Overview of Pilgrim Liquid Discharge Considerations

Briefing for NRC Chairman Hanson

U.S. NRC Region 1 – Pilgrim Station

16 MAR 2022

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Agenda

1. Review of Regulatory Approach to Effluents
2. History of Effluent Releases at Pilgrim
3. History of Environmental Monitoring Near Pilgrim
4. Tritium in Perspective
5. Radiopharmaceuticals in Comparison
6. YOUR questions

1. The Regulatory Approach

- 10 CFR 20 (U.S. NRC)
- 40 CFR 190 (U.S. EPA)
- NPDES Permit (State of Massachusetts and EPA)

Regulations - NRC

- Radiation safety regulations apply to all types of NRC licensees (medical, manufacturing, power, etc…)
- Objectives based (*What vs How*)
- Radiation dose-based
  - Absorbed dose is the best indicator of potential health risks
- Regulatory limits **are not safety limits** (10 CFR 20)

> *Limits* (dose limits) means the permissible upper bounds of radiation doses.

NRC – 10 CFR 20

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

Subpart K—Waste Disposal

20.2001 General requirements.

20.2002 Method for obtaining approval of proposed disposal procedures.

20.2003 Disposal by release into sanitary sewerage.

20.2004 Treatment or disposal by incineration.

20.2005 Disposal of specific wastes.

20.2006 Transfer for disposal and manifests.

20.2007 Compliance with environmental and health protection regulations.

20.2008 Disposal of certain byproduct material.

§ 20.2001 General requirements.

(a) A licensee shall dispose of licensed material only—

(1) By transfer to an authorized recipient as provided in § 20.2006 or in the regulations in parts 30, 40, 60, 61, 63, 70, and 72 of this chapter;

(2) By decay in storage; or

(3) By release in effluents within the limits in § 20.1301; or

§ 20.2007 Compliance with environmental and health protection regulations.

Nothing in this subpart relieves the licensee from complying with other applicable Federal, State, and local regulations governing any other toxic or hazardous properties of materials that may be disposed of under this subpart.

NRC – 10 CFR 20

§ 20.1301 Dose limits for individual members of the public.

(a) Each licensee shall conduct operations so that—

(1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 mSv) in a year, exclusive of the dose contributions from background radiation, from any administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003, and

(2) The dose in any unrestricted area from external sources, exclusive of the dose contributions from patients administered radioactive material and released in accordance with § 35.75, does not exceed 0.002 rem (0.02 millisievert) in any one hour.

(b) If the licensee permits members of the public to have access to controlled areas, the limits for members of the public continue to apply to those individuals.

(c) Notwithstanding paragraph (a)(1) of this section, a licensee may permit visitors to an individual who cannot be released, under § 35.75, to receive a radiation dose greater than 0.1 rem (1 mSv) if—

(1) The radiation dose received does not exceed 0.5 rem (5 mSv); and

(2) The authorized user, as defined in 10 CFR Part 35, has determined before the visit that it is appropriate.

(d) A licensee or license applicant may apply for prior NRC authorization to operate up to an annual dose limit for an individual member of the public of 0.5 rem (5 mSv). The licensee or license applicant shall include the following information in this application:

(1) Demonstration of the need for and the expected duration of operations in excess of the limit in paragraph (a) of this section;

(2) The licensee's program to assess and control dose within the 0.5 rem (5 mSv) annual limit; and

(3) The procedures to be followed to maintain the dose as low as is reasonably achievable.

(e) In addition to the requirements of this part, a licensee subject to the provisions of EPA's generally applicable environmental radiation standards in 40 CFR part 190 shall comply with those standards.

(f) The Commission may impose additional restrictions on radiation levels in unrestricted areas and on the total quantity of radionuclides that a licensee may release in effluents in order to restrict the collective dose.

NRC – 10 CFR 20

Another Option Available

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

§ 20.2003 Disposal by release into sanitary sewerage.

(a) A licensee may discharge licensed material into sanitary sewerage if each of the following conditions is satisfied:

(1) The material is readily soluble (or is readily dispersible biological material) in water; and

(2) The quantity of licensed or other radioactive material that the licensee releases into the sewer in 1 month divided by the average monthly volume of water released into the sewer by the licensee does not exceed the concentration listed in table 3 of appendix B to part 20; and

(3) If more than one radionuclide is released, the following conditions must also be satisfied:

(i) The licensee shall determine the fraction of the limit in table 3 of appendix B to part 20 represented by discharges into sanitary sewerage by dividing the actual monthly average concentration of each radionuclide released by the licensee into the sewer by the concentration of that radionuclide listed in table 3 of appendix B to part 20; and

(ii) The sum of the fractions for each radionuclide required by paragraph (a)(3)(i) of this section does not exceed unity; and

(4) The total quantity of licensed and other radioactive material that the licensee releases into the sanitary sewerage system in a year does not exceed 5 curies (185 GBq) of hydrogen-3, 1 curie (37 GBq) of carbon-14, and 1 curie (37 GBq) of all other radioactive materials combined.

EPA – 40 CFR 190

PART 190 - ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NUCLEAR POWER OPERATIONS

Authority: Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3, of 1970.

Source: 42 FR 2860, Jan. 13, 1977, unless otherwise noted.

Subpart A - General Provisions

§ 190.01 Applicability.

The provisions of this part apply to radiation doses received by members of the public in the general environment and to radioactive materials introduced into the general environment as the result of operations which are part of a nuclear fuel cycle.

EPA – 40 CFR 190

Subpart B - Environmental Standards for the Uranium Fuel Cycle

§ 190.10 Standards for normal operations.

Operations covered by this subpart shall be conducted in such a manner as to provide reasonable assurance that:

(a) The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations.

(b) The total quantity of radioactive materials entering the general environment from the entire uranium fuel cycle, per gigawatt-year of electrical energy produced by the fuel cycle, contains less than 50,000 curies of krypton-85, 5 millicuries of iodine-129, and 0.5 millicuries combined of plutonium-239 and other alpha-emitting transuranic radionuclides with half-lives greater than one year.

H-3 (Tritium) not listed

Existing NPDES Permit

NPDES Permit No. MA0003557 2020 Final Permit Page 27 of 36

23. Radioactive materials

The discharge of radioactive materials shall be in accordance with and regulated by the Nuclear Regulatory Commission (NRC) requirements (10 C.F.R. Part 20 and NRC Technical Specifications set forth in facility operating license, DPR-35).

