Background Tritium in Environmental Water Samples

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Tritium Basics

- Tritium (^{3}H) is a radioactive isotope of hydrogen
- Nucleus has one proton and two neutrons
- Half-life = 12.3 years
- Emits low energy beta particle (average energy of 5.69 keV)
- Transforms into stable helium
- Can be a gas, but most commonly is water (like other hydrogen atoms, tritium reacts with oxygen to form water)

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Tritium Sources

- Cosmogenic – naturally produced in the upper atmosphere as cosmic rays interact with atmospheric nitrogen and oxygen (spallation)
- Atmospheric nuclear weapons testing in the 1940s through 1970s
- Industrial effluents from laboratories, waste incinerators, manufacturing, etc.
- Byproduct in nuclear reactors producing electricity

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Cosmogenic Tritium

- Naturally produced tritium due to spallation is primordial – its always been here at a relatively constant level
- Accounts for 3 to 15 pCi/l “baseline” in precipitation
- Subject to tropopause influence (both seasonal and latitude)
  - Tropopause is the boundary layer between statosphere and troposphere (11-16 km altitude)
  - Seasonal opening centered at 43 to 48 degrees latitude

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Weapons Testing Tritium

- Prior to weapons testing, global equilibrium of tritium estimated at about 80 megaCuries
- Nuclear weapons testing increased baseline by a factor of about 200
- Atmospheric tritium levels peaked in early 1960s (about 3000 pCi/l in precipitation)
- Modern-day levels range from 100 to 300 pCi/l
- Also subject to tropopause influence

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Industrial Tritium

- Tritium effluents from laboratories and research facilities
  - Life science research
  - Metabolism investigations of new drugs
- Incinerators of biological or medical wastes containing tritium
- Manufacturing
  - Explosive detectors
  - Illuminated signs
- DOE triggering mechanisms in fusion weapons

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Tritium in Nuclear Power Plants

- Ternary fission is the primary production mechanism for tritium in light water reactors
- Only a very small fraction of this tritium diffuses out of the fuel and cladding into the reactor coolant
- Neutron activation of soluble boron and lithium in the coolant of PWRs or boron in the control rods of BWRs is the primary contributor to tritium inventories that become effluents for LWRs.

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Tritium Production via Boron

- Boron is 19.9% Boron-10 which has a high thermal neutron cross-section.
- Boron is used in PWRs for chemical shim and reactivity control and in control rods in PWRs and BWRs
- Principal reactions:
  - $^{10}B(n,2\alpha) \rightarrow {}^{3}H$
  - $^{10}B(n,\alpha) \rightarrow {}^{7}Li(n,n\alpha) \rightarrow {}^{3}H$

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Tritium Production via Lithium

- Lithium hydroxide is used for pH control in the primary coolant in some PWRs
- Principal reactions:
  - $^{7}Li(n,n\alpha) \rightarrow {}^{3}H$
  - $^{8}Li(n,\alpha) \rightarrow {}^{3}H$

