Environmental Protection Note 31

Potential Tritium Uptake by Members of the Public Due to Consumption of Fish Caught in the Fermilab Pond System

October 11, 2016

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Introduction

Fermi National Accelerator Laboratory (Fermilab) is a high energy accelerator facility under contract with the Department of Energy (DOE). As a byproduct of accelerator operations, tritium is produced in the Neutrinos at the Main Injector (NuMI) and Booster Neutrino Beam (BNB) enclosures and tunnels. Tritiated water, from evaporating the air in the enclosures or from floor drains, is then pumped out of the enclosures and used in our industrial cooling water (ICW) system, cooling ponds, or evaporated into the atmosphere. Figures 1 and 2 illustrate the entire Fermilab complex and the pond system on site, respectively, while Figure 3 highlights the NuMI and BNB buildings and enclosures.

Figure 1. Fermilab Site Map. (GIS16)

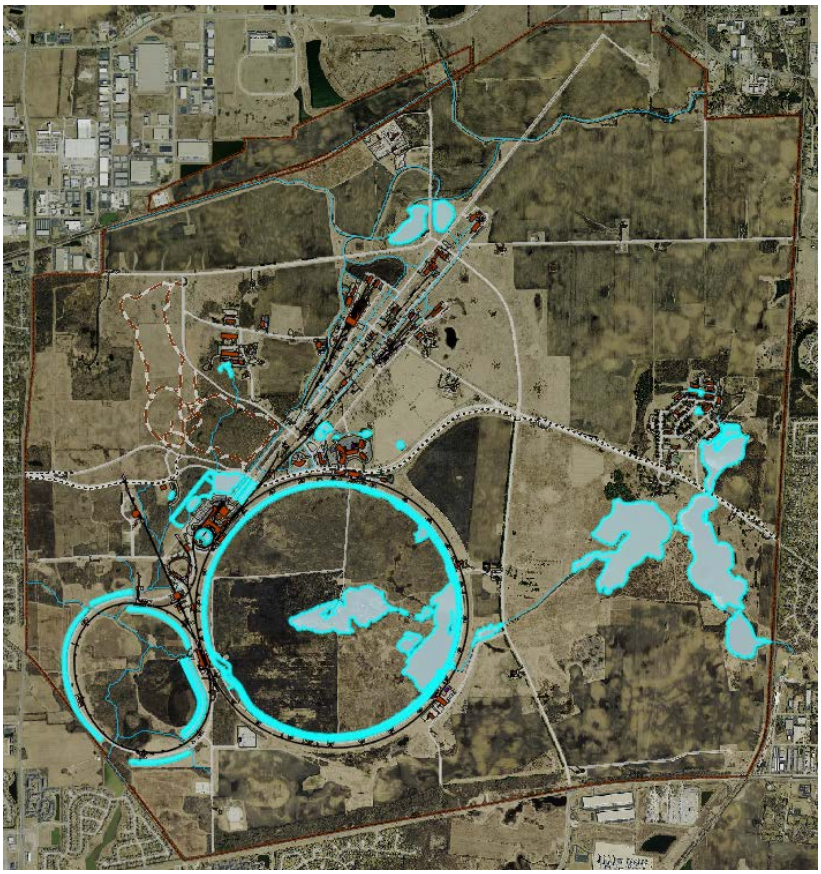

Figure 2. Fermilab Pond System. (GIS16)

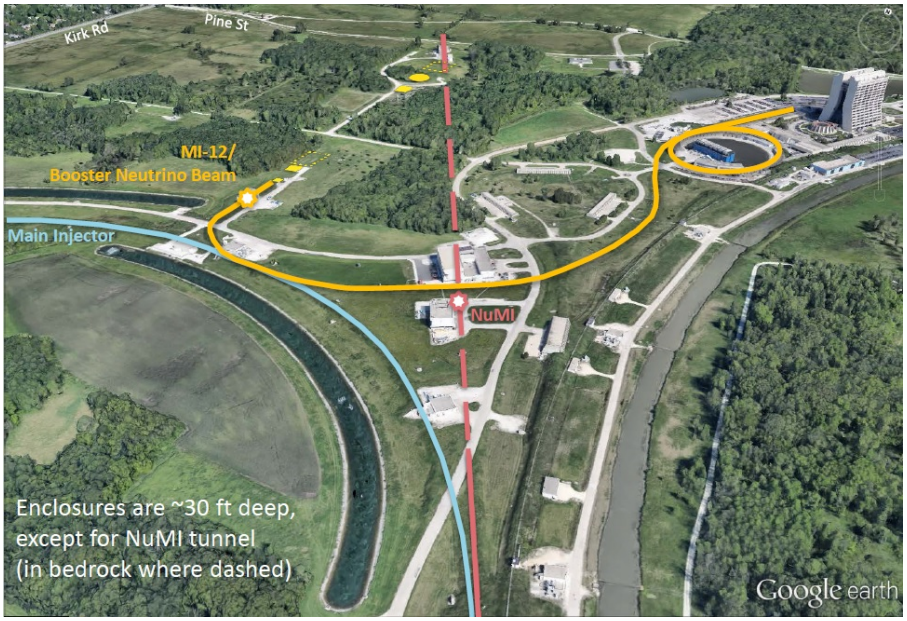

Figure 3. NuMI and BNB Enclosures. (Co16)

