Fermilab
ES&H Section

ENVIRONMENTAL PROTECTION NOTE No. 28

Background Levels of Tritium

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Initial Issue: September 2012

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Distribution via Electronic Mail*

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Ordinary hydrogen atomic nuclei, also called hydrogen-1 or ^{1}H, consist each of only one proton. A small amount of the hydrogen found in nature (0.0115%) is another isotope, called deuterium, also called hydrogen-2 or ^{2}H. Each atomic nucleus of deuterium consists of one neutron and one proton. Neither ^{1}H nor ^{2}H are radioactive. Tritium, also called hydrogen-3 or ^{3}H, is the third isotope of hydrogen that exists. Each tritium nucleus is comprised of two neutrons and one proton. Unlike the other two isotopes, tritium is radioactive and has a half-life of 12.32 years. When a tritium nucleus decays it emits an electron with a maximum energy of 18.6 keV, and a type of neutrino, technically an "electron anti-neutrino", and also leaves behind a nonradioactive nucleus of helium called helium-3 or ^{3}He. All three hydrogen isotopes readily combine with oxygen in the atmosphere to become water molecules and thus mix well with water present in the atmosphere and on the earth's surface. Tritium is produced naturally in the earth's atmosphere due to interactions of cosmic rays from outer space and also is produced in particle accelerators, nuclear reactors, and in atmospheric tests of nuclear weapons.

In the earth's atmosphere the interactions of cosmic rays from outer space with the chemical elements found in the air produce tritium. This has been going on during all epochs of the earth's history. Due to finite half-life of tritium, over the most recent millennia of the earth's history this production of tritium has come into equilibrium with its decay in the water systems of the world. The National Council on Radiation Protection and Measurements (NCRP) in its Report No. 62 provides the world-wide average equilibrium concentrations in environmental media due to natural production[1]:

Water Vapor in Air: 1.66×10^{-2} pCi/ml

Surface Streams: 1.04×10^{-2} pCi/ml

Surface of Ocean: 1.60×10^{-3} pCi/ml.

Since the natural production of tritium occurs in the atmosphere, with much meteorological mixing, world-wide average concentrations in water due to this natural production process do not vary a lot from place to place and do not change with time. Ref. 1 assigns an average annual dose to an individual due to this natural source of radiation exposure of 1.2×10^{-3} mrem, a value quite small compared with the average annual dose in the United States due to all natural background sources of 311 mrem, a value resulting from a recent comprehensive reassessment of all radiation exposures by the NCRP[2] in its Report No. 160.

The concentrations in air and surface water have been elevated considerably as a result of atmospheric fallout due to atmospheric nuclear weapons tests that were conducted in the late 1940s, 1950s and early 1960's. Most, but not quite all, nations ended atmospheric nuclear weapons testing in 1963 under the Limited Test Ban Treaty. Thereafter, the tritium concentrations in the atmospheric, and thus eventually in surface water began to decline in the late 1960s since no more tritium was being added by this man-made mechanism. These levels were of considerable concern and have been studied extensively. Readers of published

documents and the internet are likely to encounter a special unit of measurement called the tritium unit, the TU, chosen to quantify tritium concentrations. A publication of the Michigan Department of Environmental Quality[3] and other references discuss this unit, defined to be, in water, one tritium atom per 10^{18} hydrogen atoms. Ignoring the small component of deuterium, this is equivalent to 3.23 pCi/l in water, or 3.23×10^{-3} pCi/ml. Ref. 3 states that pre-fallout values at any given time and place in rain water were typically 5-10 TU, consistent with the average values from Ref. 1 listed above, while at the height of atmospheric testing, the atmospheric levels approached 1000 TU. The Illinois Environmental Protection Agency posts a similar website.[4] Refs. 3 and 4 report that present values in rain water are about 50 to 100 TU, or 0.16 to 0.32 pCi/ml. These levels are well below the U. S. Environmental Protection Agency standard for the allowable tritium concentration in community drinking water systems of 20 pCi/ml.

Groundwater resources are commonly protected from direct mingling with surface water especially in the vicinity of Fermilab due to the presence of intervening layers of clay, rock, etc. While groundwater resources are said to be "recharged" by rainfall, etc., it usually takes a lengthy period of time for surface water to migrate down to groundwater. This allows any tritium to decay and for other radionuclides found in fallout and chemical contaminants that might be present to be filtered out. Given the reliance of many people on wells as a source of drinking water this cleansing of the water as it vertically migrates is recognized as being of great importance. As explained in Refs. 3 and 4, advantage has been taken of this otherwise undesired man-made increase in tritium concentrations in surface waters by using the value of the tritium concentration in water as tool to see if groundwater resources are vulnerable to leakage from surface waters of other types of chemical contaminants aside from radioactivity. To simplify, if a sample from a well is analyzed and found to have a tritium concentration of, for example, less than 1.0 TU (i.e., 3.23×10^{-3} pCi/ml) this would be one indicator among others that transit time of the water from the surface to the well is very long, implying that the intervening material serves to protect it. Thus, additional protective measures called "wellhead protection" may not be needed. On the other hand, if higher levels of tritium are found, this is indicative of rapid downward migration of pollutants; a result indicating that the groundwater in a particular locale merits additional protective measures, for example so-called wellhead protection.

Detailed measurements of tritium concentrations at these low values must be performed using specialized analytical processes beyond the capabilities of most analytical laboratories used to support the activities of radiological and nuclear facilities, including Fermilab.

From 1989-1996, the U. S. Geological Survey measured tritium concentrations in groundwater near Belvidere, IL[5] in geological media similar to those found beneath the Fermilab site. The work reported in Ref. 5 was comprehensive in scope looking at many chemical contaminants in addition to tritium. A total of 52 wells and 8 boreholes were studied. Four of these wells and boreholes were analyzed for tritium, with results ranging from 1.2×10^{-3} to 4.1×10^{-2} pCi/ml, well below the drinking water standard of 20 pCi/ml.

Several previous versions of this note have been informally distributed in the past several years. The helpful comments of Kamran Vaziri, Kurt Riesselmann, Diane Reitzner, and Matt Quinn are acknowledged.

References

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3. Michigan Department of Environmental Quality, website, Updated August 2009: http://www.michigan.gov/documents/deq/deq-wb-dwehs-swpu-tritiumanalysisguidance_212715_7.pdf (accessed August 21, 2012).
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5. "Geologic, Hydrologic, and Water-Quality Data from Selected Boreholes and Wells In and Near Belvidere, Illinois, 1989-96", P. C. Mills (U. S. Geological Survey, D. J. Yeskis (U. S. Environmental Protection Agency, and T. D. Straub (U. S. Geological Survey), Open-File Report 97-242 (Urbana, Illinois 1998).