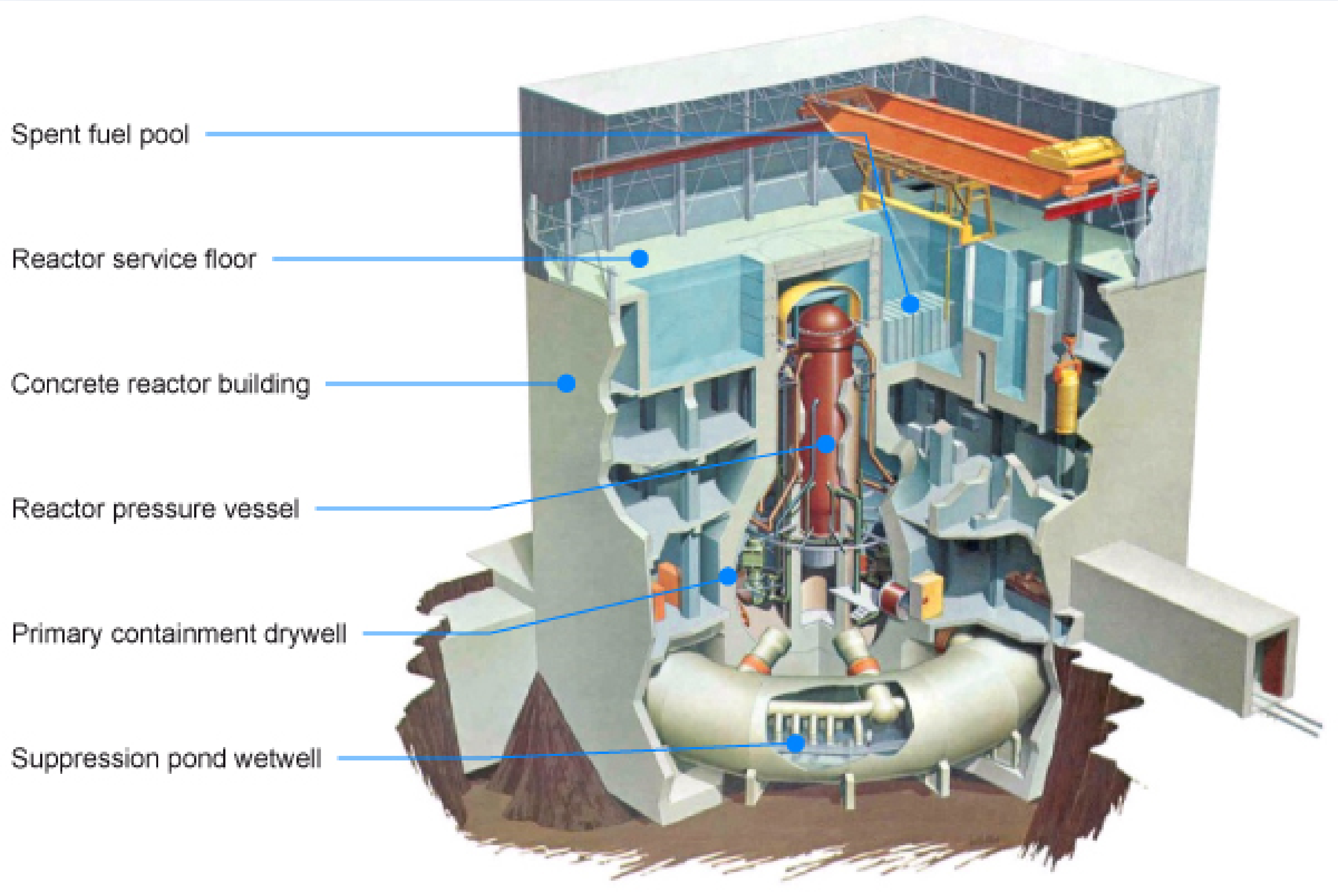
Existing NPDES Permit

B. UNAUTHORIZED DISCHARGES

1. The Permittee is authorized to discharge only in accordance with the terms and conditions of this permit and only from the outfalls listed in Parts I.A. through I.C. of this permit. Discharges of wastewater from any other point sources not authorized by this permit shall be reported in accordance with the twenty-four-hour reporting provision found in Section D.1.e.(1) of Part II (Standard Conditions) of this permit. The Permittee must report any planned physical alterations or additions to the permitted facility in accordance with the reporting provision found in Section D.1.a of Part II (Standard Conditions) and give advance written notice (including notice to MassDEP) of any planned changes which may result in noncompliance with permit requirements in accordance with the reporting provision found in Section D.1.b of Part II (Standard Conditions).

2. The discharge of pollutants in spent fuel pool water (including, but not limited to, boron) is not authorized by this permit.

Water is Fungible - Can water in the Spent Fuel Pool be handled differently?



2. History of Effluent Releases

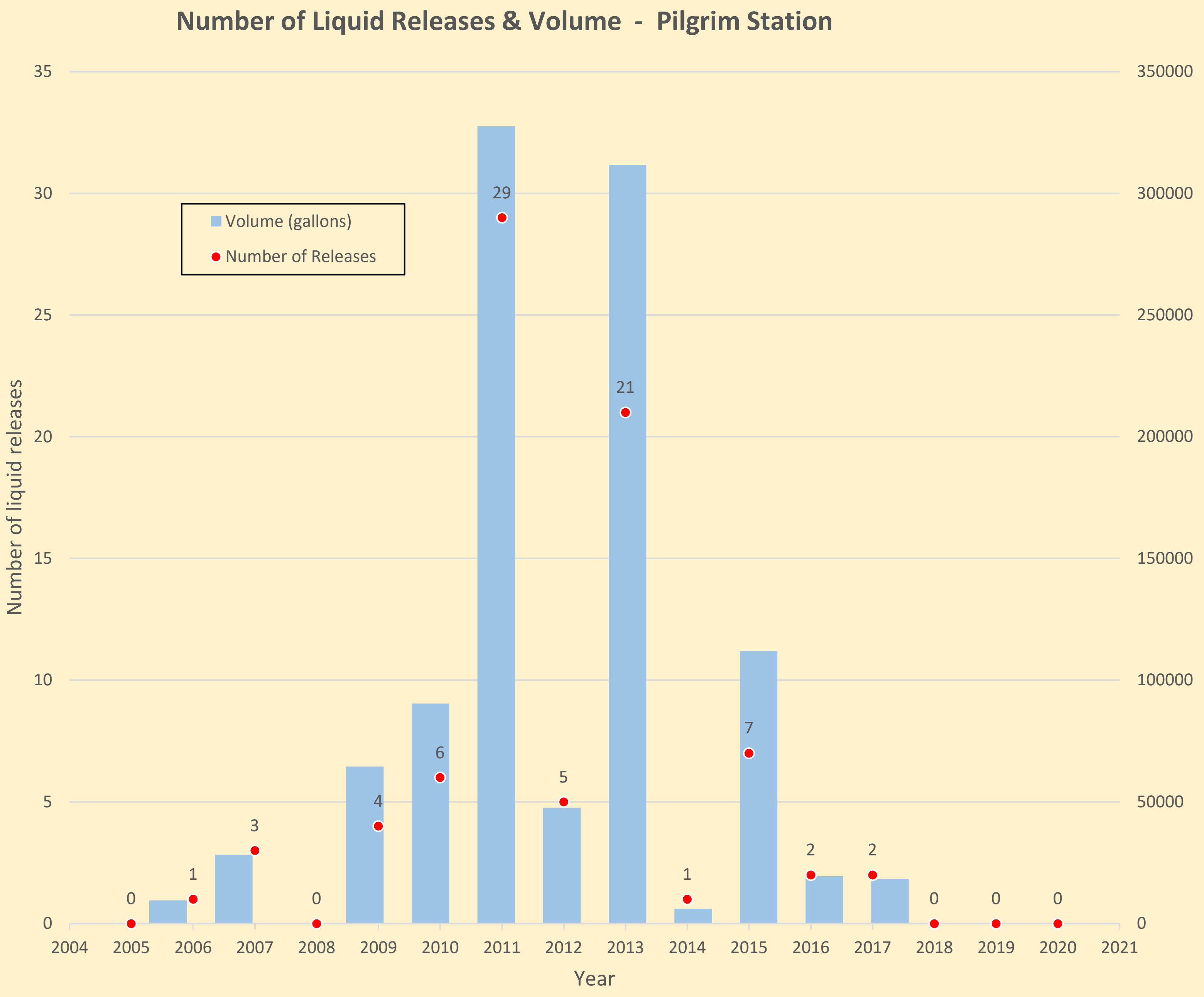
Radioactive Effluent and Environmental Reports

