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) 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 do not leave the power plant property or involve such low levels of tritium that they do not pose a threat to public health and safety. Nonetheless, the NRC takes these unanticipated and unmonitored releases very seriously, and continues to review these incidents to ensure that nuclear power plant operators take appropriate action.

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

The NRC has revised its inspections of nuclear power plants to evaluate licensees' programs to inspect, assess and repair equipment and structures that could potentially leak. The NRC has also placed additional emphasis on evaluating the licensees' abilities to analyze additional discharge pathways, such as groundwater, as a result of a spill or leak. The agency's resident inspectors, who work full-time at operating U.S. nuclear power plants, regularly monitor all these activities and any deficiencies can trigger more intensive NRC oversight of a plant.

In 2006 an NRC "lessons learned" task force examined previous inadvertent, unmonitored liquid releases of radioactivity from U.S. commercial nuclear power plants. The task force recommended changes in the agency's regulatory program and industry efforts. The task force's findings and the NRC's response are available on the NRC website at: http://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html.

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, 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 (see: http://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html).

- 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 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.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html.

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.

- 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.

Can the radiation dose from tritium produced in nuclear power be compared 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 radiation dose from tritium can be directly compared to the radiation dose from any other type of radiation, including natural background radiation and those received during medical procedures.

- 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% of their annual radiation dose from natural background radiation, 48% from medical procedures (e.g., x-rays), and 2% 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, 2009) 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 (using EPA assumptions) is 0.3 millirem (mrem), which is:

    - <u>at least two thousand to five thousand times</u> lower than the dose from a medical procedure involving a full-body computed tomography (CT) scan (e.g., 500 to 1,500 mrem from a CT scan)
    - <u>one thousand times lower</u> than the approximate 300 mrem dose from natural background radiation
    - <u>fifty times lower</u> than the dose from natural radioactivity (potassium) in your body (e.g., 15 mrem from potassium)
    - <u>twelve times lower</u> than the dose from a round-trip cross-country airplane flight (e.g., 4 mrem from Washington, DC 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).]

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.

> 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 620 mrem every year from natural (e.g., radon) and human-made (e.g., medical) radiation sources.

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).

For comparison, the NRC calculated a maximum annual dose of less than 0.1 mrem to a member of the public from the unintended tritium releases at the Braidwood Station nuclear power plant in Illinois. 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 310 millirem from natural sources (NCRP, 2009). 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, Man-made sources of radiation from medical, commercial, and industrial activities contribute about another 310 mrem to our annual radiation exposure. One of the largest of these sources of exposure is computed tomography (CT) scans, which account for about 150 mrem of the total from man-made sources. Other medical procedures together account for about another 150 mrem each year. In addition, some consumer products such as tobacco, fertilizer, welding rods, exit signs, luminous watch dials, and smoke detectors contribute about 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, 2011).

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, do 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 3 mrem 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 realistically 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 Council 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

The EPA uses its authority under the Safe Drinking Water Act to set the Federal legal limits for contaminants in drinking water. Water suppliers must provide water that meets these standards, called maximum contaminant levels. 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).

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).

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.

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.

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