IAEA

International Atomic Energy Agency

Second Technical Meeting (TM) on the Environmental Modelling for Radiation Safety (EMRAS II) Intercomparison and Harmonization Project

EMRAS II - Biota Modelling Group (WG4)

Estimating radionuclide activity concentrations in organisms, by using the ERICA Tool

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CONTENTS

1. Introduction
2. The ERICA Tool
3. Case Study
4. Probabilistic Assessment
5. Radiological Risk Assessment
6. Remarks
7. Conclusions - Perspectives

CONTENTS

OBJECTIVES

- Exercise

  Investigate the cause of communities and population level effects observed in Beaverlodge Lake and bays of Lake Athabasca.

  – Phase 1

    Estimate radionuclide activity concentrations in specific organisms, living in contaminated areas.

    - Presentation

      ✓ Estimate radionuclide activity concentrations in these organisms, by using the **ERICA Tool**.

      ✓ Conduct an initial radiological assessment

DEFINITIONS

- Absorbed Dose *(eV/gr) or (Gy)*
  the energy deposited in unit mass of absorbing material by ionizing radiation
- Dose Rate *(Gy/time unit)*
  the absorbed dose received over a unit of time
- Activity Concentration *(Bq/kg) or (Bq/l)*
  the activity of a specific radionuclide per unit mass or volume of matter