Each commercial nuclear power plant is required to submit two annual reports, which detail (1) the radioactive effluents discharged from the site, and (2) the effects (if any) on the environment. In addition to these two annual reports, in 2007 each power plant voluntarily submitted answers to a questionnaire related to the voluntary initiative on groundwater protection, initiated by the commercial nuclear power industry.

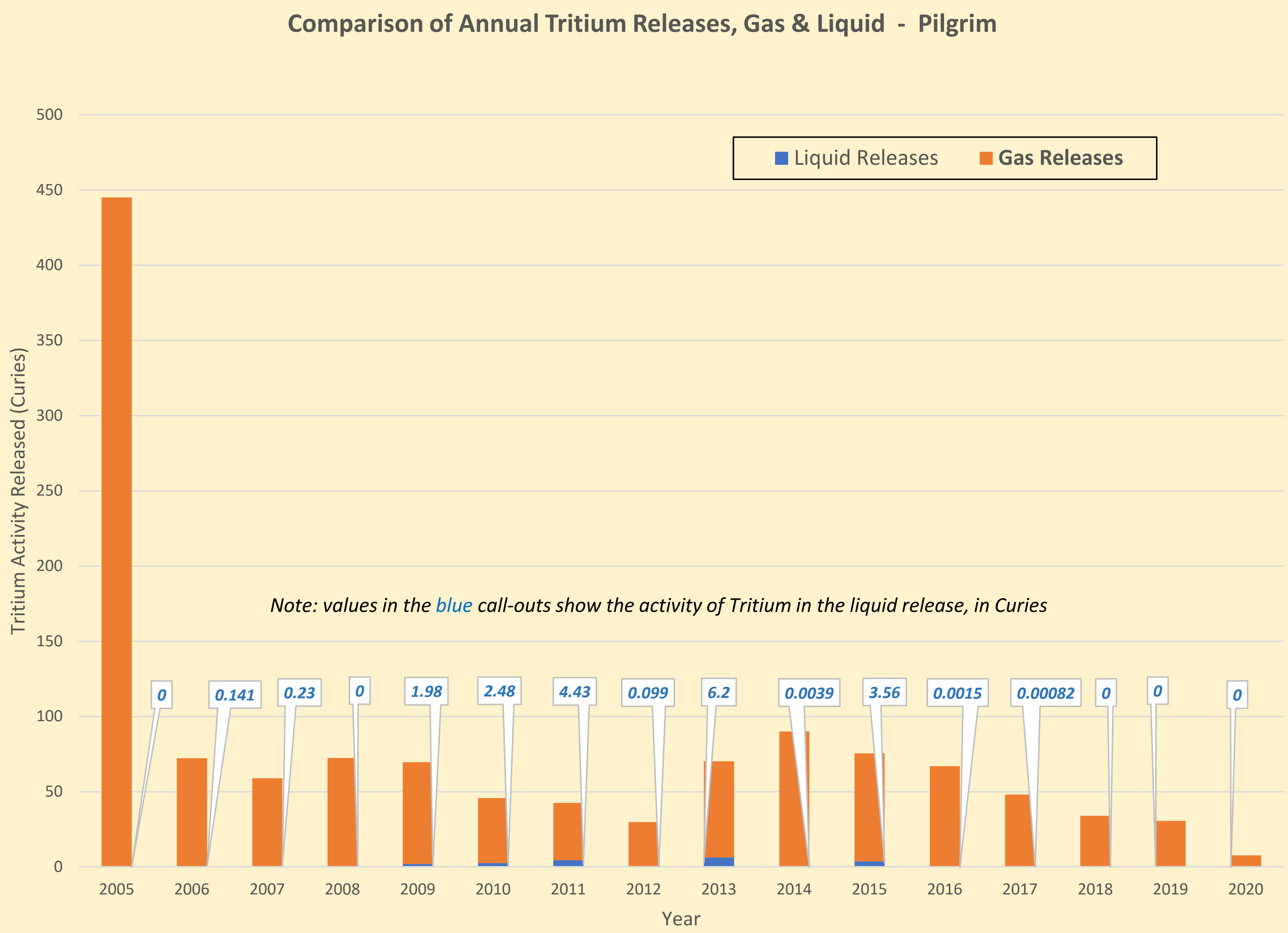
To see these reports and questionnaires for a particular nuclear power plant, select the plant name from the following table.

Alphabetical List of Operating Nuclear Power Reactors		
A - G	**H - P**	**Q - W**
Arkansas Nuclear One 1 & 2 Beaver Valley 1 & 2 Braidwood 1 & 2	H.B. Robinson 2 Haddam Neck* Hope Creek 1	Quad Cities 1 & 2 River Bend 1