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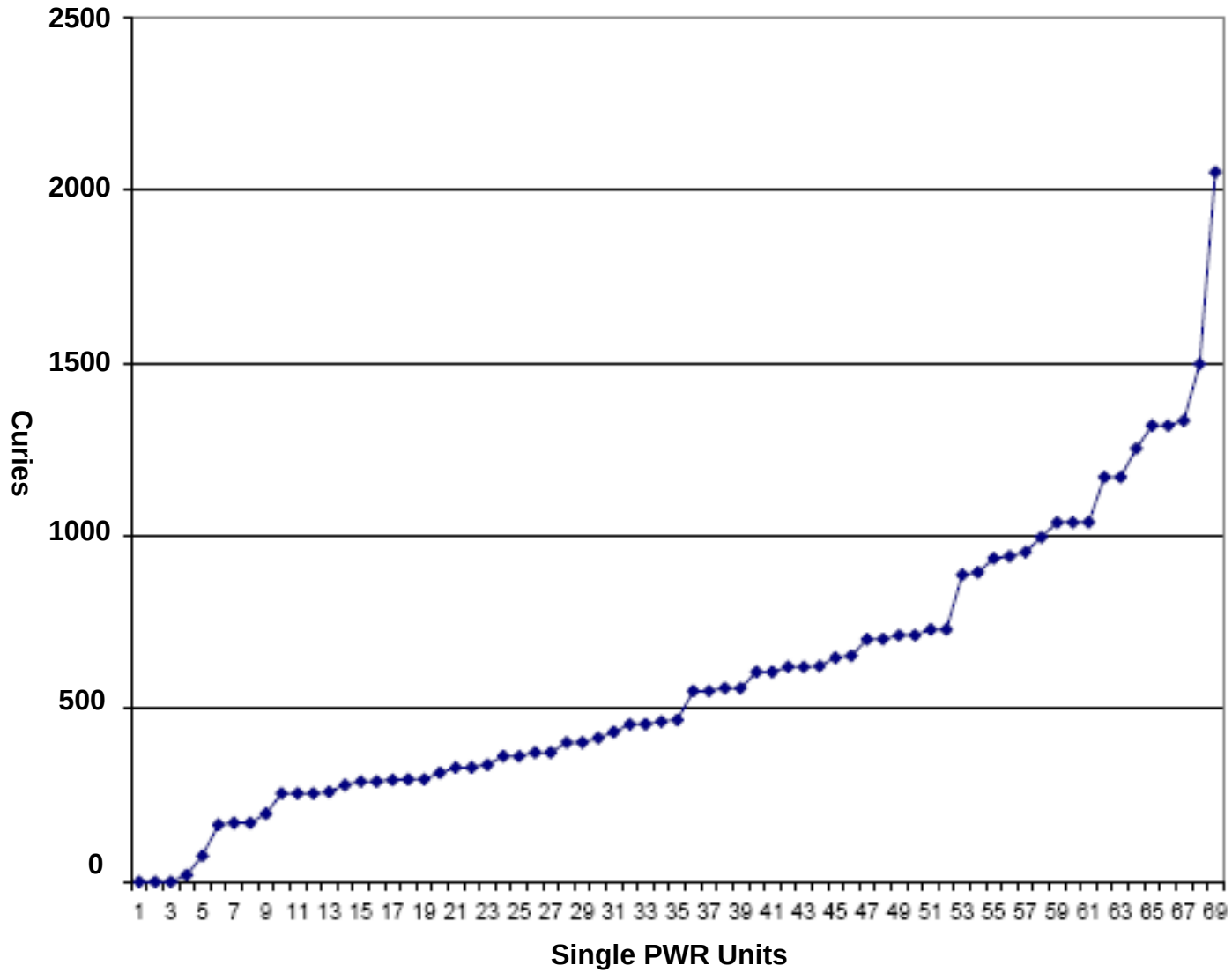
2003 US PWR Liquid Tritium Effluents