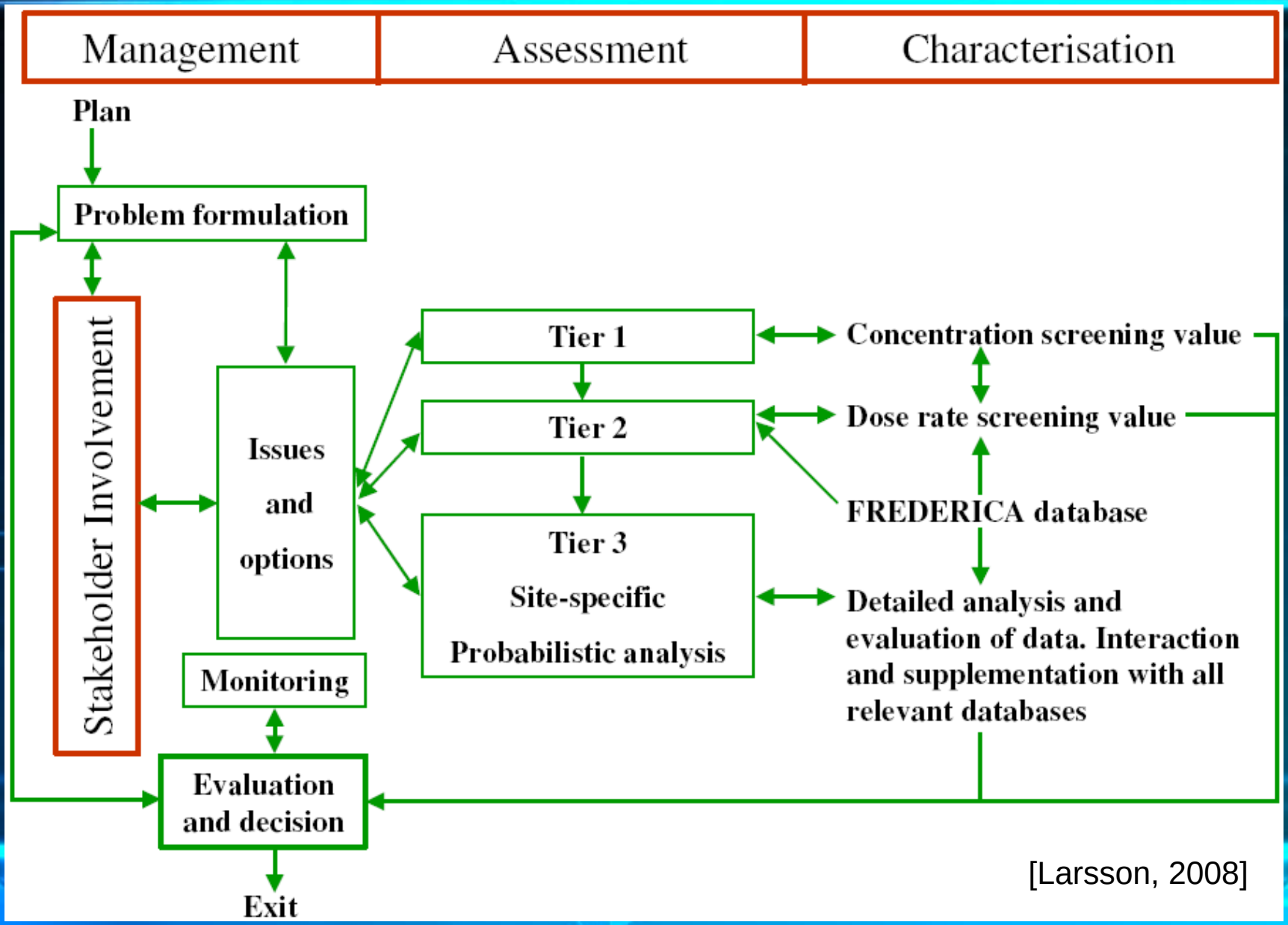
CONTENTS

ERICA Assessment Tool

Environmental Risk from Ionizing Contaminants: Assessment and management

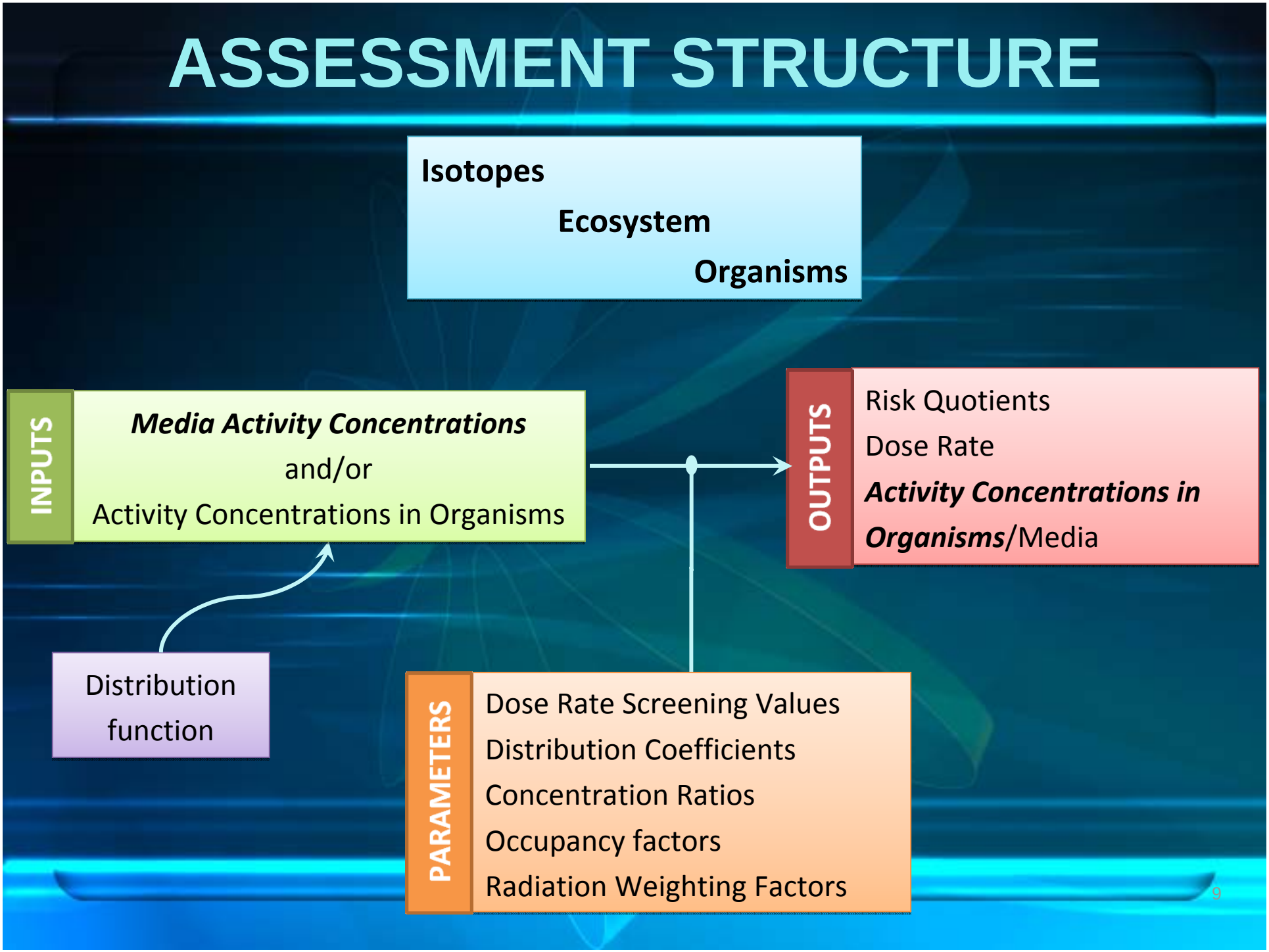
- ERICA Assessment Tool 1.0 May 2009
- 15 Institutions / 7 European Countries 2004-2007
- Supporting software program - facilitates the ERICA Integrated Approach
- Freshwater, terrestrial and marine ecosystems
- 38 reference organisms
- 63 radionuclides of 31 elements
- Addition radionuclides and organisms
- Probabilistic ability
- Linked to on-line radiation effects [FREDERICA] database

ERICA Assessment Tool



[Larsson, 2008]

