Regulation of Nuclear Facilities and Protection of Drinking Water Supplies

Presented by Patsy Thompson, Ph.D.

Director General, Directorate of Environmental and Radiation Protection and Assessment

National Water Sector Ottawa Emergency Management Conference

November 23, 2011

Presentation Outline

- Overview of the Canadian Nuclear Safety Commission (CNSC)
- Radiation, radiation exposures to Canadians in our day to day activities and what health effects may be associated with exposure to radiation
- Regulatory requirements for spills and accidents and for emergency management
- Drinking water standards for radionuclides
- Potential impacts of nuclear facilities on drinking water supplies during normal operations and under spills and accidents
- Review of industry performance over the last 20+ years
- Summary and conclusions

Canadian Nuclear Safety Commission

Established May 2000, under the
Nuclear Safety and Control Act

Replaced the AECB of the 1946
Atomic Energy Control Act

Canada's Independent Nuclear Regulator - 65 Years of Experience

Our Mission is Clear

Mandate: To protect the health, safety and security of persons and the environment

Object of the Commission: To prevent unreasonable risk to the environment and to the health and safety of persons…

CNSC Regulates all Nuclear-related Facilities and Activities

- Uranium mines and mills
- Uranium fuel fabricators and processing
- Nuclear power plants
- Waste management facilities
- Nuclear substance processing
- Industrial and medical applications
- Nuclear research and education
- Export/import control

…From Cradle to Grave

Independent Commission

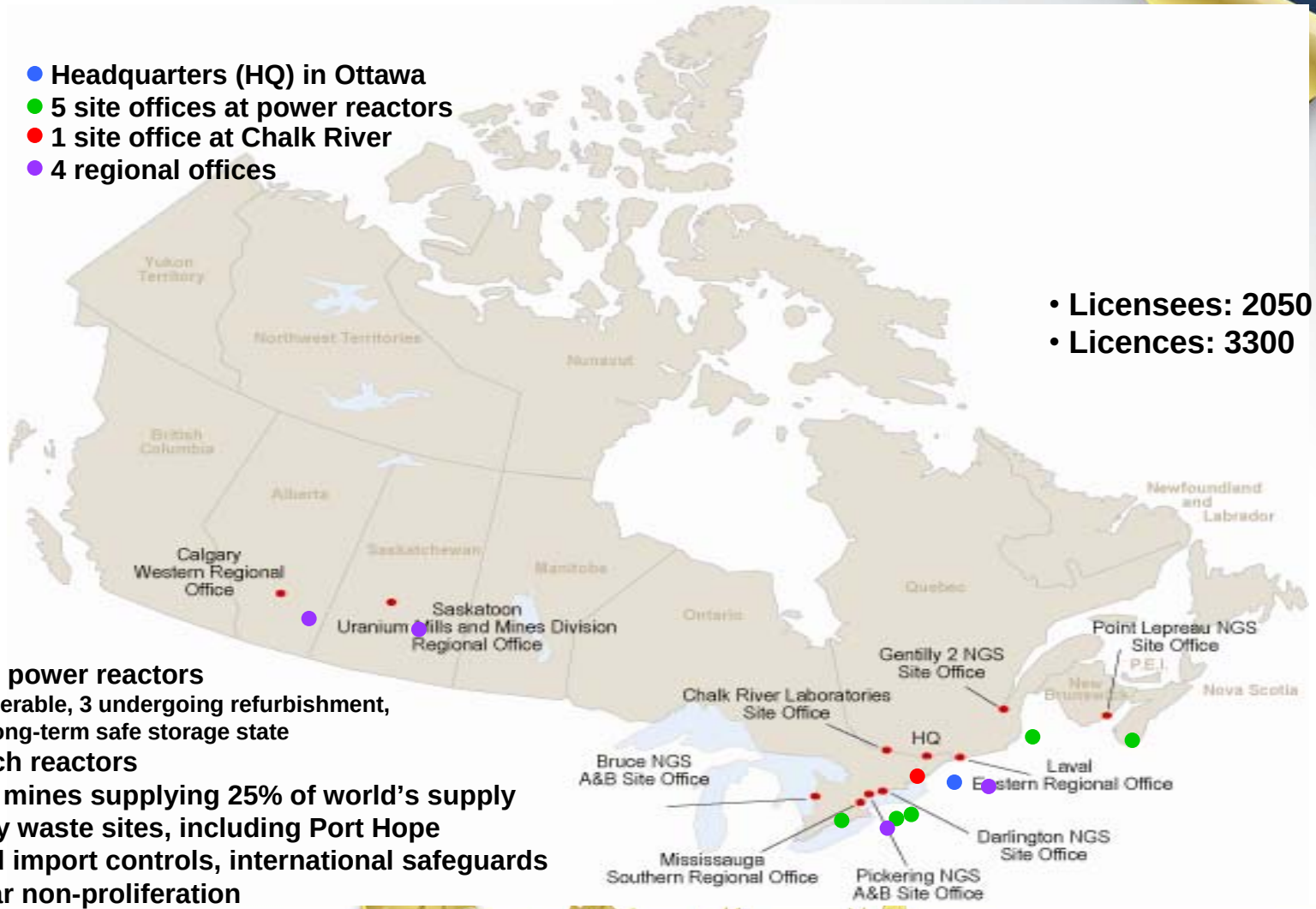
- Quasi-judicial administrative tribunal
- Commission members are independent
- Commission hearings are public and Webcast
- Supported by staff, a secretariat and independent legal services



