IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Contribution of U-235 family to dose rates received by aquatic wildlife

EMRAS II BMG

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Photo provided by Richard R. Goulet CNSC

Context

↗ Beaverlodge scenario

- Incremental risk assessment
  - Exposure concentration (added) = measurement – background
  - For each exposure media (water, sediment and biota)
- Additive risk
  - three isotopes of uranium: 234, 235 and 238
  - decay chains
- Data gaps
  - assumptions

↗ an ERE as realist and exhaustive as possible

Data set

↗ Water concentration

- Priority to measurements
- When gaps
  - If data in sediment at the same site, back calculation applying a Kd
  - If no data :
    - Equilibrium with mother
    - For Rn, outgassing taken into consideration
    - For U-235, natural U-235/U-238 applied

↗ A value for each RN

Data set

↗ Water concentration

Radionuclide	Data origin
^{238}U	Measured/back calculated from sediment
^{234Th} to ^{234}U	In equilibrium with ^{238}U
^{230}Th	Measured/back calculated from sediment/equilibrium with mother
^{226}Ra	Measured/back calculated from sediment/equilibrium with mother
^{222}Rn	In equilibrium with ^{226}Ra after devolatilisation
^{218}Po to ^{214}Po	In equilibrium with ^{222}Rn
^{210}Pb	Measured/back calculated from sediment/equilibrium with mother
^{210}Bi	In equilibrium with ^{210}Pb
^{210}Pb	Measured/back calculated from sediment/equilibrium with mother
^{235}U	Equilibrium with ^{238}U after application of the isotopic ratio
^{231}Th to ^{223}Ra	Equilibrium with ^{235}U
^{219}Rn	In equilibrium with ^{223}Ra after devolatilisation
^{215}Po to ^{207}Tl	In equilibrium with ^{219}Rn

Data set

↗ other concentrations

Sediment

- Priority to measurements, background (reference site) considered
- When no data, use of Kd from site (Pb214 as Pb210) else from literature (ERICA + extrapolation methods)

Biota

- Priority to measurements, background (reference site) considered
- When no data, use of CF from site (U-235 as U-238) else from literature (ERICA data + extrapolation methods)

↗ Again a value for each RN

Data set

↗ other concentrations

Table 5 : summary of transfer parameters related to freshwaters

Color code regarding extrapolation (data origine) : yellow : freshwater crustacean - violet : freshwater fish - blue : marine ecosystemn - orange : marine crustacean -

	Kd[a] (l.kg^{-1})	Concentration ratio CR (kg.kg^{-1})				
	Sediment	Insect	mollusc	Benthic fish	Pelagic fish	Reference
U	5.0 10^{1}	5.0 10^{2}	1.8 10^{2}	3.0 10^{1}	3.0 10^{1}	ERICA, 2006
Th	1.8 10^{7}	1.0 10^{2}	1.0 10^{2}	1.1 10^{2}	1.1 10^{2}	ERICA, 2006
Pa	1.0 10^{6}					AIEA, 2001
		3.0 10^{1}	3.0 10^{1}	1.0 10^{1}	1.0 10^{1}	Staven *et al*, 2003
Ac	2.0 10^{6}					AIEA, 2001
		1.0 10^{3}	1.0 10^{3}	2.5 10^{1}	2.5 10^{1}	Staven *et al*, 2003
Ra	1.5 10^{4}	1.5 10^{3}	1.5 10^{3}	8.0 10^{1}	8.0 10^{1}	ERICA, 2006
Rn	8.0 10^{-}	8.0 10^{-1}	8.0 10^{-1}	8.0 10^{-1}	8.0 10^{-1}	Brown *et al*, 2004
Po	2.0 10^{7}	9.9 10^{3}	3.8 10^{4}	2.4 10^{2}	2.4 10^{2}	ERICA, 2006
Pb	1.0 10^{5}	1.0 10^{4}	1.7 10^{3}	3.0 10^{2}	3.0 10^{2}	ERICA, 2006
Bi	1.2 10^{3}					Wang *et al*, 2001 - Wang *et al*, 2003
		1.0 10^{5}	1.0 10^{5}	1.5 10^{1}	1.5 10^{1}	Staven *et al*, 2003
Tl	2.0 10^{-4}					AIEA, 2001
		1.0 10^{3}	5.0 10^{3}	1.0 10^{4}	1.0 10^{4}	Staven *et al*, 2003

[a]liter par kilogram of dry weight

Results

↗ Study on 2 lakes

- Beaverlodge and Key lakes
- Benchmarks : 2 µGy.h^{-1} vertebrates, 200 µGy.h^{-1} invertebrates (PROTECT)

	Fish			Chironomus	Pisidium	Caddisfly
	pelagic	benthic				
		large	small			
Beaverlodge Lake						
Dubyna Lake	21.8	57.7	55.8	10.3	4.25	4.04
Hanson Bay	13.6	12.4	7.71	7.16	1.87	1.43
Beaverlodge	5.67	13.4	16.7	9.97	1.63	1.40
Keddy Bay	6.01	16.0	7.82	9.17	1.06	1.08
Key Lake						
Delta Lake	122	12.7	10.3	12.2	1.41	1.44

↗ Organisms at risk for each site

Interpretation

↗ Levels of conservatism?

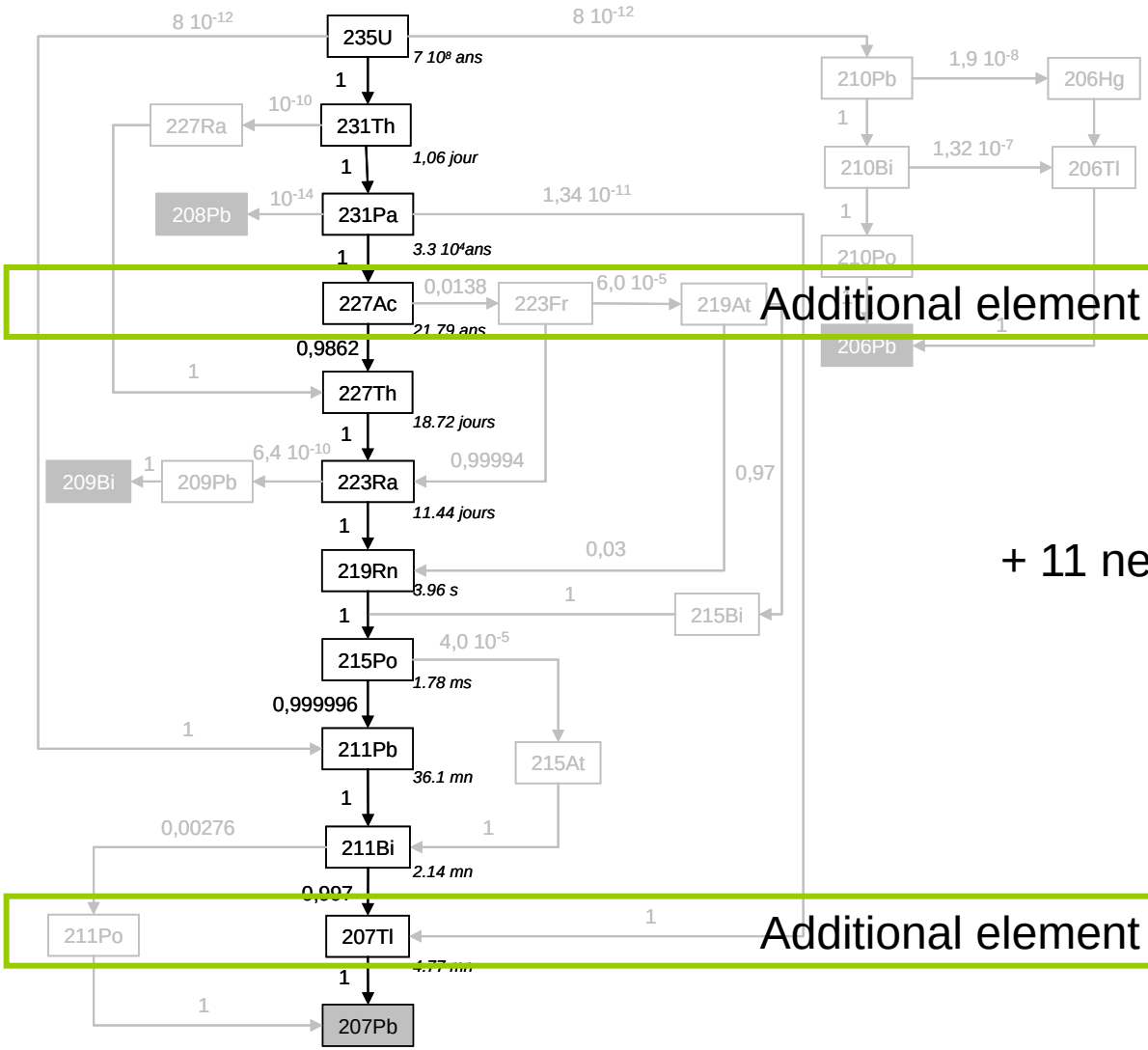
- CF and Kd from sites or literature
- All « significant » daughter products included
  - Most of the other approaches neglect U-235 and its daughter products
- Measures + equilibrium assumption for radioactive decay

↗ Contribution of the U-235 family ?