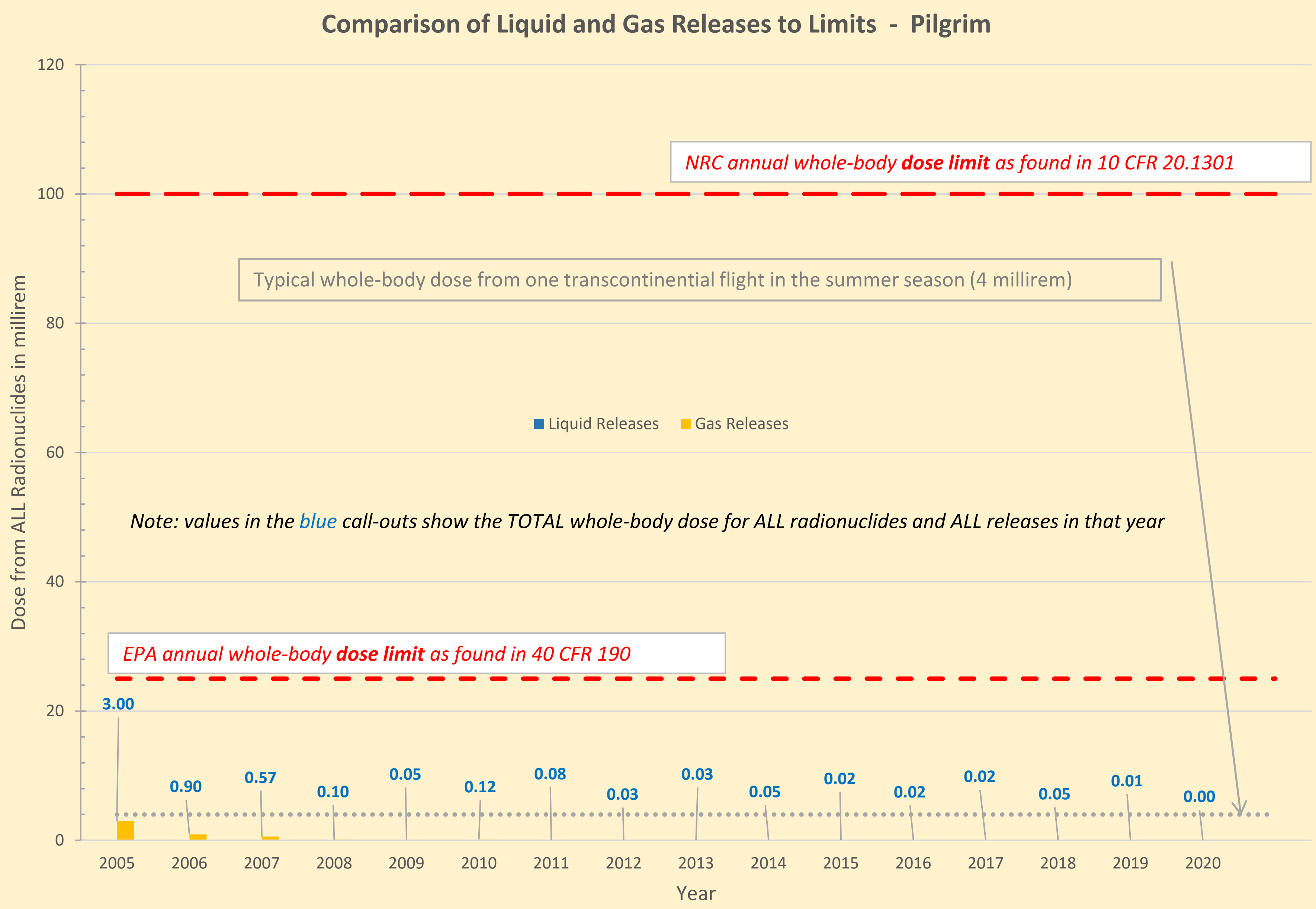
Publicly available at: https://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html



Number of Liquid Releases & Volume - Pilgrim Station
Volume (gallons)
Number of Releases
Number of liquid releases
Year
0
5
10
15
20
25
30
35
0
50000
100000
150000
200000
250000
300000
350000
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
0
1
3
0
4
6
29
5
21
1
7
2
2
0
0
0



Comparison of Annual Tritium Releases, Gas & Liquid - Pilgrim
Liquid Releases
Gas Releases
Tritium Activity Released (Curies)
500
450
400
350
300
250
200
150
100
50
0
Note: values in the blue call-outs show the activity of Tritium in the liquid release, in Curies
0
0.141
0.23
0
1.98
2.48
4.43
0.099
6.2
0.0039
3.56
0.0015
0.00082
0
0
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year


Comparison of Liquid and Gas Releases to Limits - Pilgrim
NRC annual whole-body dose limit as found in 10 CFR 20.1301
Typical whole-body dose from one transcontinential flight in the summer season (4 millirem)
Liquid Releases
Gas Releases
Note: values in the blue call-outs show the TOTAL whole-body dose for ALL radionuclides and ALL releases in that year
EPA annual whole-body dose limit as found in 40 CFR 190
Dose from ALL Radionuclides in millirem
120
100
80
60
40
20
0
3.00
0.90
0.57
0.10
0.05
0.12
0.08
0.03
0.03
0.05
0.02
0.02
0.02
0.05
0.01
0.00
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year

3. History of Environmental Monitoring

Radioactive Effluent and Environmental Reports

Each commercial nuclear power plant is required to submit two annual reports, which detail (1) the radioactive effluents discharged from the site, and (2) the effects (if any) on the environment. In addition to these two annual reports, in 2007 each power plant voluntarily submitted answers to a questionnaire related to the voluntary initiative on groundwater protection, initiated by the commercial nuclear power industry.

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Publicly available at: https://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html

Radiological Environmental Monitoring Program

- Required as part of the facility's licensing basis
- Results reported annually
- Described in Regulatory Guide 04-001
- Objectives
  - Evaluate the local environment to establish a baseline prior to operation
  - Determine if any measurable radiation or radioactive materials are attributable to plant operation
  - Determine if any measurable radiation or radioactive materials that are attributable to plant operation are commensurate with the reported effluents and meet design objectives

Samples and Monitoring

OPERATIONAL RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway, Sample, or Measurement Type	Sampling, Measurement, and/or Collection Locations(1)	Sampling, Measurement, and/or Collection Frequency	Type and Frequency of Analysis or Measurement
MARINE/AQUATIC			
Surface Water (7)	Discharge Canal, ------------------ Powder Point Control (6)	Continuous Composite Sample ------------------ Weekly grab sample	Gamma isotopic (4) analysis of monthly composite samples; AND H-3 analysis of quarterly composite samples
Sediment	Discharge Canal Outfall, Manomet Point, Plymouth Beach, Plymouth Harbor, Green Harbor Control (6)	Semiannual Collection	Gamma isotopic analysis (4)
Mussels	Discharge Canal Outfall, Plymouth Harbor, Green Harbor Control (6	Semiannual Collection	Gamma isotopic analysis (4) on edible portions
Soft-shelled clams	Plymouth Harbor, Duxbury Bay Control (6)	Semiannual Collection	Gamma isotopic analysis (4) on edible portions
Lobster	Discharge Canal Outfall ------------------ Offshore Control (6)	Four times per season, from May through October ------------------ Once per season	Gamma isotopic analysis (4) on edible portions
Fishes	Discharge Canal Outfall ------------------ Offshore Control (3)	Semiannual for Group I(8); annually in season for Groups II, III, and IV (8) ------------------ Annually for each group (8);	Gamma isotopic analysis (5) on edible portions

(8) Fish analyses will be performed on samples from each of the following groups:

I. Bottom Oriented	II. Near Bottom Distribution	III. Anadromous	IV. Coastal Migratory
Winter Flounder Yellowtail Flounder	Tautog Cunner Atlantic Cod Pollock Hakes	Alewife Rainbow Smelt Striped Bass	Bluefish Atlantic Herring Atlantic Menhaden Atlantic Mackerel

Sampling Results - Aquatic Edibles 2020

- Shellfish:
  - Blue mussels and soft-shelled clams
  - **Natural K-40** detected, as expected
  - No plant-related radionuclides, **results similar to pre-operational period**
- Lobster:
  - Collected from outfall June, July, August, September
  - Results same as shellfish
- Fish:
  - Some species harder to collect as warm discharge water has stopped
  - Results same a shellfish