ASSESSMENT STRUCTURE



CONTENTS

CASE STUDY- ECOSYSTEM

Freshwater Ecosystem

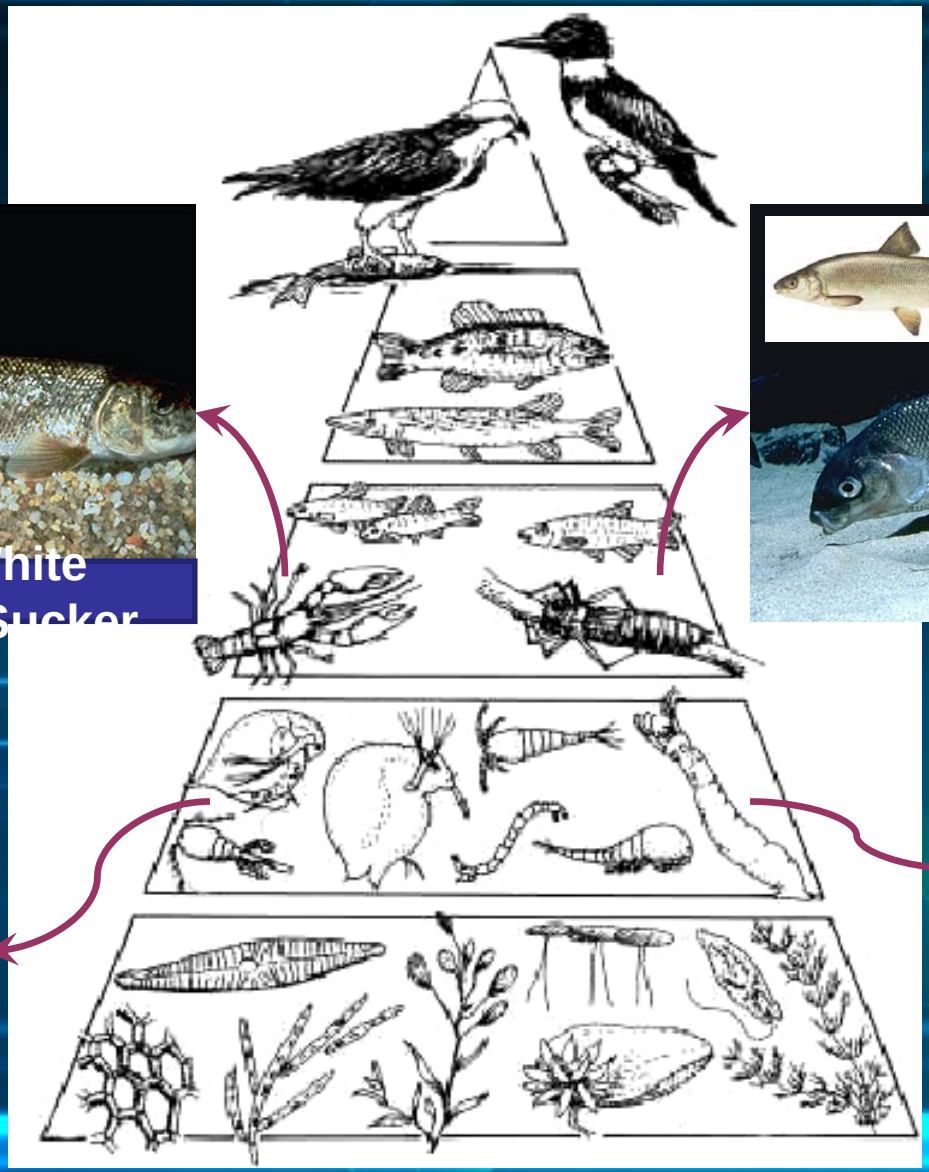
CASE STUDY- LOCATION

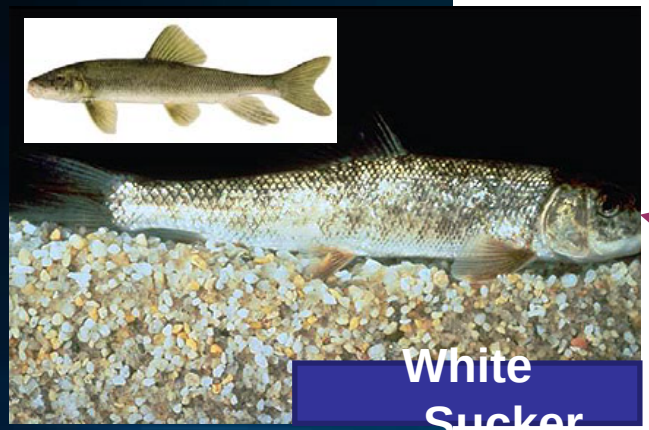
Beaverlodge Lake

- 16 Sites

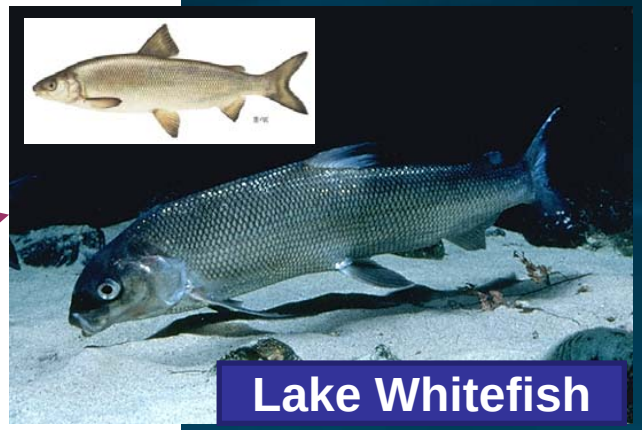
Lake Athabasca

CASE STUDY- ORGANISMS

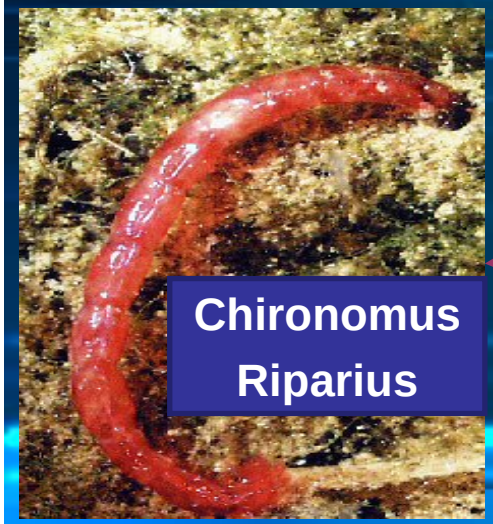




White Sucker



Lake Whitefish



Chironomus Riparius

Pisidium sp.

CASE STUDY- CONTAMINATION

- Metals
- Radionuclides
  - ^{210}Pb
  - ^{210}Po
  - ^{226}Ra
  - ^{230}Th
  - ^{238}U

CONTENTS

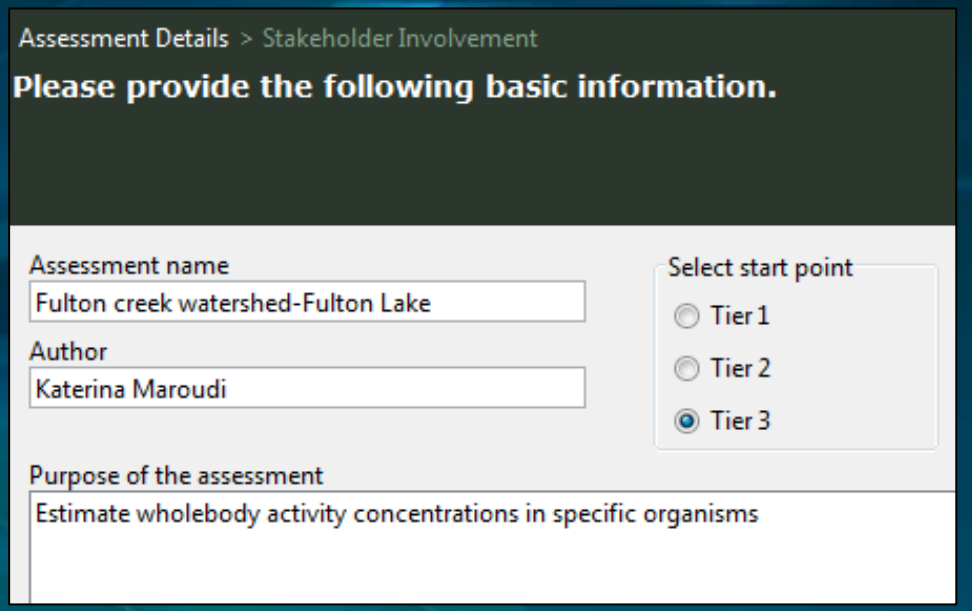
PROBABILISTIC ASSESSMENT

Assessment where probability distributions are assigned to model parameters and a probability distribution of the assessment endpoint is obtained by performing Monte Carlo simulations.