Wildlife exposure to U-235 family

Theoretical approach

The U-235 decay chain



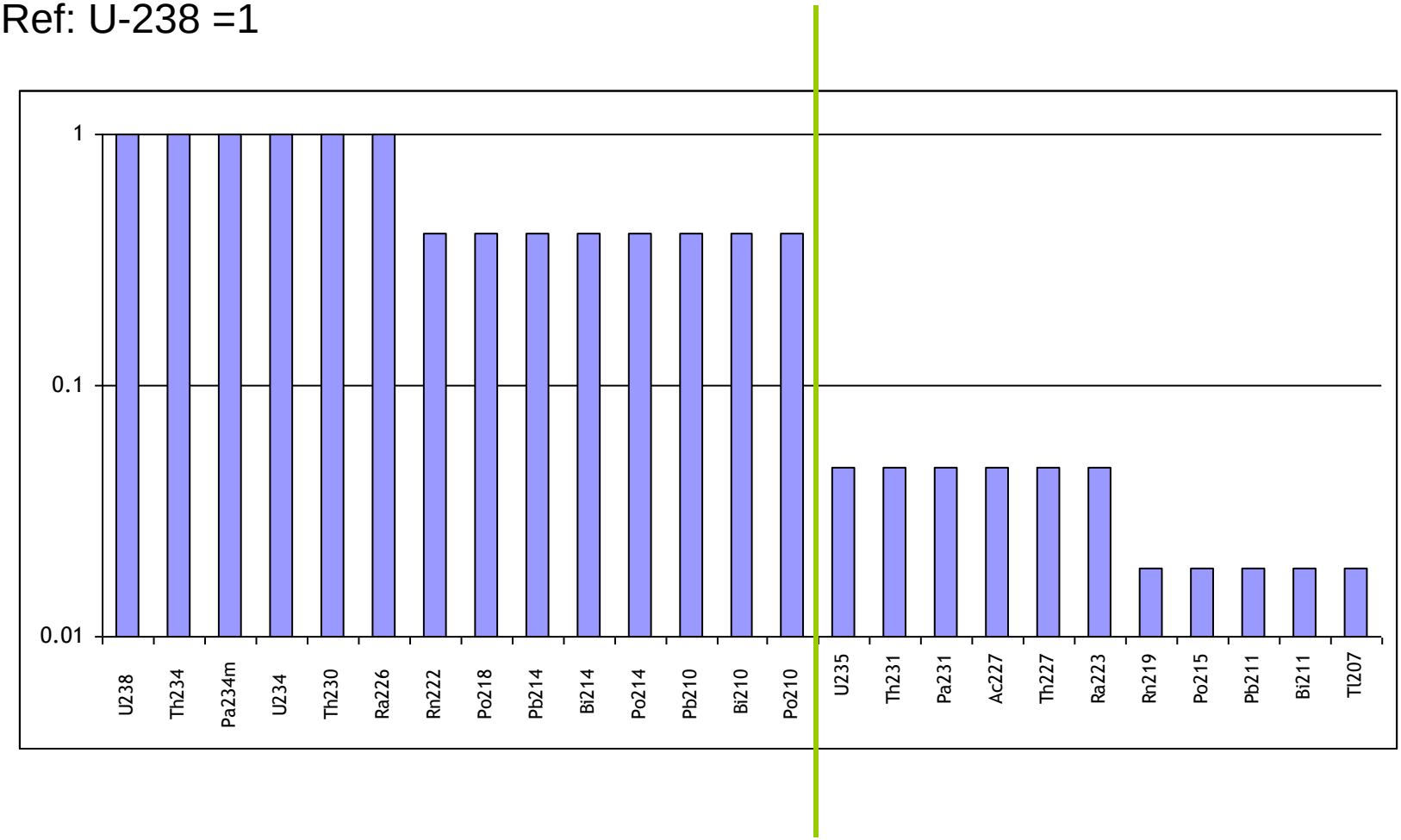
Additional element to take on board/ U-238 chain