One area of concern is the amount of tritium in the water removed from these enclosures and tunnels and stored in the cooling ponds, therefore entering the Fermilab pond system in the form of tritiated water, HTO. Measurable amounts of tritium are routinely found in the pond system, and it will most likely also be found in the fish living in the ponds. Fermilab is an open site, and allows members of the public as well as employees to fish in the ponds on site. By catching and eating fish from the Fermilab ponds, members of the public are also ingesting tritium. This issue was first discussed in Environmental Protection (EP) Note 10, *Analysis of Radiological Exposure Pathways for Tritium Discharged to On-Site Surface Waters* (Mar95), along with other exposure pathways for tritium. This Note is intended to expand upon EP Note 10, focusing solely on the potential uptake of tritium due to the consumption of fish caught in the Fermilab ponds.

Background Information

It is important to note that everyone is exposed to radiation levels just by living on Earth, either through ubiquitous background (natural) radiation or medical sources of radiation. In the United States, individuals annually receive approximately 311 mrem from natural sources of radiation and approximately 300 mrem from medical sources of radiation (NC09). The total value is commonly rounded to 620 mrem per year, and is known as "natural background". Additionally, tritium is found in environmental waters due to a number of sources: natural production of cosmic rays, nuclear fallout, and the nuclear industry (NC79).

The Department of Energy (DOE) limits the amount of radiation that a member of the public may receive due to its operations to 100 mrem in a year (DOE11). In order to stay well below this limit, Fermilab has imposed a site boundary limit on itself of 10 mrem in a year (FRCM2). The site boundary is shown as a red line around the Fermilab site in Figure 1. The DOE also limits the concentration of tritium found in surface water to 1,900 pCi/ml (DOE11) (FRCM3). This limit is based on a documented determination that a member of the public who uses the water source as their full time water supply at this concentration would receive 100 mrem in a year, the DOE dose limit to a member of the public. As of the writing of this Note, the maximum concentration of tritium found in any of the Fermilab surface water in the past six months[1] is 17.7±0.4 pCi/ml (RAF), shown in Table 1.

Table 1. Tritium Concentration in Various Fermilab Surface Water, in pCi/ml, Over the Past Six Months (RAF).

	3/4/16	4/7/16	5/12/16	6/24/16	7/27/16	8/29/16
MI Pond C	1.6±0.1	2.1±0.2	1.9±0.1	1.9±0.2	2.5±0.1	n/a
MI Pond F	1.6±0.1	1.9±0.3	1.8±0.1	2.1±0.2	2.5±0.1	1.8±0.4
Booster Pond East	10.9±0.3	17.7±0.4	5.9±0.2	13.3±0.4	15.1±0.2	10.4±0.3
Kidney Pond	<1.0	<1.0	<1.0	1.2±0.4	1.7±0.1	<1.0
Kress Creek Transfer Ditch Spillway	<1.0	<1.0	<1.0	<1.0	<1.0	n/a
Kress Creek at Fabyan Parkway	n/a	n/a	n/a	n/a	<1.0	n/a
Kress Creek at Town Road	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Indian Creek Boundary	<1.0	<1.0	<1.0	1.0±0.2	1.43±0.09	2.1±0.1

[1] The highest tritium concentration ever found in Fermilab surface water was 31.8 pCi/ml, found in the Booster Pond East on May 13, 2015 (RAF).

Assumptions

In order to calculate the potential uptake of tritium by a member of the public eating fish caught on the Fermilab site, several assumptions must be made. All assumptions made are for the purpose of this Note, and are made in order to be conservative.

First, one must determine the amount of fish eaten by the average American in a year. The National Oceanic and Atmospheric Administration reports that the average American eats one meal with fish per week, which comes out to 15.8 lbs per year (Na16). The United States Department of Agriculture (USDA) recommends increasing the amount of fish eaten to 31.6 lbs per year (Un03). For the purpose of this Note, this number is rounded to 50 lbs of fish consumed per year. It is also assumed that all of the fish consumed were caught in a Fermilab pond.

Next, one must look at the concentration of tritium in the water and fish. In order to be conservative, the concentration of the pond water is taken to be the maximum allowable limit of 1,900 pCi/ml. Since tritium is completely absorbed rather easily by the body after being ingested (NC79), and that fish living in the water will be constantly ingesting the water, the concentration of tritium found in the fish is assumed to be equal to the concentration of tritium found in the water. It is also assumed that the fish are prepared for consumption soon after being caught, so the biological half-life of tritium in fish of 12 days (Br82) does not reduce the concentration, and that no water gets cooked out when preparing the fish, leaving the concentration of tritium in the fish at a constant, conservative 1,900 pCi/ml.