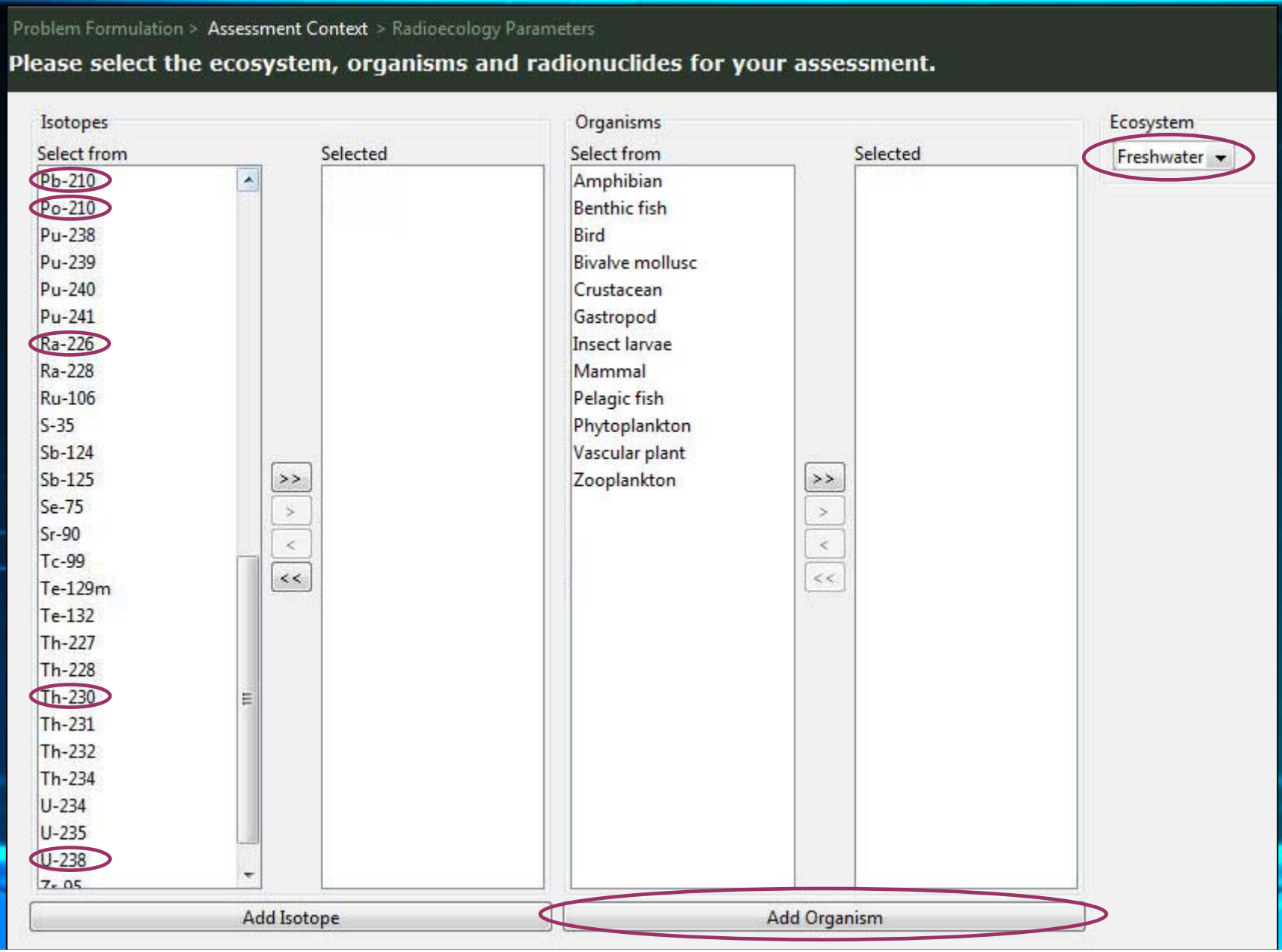
➢TIER 3

ASSESSMENT DETAILS

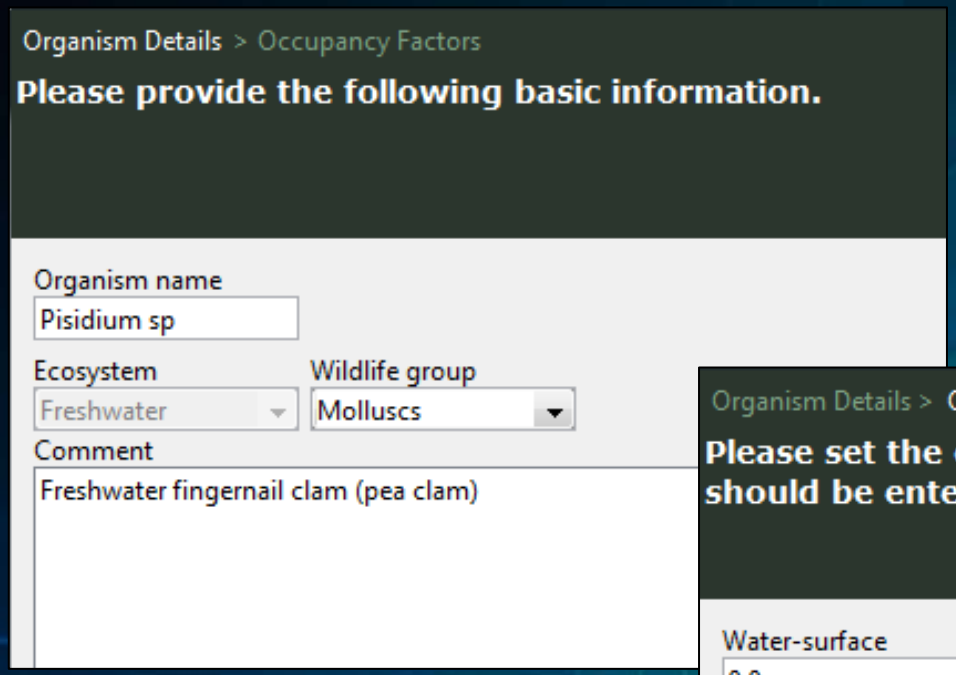
- Assessment details
- Stakeholder involvement
- Problem formulation

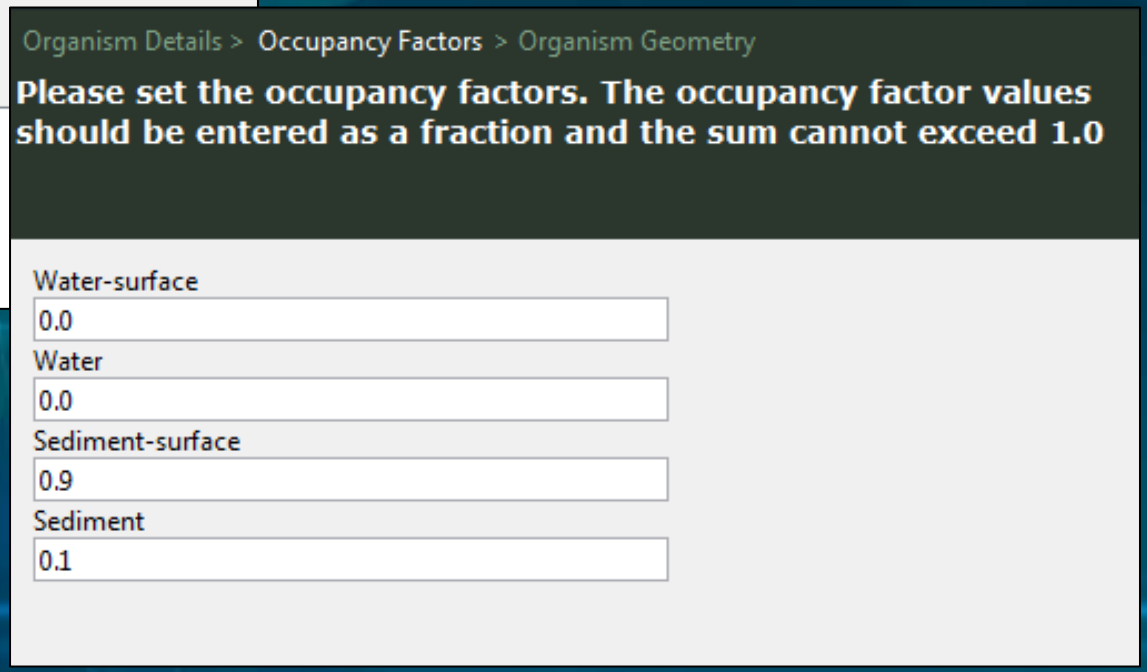


ASSESSMENT CONTEXT



ADD ORGANISM (1)





ADD ORGANISM (2)

Occupancy Factors > Organism Geometry > Calculation

Please give information of the organism's geometry and mass.

Mass

Mass range allowed for **aquatic species** in the BIOTA_DCC tool:

Min: 1.00E-6 Max: 1.00E3

The user-entered mass must fall within this range.

Enter new organism mass [kg]: 1.25E-6

Calculation

The DCC is derived using mass as the primary parameter assuming a density of 1 g cm-3. The user-entered values of height, width and length are used to create scaling parameters that are implemented directly in the subsequent calculations.

Geometry

Dimensions

Enter new organism dimensions. The organisms are represented by ellipsoids.

Height [m] 0.0010

Width [m] 0.0015

Length [m] 0.0050

Scaling parameters

Scaling parameters represent the lengths of the minor axes in terms of the length of the major axis of the ellipsoid. These scaling parameters are used in the DCC calculation module.