+ 11 new isotopes

Additional element to take on board/ U-238 chain

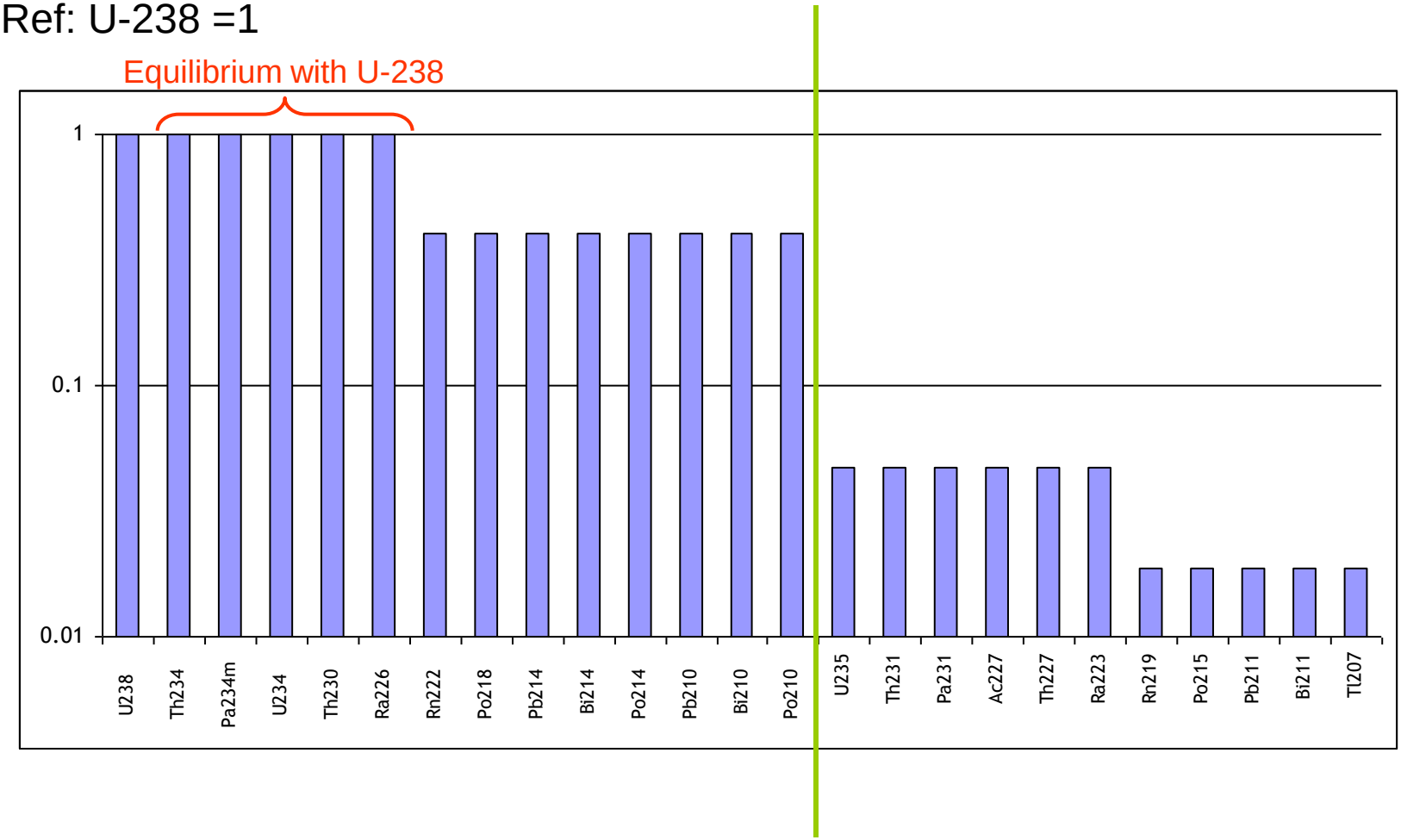
Water concentrations

Ref: U-238 =1

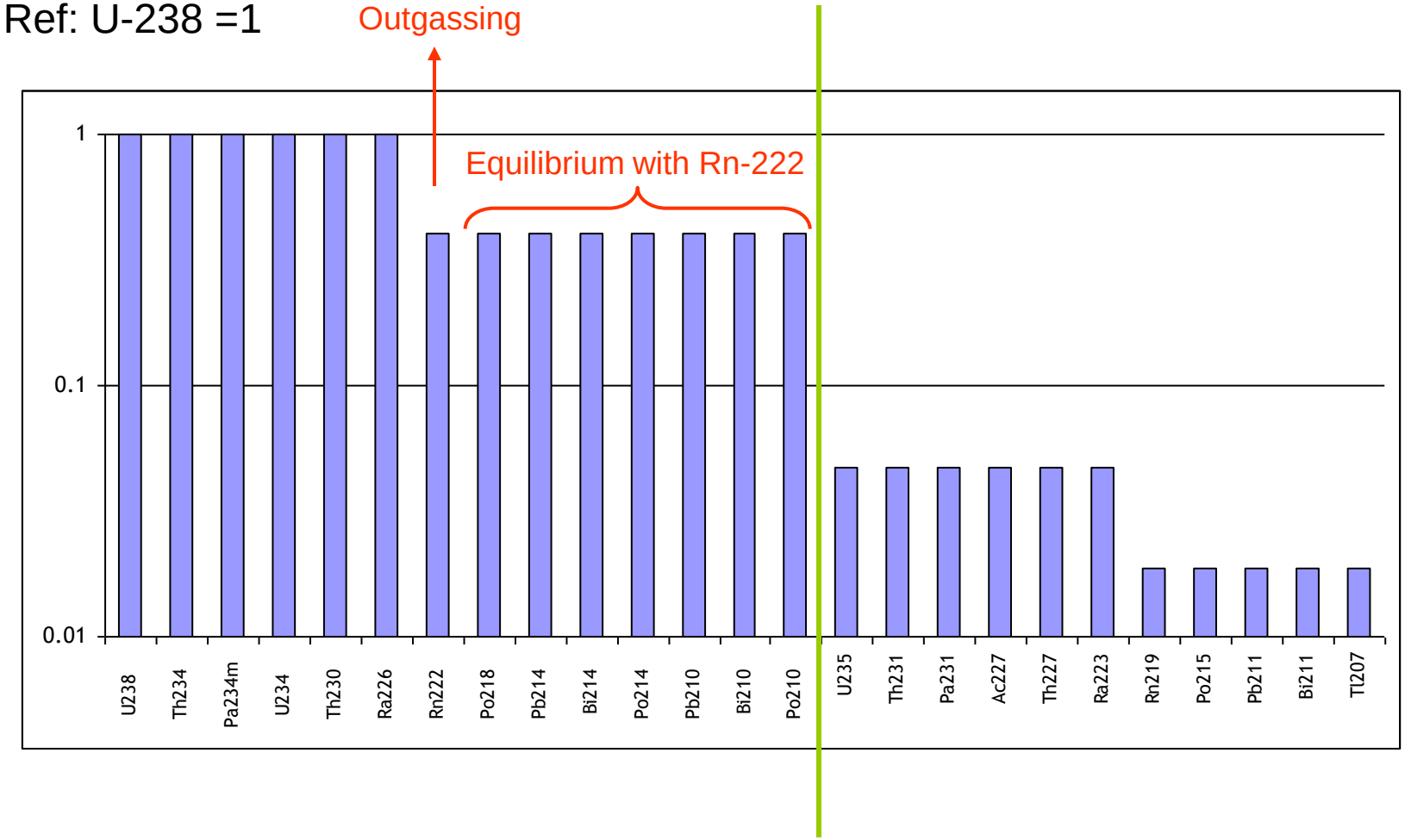


Water concentrations

Ref: U-238 =1

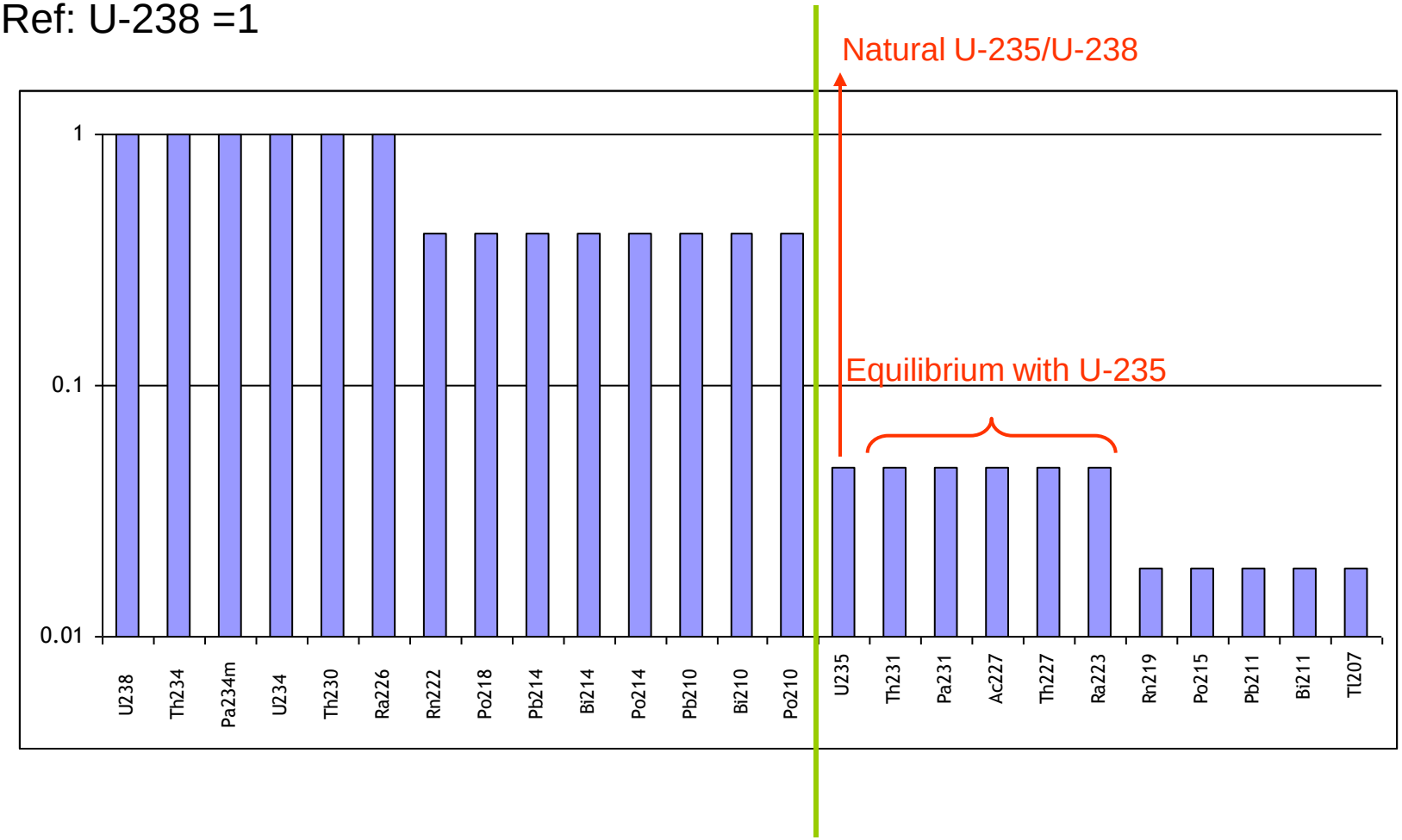


Water concentrations



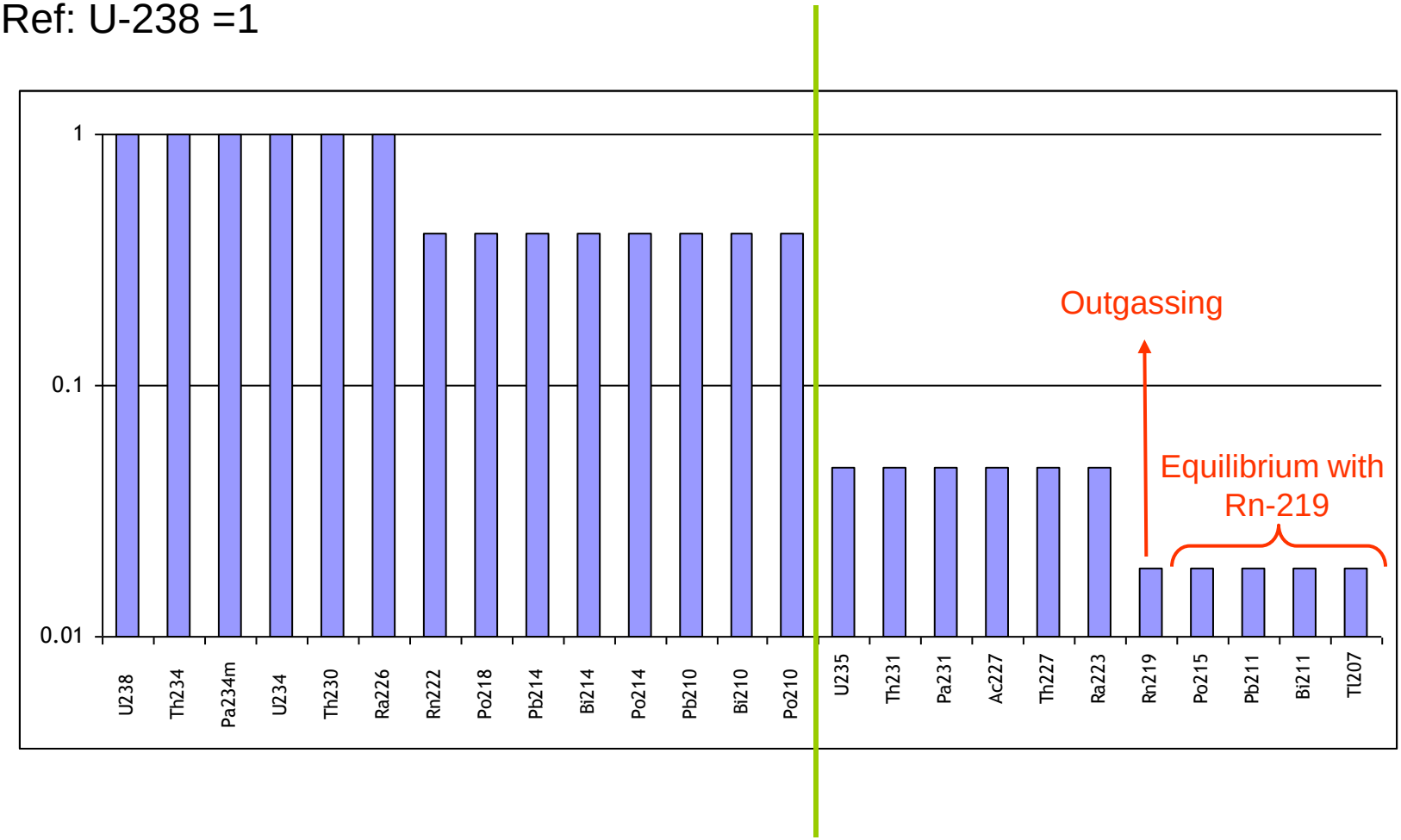
Water concentrations

Ref: U-238 =1