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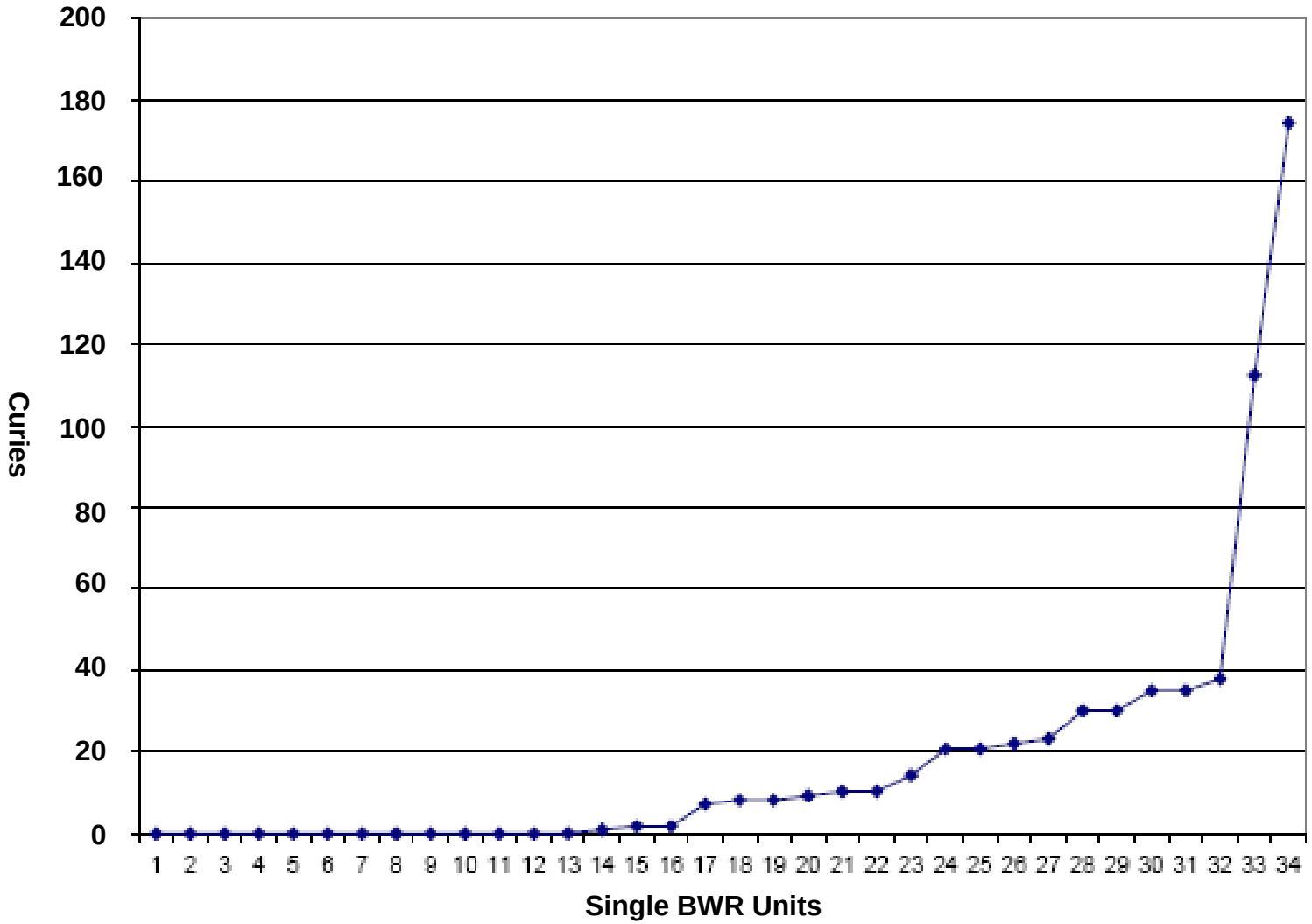
2003 US BWR Liquid Tritium Effluents