Chi: 0.2

Ksi: 0.3

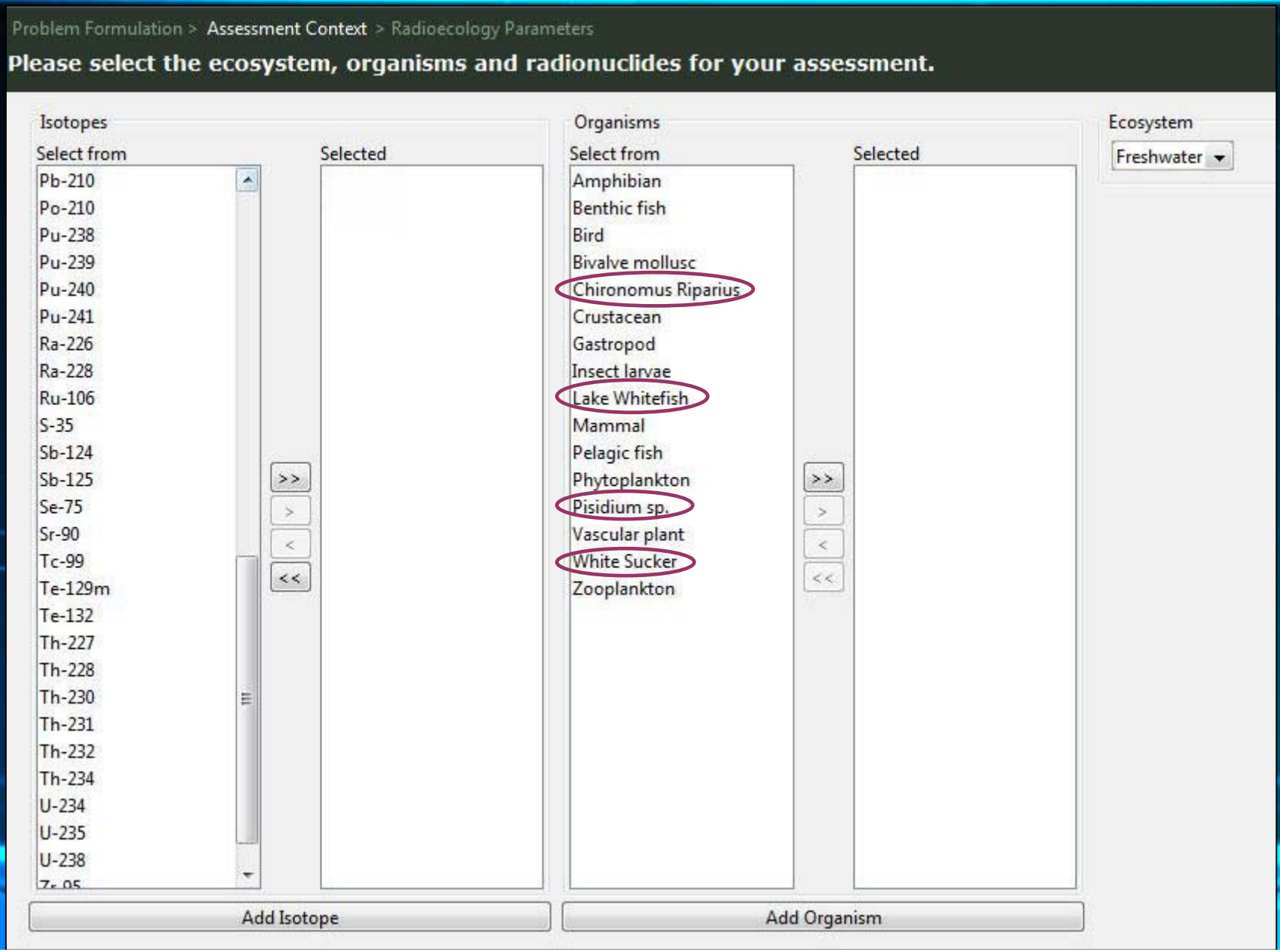
ADD ORGANISM (3)

Name	Chironomus Riparius	Pisidium sp.	Lake Whitefish [Coregonus clupeaformis]	White Sucker [Catostomus commersoni]
Wildlife Group	Aquatic Invertebrate	Mollusc	Fish	Fish
Comments	Freshwater benthic invertebrate	Freshwater fingernail clam (pea clam)	•Bottom feeding freshwater fish •Salmon family •Eat cruastacens, snails, insects, etc	•Bottom feeding freshwater fish •Eat small invertebrates and plant matter

ADD ORGANISM (4)

	Chironomus Riparius	Pisidium sp.	Lake Whitefish	White Sucker
Geometry (m)				
Length	3.4E-04	5.0E-03	4.36E-01	4.5E-01
Width	1.7E-04	1.5E-03	1.4E-02	1.5E-02
Depth	1.5E-04	1.0E-03	1.0E-02	1.0E-02
Mass (kg)				
	~1.6E-07	~1.25E-06	1.362	1.191
Occupancy factors				
Water-Surface	0.0	0.0	0.0	0.0
Water	0.0	0.0	0.1	0.1
Sediment-Surface	0.1	0.9	0.9	0.9
Sediment	0.9	0.1	0.0	0.0

ASSESSMENT CONTEXT



RADIOECOLOGY PARAMETERS (1)

1. Concentration Ratio (CR)

$$CR = \frac{Activity\ concentration\ in\ biota\ whole\ body\ (Bq \cdot kg^{-1}\ f.w.)}{Activity\ concentration\ in\ media\ (Bq \cdot kg^{-1}\ d.w./\ Bq \cdot m^{-3}\ /\ Bq \cdot l^{-1})}$$

2. Distribution Coefficient (K_d), for aquatic ecosystem

$$K_d = \frac{Activity\ concentration\ in\ sediment\ (Bq \cdot kg^{-1}\ d.w.)}{Activity\ concentration\ in\ water\ (Bq \cdot l^{-1})}$$

RADIOECOLOGY PARAMETERS (2)

Assessment Context > Radioecology Parameters > Occupancy Factors and Radiation Weighting Factors

Please review and edit the radioecology parameters: Distribution Coefficient (Kd) and Concentration Ratio (CR). The default CR values presented are empirically derived means (not 95th percentile values).

Distribution Coefficient (Kd) [L kg-1] | Concentration Ratio (CR) [Bq kg-1(f.w.) per Bq L-1]

Nuclide	Distribution Coefficient (Kd)
Pb	1.00E5
Po	2.00E7
Ra	1.52E4
Th	1.84E7
U	5.00E1

Incomplete data for the Concentration Ratio (CR)

Distribution Coefficient (Kd) [L kg-1] | Concentration Ratio (CR) [Bq kg-1(f.w.) per Bq L-1]

Nuclide	Chironomus Riparius	Pisidium sp.	Lake Whitefish	White Sucker
Pb				
Po				
Ra				
Th				
U				

RADIOECOLOGY PARAMETERS (3)

Distribution Coefficient (Kd) [L kg-1] | Concentration Ratio (CR) [Bq kg-1(f.w.) per Bq L-1]

Nuclide	Chironomus Riparius	Pisidium sp.	Lake Whitefish	White Sucker
Pb				
Po				
Ra				
Th				
U				

Distribution Coefficient (Kd) [L kg-1] | Concentration Ratio (CR) [Bq kg-1(f.w.) per Bq L-1]

Nuclide	Insect larvae	Bivalve mollusc	Benthic fish
Pb	1.00E4	1.70E3	3.00E2
Po	9.90E3	3.80E4	2.40E2
Ra	1.50E3	1.50E3	8.00E1
Th	1.00E2	1.00E2	1.10E2
U	5.00E2	1.80E2	3.00E1