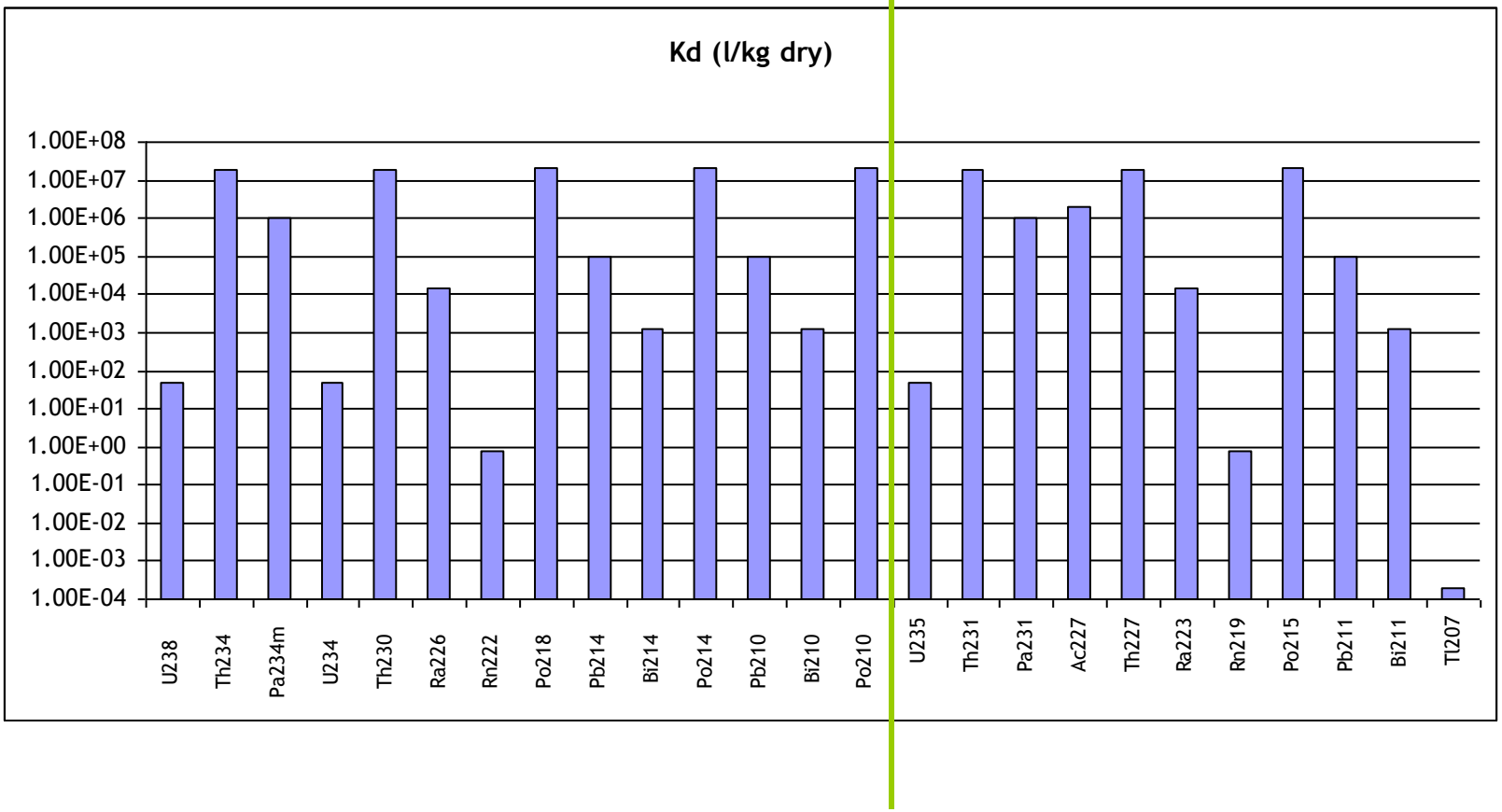


Water concentrations

Ref: U-238 =1

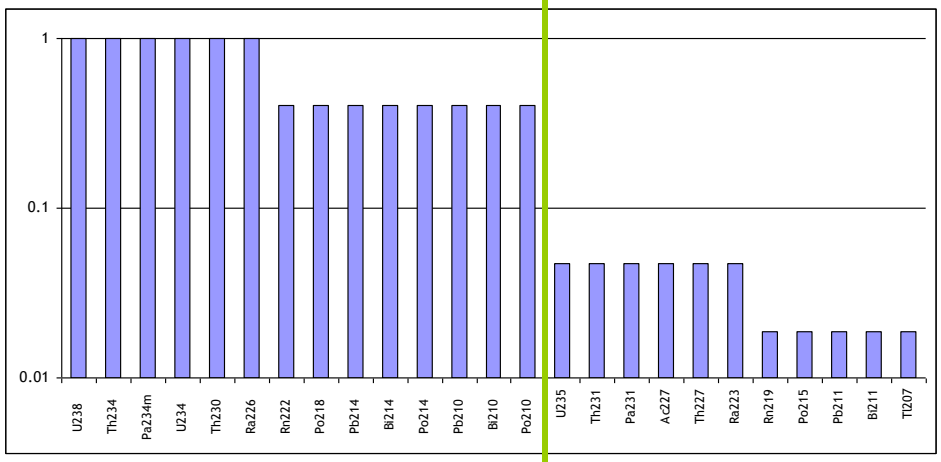


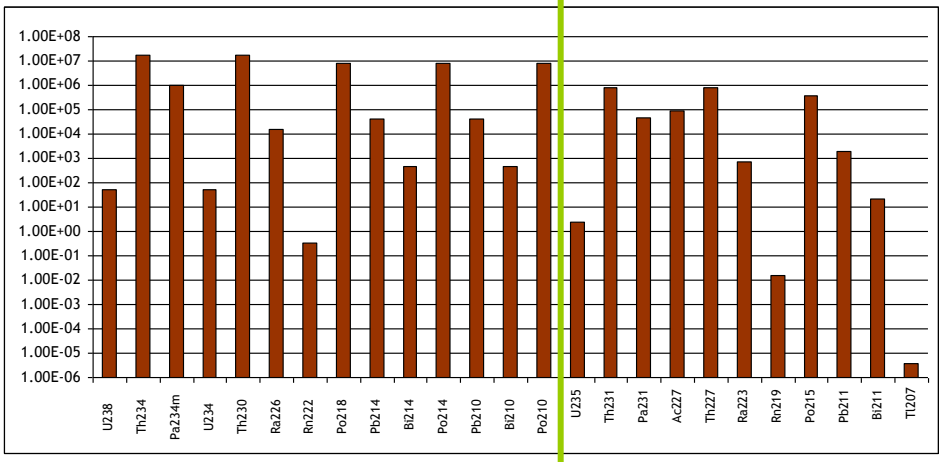
Transfer parameters



Media concentrations

Ref: U-238 =1

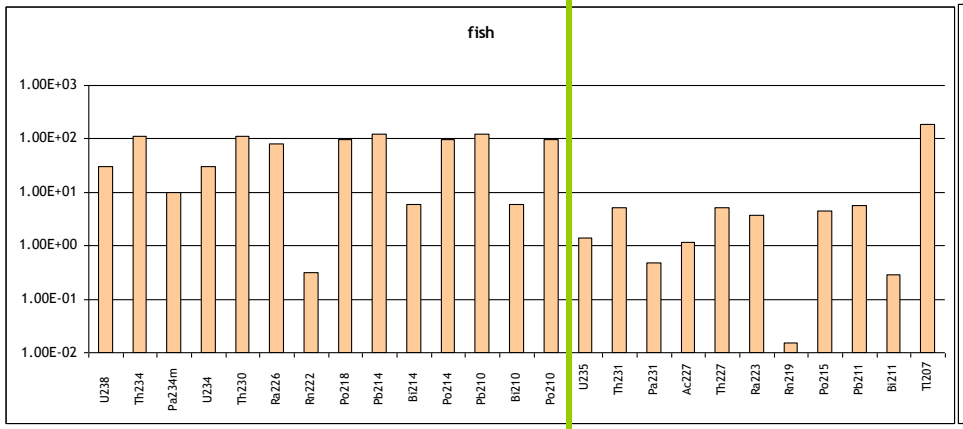


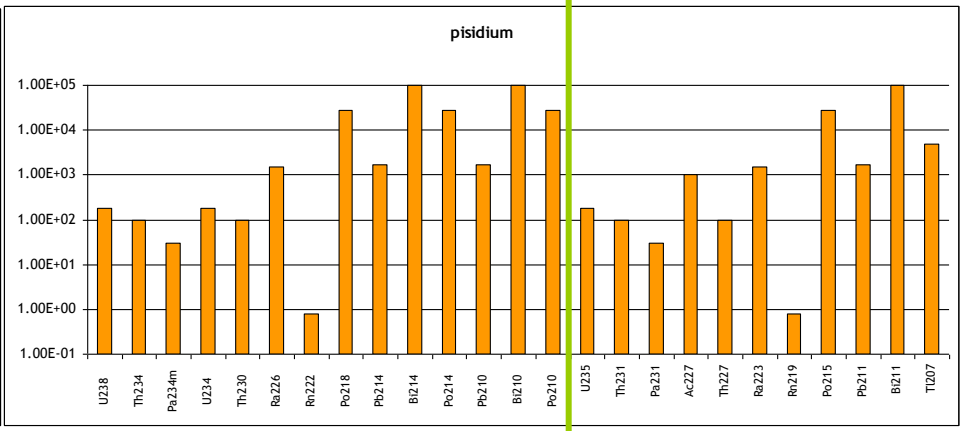


water

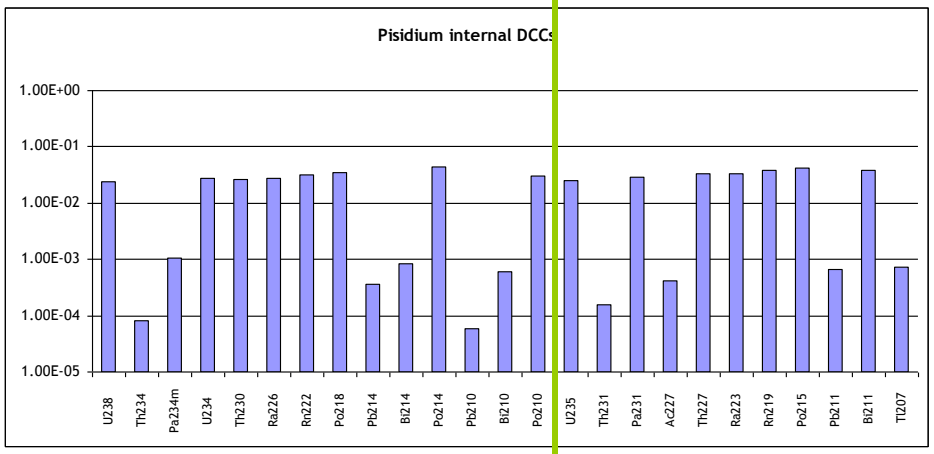
sediment