Transparent Decision-Making

CNSC Offices and Major Licensed Sites

- Headquarters (HQ) in Ottawa
- 5 site offices at power reactors
- 1 site office at Chalk River
- 4 regional offices

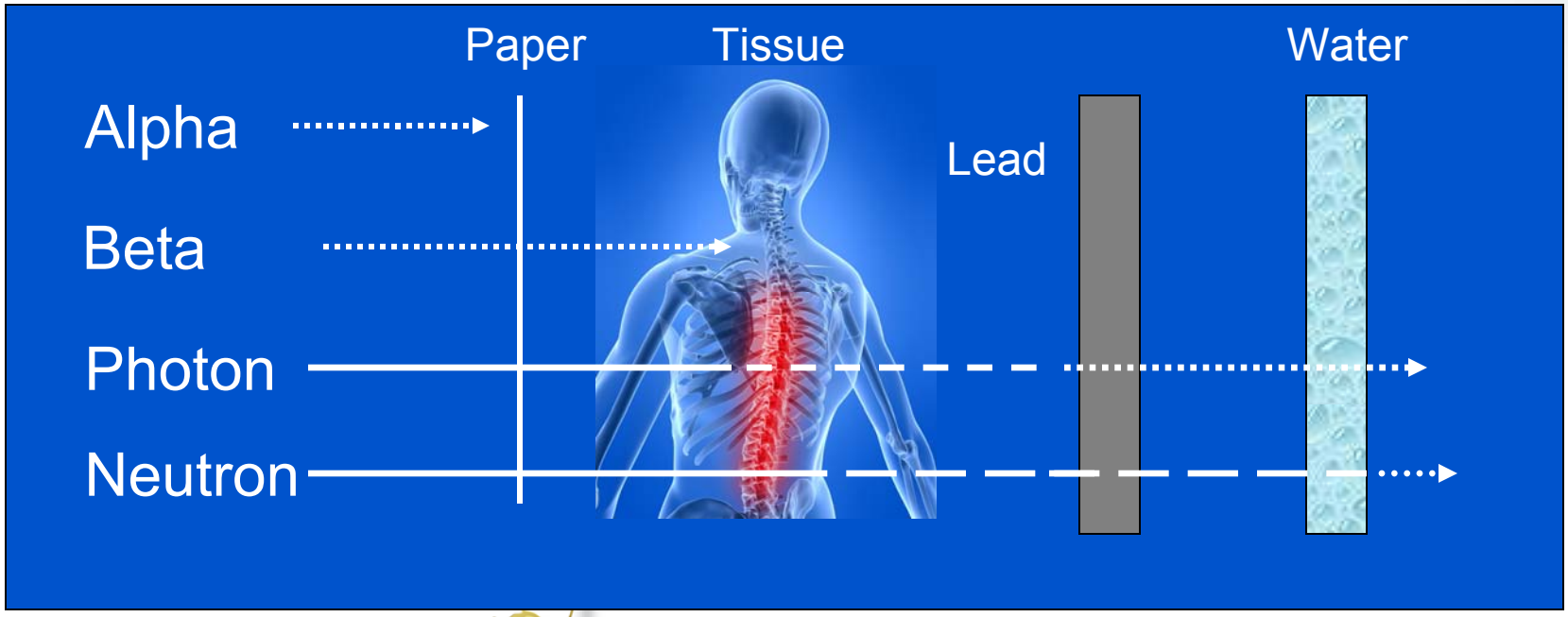


- Licensees: 2050
- Licences: 3300

- 22 Nuclear power reactors
  - 17 operable, 3 undergoing refurbishment, 2 in long-term safe storage state
- 10 Research reactors
- 6 Uranium mines supplying 25% of world's supply
- 25+ Legacy waste sites, including Port Hope
- Export and import controls, international safeguards and nuclear non-proliferation