Distribution Coefficient (Kd) [L kg-1] | Concentration Ratio (CR) [Bq kg-1(f.w.) per Bq L-1]

Nuclide	Chironomus Riparius	Pisidium sp.	Lake Whitefish	White Sucker
Pb	1.00E4	1.70E3	3.00E2	3.00E2
Po	9.90E3	3.80E4	2.40E2	2.40E2
Ra	1.50E3	1.50E3	8.00E1	8.00E1
Th	1.00E2	1.00E2	1.10E2	1.10E2
U	5.00E2	1.80E2	3.00E1	3.00E1

Select ERICA default CR values

Method used to derive ERICA default CR value when no empirical data:

- [x] 1 similar taxonomy
- [x] 2 similar reference organism
- [x] 3 from published reviews
- [ ] 4 specific activity models
- [ ] 5 similar biogeochemistry
- [ ] 6 similar biogeochemistry and taxonomy
- [ ] 7 similar biogeochemistry and reference organism
- [ ] 8 allometric or other modelling approaches
- [ ] 9 highest available value
- [x] 10 reference organism in a different ecosystem
- [x] 11 combination of approaches
- [ ] Select/Unselect all check boxes

INPUTS (1)

Occupancy Factors and Radiation Weighting Factors > **Inputs** > Probabilistic Simulation Settings

Please enter your media and/or organism concentrations. At least one concentration must be entered for each radionuclide but not all cells have to be filled in.

Isotope	Activity Concentration in water [Bq L-1]	Activity Concentration in sediment [Bq kg-1 d.w.]
Pb-210	2.00E-2	8.20E1
Po-210	7.50E-3	8.20E1
Ra-226	6.50E-3	3.60E1
Th-230	6.50E-2	2.40E1
U-238	1.53E-2	2.03E1

Activity Concentration

Please enter into the table the best estimate measured or modelled media concentration, or, depending on your problem formulation, the activity concentration at the edge of the mixing zone.

Percentage dry weight value

To enable a conversion to fresh weight activity concentrations enter a percentage dry weight sediment or soil value.

100.0 % d.w. soil or sediment

Water

Area	Site	Date		Pb210	Po210	Ra226	Th230	U-238
				Bq/L	Bq/L	Bq/L	Bq/L	Bq/L
Summary Statistics								
Fulton creek watershed	Fulton Lake	2004	mean	2,00E-02	7,50E-03	6,50E-03	6,50E-02	1,53E-02
			std		3,54E-03	2,12E-03	7,78E-02	2,59E-03
			min	2,00E-02	5,00E-03	5,00E-03	1,00E-02	1,34E-02
			max	2,00E-02	1,00E-02	8,00E-03	1,20E-01	1,71E-02

- At least one concentration for each radionuclide must be given, but not all cells have to be filled in.

INPUTS (2)

Isotope	Activity Concentration in water [Bq L-1]	Activity Concentration in sediment [Bq kg-1 d.w.]	Chironomus Riparius [Bq kg-1 f.w.]	Pisidiu [Bq kg-
Pb-210		normal(82.0,17.9,70.0,110.0)		
Po-210	normal(0.0075,0.00354,0.0050,0.01)	normal(82.0,29.5,50.0,130.0)		
Ra-226	normal(0.0065,0.00212,0.0050,0.0080)	normal(36.0,15.2,10.0,50.0)		
Th-230	normal(0.065,0.0778,0.01,0.12)	normal(24.0,5.48,20.0,30.0)		
U-238	normal(0.0153,0.00259,0.0134,0.0171)	normal(20.3,7.46,13.4,33.0)		

Selected cell: [Activity Concentration in water[Bq L-1], Po-210]

Edit Value | Edit Distribution

Edit distribution function for selected cell(s)

Distribution Functions	mean	standard-deviation	lower-cut-off	upper-cut-off	
normal	0.0075	0.00354	0.0050	0.01	Enter

Water

Area	Site	Date		Pb210	Po210	Ra226	Th230	U-238
				Bq/L	Bq/L	Bq/L	Bq/L	Bq/L
Summary Statistics								
Fulton creek watershed	Fulton Lake	2004	mean	2,00E-02	7,50E-03	6,50E-03	6,50E-02	1,53E-02
			std		3,54E-03	2,12E-03	7,78E-02	2,59E-03
			min	2,00E-02	5,00E-03	5,00E-03	1,00E-02	1,34E-02
			max	2,00E-02	1,00E-02	8,00E-03	1,20E-01	1,71E-02

OUTPUTS (1)

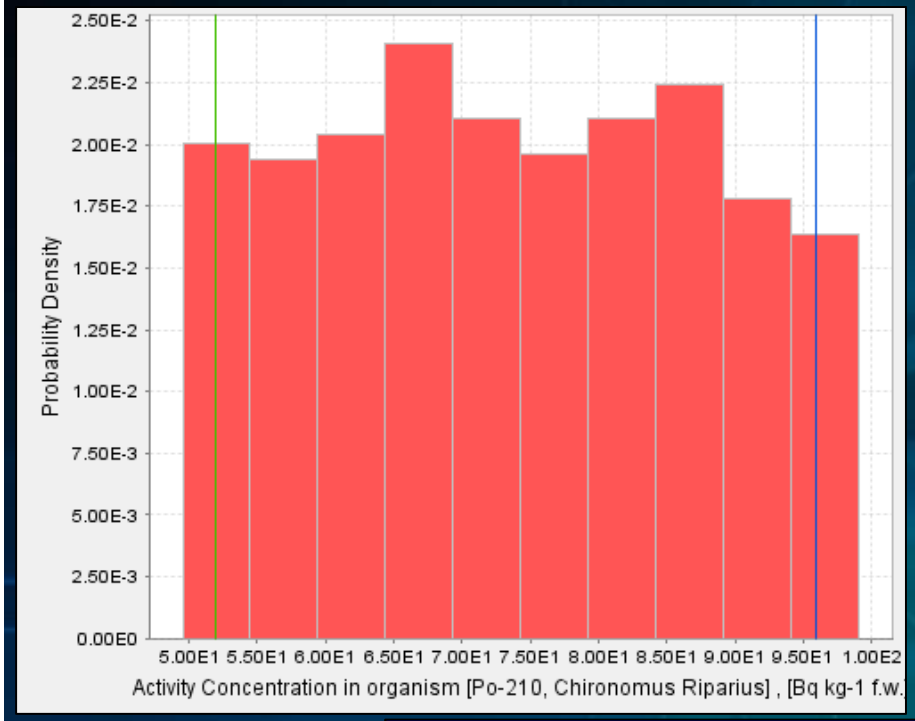
Deterministic Values: for deterministic inputs only

Activity Concentration in organism [Bq kg-1 f.w.] ----- Isotope	Chironomus Riparius	Pisidium sp.	Lake Whitefish	White Sucker
Pb-210	2.00E2	3.40E1	6.00E0	6.00E0
Po-210	N/A	N/A	N/A	N/A
Ra-226	N/A	N/A	N/A	N/A
Th-230	N/A	N/A	N/A	N/A
U-238	N/A	N/A	N/A	N/A