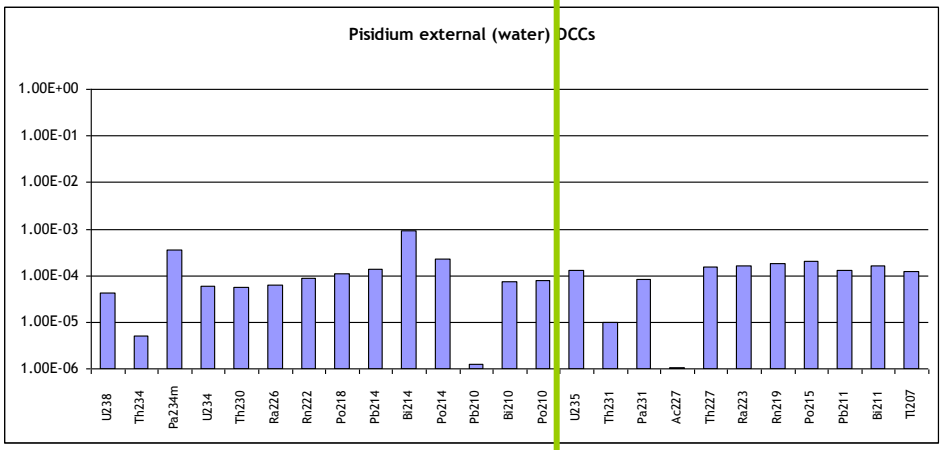
Organims concentrations



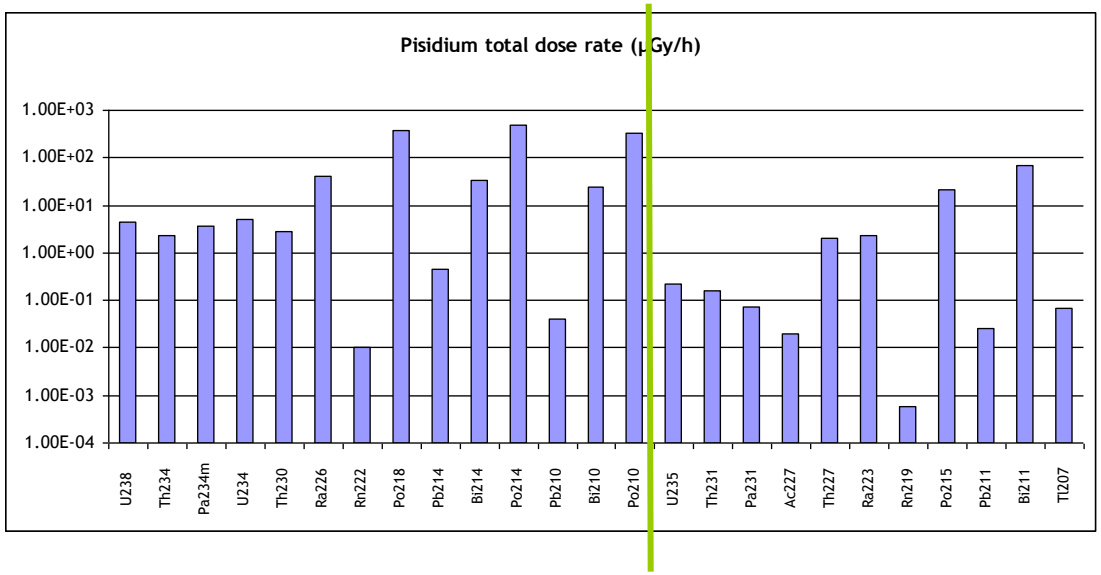


DCCs

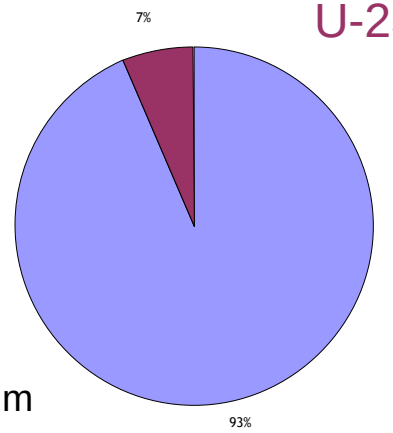

Pisidium internal DCCs
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
U238
Th234
Pa234m
U234
Th230
Ra226
Rn222
Po218
Pb214
Bi214
Po214
Pb210
Bi210
Po210
U235
Th231
Pa231
Ac227
Th227
Ra223
Rn219
Po215
Pb211
Bi211
Tl207