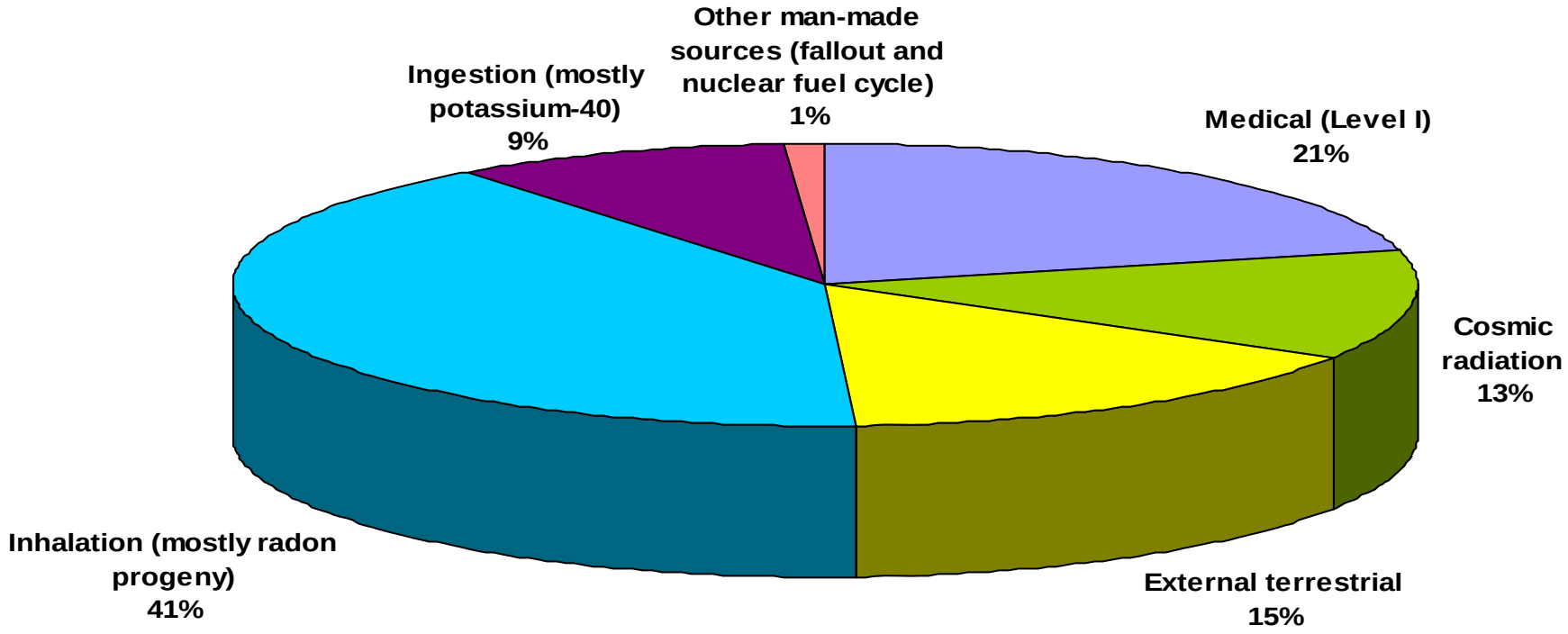
Types of Radiation

- All ionizing radiation interacts with matter
- The energy and type of radiation affects penetration depth

