Dynamics of Organically Bound Tritium (OBT) Accumulation in Rainbow Trout (*Oncorhynchus mykiss*): HTO Exposure Experiment

September 6-9, 2010

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Background in Canada

- Canada has 20 CANDU reactors
  - 17 are operating
  - 3 are being refurbished
- Tritium is a Canadian priority
- Tritium in Drinking Water Regulation is 7,000 Bq/L
- Released forms (HT, HTO) and measured forms (HTO, OBT) are different
- Two different dose conversion factors (DCF) and retention times

Tritium Releases in Canada (2006)

Facility	Gas Releases HTO (Bq/yr)	Gas Releases HT (Bq/yr)	Liquid Releases HTO (Bq/yr)
Nuclear power plants	2.0×10^{15}	9.5×10^{13}	1.6×10^{15}
Waste management	5.5×10^{13}	0	4.4×10^{10}
Facilities using tritium	8.5×10^{13}	3.1×10^{14}	4.5×10^{10}
Research facilities	3.2×10^{14}	9.6×10^{11}	9.5×10^{13}
Chemical laboratories	7.8×10^{11}	1.7×10^{11}	6.6×10^{10}

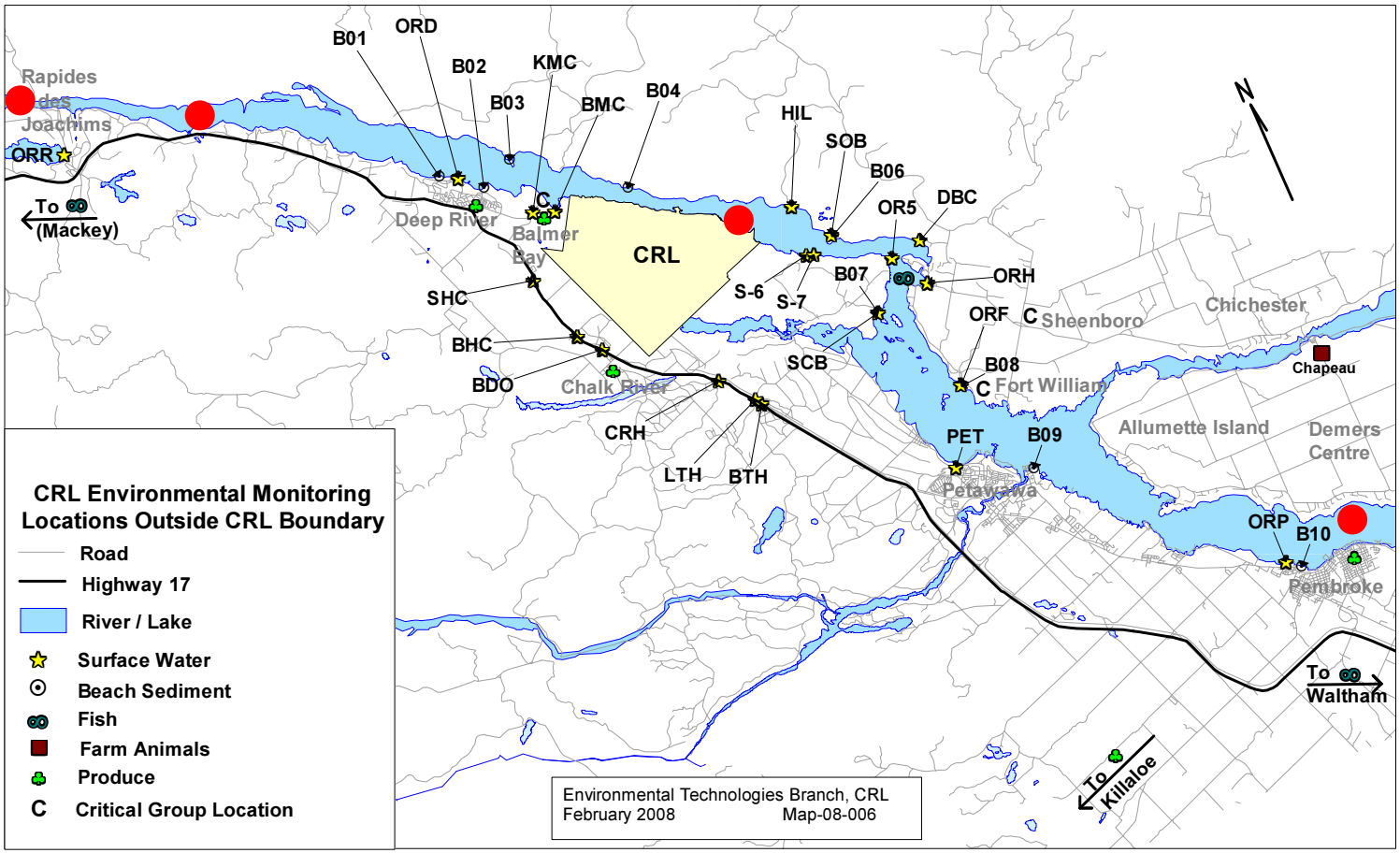
Source from CNSC

Tritium Releases at CRL (2009)

Emission Type	DRL*	Average release
Air Emission (Bq/week)		
HTO	1.8×10^{15}	1.8×10^{13}
HT	6.6×10^{16}	2.6×10^{10}
Liquid Emission (Bq/week)		
HTO to Ottawa River	2.9×10^{16}	8.9×10^{12}
HTO to Maskinonge Lake	5.5×10^{15}	5.0×10^{11}
Groundwater Monitoring	2.9×10^{16}	4.0×10^{11}

* = Derived release limit

Sampling Locations – Fish Study



Map A-1b: CRL Liquid and Biological Environmental Monitoring Locations - Outside CRL Boundary

Point Aux Baptême

Working on the Ottawa River