Sample Results – Surface Water 2020

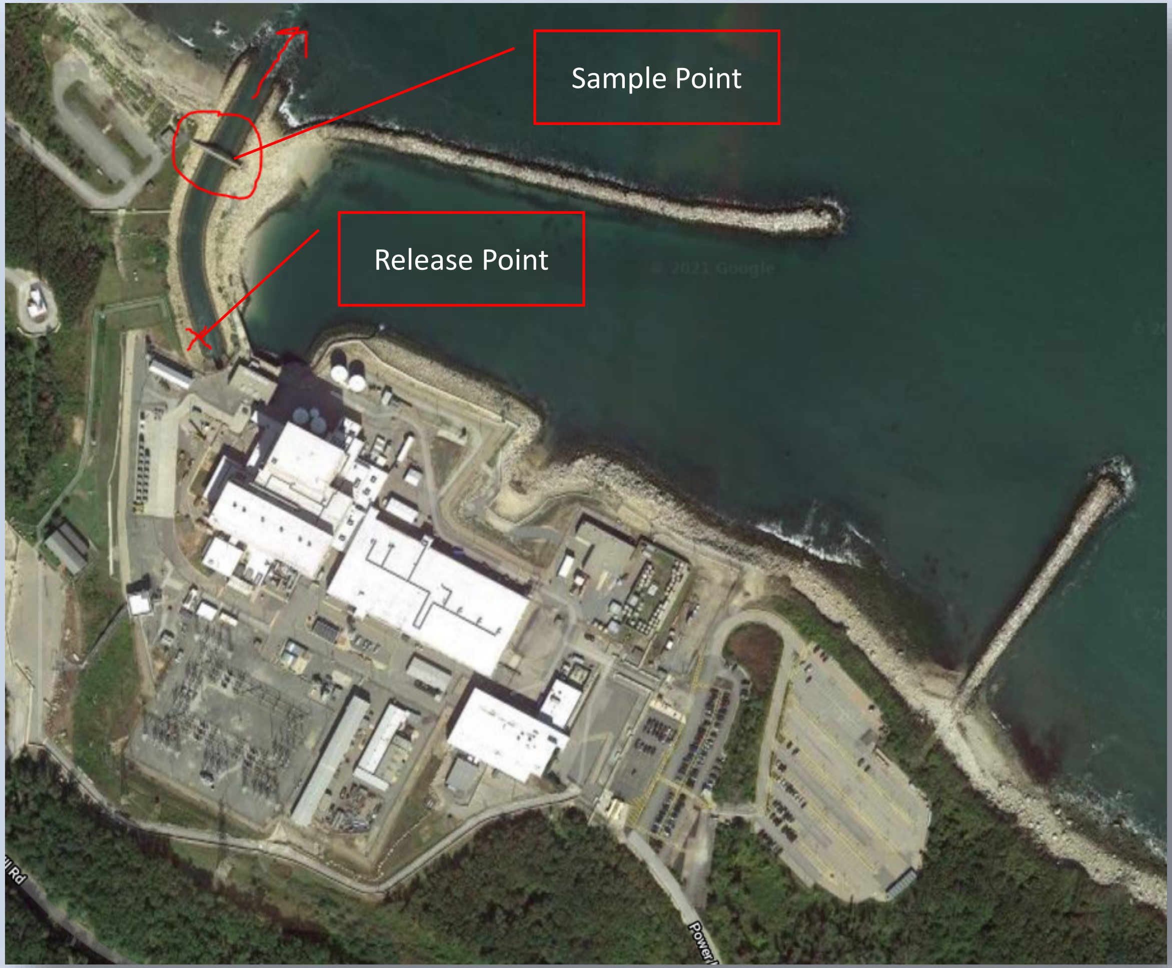


Table 2.8-1
Surface Water Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

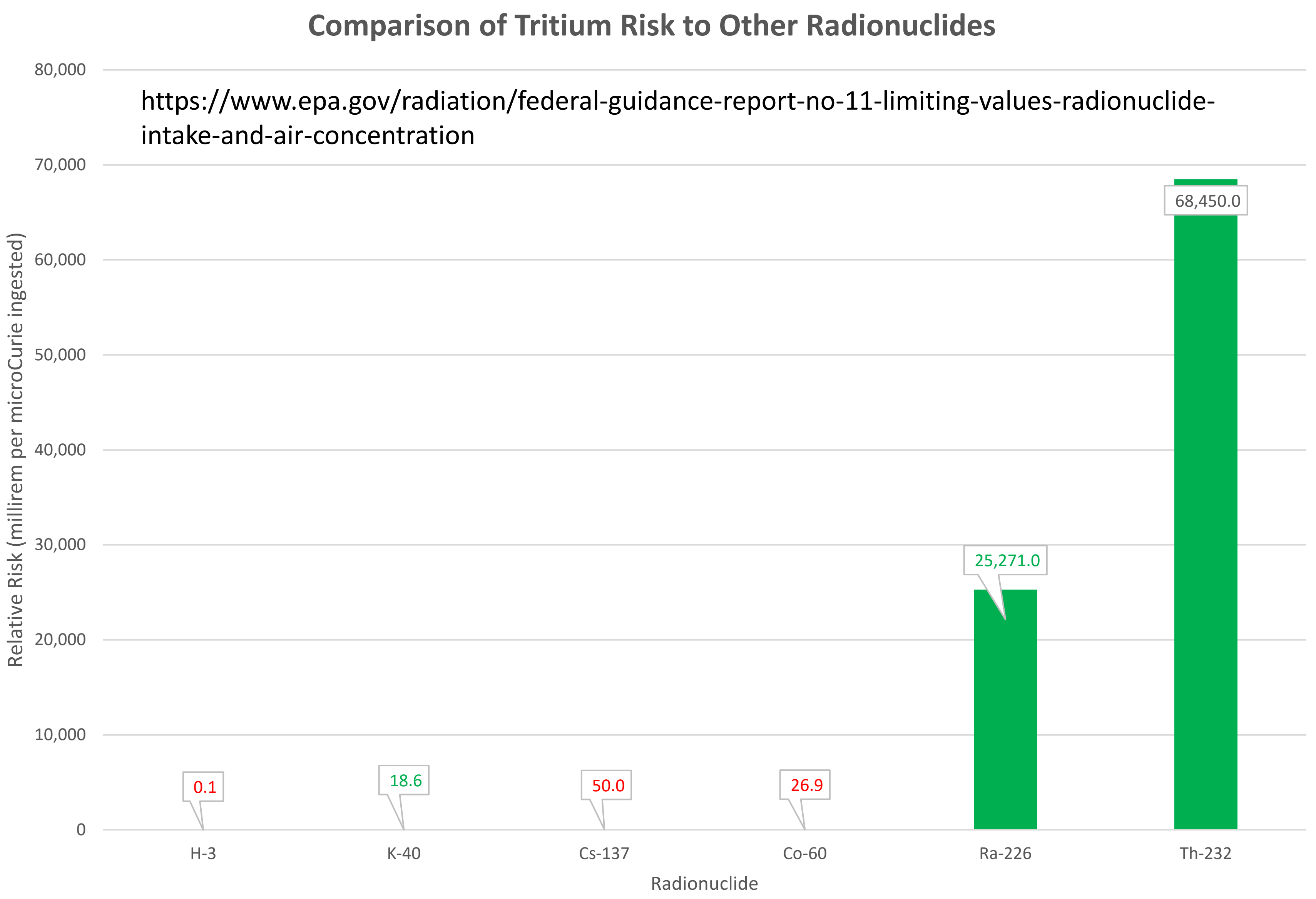
MEDIUM: Surface Water (WS) UNITS: pCi/L

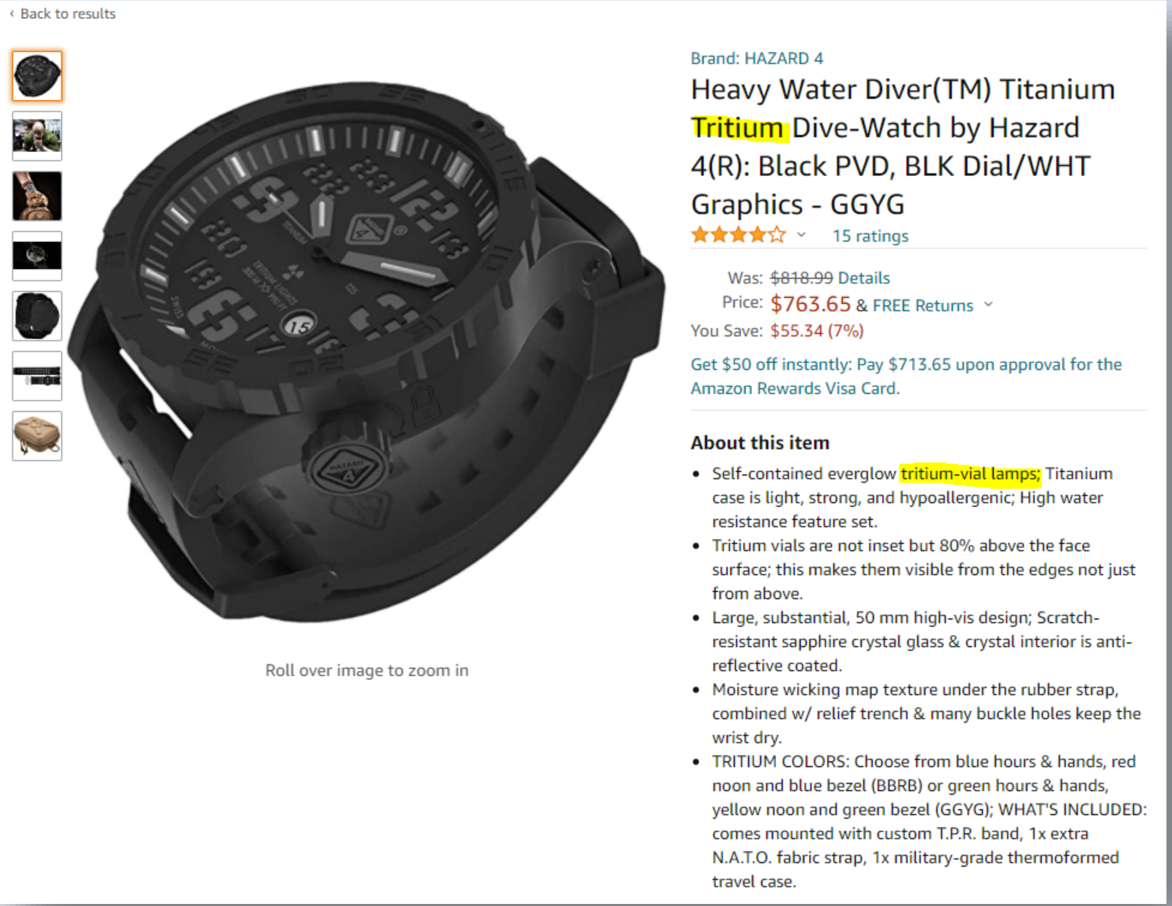
Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD
H-3	8 0	3000	4.9E+1 ± 1.3E+2 -7.5E+1 - 2.1E+2 0 / 8	PwtPt: 4.9E+1 ± 1.3E+2 -7.5E+1 - 2.1E+2 0 / 4
K-40	24 0		2.8E+2 ± 3.4E+1 2.1E+2 - 3.3E+2 12 / 12	PwdPt: 2.9E+2 ± 2.4E+1 2.4E+2 - 3.3E+2 12 / 12

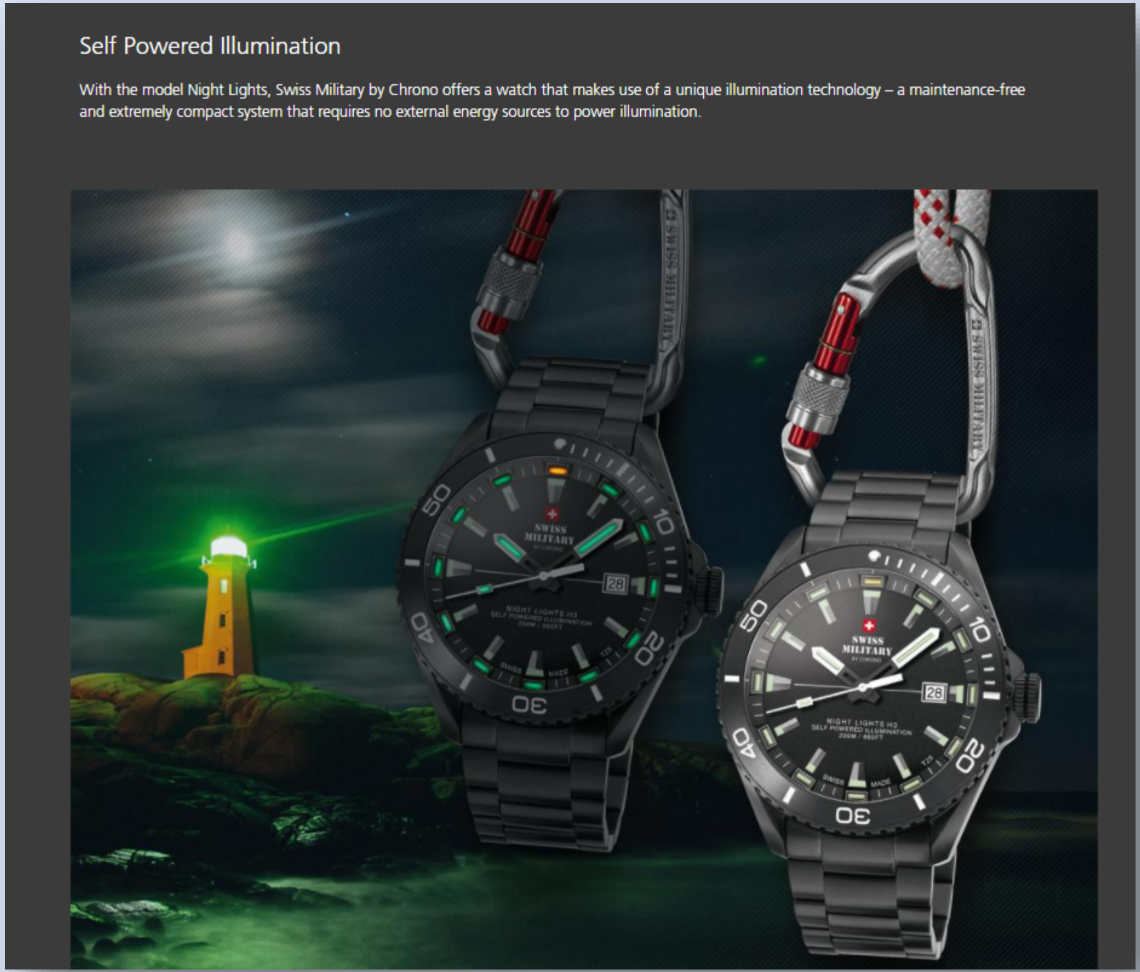
Note: No H-3 (tritium) was detected in 2011, the year with the largest number of liquid releases