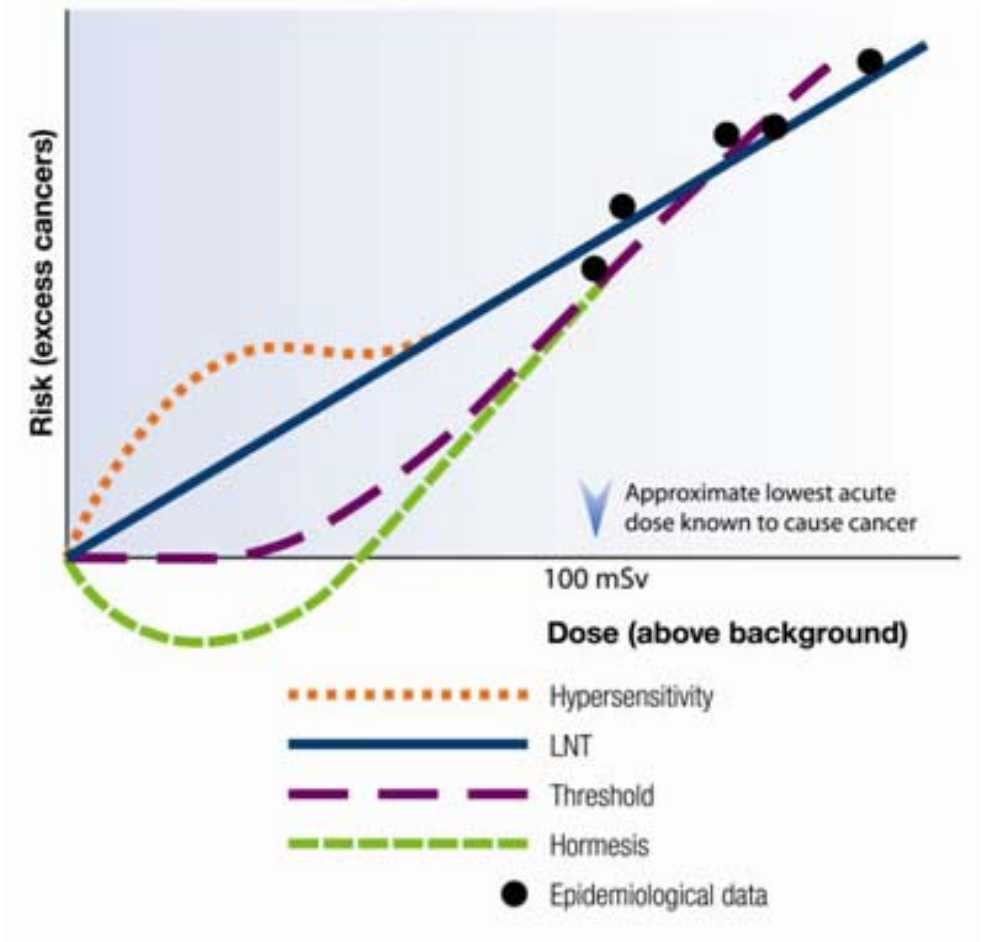


Typical Radiation Exposure in Developed Countries (i.e. Canada)

- Varies widely (1-10 mSv/yr) mainly due to radon progeny
- Total average dose is approximately 3.1 mSv/year



Radiation Protection (RP) Risk Models



- Cancer risk determined mainly from Atomic bomb survivor data
- Several models exist
- International approach to RP is to use the Linear non-threshold model (LNT)

Radiation Health Effects

- Stochastic
  - Risk: The probability of their occurrence increases proportionally to the radiation dose received
  - Dose: The lowest level of radiation shown to cause cancer after an acute exposure is ~100 mSv
  - Effect: Cancer or heritable diseases

- Deterministic (also called tissue reactions)
  - Risk: Certain to occur after an acute dose of radiation, below which there is no effect
  - Dose: In excess of a threshold value of at least 1000 mSv
  - Effect: Skin reddening, burns, and hair loss

Stochastic Effects - Cancer

- Moderate to high dose radiation exposures can lead to excess incidence of solid tumours and of leukaemia
- All cancer cases (not just radiation-related cancers) account for ~ 25% of deaths in Canada each year
- Any increase in cancer incidence thought to be caused by low-dose radiation exposures is modest by comparison
- ICRP recommends to use a risk of 5% cancer risk per 1,000 mSv at low doses and dose rates
  - For this reason, the use of dose limits and the ALARA principle are considered sufficiently protective of all Canadians and the environment

Stochastic Effects – Hereditary Effects

- Hereditary effects to person from radiation exposure have never been observed
  - Including ongoing studies on the children of the atomic bomb survivors
  - Difficult to detect hereditary effects due to radiation exposure in addition to normal incidence
  - Studies provide upper limit to risk of hereditary effects from radiation exposure of persons

Deterministic Effects – Tissue Reactions

- Damage to tissue occurs when the number of damaged cells reaches a certain number
- Occurs at high doses (a rare occurrence)

Examples of Effects and the Corresponding Dose Threshold	
Radiation sickness	1 Sv
Transient erythema (skin reddening)	2-5 Sv
Haematological effects (reduced blood count, infection)	3-5 Sv
Potential hair loss	2-5 Sv
Skin loss	10-15 Sv
Death	10-15 Sv