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Total Fish Sampled

Mackey	35
Rolphton	26
Sand Spit	36
Cotnam	26
TOTAL # of fish:	123

Concentrations of Tritium in Aquatic Biota in Canada (1)

Location	Sample (n)	Type	HTO (Bq/L)	OBT (Bq/L)	OBT/ HTO
Discharge A	Salmonid (3)	Pelagic	10.3 – 10.8	2.7 – 5.7	0.26 – 0.50
	Sucker (3)	Benthic	19.1 – 19.7	9.0 – 19.4	0.46 – 1.02
Discharge B	Salmonid (4)	Pelagic	13.9 – 60.2	2.0 – 8.4	0.10 – 0.52
	Sucker (3)	Benthic	14.3 – 21.3	8.6 – 14.3	0.47 – 1.00
	Algae (2)	-	11.4 – 13.1	32.1 – 38.5	2.45 – 3.38
Creek	Salmonid (3)	Pelagic	14.7 – 19.8	6.3 – 16.3	0.37 – 0.99
	Sucker (3)	Benthic	13.9 – 23.4	8.2 – 12.8	0.35 – 0.91

Concentrations of Tritium in Aquatic Biota in Canada (2)

Location	Sample (n)	Type	HTO (Bq/L)	OBT (Bq/L)	OBT/ HTO
Effluent	Bass (2)	Pelagic	20.9 – 22.6	114.5 – 153.9	5.48 – 6.81
	Catfish (4)	Benthic	73.1 – 85.0	39.1 – 759.1	0.46 – 9.42
	Carp (4)	Benthic	54.1 – 56.4	18.9 – 51.2	0.34 – 0.95
Bay	Clam (2)	Benthic	6.3 – 8.9	68.2 – 169.4	7.66 – 26.8
	Mussel (1)	Benthic	9.1	310.4	34.1
Intake	Carp (4)	Benthic	7.1 – 14.6	9.5 – 32.6	1.04 – 2.39
	Catfish (2)	Benthic	11.6 – 12.9	40.1 – 42.5	3.29 – 3.46

Concentrations of Tritium in Aquatic Biota in Cardiff

Group	Species	HTO (Bq/kg-wet)	OBT (Bq/kg-wet)	OBT/ HTO
Crustacea	Shore crab	2500	56900	22.76
	Shrimp	250	39250	157
Mollusca	Mussel	3600	15700	4.36
	Whelk	8700	65200	7.49
	Winkle	0	4000	-
Marine fish	Grey mullet	30	420	14
	Sole (fillet)	500	4700	9.4
	Sole (whole)	19000	50500	2.66