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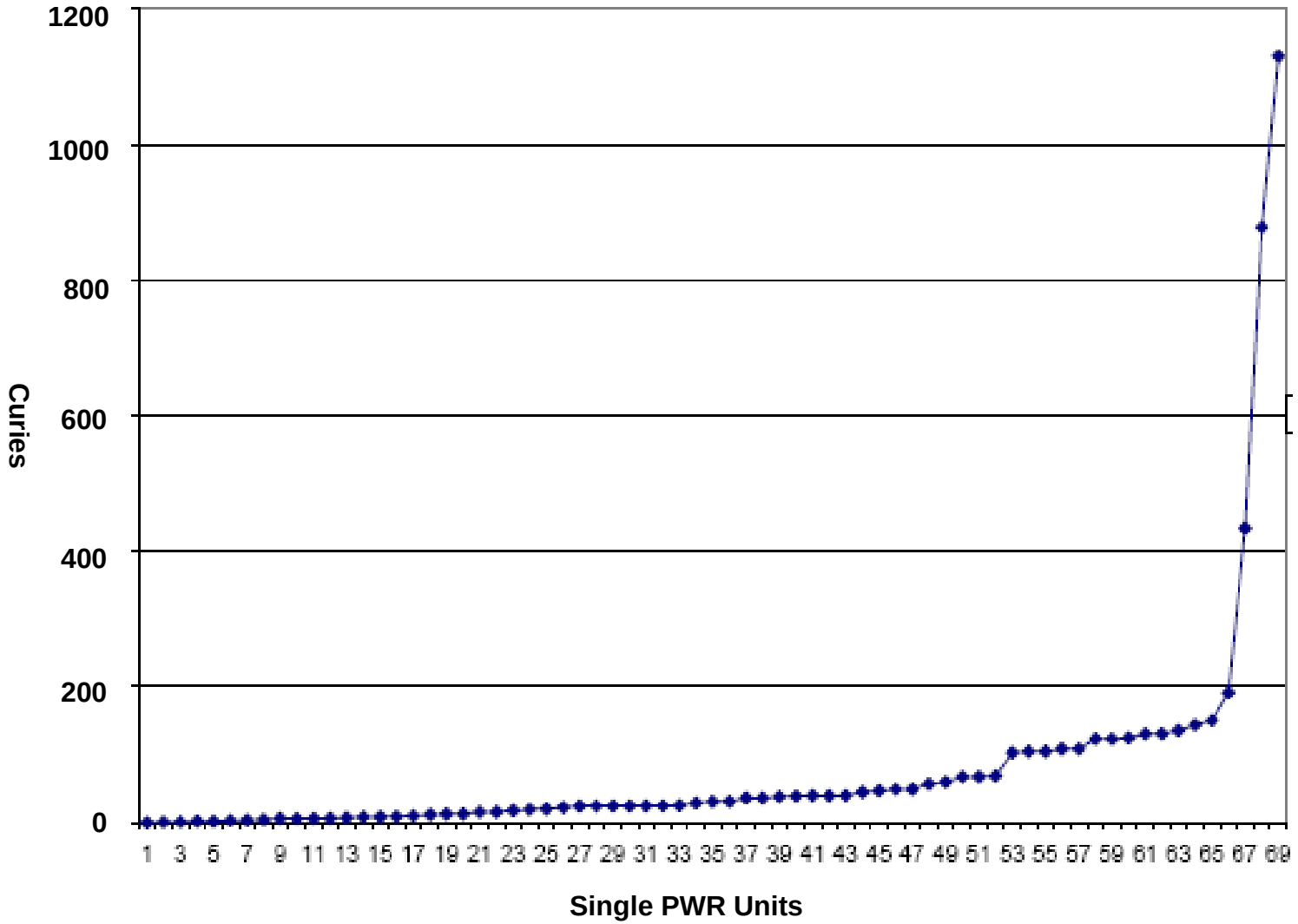
2003 US PWR Gaseous Tritium Effluents