Regulatory Requirements

Accident and Emergency Response Requirements under the NSCA, Associated Regulations and CEAA

- General Nuclear Safety and Control Regulations:
  - 29.(1),b,c,d,f
- Class I Nuclear Facilities Regulations:
  - 6.(k) i, ii, iii, iv, v
  - 6.(l)
- Uranium Mines and Mills Regulations:
  - 3.(x),(A), (B), (C), (D), (E)
- Radiation Protection Regulations:
  - 15(1),(2), (3)
- CEAA:
  - 16.(1)

General Regulations (GNSCRegs) (Section 29)

(1) Requirement for immediate reporting of:

(b) An event with potential for an exceedance of radiation dose limits

(c) Unauthorized releases to the environment

(d) A situation or event that requires implementation of a contingency plan

(f) Info revealing the incipient failure, abnormal degradation or weakening of any component or system required to prevent serious environmental or human health effects

Class I Nuclear Facilities Regulations (Section 6) (UM&M S3 Regs are Similar)

Application for licence to operate shall contain measures to:

(*k*) Prevent or mitigate the effects of accidental releases, including measures to:

(i) assist off-site authorities in planning and preparing to limit the effects,

(ii) notify off-site authorities of a release or the imminence of one,

(iii) report info to off-site authorities during and after a release,

(iv) assist off-site authorities in dealing with the effects of a release,

(v) test implementation of measures to prevent or mitigate the effects;

(*l*) Prevent acts of sabotage or attempted sabotage

Radiation Protection Regulations: Emergencies (Section 15)

(1) During an emergency and consequent immediate and urgent remedial work,
   - effective dose shall not exceed 500 mSv
   - equivalent dose to skin shall not exceed 5 000 mSv

(2) Above lifting of dose limits not acceptable for worker classification of pregnant nuclear energy worker (NEW)

(3) Dose limits (operational/emergency) may be exceeded by a person who acts voluntarily to save or protect human life

Canadian Environmental Assessment Act (CEAA) (Section 16)

(1) Every Screening Comp Study or Panel shall include:
   - the environmental effects of malfunctions or accidents

Emergency Preparedness

- Emergency Plans are required for all major facilities
- Class I Facilities:
  - Power Reactors, Uranium Processing and Radioisotope Manufacturing Facilities
  - Uranium Mines and Mills

Licensee Emergency Program Requirements

- Assist off-site authorities in planning and preparing to limit the effects of an accidental release
- Notify off-site authorities of an accidental release or the imminence of such
- Report information to off-site authorities during and after an accidental release

Program Requirements (continued)

- Assist off-site authorities in dealing with the effects of an accidental release
- Test the implementation of the measures to prevent or mitigate the effects of an accidental release
- Plan complexity is determined through the design basis for emergency planning as set out in the Safety Analysis

Duty Officer Program

CNSC maintains a 24/7 response line to assist:

- Licensees
- Emergency Response Groups
  - Police, Fire, Hazmat
- First line for radiation emergency notification in Canada

Emergency Preparedness in Canada

- The CNSC is responsible for all on-site licensee emergency preparedness activities
- The provinces are responsible for off-site planning and response
- CNSC ensures that licensee co-operates and assists the province in planning and responding

Federal Nuclear Emergency Plan (FNEP)

- Plan to co-ordinate federal resources to control a nuclear event in Canada
- Partners include CNSC, HC, DND, Public Safety
- Can be activated to assist in a provincial emergency
- Activated for events with international (trans-border) impacts

Drinking Water Quality Guideline: Radionuclides Maximum Acceptable Concentration (MAC)

Sum of ratios of observed concentration to MAC for each contributing radionuclide should not exceed 1

Natural Radionuclides	MAC	Artificial Radionuclides	MAC
Total Uranium	20 µg/L	Tritium	7 000 Bq/L
Lead-210	0.2 Bq/L	Strontium-90	5 Bq/L
Radium-226	0.5 Bq/L	Iodine-131	6 Bq/L
		Cesium-137	10 Bq/L

Natural Radionuclides

(Ra-226 MAC: 0.5 Bq/L U MAC: 20 µg/L)

Active Uranium Mines

- Remote hence, no drinking water plants or wells

Elliot Lake: uranium mining and milling

- Ra-226: 0.007 – 0.019 Bq/L U: 0.4 – 2 µg/L

Port Hope: uranium conversion facility (fuel)