Food Standards Agency (2003)

New Drinking Water Standard

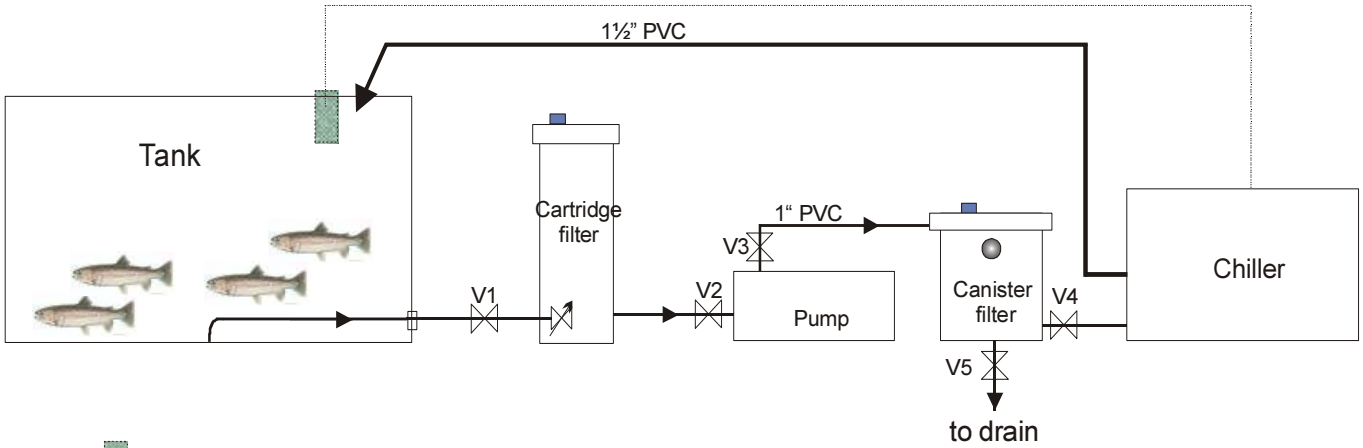
- Canadian Nuclear Safety Commission (CNSC) proposed the 100 Bq/L design objective for protection of potable groundwater resources in Canada

- Average OBT/HTO ratios were on the order of 2-3 for plant products and 10 for animal product near nuclear facilities

Tritium Experiments

- Mussel (*Elliptio complanata*) experiment: 2006 – 2007
  - Field experiment
- Minnow (*Pimephales promelas*) experiment: 2008
  - Laboratory experiment
- Rainbow trout (*Oncorhynchus mykiss*) experiment: 2009 ~
  - Biological Research Facility (BRF) and Canadian Animal Care Committee (CACC)
  - HTO exposure alone
  - OBT exposure alone
  - HTO and OBT exposure

Biological Research Facility (1)



temperature display/controller (at back of tanks)

