNSCEAR 1988).
- Like normal hydrogen, tritium can bond with oxygen to form water. When this happens, the resulting water (called “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 Web site at http://www.reirs.com/effluent/ .

How do people become exposed to tritium?

- Tritium is almost always found as a liquid 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.
- 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.

Is the radiation dose from tritium any different than the dose from natural background radioactivity or medical administrations?

- The type of radiation dose from tritium is the same as from any other type of radiation, including natural background radiation and medical administrations.
- The tritium dose from nuclear power plants is much lower than the exposures attributable to natural background radiation and medical administrations.
- Humans receive approximately 82% of their annual radiation dose from natural background radiation, 15% from medical procedures (e.g., x-rays), and 3% from consumer products. Doses from tritium and nuclear power plant effluents are a negligible contribution to the background radiation to which people are normally exposed, and they account for less than 0.1% of the total background dose (NCRP, 1987).

  As an example, assume that a residential drinking water well sample contains tritium at the level of 1,600 picocuries per liter (a comparable tritium level was identified in a drinking water well near the Braidwood Station nuclear facility). The radiation dose from drinking water at this level for a full year is characterized as follows (using EPA assumptions):

  - <u>at least ten thousand times lower</u> than the dose from a medical procedure involving a full-body computed tomography (CT) scan (e.g., 3,000 to 10,000 mrem from a CT scan vs. 0.3 mrem from tritiated drinking water)
  - <u>one thousand times lower</u> than the dose from natural background radiation (e.g., 300 mrem from natural background radiation vs. 0.3 mrem from tritiated water)
  - <u>one hundred times lower</u> than the dose from either dental x-rays or natural radioactivity (potassium) in your body (e.g., 30 mrem from potassium vs. 0.3 mrem from tritiated water)
  - <u>ten times lower</u> than a round-trip cross-country airplane flight (e.g., 3 mrem from New York to Los Angeles and back vs. 0.3 mrem from tritiated water)

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).]

Along with other national and international regulatory agencies responsible for radiation protection, the NRC assumes that any exposure to radiation poses some health risk, and that risk increases as exposure increases in a linear, no-threshold (LNT) manner. The LNT assumption suggests that any increase in dose, no matter how small, incrementally increases risk. Conversely, lower levels of radiation proportionately decrease the risk, such that very small radiation doses have very little risk. The health risks include increased occurrence of cancer and genetic abnormalities in future generations. Since it is assumed that any exposure to radiation poses some health risk, it makes sense to keep radiation doses as low as reasonably achievable (ALARA). The NRC's radiation dose limits and ALARA requirements minimize the health risk and ensure that no individual is disproportionately exposed as a result of NRC-licensed activities.

The NRC's dose limits for radiation workers and the general public are significantly lower than the levels of radiation exposure that cause health effects in humans — including a developing embryo or fetus. Although high doses and high dose rates may cause cancer in humans and genetic abnormalities in an embryo or fetus, public health data have not established the occurrence of these health risks following exposure to low doses and low-dose rates — below about 10,000 millirem (mrem).

> A **millirem** (mrem) is a term that scientists use to describe how much radiation the body absorbs. For example, scientists estimate that we receive a dose of 360 mrem every year from natural (e.g., radon) and human-made (e.g., medical) radiation sources.

For comparison, the NRC calculated a maximum annual dose of less than 0.1 mrem to a member of the public from the recent unintended tritium releases at the Braidwood Station. This is a very low dose, which is not considered a risk to public health and safety because it 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, a typical individual in the United States receives an average annual radiation exposure of about 300 millirem from natural sources (NCRP, 1987). Radon gas accounts for two-thirds of this exposure, while cosmic, terrestrial, and internal radiation account for the remainder. No adverse health effects have been discerned from doses arising from these levels of natural radiation exposure.

In addition, human-made sources of radiation from medical, commercial, and industrial activities contribute another 60 mrem to our annual radiation exposure. Of these sources of exposure, medical x-rays are among the greatest contribution, and diagnostic medical procedures account for about 40 mrem each year. In addition, consumer products (such as tobacco, fertilizer, welding rods, gas mantles, luminous watch dials, and smoke detectors) contribute another 10 mrem to our annual radiation exposure. For more information on the health effects of radiation, visit http://www.nrc.gov/reading-rm/ doc-collections/fact-sheets/bio-effects-radiation.html (NRC, 2004).

Radiation Protection Limits

The NRC is continuously evaluating the latest radiation protection recommendations from international and national scientific bodies to ensure the adequacy of the standards the agency uses. Among those standards, the NRC and EPA have established three layers of radiation protection limits to protect the public against potential health risks from exposure to radioactive liquid discharges (effluents) from nuclear power plant operations. The NRC has determined that doses to the general public from the unintended release of tritium at nuclear power plants are significantly below even the most stringent layer of these protective limits and, therefore, does not pose a 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 radiation doses from gas and liquid effluents as low as reasonably achievable (ALARA) to people offsite. For liquid effluent releases, such as diluted tritium, the ALARA annual offsite dose objective is 3mrem to the whole body and 10 mrem to any organ
of a maximally exposed individual who lives in close proximity to the plant boundary. This ALARA objective is 3% of the annual public radiation dose limit of 100 mrem.