- Ra-226: ND U: 0.4 – 1 µg/L

Regina: well water natural host rock

- Ra-226: ND U: 1.3 – 7.7 µg/L

Artificial Radionuclides Reactor Emissions

(Tritium MAC: 7 000 Bq/L)

Average in Canadian Waters: < 5 – 12 Bq/L

Great Lakes Reactors

- **Open Water:** ~ 3.5 Bq/L (INFO-0792)
  - 1.8 Bq/L is due to power station sources (true background + fallout is estimated at 1.7 Bq/L)
- **Operators design to not exceed 100 Bq/L at drinking water plants**

Monitoring of WSPs Near Multi-station NPP
(Annual Average Values)

Water Supply Plant	Tritium Activity Level (BqL)	Gross Beta (Bq/L)
Guideline/Screening Value	7 000	< 1
Provincial Background	< 4.5	0.03 – 0.12
Darlington Area		
Bowmanville	4.8	0.11
Newcastle	4.6	0.1
Oshawa	5.8	0.12
Pickering Area		
Toronto (Harris)	4.3	0.12
Scarborough (Horgan)	4.2	0.11
Ajax	5.5	0.11
Whitby	5.4	0.11
Bruce Area		
Kincardine	7.9	0.07
Southhampton	10.1	0.08

Accidental Releases

(Tritium MAC: 7 000 Bq/L)

Chalk River Nuclear Laboratory 1991

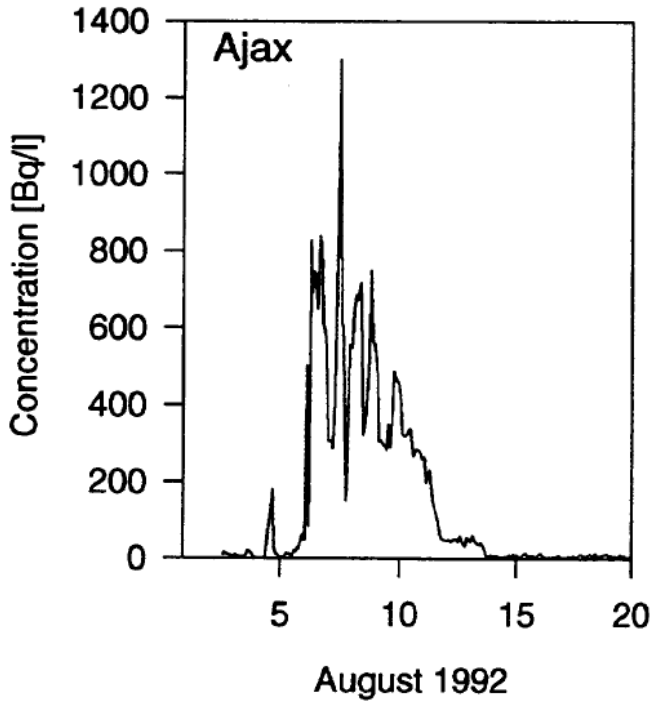
- **Tritium Spill in Plant with Atmospheric Venting**
  - Highest tritium measurement at drinking water plant
  - 440 Bq/L at Petawawa
  - 150 Bq/L at City of Ottawa
- **Pickering Nuclear Generating Station 1992**
  - Highest Lake Ontario concentration 57,000 Bq/L shortly after release, 10 x lower soon afterwards
  - 1,300 Bq/L: maximum at drinking water plant at Ajax a few days after release (5 km to the east)

Tritium in Ajax Drinking Water after 1992 Spill at Pickering NGS

Spill occurred on August 2

2,900 kg of tritiated water

2.3 E+15 Bq of tritium



Modelling Malfunctions and Accidents: New Build

Darlington New Nuclear Power Plant:

- Considered nuclear accidents, conventional accidents and malevolent acts
- Bounding approach used by Ontario Power Generation
- Based on CNSC Regulatory Document 337 – Design of New Nuclear Power Plants
- Beyond design basis accident that could have off-site radiological consequences
  - Safety-goal Based Release
  - Confirmed sufficient time available for emergency off-site response to be effective

Summary and Conclusions

- The health effects of ionizing radiation are well understood
- Nuclear facilities are regulated to keep releases to levels at which no health effects would be observed
- Regulation includes requirements to prevent or minimize the risk of accidents and malfunctions with radiological consequences
- Regulation includes requirements for emergency response plans and testing of these plans

nuclearsafety.gc.ca