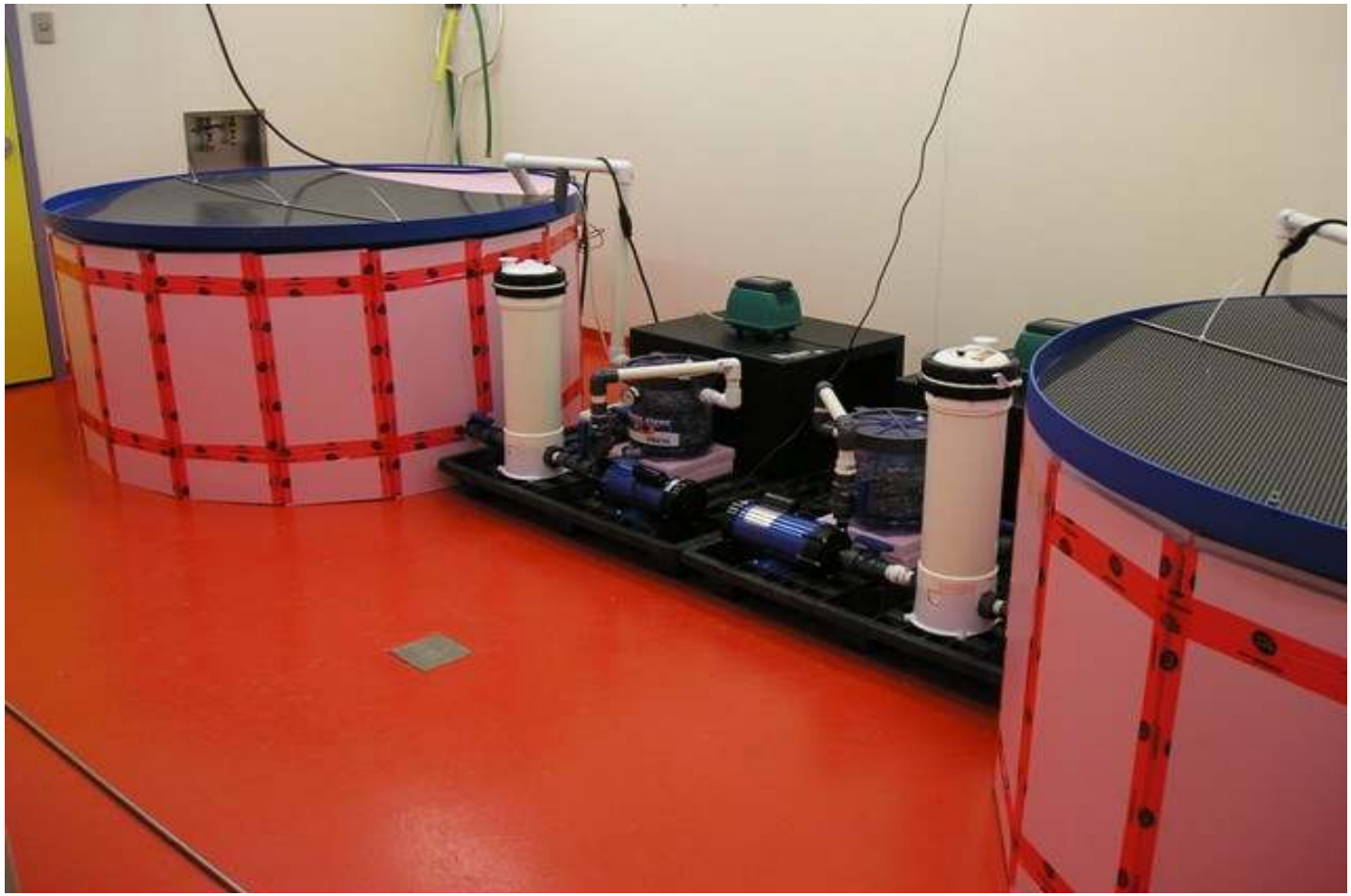
vent plug

pressure gauge

cartridge filter holds pleated polyester cartridge

cannister filter holds polyester cloth over 7 L Siporax

Biological Research Facility (2)



Biological Research Facility (3)

Biological Research Facility (4)

Rainbow Trout

Water Chemistry Parameters

Parameter	Acceptable Range	Measurement	Frequency
Dissolved oxygen	5 – 10 ppm	Polarographic probe	Daily
Temperature	12 -14 ºC	Thermocouple	Daily
NO_2	0 – 2 ppm	Colorimetric kit	Weekly
pH	7.0 – 8.4	pH meter	Weekly
Conductivity	200 – 1000 µS/cm	Conductivity meter	Weekly
Alkalinity	30 – 150 ppm	Colorimetric kit	Weekly
NH_3/NH_4	0 – 1 ppm	Colorimetric kit	Monthly
NO_3	0 – 100 ppm	Colorimetric kit	Monthly