4. Tritium in Perspective

- A radioactive isotope of Hydrogen (one proton, two neutrons)
- Produced naturally in the upper atmosphere when cosmic rays interact with Nitrogen atoms (along with C-14 and Be-7)
- Produced by reactors, “however releases are at fractions of the natural background production rate” [EPA fact sheet]
- Can be found at very low concentrations in lakes and streams (about 4 pCi/L)
- Radiation emitted as Beta particles of very low energy (cannot penetrate the skin surface)
- Rapidly incorporates with water molecules and cannot be removed
- Because water turns over rapidly in the body, **tritium in the body is rapidly cleared from tissues** [EPA fact sheet, *10-day biological half-life*]


Comparison of Tritium Risk to Other Radionuclides
https://www.epa.gov/radiation/federal-guidance-report-no-11-limiting-values-radionuclide-intake-and-air-concentration
Relative Risk (millirem per microCurie ingested)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0.1
18.6
50.0
26.9
25,271.0
68,450.0
H-3
K-40
Cs-137
Co-60
Ra-226
Th-232
Radionuclide





- Popular shopping site
- Tritium activity not even listed
- No warning or precautions

- Found online
- Each watch contains 27,000 microCuries of H-3

5. Radiopharmaceuticals in Comparison

Abundance Of Radionuclides In Water

Go to:

Minute traces of radioactivity are normally found in all drinking water. The concentration and composition of these radioactive constituents vary from place to place, depending principally on the radiochemical composition of the soil and rock strata through which the raw water may have passed.

Many natural and artificial radionuclides have been found in water, but most of the radioactivity is due to a relatively small number of nuclides and their decay products. Among these are the following emitters of radiation of low linear energy transfer (LET): potassium-40 (^{40}K), tritium (^{3}H), carbon- 14 (^{14}C), and rubidium-87 (^{87}Rb). In addition, high-LET, alpha-emitting radionuclides, such as radium-226 (^{226}Ra), the daughters of radium-228 (^{228}Ra), polonium-210 (^{210}Po), uranium (U), thorium (Th), radon-220 (^{220}Rn), and radon-222 (^{222}Rn), may also be present in varying amounts.

https://www.ncbi.nlm.nih.gov/books/NBK234160/

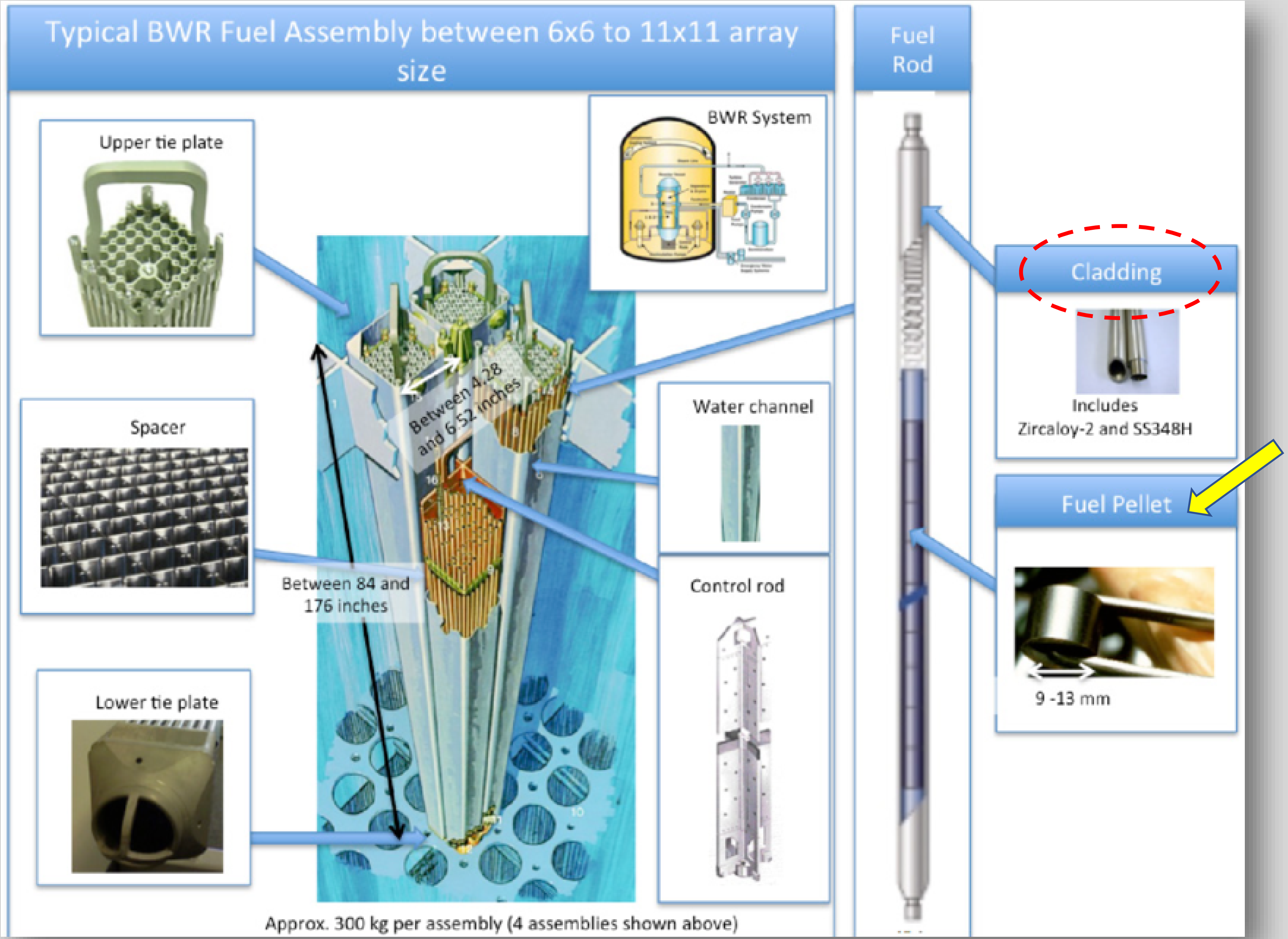
5. Radiopharmaceuticals in Comparison

It was estimated that between 10% and 30% of the total amount of technetium-99m given to patients in Cincinnati hospitals was discharged in sewage effluent into the Ohio River. Typically, about 300 mCi/week of this nuclide were estimated to reach the river, where dilution with river water was calculated to give concentrations downstream of about 1 pCi/liter. In fact, analysis of river water showed identical values upstream and downstream of 3-4 ± 3 pCi/liter. These are lower, by a factor of about a million, than the current maximum permissible concentration (6 μCi/liter; NRC, 1976) of technetium-99m in water for the general population. Comparable results were obtained for iodine-131. Smaller amounts were used, and the concentrations in sludge and water were lower than those of teclmetium. No differences between upstream and downstream levels were detected. Under the assumption that the same dilution had occurred, the medical uses of iodine-131 in the area were calculated to produce a maximal increase in concentration in the river of about 0.3 pCi/liter. This value is about one thousandth of the current maximum permissible concentration of iodine-131 in water (300 pCi/liter; NRC, 1976) for the general population.