Pisidium external (water) DCCs
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
U238
Th234
Pa234m
U234
Th230
Ra226
Rn222
Po218
Pb214
Bi214
Po214
Pb210
Bi210
Po210
U235
Th231
Pa231
Ac227
Th227
Ra223
Rn219
Po215
Pb211
Bi211
Tl207

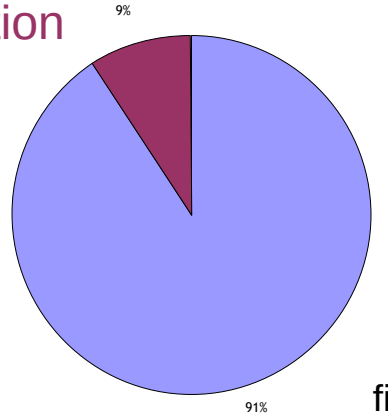
Total dose rates



U-235 family contribution



pisidium



fish

Wildlife exposure to U-235 family

Case study

Beaverlodge Lake

↗ Results

U-235 family contribution

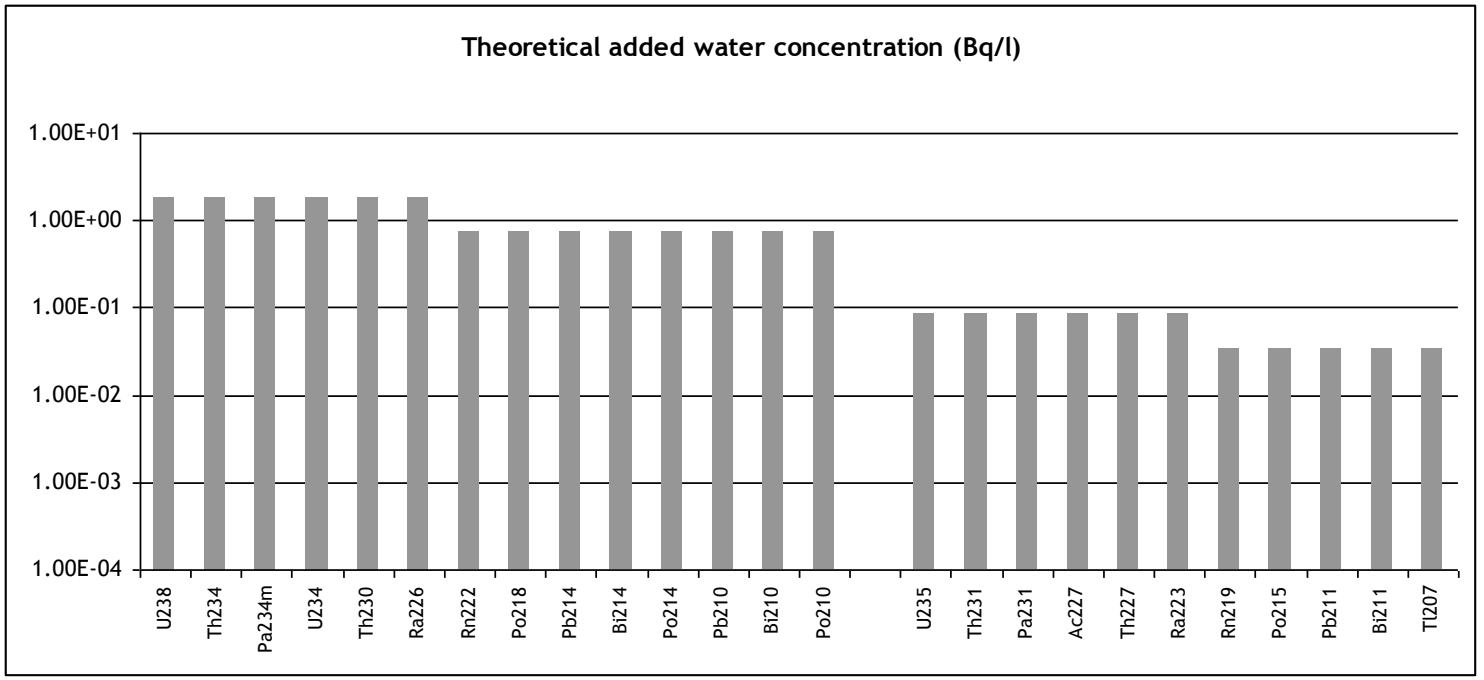
	Fish			Chironomus	Pisidium	Caddisfly
	pelagic	benthic				
		large	small			
Dubyna Lake	33.47	20.07	14.94	45.00	73.66	66.93
Hanson Bay	10.52	20.02	21.78	38.55	48.40	54.56
Beaverlodge	23.72	21.64	11.20	14.65	60.72	61.23
Keddy Bay	38.22	21.88	30.85	18.72	83.62	70.64