Initial Weight Ranges (g) of Fish

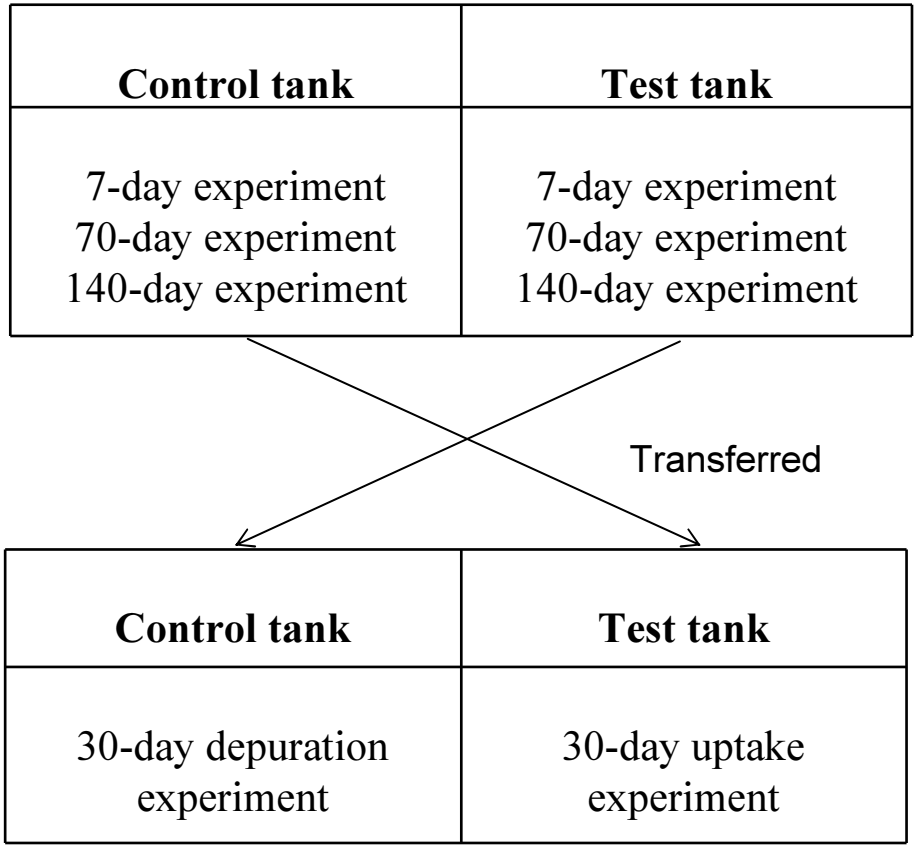
Exposure	Control tank	Test tank
7 days	N=26 (45.1 – 215.0)	N=26 (60.7 – 200.7)
30 days	N=6 (250.2 – 432.0)	N=5 (374.0 – 587.0)
70 & 140 days	N=22 (31.9 – 285.7)	N=23 (33.3 – 171.6)

Total fish weights were distributed evenly in both tanks.

Total Feed Amounts (2009)

	Exposure Time			
Date	7 days	70 days	140 days	30 days
April 7 – April 13	290 g	-	-	-
April 23 – June 29	-	1735 g	1735 g	-
April 23 – September 9	-	-	2225 g	-
September 10 – October 9	-	-	-	232 g
Total	290 g	1735 g	3960 g	232 g

Experimental Scheme For the Rainbow Trout



Tritium Concentrations in Tanks

Month (n*)	Test tank (Bq/L)	Control tank (Bq/L)	Comments
April (3)	7870 - 8543	58 - 110	Changed water (212 L) and added HTO
May (4)	7937 - 8213	107 - 237	Changed water (200 L) and added HTO
June (4)	8036 - 8286	330 - 535	Changed water (80 L)
July (2)	7871 - 7965	583 - 592	-
August (3)	6957 - 8012	449 - 481	Changed water (200 L) and added HTO
September (2)	7766 - 9381	461 - 477	Changed water (500 L) and added HTO
October (1)	9174	329	