https://www.ncbi.nlm.nih.gov/books/NBK234160/


Any
Questions

Supplementary Slides


Typical BWR Fuel Assembly between 6x6 to 11x11 array size
Upper tie plate
BWR System
Between 4.28 and 6.52 inches
Spacer
Water channel
Between 84 and 176 inches
Control rod
Lower tie plate
Approx. 300 kg per assembly (4 assemblies shown above)
Fuel Rod
Cladding
Includes Zircaloy-2 and SS348H
Fuel Pellet
9 -13 mm

Dose Calculations – Assumptions and Example

PNPS-ODCM
Rev. 13

10.0 RECEPTOR LOCATIONS, HYDROLOGY, AND METEOROLOGY

The purpose of this section is to identify those receptor locations which represent critical pathway locations and the methods used to estimate dilution and dispersion factors for these locations.

For the dose calculations from liquid effluents, the maximum individual is assumed to: 1) ingest fish and shellfish from the discharge canal, 2) receive direct radiation from shoreline deposits at both the discharge canal and PNPS shoreline recreational area, and 3) receive external radiation while swimming at White Horse Beach as well as while boating on the Cape Cod Bay. The doses are calculated for the various age groups (i.e., infant, child, teenager and adult), as well as for the various organs, (i.e., bone, liver, thyroid, kidney, lung, gastrointestinal tract/lower large intestine, skin, and total body). The maximum total body and organ doses are selected from the totals of the various age groups and organ doses calculated as described above.

For liquid effluent pathways, Table A-3 lists the conservative values for the mixing ratio and shore width factor for the various aquatic receptor locations.

9.2.1.1 Aquatic Food Ingestion (Fish, Shellfish)

$$DA_{ajp} = UA_{ap} \sum_i \left[CA_{ip} \; DFI_{aij} \right]$$

where:

$$CA_{ip} = CW_{il} \; B_{ip} \; e^{-\lambda_i t_h}$$

$$CW_{il} = \frac{1.00E12 \; Q_i \; M_l \; e^{-\lambda_i t_l}}{V}$$

Fish: 21 kg/yr
Shellfish: 9 kg/yr
Swimming: 52 hrs/yr
Boating: 52 hrs/yr

Groundwater – 2020 Annual Report

Concentrations of tritium detected in the onsite wells ranged from non-detectable at less than 257 pCi/L, up to a maximum concentration of 3,700 pCi/L. The average quarterly concentrations from these onsite wells are well below the voluntary communication reporting level of 20,000 pCi/L as established by the EPA Drinking Water Standard. Although the EPA Standard provides a baseline for comparison, no drinking water sources are affected by this tritium. All of the affected wells are onsite, and the general groundwater flow pathway is under Pilgrim Station and out into the salt water of Cape Cod Bay. As such, there is no potential to influence any off-site drinking water wells. Even if worst-case assumptions were made and the water from monitoring well with an average concentration of 3,246 pCi/L was consumed as drinking water for an entire year, the maximum dose consequence would be less than 0.25 mrem/yr. In actuality, any dose consequence would be much less than this, as any tritium-laden water potentially leaving the site would be diluted into the seawater of Cape Cod Bay before being incorporated into any ingestion pathways. No drinking water ingestion pathway exists at the Pilgrim Station site.

EPA Drinking Water Standard:

- *Assumes that all drinking water in a year contains tritium at this level*
- *Is assumed to equal 4 mrem/yr (not correct and a significant over-estimate)*

cross-section at the mouth. The mean depth at the mouth of the bay is 150 ft, and the width is 17.5 nautical mi, or 1.064×10^5 ft. The cross-sectional area of the mouth is therefore 1.6×10^7 ft^2. The volume rate of inflow of new water into the bay with the current is then 1.4×10^{11} ft^3/day. Since the volume of the bay is 1.6×10^{12} ft^3, the fractional rate of renewal by this process is about 8.8 percent per day.

Considering that, in addition to the combined effect of tidal flushing and renewal by the general circulation pattern, wind induced flows will also, in the long run, contribute to renewal of water in the bay, we can assume that the mean renewal rate is at least on the order of 10 percent per day and probably larger. A renewal rate of 10 percent per day would provide a mean residence time for water, or for any waterborne component, of 10 days.

This means that no more than 10 days of discharge from the station could accumulate in the bay before being effectively flushed out of this water body. During a 10 day period, the volume of water discharged from the plant at full load (historical condition using circulating water values) would be approximately 6.2×10^8 ft^3.

This volume, mixed into the volume of the bay (1.6×10^{12} ft^3) would be diluted by the ratio 1:2580. This dilution is sufficiently large, so that in computing the close-in pattern of concentration of excess heat (temperature) or of any other component of the condenser cooling water discharge, we can consider that the discharge is made into a water body of infinite size.

3. DESCRIPTION OF 10 CFR 20, NRC BASIC STANDARDS FOR RADIATION PROTECTION (1960)

Issuances:

22 FR 548, January 29, 1957; and 25 FR 10914, November 17, 1960.

Effective Date: November 17, 1960 (ongoing revisions).

Background:

National Committee on Radiation Protection and Measurement (NCRP) Handbook 52, "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water" (Revised June 1959, NBS Handbook 69); and FRC Staff Report No. 1, (May 13, 1960) and 25 FR 4402, May 18, 1960.

3.1 General Radiation Protection Provisions:

10 CFR 20 contains standards for the protection of licensees, their employees, and the general public against radiation hazards arising out of the possession or use of special nuclear, source, or byproduct material under a license issued by the NRC. These regulations prescribe limitations which govern: occupational exposure to radiation and concentrations of radioactive material; concentrations of radioactive material which may be discharged into air or water; and limits on levels of radiation to the general population.

3.2 Rationale for Detailed Requirements:

3.2.1 Limits were established at levels for which biological damage or health effects would not be observed. The standards provide what, at that time (1960 and following revisions), was considered to be "a very substantial margin of safety for exposed individuals."

3.2.2 Internal exposure limits were based on the critical organ concept developed by the International Commission on Radiological Protection (ICRP). Tables of "Maximum Permissible Concentrations" (MPC)