The Radiation Dose Response of Mollusc Shells from the Great Lakes

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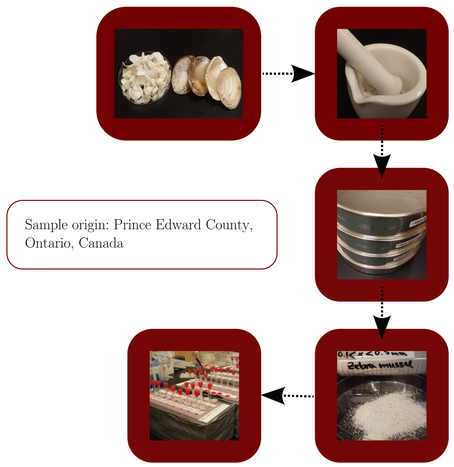
Abstract

The EPR spectra and dose response of one endemic and one invasive species of bivalve mollusks, eastern elliptio (Elliptio complanata) and zebra mussel (Dreissena polymorpha) were studied with the intention of determining their usefulness as indicators of radioactive material contamination in the environment. The shells were irradiated with a 15 MeV LINAC to doses from 15 to 35 Gy and a Cs-137 gamma irradiator to doses between 1 and 10 Gy. Reference measurements and dosimetry were done with alanine powder and OSLDs. Eastern elliptio showed a composite spectrum with overlapping signals, and while it may be used for identifying the specimens, it is inaccurate for dose estimation. Zebra mussels have a strong EPR signal, even when unirradiated, that could be measured and used for determining the dose response. For zebra mussels the larger grain sizes showed a larger deviation of signal height measurements which was attributed to a greater variance in packing densities. The optimal grain size for measurements of zebra mussels was determined to be between 0.1 mm and 0.5 mm. Both the peak-to-peak signal height and the double integral of the EPR signal show a linearity with the absorbed dose. However, due to small sample sizes (4-6 samples per dose), the errors are as high as 23%, especially in the lower dose range.

Sample Preparation



Sample origin: Prince Edward County, Ontario, Canada

Grain size effects

Grain sizes tested : 0.1-0.5 mm, 0.5-1mm

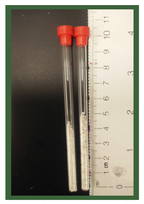


Figure 1: Sample tube with zebra mussel sample of 0.1-0.5 mm grain size (left) and 0.5-1 mm (right)

- Signal intensity and peak-to-peak height standard deviation between 39 and 44% for 20 Gy irradiation.
- Attributed to packing density deviations

Table 1: Peak-to-peak height and DI/N measurements in a zebra mussel sample after 20 Gy irradiation.

grain size	0.5-1 mm	0.1-0.5 mm
p-p height	$1.2 \pm 0.4 \times 10^7$	$1.8 \pm 0.1 \times 10^7$
DI/N	4.9 ± 2	8.1 ± 0.7

Irradiation Geometry: LINAC and Cs-137

15 kV LINAC

- 15 and 20 Gy delivered (Lakeridge Health Hospital)
- positioned on an isodose under the LINAC head
- solid water for electron equilibrium

Figure 2: Alanine powder and zebra mussel samples for Cs-137 irradiation.

Cs-137

- 1, 3, 5, 10 Gy delivered (FESNS, UOIT)
- dose plateau: 3 cm
- 7.8 Ci Cs-137 source (irradiation distance 35 cm)

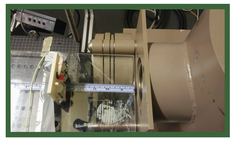


Figure 3: Irradiation with Hopewell G-10 Cs-137 source at FESNS (UOIT).

EPR Signal of Elliptio and Zebra mussels

Figure 4: Eastern elliptio shells after cleaning.

Eastern elliptio

Zebra mussels

- Zebra mussels have a clearly distinguishable peak
- Peak width of 0.15 G, peak-to-peak height radiation dependent
- No effect of irradiation on eastern elliptio

Figure 5: Zebra mussel shells after cleaning.

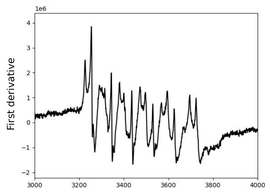


Figure 6: EPR signal of eastern elliptio.