Water								
Area	Site	Date		Pb210	Po210	Ra226	Th230	U-238
				Bq/L	Bq/L	Bq/L	Bq/L	Bq/L
Summary Statistics								
Fulton creek watershed	Fulton Lake	2004	mean	2,00E-02	7,50E-03	6,50E-03	6,50E-02	1,53E-02
			std		3,54E-03	2,12E-03	7,78E-02	2,59E-03
			min	2,00E-02	5,00E-03	5,00E-03	1,00E-02	1,34E-02
			max	2,00E-02	1,00E-02	8,00E-03	1,20E-01	1,71E-02

OUTPUTS (2)

Probabilistic Data: for probability distributions



Statistic	Result
Mean	7.37E1
Variance	1.93E2
Minimum	4.95E1
Maximum	9.90E1

$$\text{Standard Deviation} = \sqrt{\text{Variance}}$$

Water

Area	Site	Date		Pb210	Po210	Ra226	Th230	U-238
				Bq/L	Bq/L	Bq/L	Bq/L	Bq/L
Summary Statistics								
Fulton creek watershed	Fulton Lake	2004	mean	2,00E-02	7,50E-03	6,50E-03	6,50E-02	1,53E-02
			std		3,54E-03	2,12E-03	7,78E-02	2,59E-03
			min	2,00E-02	5,00E-03	5,00E-03	1,00E-02	1,34E-02
			max	2,00E-02	1,00E-02	8,00E-03	1,20E-01	1,71E-02

CONTENTS

RADIOLOGICAL RISK ASSESSMENT

A qualitative or quantitative evaluation of the risk posed to human health and/or the environment by the actual and/or potential presence of pollutants.

- **TIER 1 - TIER 2**

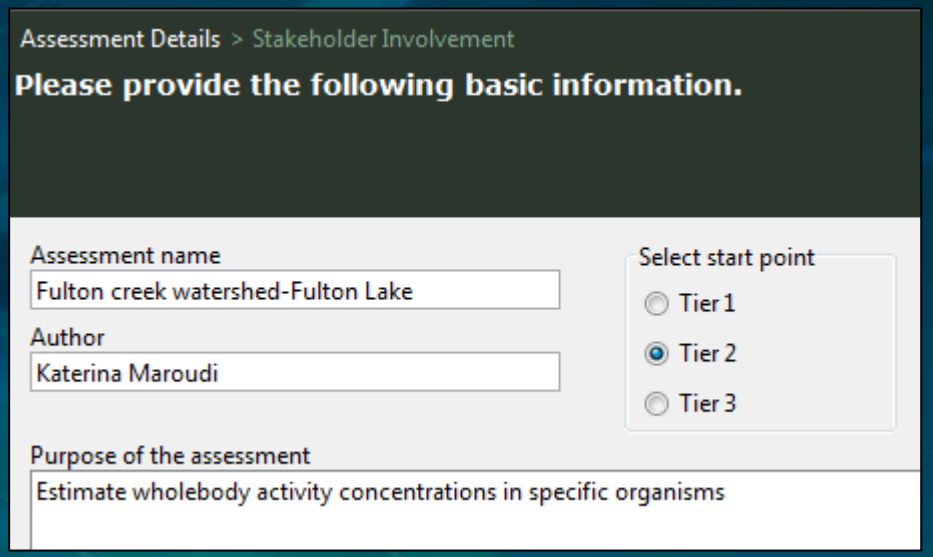
RISK QUOTIENT

- A measure of the risk caused by each contaminant to an organism.
- For radioactive substances:

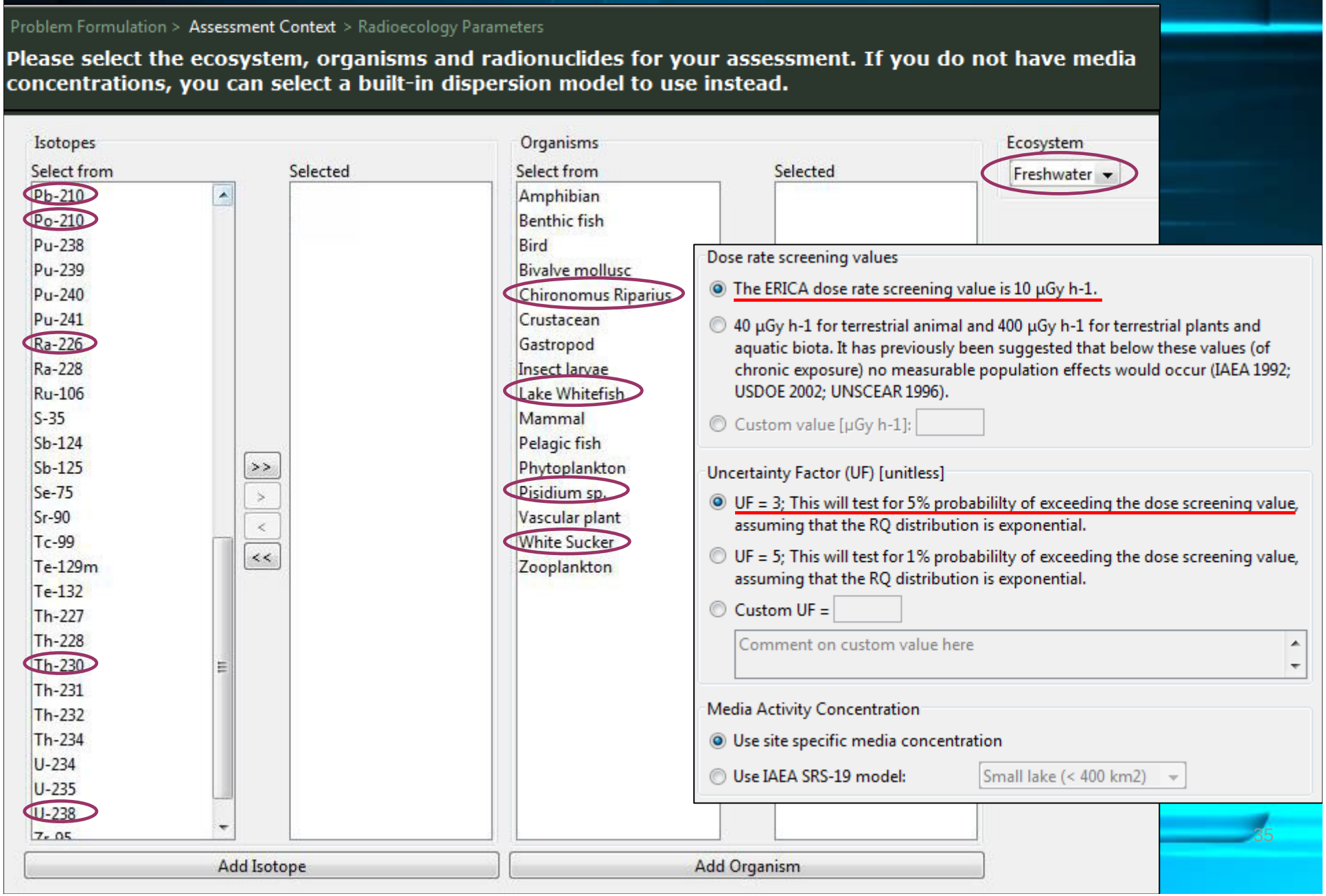
$$Risk\_Quotient = \frac{Media\_Activity\_Concentration}{Environmental\_Media\_Concentration\_Limit}$$

ASSESSMENT DETAILS

- Assessment details
- Stakeholder involvement
- Problem formulation



ASSESSMENT CONTEXT



INPUTS

Occupancy Factors and Radiation Weighting Factors > **Inputs** > Probabilistic Simulation Settings

Please enter your media and/or organism concentrations. At least one concentration must be entered for each radionuclide but not all cells have to be filled in.