↗ A higher contribution that the theoretical one

Explanation

Keddy Bay

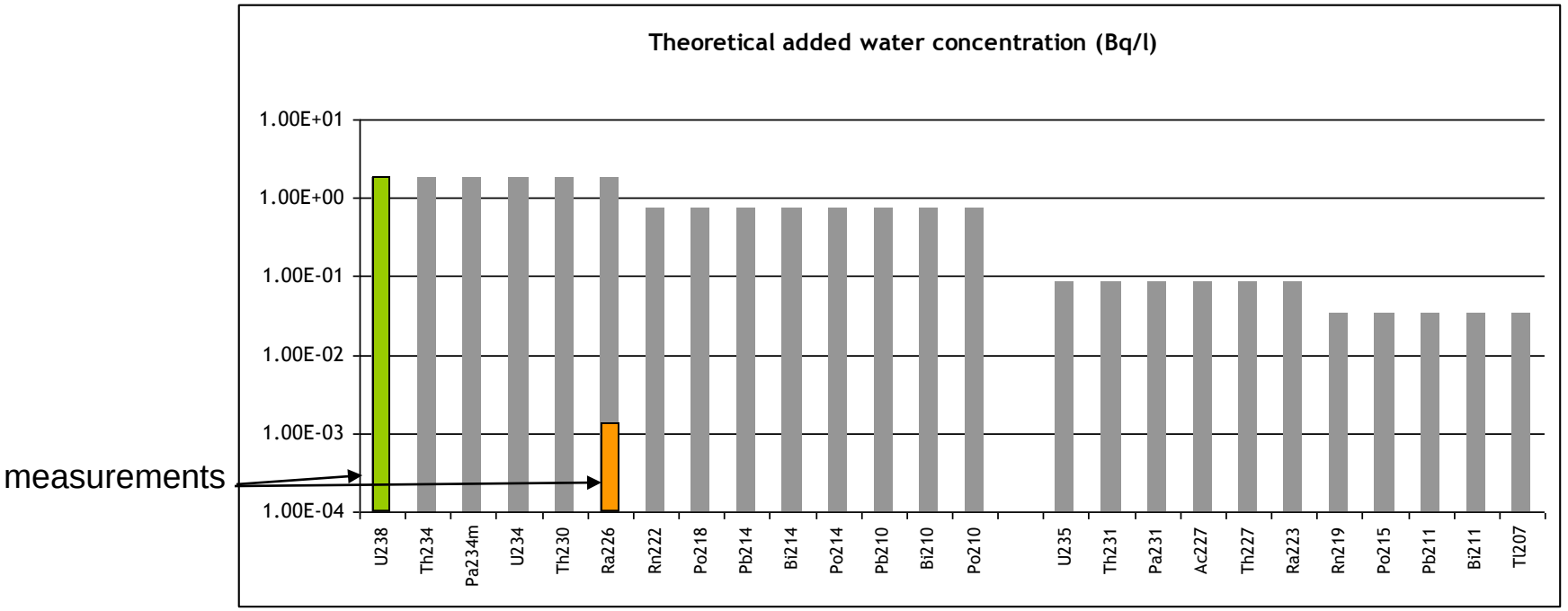
Water concentration



Explanation

↗ Keddy Bay

Water concentration

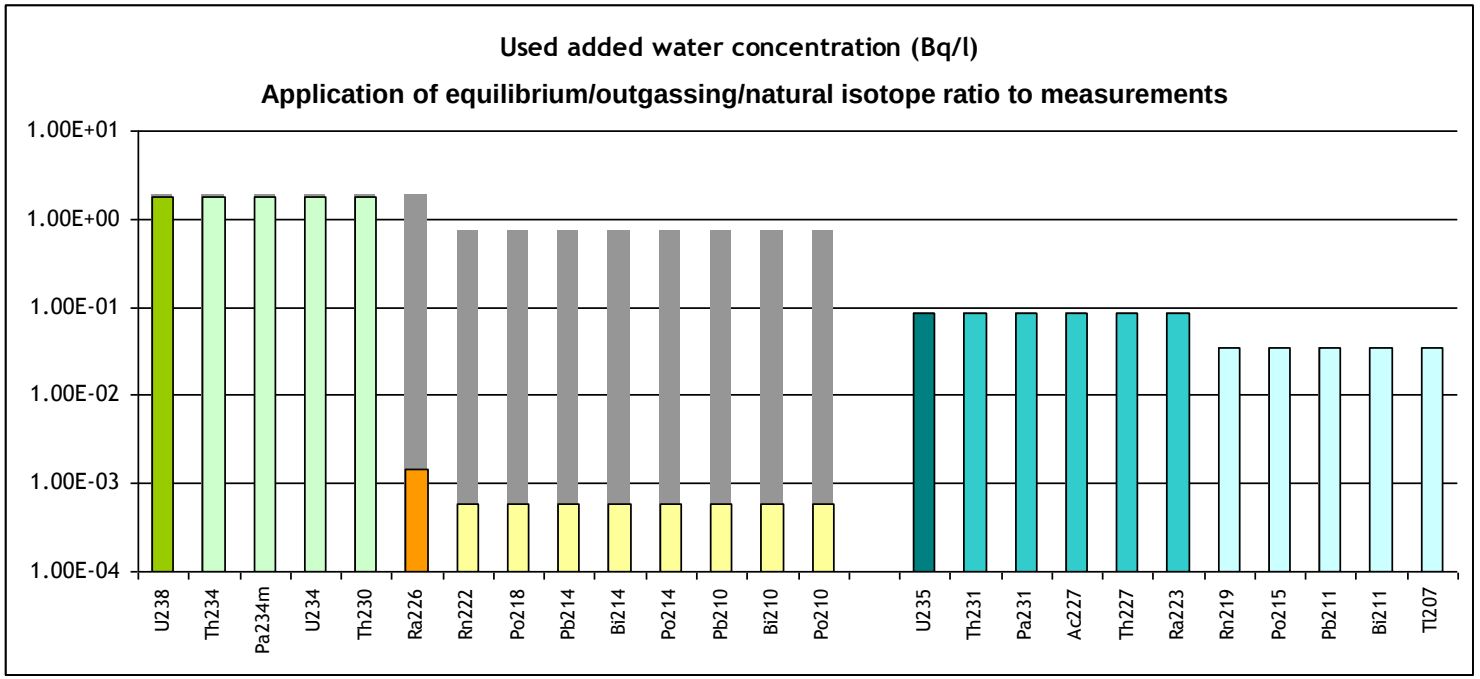


↗ decay chain not at equilibrium or/and metrology bias?

Explanation

Keddy Bay

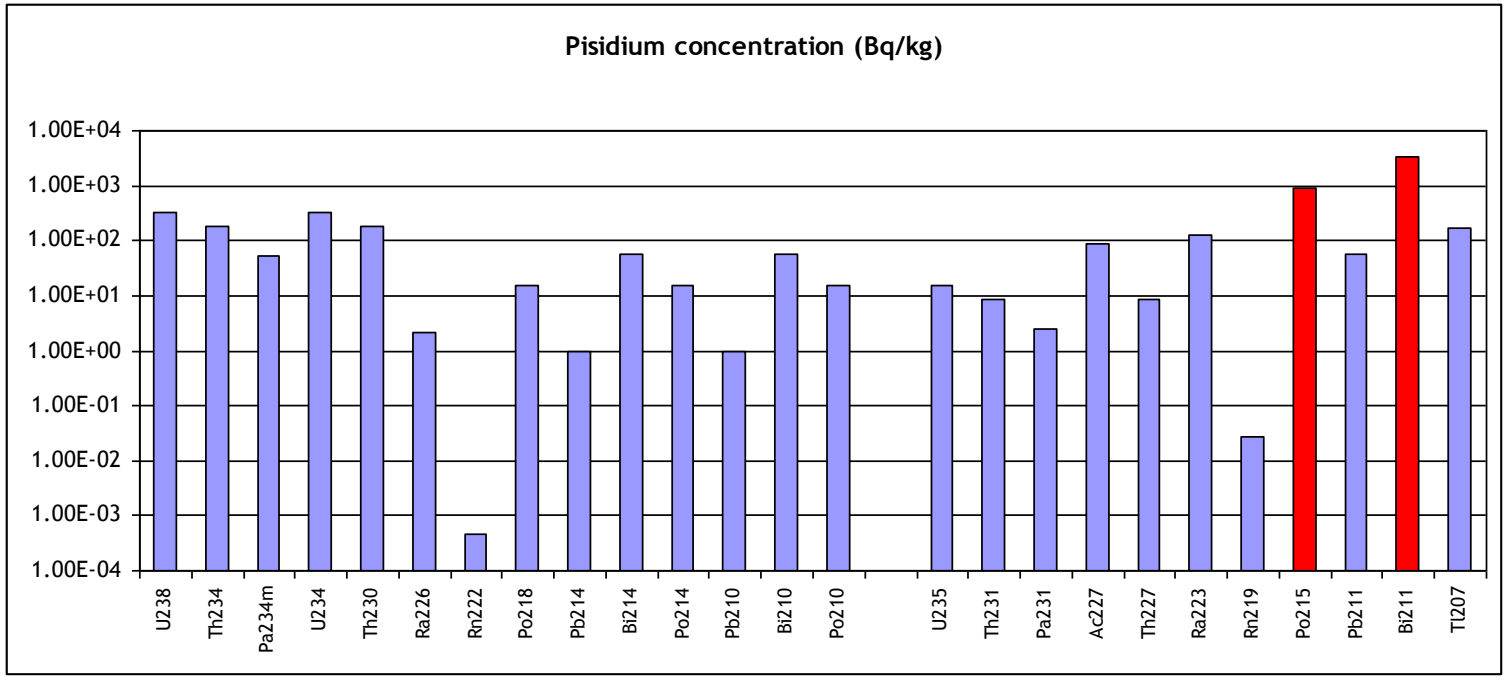
Water concentration



Explanation

Keddy Bay

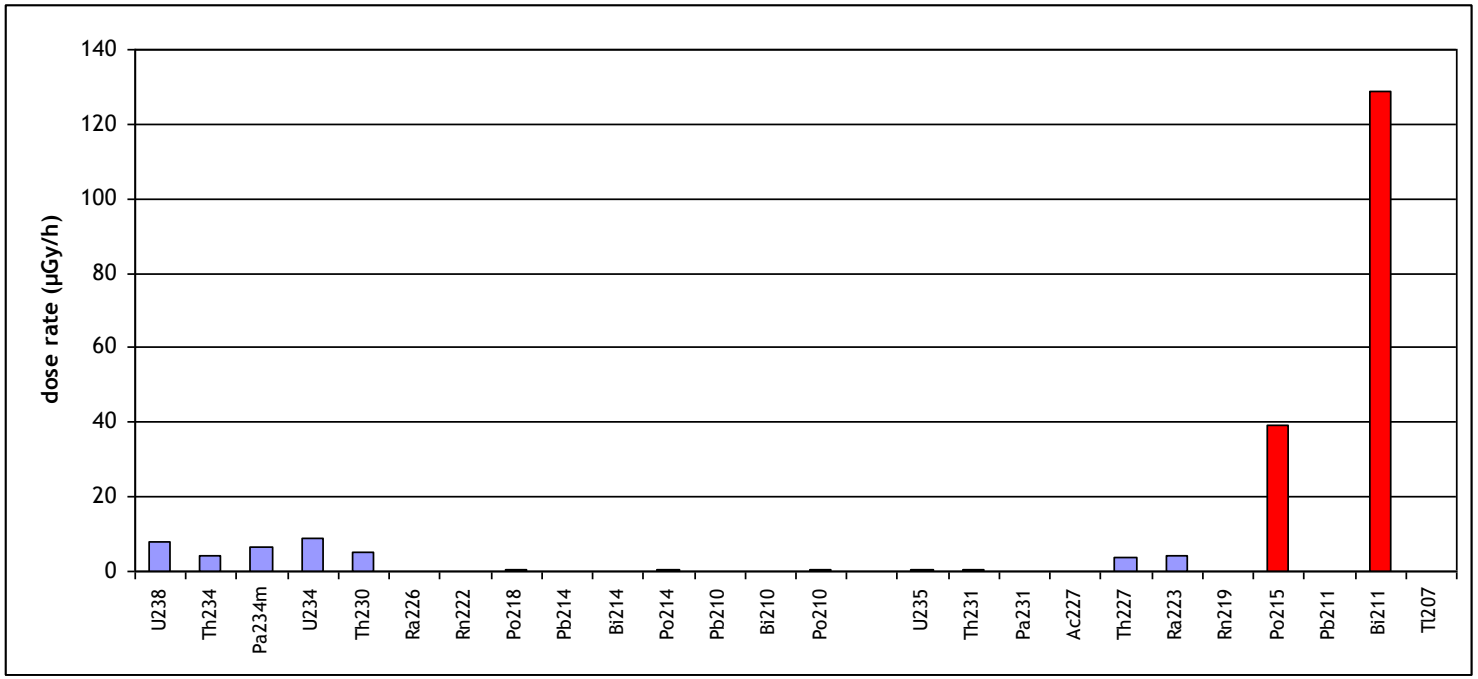
- Pisidium concentration (Water concentration x CF)