List of Assumptions:

1) The average American consumes 50 lbs of fish per year
2) All fish consumed were caught in Fermilab pond
3) Concentration of tritium in all water is 1,900 pCi/ml
4) Concentration of tritium in fish is 1,900 pCi/ml
5) 12 day half-life not applicable
6) No water gets cooked out, concentration of tritium doesn't change
7) Since fish are buoyant, we are assuming that the density of the fist is 1 g/cm^3

Helpful Conversion Factors

- 1 lb = 453.6 g
- 1 Ci = 3.7x10^{10} Bq
- Dose coefficient for ingestion of tritiated water is 2.1x10^{-11} Sv Bq^{-1} (DOESTD11)
- 1 Sv = 100 rem

Calculation

Assuming that a member of the public catches and eats 50 lbs of fish from the Fermilab ponds in a year, with the pond water, and therefore the fish, at the maxim concentration limit of 1,900 pCi ml^{-1} of tritium, Equation 1 finds the uptake of tritium in a year due to the consumption of fish from Fermilab ponds.

$$\frac{50\ lb}{year} \times \frac{453.6\ g}{1\ lb} \times \frac{1\ ml}{1\ g} \times \frac{1{,}900\ pCi}{1\ ml} = 4.31x10^7\ \frac{pCi}{year} \qquad (1)$$

Using Equation 2, convert the uptake of tritium in a year from pCi to Bq.

$$4.31x10^{7}\ \frac{pCi}{year} \times \frac{1\ Ci}{1x10^{12}\ pCi} \times \frac{3.7x10^{10}\ Bq}{1\ Ci} = 1.59x10^{6}\ \frac{Bq}{year} \tag{2}$$

Use the dose coefficient for ingestion of tritiated water in Equation 3 to convert the uptake of tritium in a year from Bq to mrem.

$$1.59x10^{6}\ \frac{Bq}{year} \times \frac{2.1x10^{-11}\ Sv}{1\ Bq} \times \frac{100\ rem}{1\ Sv} \times \frac{1{,}000\ mrem}{1\ rem} = 3.36\ \frac{mrem}{year} \tag{3}$$

Conclusion

The potential uptake of tritium to a member of the public from eating fish caught in the Fermilab ponds, using our overly conservative assumptions, is 3.36 mrem in a year. This is less than half of the 10 mrem in a year limit at the Fermilab site boundaries, and well below the 100 mrem in a year DOE dose limit to members of the public. When the differences in assumptions and small differences in dose coefficients[2] are taken into account, this result is quite consistent with that reported in (Mar95).

The U. S. Environmental Protection Agency (USEPA) sets forth an upper limit of 20 pCi/ml on the concentration of tritium in water supplied by drinking water systems (USEPA). A member of the public using such water as their full time household is assigned an annual dose of 4 mrem/year due to this radioactivity. Thus the calculated dose due to consuming this large quantity of fish obtained from the Fermilab ponds at the maximally allowed concentration is less than that allowable from drinking water.

At the highest tritium concentration levels found in the Fermilab ponds in the past six months, 17.7±0.4 pCi/ml, rounding to 18.1 pCi/ml, the uptake of tritium would be 0.032 mrem/year. At the maximum tritium concentration level ever found in the Booster Pond East, 31.8 pCi/ml on 5/13/2015, the uptake of tritium would be 0.056 mrem/year. These values were found by going through Equations 1-3 using concentrations of 18.1 pCi/ml and 31.8 pCi/ml instead of 1,900 pCi/ml. These values are even further below the Fermilab and DOE limits, and are also below the National Council on Radiation Protection and Measurements (NCRP) negligible individual dose per single source limit of 1 mrem (NC93).

Even with all of the conservative assumptions, it is not possible through consumption of fish from Fermilab ponds to reach the 100 mrem in a year limit to members of the public set by the DOE before reaching the 1,900 pCi/ml concentration of tritium limit. It is also impossible to reach the 10 mrem in a year site boundary limit set by Fermilab, and highly unlikely to reach the NCRP negligible individual dose per single source limit of 1 mrem by consuming fish from ponds at Fermilab. Also, these levels (3.35 mrem/year conservatively, and 0.032 mrem/year and 0.056 mrem/year more realistically) are well below the amount of radiation that members of the public receive through natural sources.

[2] In 1995, DOE Order 5400.5, "Radiation Protection of the Public and Environment" was applicable and set forth slightly different dose coefficients that have now been superseded by those in (DOESTD11) that are used in the present calculation. (DOE11) replaced DOE Order 5400.5 in 2011.

Fermilab would reach the concentration limit of 1,900 pCi/ml of tritium before coming anywhere near the dose limits to members of the public from consumption of tritiated fish. Therefore, there should be no restriction placed on fishing at the Fermilab ponds.

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