n = the number of times tritium measured

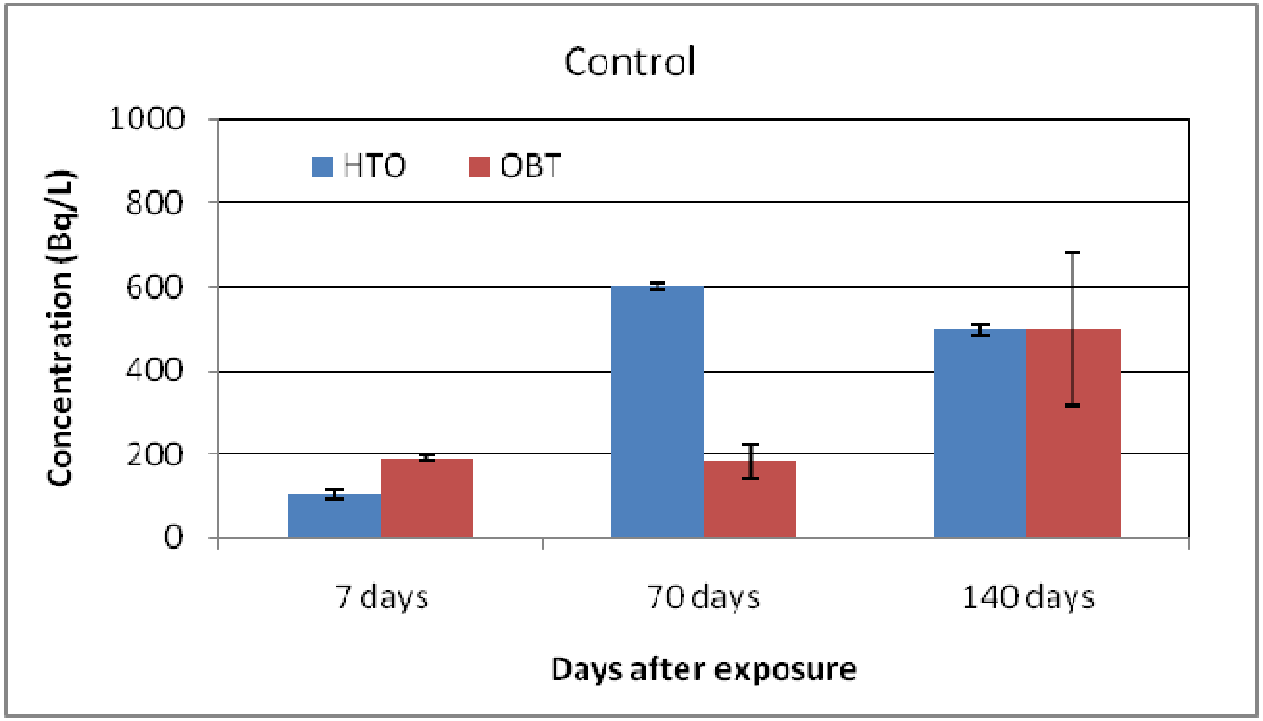
Final Weight Ranges (g) of Fish

Exposure	Control tank	Test tank
7 days	N=26 (56.1 – 286.0)	N=26 (72.7 – 226.1)
30 days	N=6 (259.7 – 445.2)	N=5 (403.8 – 664.8)
70 & 140 days	N=22 (69.4 – 694.9)	N=23 (72.2 – 484.0)