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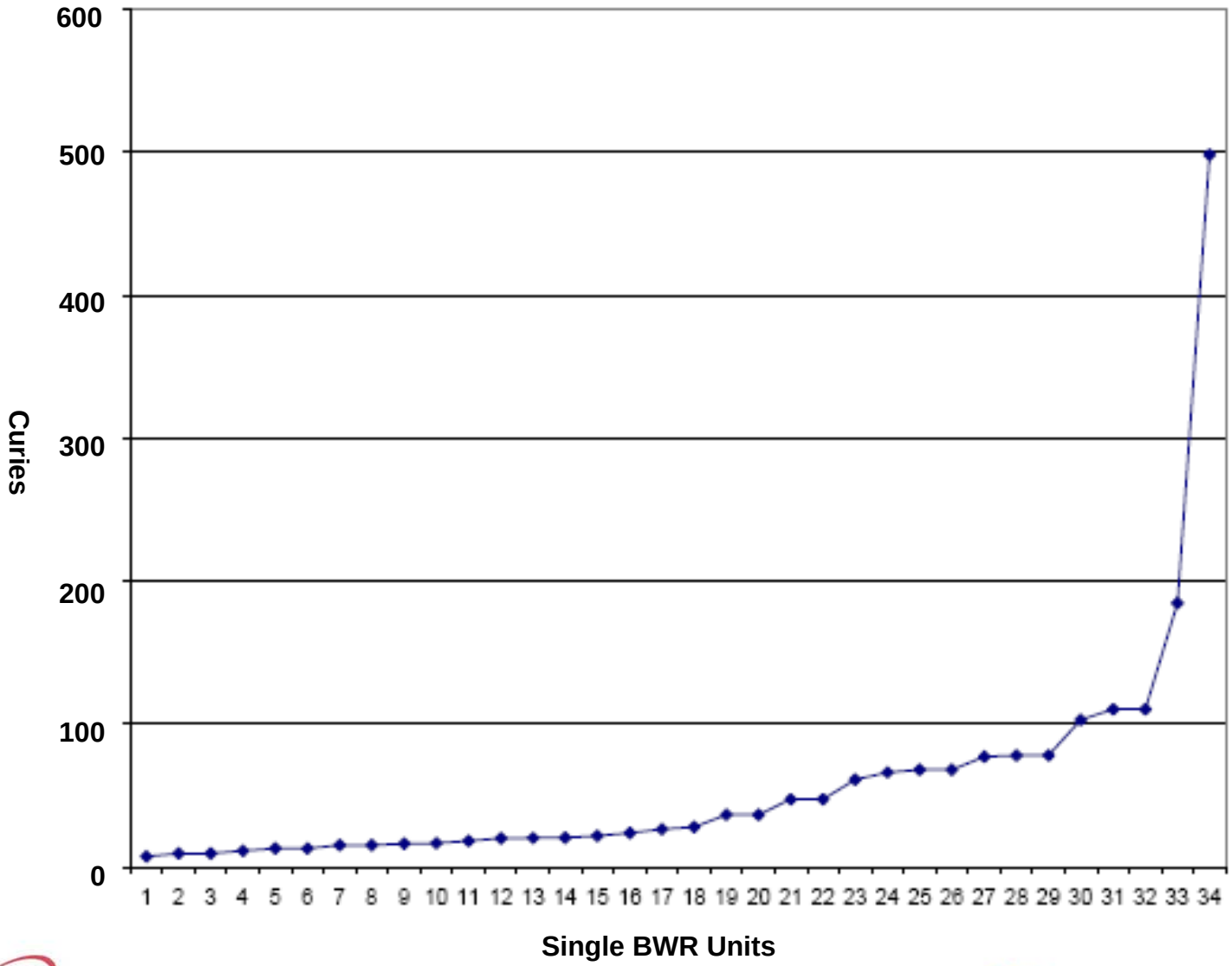
2003 US BWR Gaseous Tritium Effluents



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Precipitation Washout

- Most airborne tritium is released from nuclear plants as tritiated water vapor
- Precipitation falling during an airborne release will “washout” tritium to the ground
- This could result in tritium concentrations seen in surface water or groundwater that are the result of the airborne release
- This has been observed as a complication in evaluating detectable tritium in groundwater at some plants

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Current Limits for Liquid Tritium Effluents

- Tritium is one of the most benign radionuclides due to its weak beta emissions and rapid elimination from the body
- NRC Effl. Limit = 1E-3 uCi/ml [10 CFR 20]
- NRC Dose Limit (whole body) = 3 mrem/yr [10 CFR 50.36a]
- EPA Drinking Water Standard = 20,000 pCi/l [40 CFR 141.25, based on 4 mrem/yr SM]
- In 1991, EPA using updated methods calculated 60,900 pCi/l as producing 4 mrem/yr; however, kept the 1976 20,000 pCi/l limit in its regulations.