Isotope	Activity Concentration in water [Bq L-1]	Activity Concentration in sediment [Bq kg-1 d.w.]
Pb-210	2.00E-2	8.20E1
Po-210	7.50E-3	8.20E1
Ra-226	6.50E-3	3.60E1
Th-230	6.50E-2	2.40E1
U-238	1.53E-2	2.03E1

Activity Concentration

Please enter into the table the best estimate measured or modelled media concentration, or, depending on your problem formulation, the activity concentration at the edge of the mixing zone.

Percentage dry weight value

To enable a conversion to fresh weight activity concentrations enter a percentage dry weight sediment or soil value.

100.0 % d.w. soil or sediment

Water

Area	Site	Date		Pb210	Po210	Ra226	Th230	U-238
				Bq/L	Bq/L	Bq/L	Bq/L	Bq/L
Summary Statistics								
Fulton creek watershed	Fulton Lake	2004	mean	2,00E-02	7,50E-03	6,50E-03	6,50E-02	1,53E-02
			std		3,54E-03	2,12E-03	7,78E-02	2,59E-03
			min	2,00E-02	5,00E-03	5,00E-03	1,00E-02	1,34E-02
			max	2,00E-02	1,00E-02	8,00E-03	1,20E-01	1,71E-02

OUTPUTS

Inputs > Results

These are your results for Tier 2. Click on the tabs to see the assessment details
To finish click -Record decision- tab and provide a justification.

Risk | Background | Effects | Tables | Plots | Record decision

Total Dose Rate and Risk Quotient

For at least one organism the screening dose rate is exceeded.
We recommend you continue your assessment.

Uncertainty Factor = 3.0; This tests for 5% probabililty of exceeding the dose screening value, assuming that the RQ distribution is exponential

Organism	Total Dose Rate per organism [µGy h-1]	Screening Value [µGy h-1]	Risk Quotient (expected value) [unitless]	Risk Quotient (conservative value) [unitless]
Chironomus Riparius	4.06E0	1.00E1	4.06E-1	1.22E0
Pisidium sp.	1.03E1	1.00E1	1.03E0	3.10E0
Lake Whitefish	3.48E-1	1.00E1	3.48E-2	1.04E-1
White Sucker	3.48E-1	1.00E1	3.48E-2	1.04E-1

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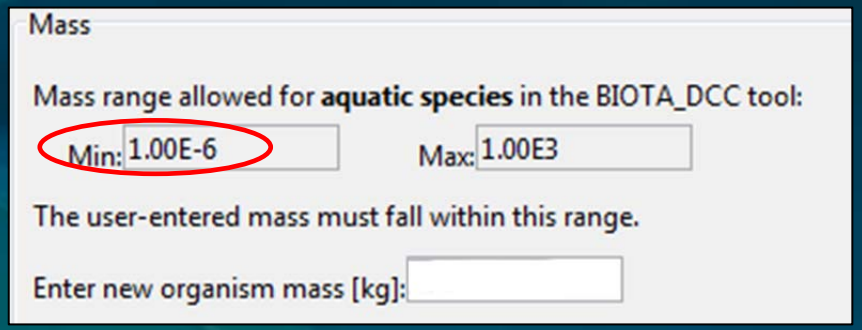
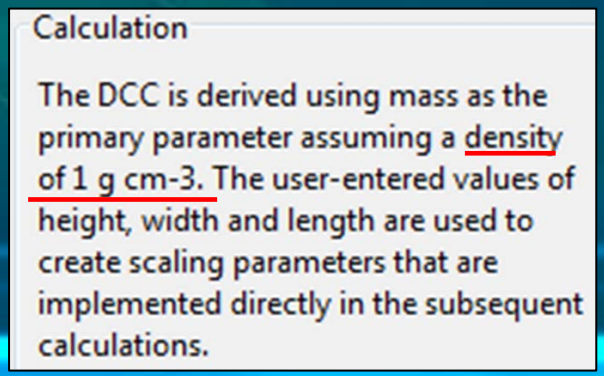
REMARKS (1)

1. Parameters defined by the ERICA Tool:
   - Dose Rate Screening Value
   - Environmental Media Concentration Limits
   - Distribution Coefficients (K_d) (per radionuclide)
   - Concentration Ratios (CR's) (per radionuclide and organism)
   - Radiation Weighting Factors

REMARKS (2)

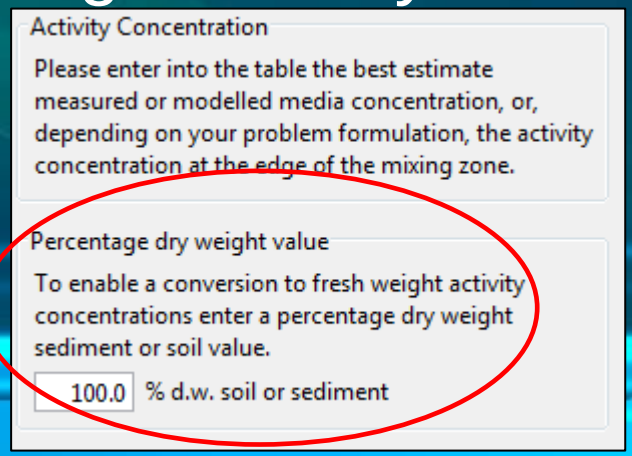
2. Creation of new organisms:
   - Occupancy factors chosen arbitrarily
   - CR values missing
   - “Chironomus Riparius” and “Pisidium sp.” ⇨ mass range
   - “Chironomus Riparius” ⇨ mass range under the minimum value
   - Organism density assumed 1g/cm^3





REMARKS (3)

3. <u>Percentage dry weight sediment or soil value:</u> enables a conversion to fresh weight activity concentrations.
   - Biota and water activity concentrations (via CRs and K_ds) ⇨ soil and sediment activity concentrations on a dry weight basis
   - External dose rates ⇨ fresh weight activity concentrations.
     - The assumption of 100% leads to conservative dose rates.



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CONCLUSIONS

- ✓ Fast and easy to use
- ✗ Assumptions
- ➢ Results dependence on parameters choice
- ➢ Results uncertainty
- ➢ Results verification

PERSPECTIVES (1)

- Consider all exposure pathways in a more realistic approach
- Take into account trophic relationships between species (Food chain)
- Study transfer parameters
- Consider biological and ecological half-lives
- Estimate effective dose equivalent
- Embody human into the Tool

PERSPECTIVES (2)

- Input organism and media composition and mass density
- Input radionuclide distribution in media and organism
- Create complex geometries - phantoms
- Provide an ERICA Tool verification
- Make a comparison of different Tiers results

Thank you
for your attention!