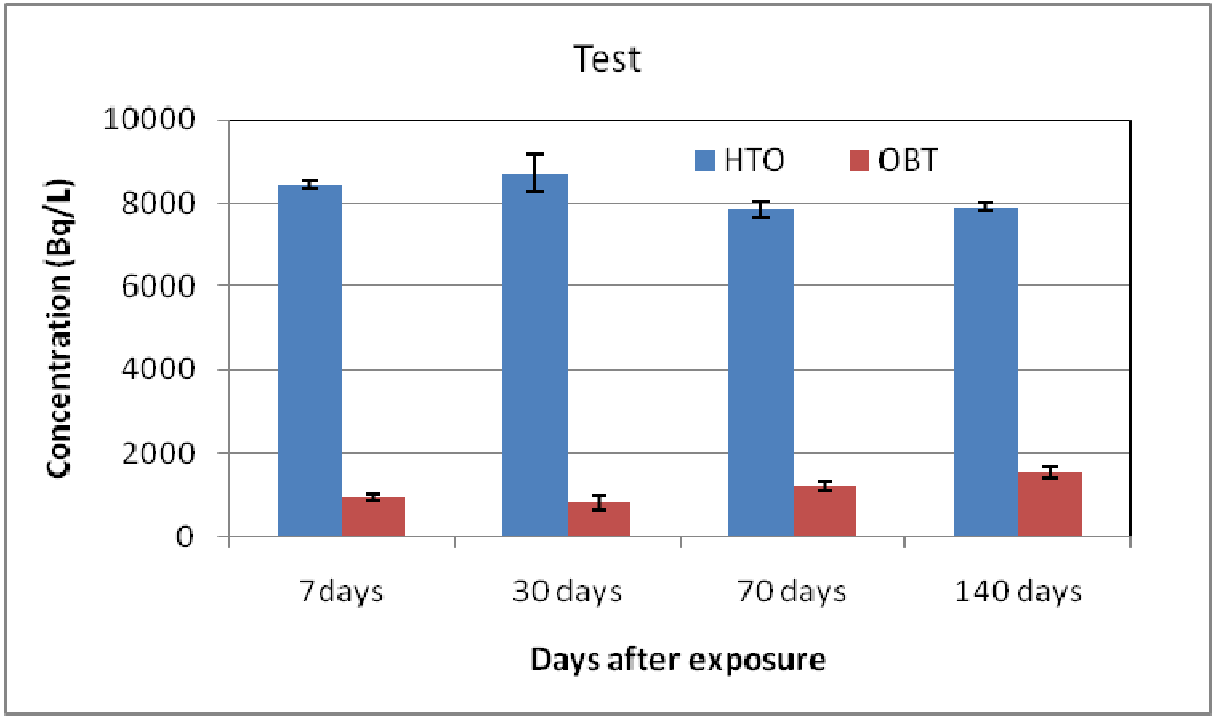
Relative Growth Rate (RGR)

Exposure	Control	Test
7 days	0.0213	0.0159
30 days	0.0006	0.0027
70 & 140 days	0.0062	0.0089

HTO and OBT Concentrations (1)



HTO and OBT Concentrations (2)



HTO and OBT Concentrations (3)

Experiment	Tank	HTO (Bq/L)	OBT (Bq/L)
7 days	Control liver	89	161
	Test liver	8,522	1,057
140 days	Control liver	493	688
	Test liver	7,791	2,211
Food pellet	Both	-	198

Average OBT Formation Rates

Experiment	Uptake (days)	Rate (h^{-1})
Clam	30	9.2×10^{-5}
	90	6.1×10^{-5}
	300	4.3×10^{-5}
	400	1.4×10^{-5}
Minnow	1	7.7×10^{-4}
	2	4.7×10^{-4}
	7	3.2×10^{-4}
	35	1.3×10^{-4}
	43	1.1×10^{-4}
Trout	7	6.7×10^{-4}
	30	1.3×10^{-4}
	70	8.5×10^{-5}
	140	5.8×10^{-5}