Public Trust and Groundwater Tritium

- During 2006, several nuclear facilities have reported unanticipated releases of tritium to groundwater
- For example, at Braidwood Station in Illinois, 1600 pCi/l was found in a residential drinking water well – The NRC estimated the dose impact from drinking this well water to be 0.3 mrem/yr (one thousand times less than the dose from natural background)
- Public concern over the groundwater tritium was great, in spite of the low potential for health risk – led to Nuclear Industry / NEI Initiative

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Public Trust and Groundwater Tritium

- NRC Task Force "lessons learned" report of October 4, 2006 noted that:

  "Although there have been a number of industry events where radioactive liquid was released to the environment in an unplanned and unmonitored fashion, based on the data available, the task force did not identify any instances where the health of the public was impacted."

- The NRC Task Force did have many recommendations to improve detection and responses to such releases – regulatory changes in this area are sure to come

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Background Environmental Tritium
EPA RadNet Program

- EPA has been collecting and analyzing water samples since 1978 via RadNet formally called Environmental Radiation Ambient Monitoring System (ERAMS)
- Radnet data is available by EPA Region or City/State
- Searchable at:
  http://oaspub.epa.gov/enviro/erams_query.simple_query
- Includes Air, Drinking Water, Precipitation, Surface Water and Milk
- Various radionuclides Sr-90, Cs-137, H-3

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Background Environmental Tritium EPA RadNet Program

- Environmental tritium concentrations vary by region
  - Central mid-west & western states have lowest levels
  - Eastern & Southern states have highest levels
- Positive outliers exist in all data sets and appear to be actual fluctuations in environmental concentrations
- Outliers remain well below EPA DW Std

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EPA RadNet Tritium Data for NC

- **Drinking Water**
  - Charlotte (1/79 to 1/06): 0 – 1106 pCi/l
  - Raleigh (10/99 to 1/06): 0 – 113 pCi/l
  - Wilmington (1/79 to 12/02): 0 – 500 pCi/l
- **Precipitation**
  - Charlotte (6/86 to 3/06): 0 – 500 pCi/l
  - Wilmington (6/86 to 3/06): 0 – 300 pCi/l
- **Surface Water**
  - Charlotte, Catawba R. (1/79 to 4/99): 110 – 1700 pCi/l
  - Southport, Atlantic O. (1/79 to 4/99): 0 – 1000 pCi/l

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Environmental Detection Limits for Tritium

- EPA and NRC have adopted 2,000 pCi/l as a Lower Limit of Detection (LLD)
- Many laboratories routinely count to an LLD of 300 to 500 pCi/l
- State of NC, Progress Energy, and Duke Energy count to LLDs of about 325 to 350 pCi/l
- Due to political pressures some are striving for LLDs less that 100 pCi/l

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Summary

- Tritium is produced by natural and man-made sources and is released to the environment
- Tritium released from nuclear power plants is primarily produced by neutron activation of Boron and is released in liquid and gaseous effluents
- Gaseous effluents can be washed out by precipitation and show up in surface and groundwater samples

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Summary (continued)

- Current public health standards and limits seem appropriate but do not satisfy public trust issues when unplanned releases occur
- Tritium exists at low background levels in water samples which are becoming more evident as detection limits are lowered
- Careful consideration should be given to the sources of tritium detected in groundwater – it may be from background or precipitation rather than an underground leak

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References

- EPRI Report # 1009903, Tritium Management Model, November 2005.
- Sejkora, Ken; Entergy; Atmospheric Sources of Tritium and Potential Implications to Surface and Groundwater Monitoring Efforts; EPRI/NEI Groundwater Workshop, Providence, RI, September 2006.
- Farr, Harvey; RSCS; Evaluation of Background Tritium Distributions and Statistical Outliers for Environmental Water Samples; EPRI/NEI Groundwater Workshop, Providence, RI, September 2006.
- USEPA Radiation Information website: www.epa.gov/radiation/radionuclides/tritium.htm
- 10 CFR 20, Table 2, Column 2
- 10 CFR 50.36a, Appendix I
- 40 CFR 141.25
- USNRC; Liquid Radioactive Release Lessons Learned Task Force Final Report; September 1, 2006

Questions?

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