The NRC selected the 3 mrem and 10 mrem per year values because they are a fraction of the natural background radiation dose, a fraction of the annual public dose limit, and an attainable objective that nuclear power plants could meet. Power plants that meet these objectives are considered to be ALARA in reducing exposures to the general public from nuclear power plant effluents (AEC 1971, NRC 1975).

Nuclear power plant operators must monitor the authorized releases (effluents) from their plants. If a given nuclear power plant exceeds half of these radiation dose levels in a calendar quarter, the plant operator is required to 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)

In 1979, EPA developed a radiation dose standard of 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. The NRC incorporated these EPA standards into its regulations in 1981, and all nuclear power plants must now meet these requirements. These standards are specific to facilities that are involved in generating nuclear power (commonly called the "uranium fuel cycle"), including where nuclear fuel is milled, manufactured, and used in nuclear power reactors. EPA determined the basis of the standards by comparing the cost-effectiveness of various dose limits in reducing potential health risks from operation of these types of facilities. EPA assumed the standards would be able to be met for up to four fuel cycle facilities (e.g., four reactors) at one location (EPA, 1976a). Notably, 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 is a dose limit of 100 mrem per year to individual members of the public. This limit applies to everyone, including academic, university, industrial, and medical facilities that use radioactive material.

The NRC adopted the 100 mrem per year dose limit from the 1990 Recommendations of the International Commission on Radiological Protection (ICRP). The ICRP is an organization of international radiation scientists who provide recommendations regarding radiation protection-related activities, including dose limits. These dose limits are often implemented by governments worldwide as legally enforceable regulations. The basis of the ICRP recommendation of 100 mrem per year is that a lifetime of exposure at this limit would result in a very small health risk and is roughly equivalent to background radiation from natural sources (excluding radon) (ICRP, 1991). Thus, the ICRP equated 100 mrem per year to the risk of riding public transportation — a risk the public generally accepts (ICRP, 1977). The U.S. National Commission on Radiological Protection and Measurements (NCRP) also recommends the dose limit of 100 mrem per year (NCRP, 1993).

For liquid effluents, including tritiated water, any licensee can demonstrate compliance with the 100 mrem per year dose standard by not exceeding the concentration values specified in Table 2 of Appendix B to 10 CFR Part 20. These concentration values, if inhaled or ingested over the course of a year, would produce a total effective dose of 50 mrem.

Drinking Water Standards

Under the authority of the Safe Drinking Water Act, EPA sets the Federal legal limits for contaminants in drinking water. These limits are called maximum contaminant levels, and water suppliers must provide water that meets these standards. EPA's drinking water standards do not apply to private drinking water wells, such as those that may be impacted by tritium that is inadvertently released from nuclear power plants. However, many State authorities have adopted the EPA's drinking water standards as legally enforceable groundwater protection standards, and those standards are often used in assessing laboratory test results of water from private wells. For more information on drinking water and health, visit http://www.epa.gov/safewater/dwh/index.html (EPA, 2006a).

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

In 1976, EPA established a dose-based drinking water standard of 4 mrem per year to avoid the undesirable future contamination of public water supplies as a result of controllable human activities. In so doing, EPA set a maximum contaminant level of 20,000 picocuries per liter (pCi/L) for tritium. This level is assumed to yield a dose of 4 mrem per year. If other similar radioactive materials are present in the drinking water, in addition to tritium, the sum of the annual dose from all radionuclides shall not exceed 4 mrem per year. Water treatment plant operators use this drinking water standard, along with monitoring requirements, to remain vigilant regarding the amount of radioactivity in drinking water and provide a means to gauge if the concentration of contaminants in finished drinking water is increasing or decreasing over time. This standard was expected to be exceeded only in extraordinary circumstances (EPA, 1975; EPA, 1976b).

Since EPA developed the 1976 drinking water standard, scientists have improved the calculation methods to equate concentrations of tritium in drinking water (pCi/L) to radiation doses in people (mrem). In 1991, EPA calculated a tritium concentration to yield a 4 mrem per year dose as 60,900 pCi/L — a threefold increase from the maximum contaminant level of 20,000 pCi/L established in 1976. However, EPA kept the 1976 value of 20,000 pCi/L for tritium in its latest regulations. For more information on the basis and history of the Radionuclide Rule, visit http://www.epa.gov/safewater/radionuc.html (EPA, 2006b).

Additional Tritium Resources

- U.S. NRC: http://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html
- U.S. EPA: http://www.epa.gov/radiation/radionuclides/tritium.htm
- U.S. DOE (Argonne National Lab): http://www.ead.anl.gov/pub/doc/tritium.pdf
- California EPA: http://www.oehha.ca.gov/water/phg/allphgs.html
  (Scroll down and click on Tritium.)
- University of Idaho: http://www.physics.isu.edu/radinf/tritium.htm

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United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), “Sources, Effects, and Risks of Ionizing Radiation, Annex B: Exposures from Nuclear Power Plant Production,” 1988.