Average OBT Depuration Rates

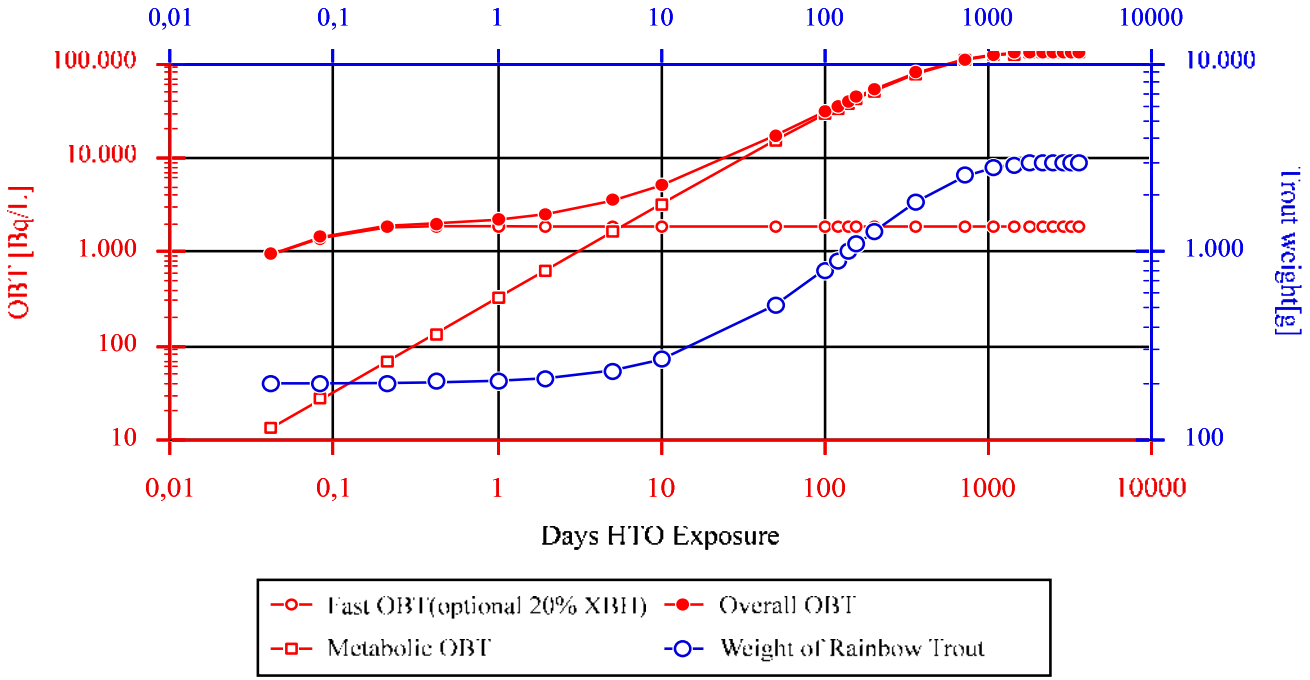
Experiment	Uptake (days)	Rate (h^{-1})
Clam	30	1.1×10^{-3}
	90	1.1×10^{-3}
	300	8.2×10^{-4}
	400	8.6×10^{-4}
	467	1.2×10^{-3}
Trout	30	1.4×10^{-3}

Measured Specific Activities

Animal	Uptake (days)	Ratio (OBT/HTO)
Mussel	30	0.066
	90	0.133
Minnow	35	0.111
	43	0.112
Trout	70	0.16
	140	0.20

EMRAS II Fish Scenario

Fig. 4. Weight and OBT Kinetic (fast + metabolic) of Rainbow Trout.
HTO 7000Bq/L, exposure start at 200g, growth rate from 200g to 1000g during 140d, final growth 3000g.



Findings

- OBT formation in fish will be close to the relative growth rate, while OBT loss will be close to the rate of metabolism in fish
- It was difficult to make a clear conclusion as to whether or not OBT can accumulate in organs
- In aquatic animals, OBT formation rates are slower than OBT loss rates
- All measured OBT/HTO values were lower than the reported value of 0.25 (conservative)

Ongoing Experiment

- Tritium contaminated food (total OBT concentration was 30,000±4,000 Bq/L, non-exchangeable OBT was 23,500±3,700 Bq/L)
- OBT formation and loss rates
- Ingredients are wheat middling, corn gluten meal, fish oil, soy protein concentrate, fish meal, poultry by-products meal, soybean oil, skim milk powder, feather meal, vitamins, minerals etc.
- Mix, Form into 4mm pellets and dry
- Food consumption of fish was not homogeneous

Future Experiment

- HTO exposure (7,000 Bq/L) and contaminated food (30,000 Bq/L) simultaneously
- Apply to fish-tagging skill
- HTO and OBT concentrations and OBT/HTO ratio
- Organ distribution if available

Discussion

- Tritium concentration levels
  - 100 Bq/L, 7,000 Bq/L and 30,000 Bq/L
- Uncertainty
  - 100 Bq/L represents an “essentially negligible” lifetime cancer risk of about 5 x 10^{-6} (from 1 x 10^{-5} to 1 x 10^{-6}, Health Canada)
  - Variability of OBT/HTO ratio in fish
  - Gaps do exist in tritium environmental science
- OBT dynamics in fish
  - Key parameters (metabolism, water temperature, prey availability) and OBT biological halftime (loss rate)

Thanks

- Carmen Shultz (Research Technologist in CRL)
- Marilyne Stuart (Research Scientist in CRL)
- Mike Bredlaw (Research Technologist in CRL)
- Who else?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