Explanation

Keddy Bay

- Pisidium total dose rate

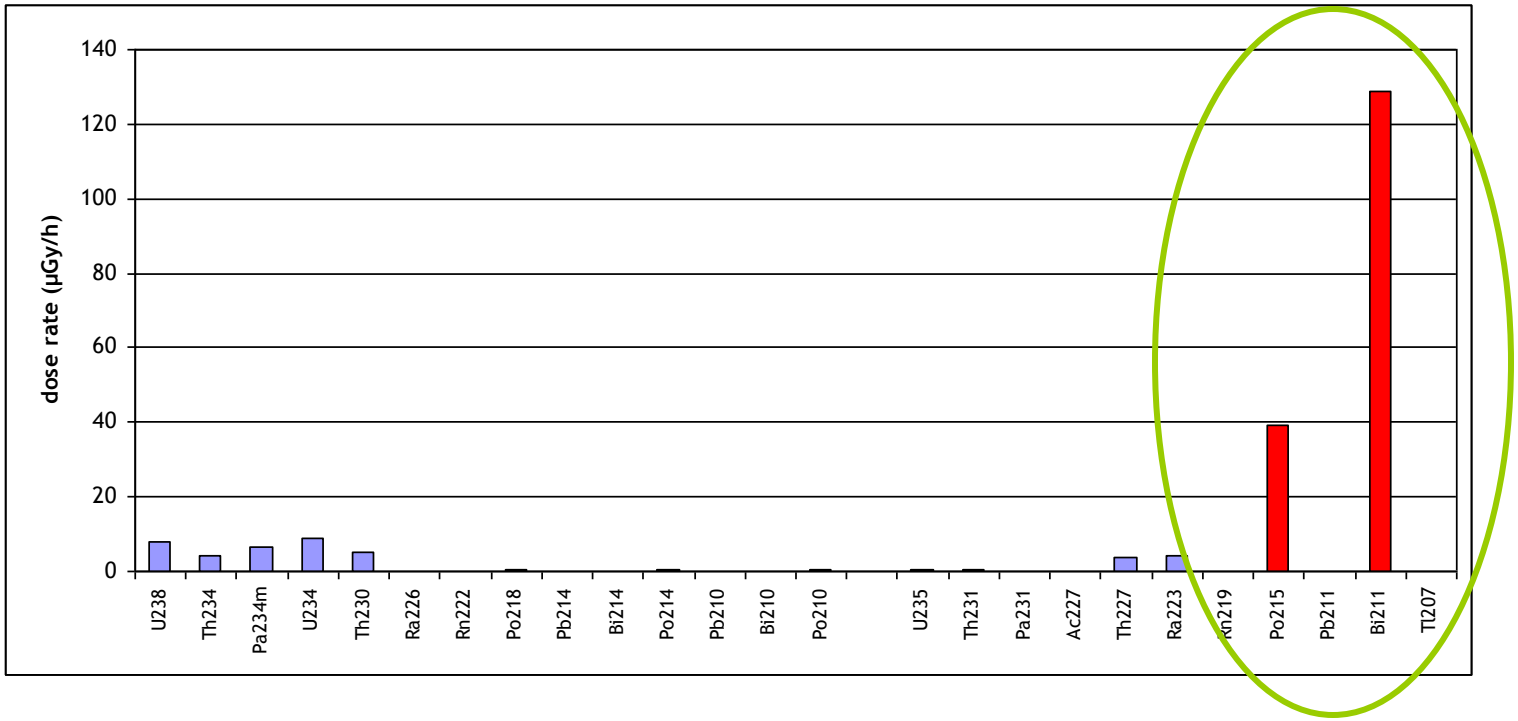


Explanation

↗ Keddy Bay

- Pisidium total dose rate

2 RNS explain the U-235 family high contribution



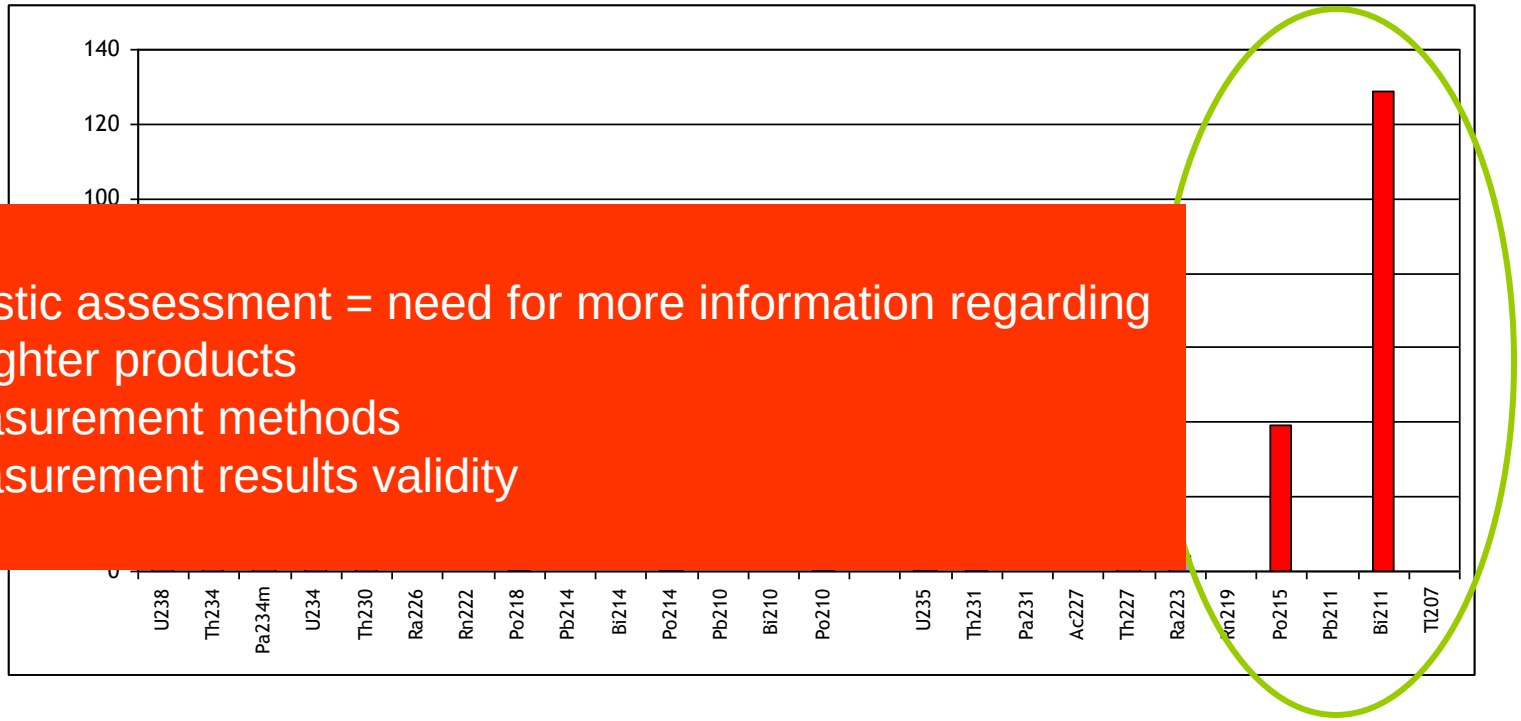
↗ Heavy weight of hypothesis about daughters

Explanation

↗ Keddy Bay

- Pisidium total dose rate

2 RNS explain the U-235 family high contribution



Realistic assessment = need for more information regarding
- daughter products
- measurement methods
- measurement results validity

↗ Heavy weight of hypothesis about daughters