Measurement parameters:

Sweep width: 800 G
Modulation amplitude: 0.2 G
Power: 0.48 mW
number of scans: 20

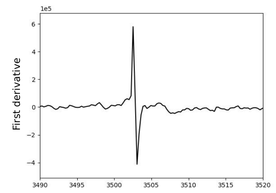


Figure 7: The peak of the EPR signal of zebra mussel .

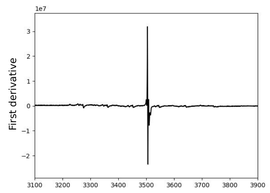


Figure 8: Full spectrum of zebra mussels.

Dose response of Zebra mussels (Dreissena Polymorpha)

normalized integral value DI/N

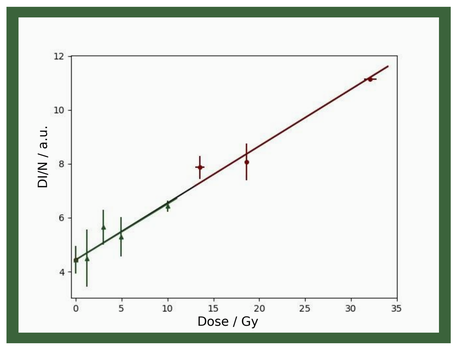


Figure 9: DI/N value for the central zebra mussel peak for irradiated samples from 1 to 35 Gy and unirradiated samples (0 Gy).

- 0-35 Gy (all): $y = 0.21(1/Gy)x + 4.1$
- 15-35 Gy (X-ray): $y = 0.21(1/Gy)x + 4.1$
- 1-15 Gy (Cs-137): $y = 0.21(1/Gy)x + 4.1$

peak-to-peak signal height

- 0-35 Gy (all): $y = 4.0 \times 10^5(1/Gy)x + 1.0 \times 10^7$
- 15-35 Gy (X-ray): $y = 4.0 \times 10^5(1/Gy)x + 1.0 \times 10^7$
- 1-15 Gy (Cs-137): $y = 4.8 \times 10^5(1/Gy)x + 1.0 \times 10^7$

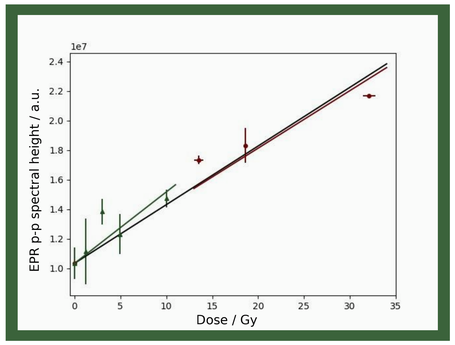


Figure 10: EPR signal height value for the central zebra mussel peak for irradiated samples from 1 to 35 Gy and unirradiated samples (0 Gy).

Dosimetry

Figure 11: Alanine powder filled in microcentrifuge tubes as dosimeters.

Figure 12: Samples, alanine dosimeters and OSL dosimeters for LINAC irradiation.

- alanine powder
- Landauer OSL Dosimeters
- alanine pellets

Table 2: Measured doses for all irradiations with alanine and OSL dosimeters.

Requested Dose (Gy)	Alanine Measured (Gy)	OSL Measured (Gy)	LINAC Setting (MU)
1	1.22	0.88	-
3	2.98	2.76	-
5	4.91	4.70	-
10	9.99	10.6	-
15	13.5 ± 0.5	14.7	1361
20	18.6 ± 0.1	19.6	1814
35	32.1 ± 0.7	-	3175

Challenges and Sources of Error

- Irradiation sources had to be changed after the first 2 irradiations.
- Very narrow isodose plateau of the CS-137 source.
- Beam profile of the Cs-137 source is sloped (up to 8% deviation between both sides.
- Small sample size.
- Vibrations of the sample and airfllow account for approximately 6% error between measurements.

Future work

- Significant increase of the sample size
- Direct comparison between X-ray and Cs-137 irradiation
- Reduction of noises and vibrations
- Comparison between different sample origins and ages.
- Characterization of EPR signal fading

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