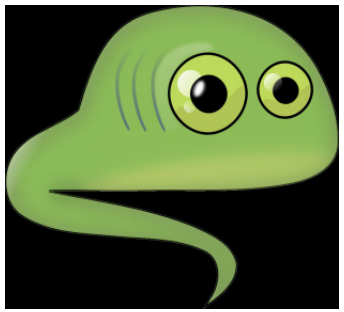
External radiation doses to biota

Monte Carlo dose model calculations with TADPOLE



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Background

- In radiological environmental protection, realistic dose models are needed in site-specific risk assessments for biota
- Little guidance exists for cases where the screening values are exceeded
- Screening dose models do not calculate doses from heterogeneous distributions of radionuclides in the soil profile
- It can be important to be able to calculate doses to organs such as skin, liver, and gonads in reference organisms

The aim of the project

- To develop Monte Carlo models applicable to detailed external dose calculations of non-human biota in the vicinity of a radioactive medium
- To develop a dose model that can calculate external dose rates to specific organs in biota from a soil profile with heterogeniously distributed radionuclides, taking the soil characteristics into account
- To verify the dose models in experiments with frog- and worm phantoms

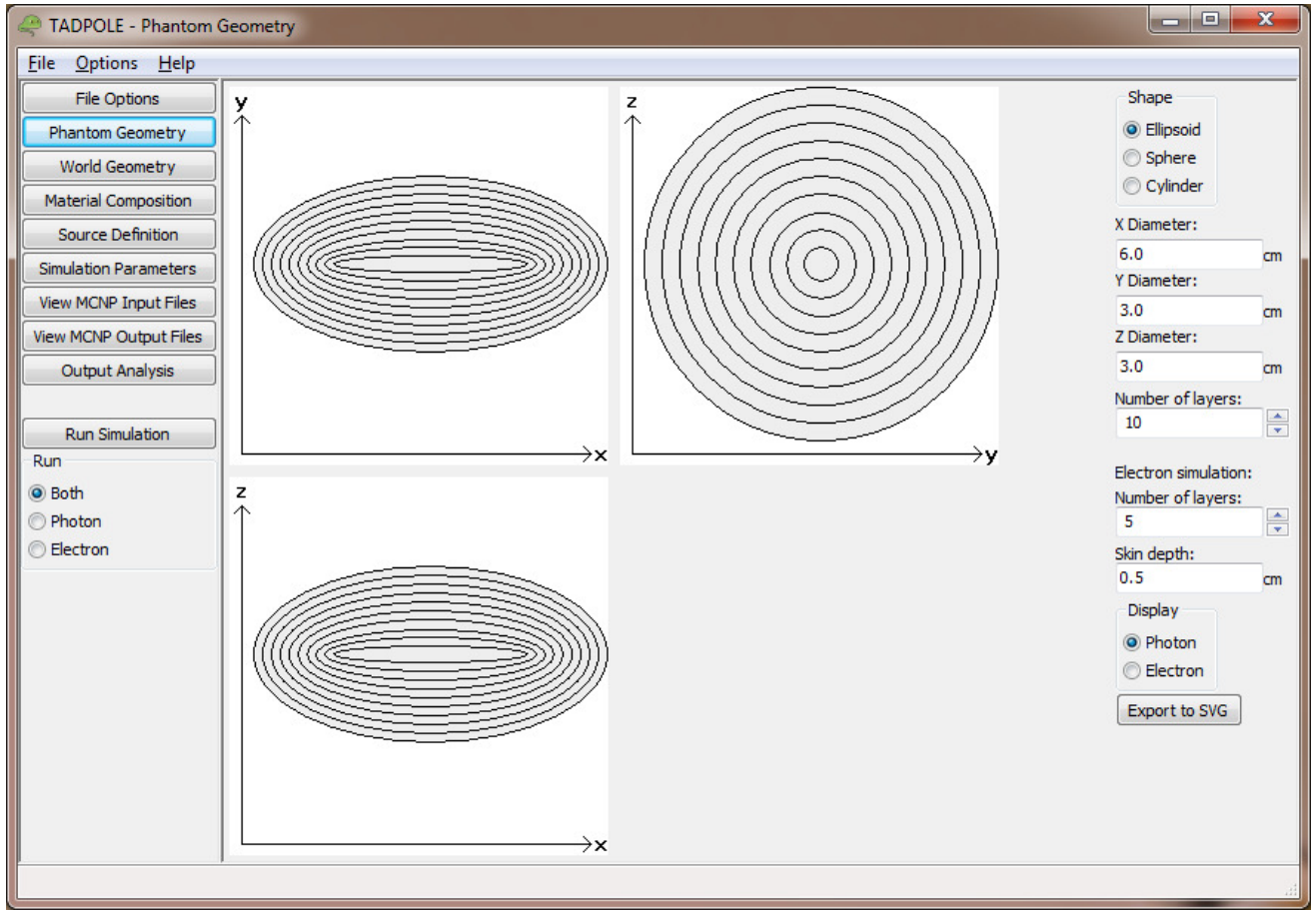
Methods

- Monte Carlo N-Particle Transport Code version 5 (MCNP5)
- Graphical user interface **TADPOLE**, **T**errestrial and **A**quatic **D**ose assessment **P**rogram for **O**rganisms in their **L**ocal **E**nvironment
- Only a few parameters are fixed to make it applicable to a wide range of exposure situations
- Created a user manual for TADPOLE

TADPOLE

- The radioactive medium has the shape of a cylinder
- The organism can be placed at any depth
- The size and shape of the organism can be defined
- The size of the surrounding material volumes can be defined
- The depth distribution of elemental compostions and activity concentrations can be defined
- Determines the absorbed dose per day to the organism as a function of depth

TADPOLE: phantom geometry menu



Size and shape of the organism

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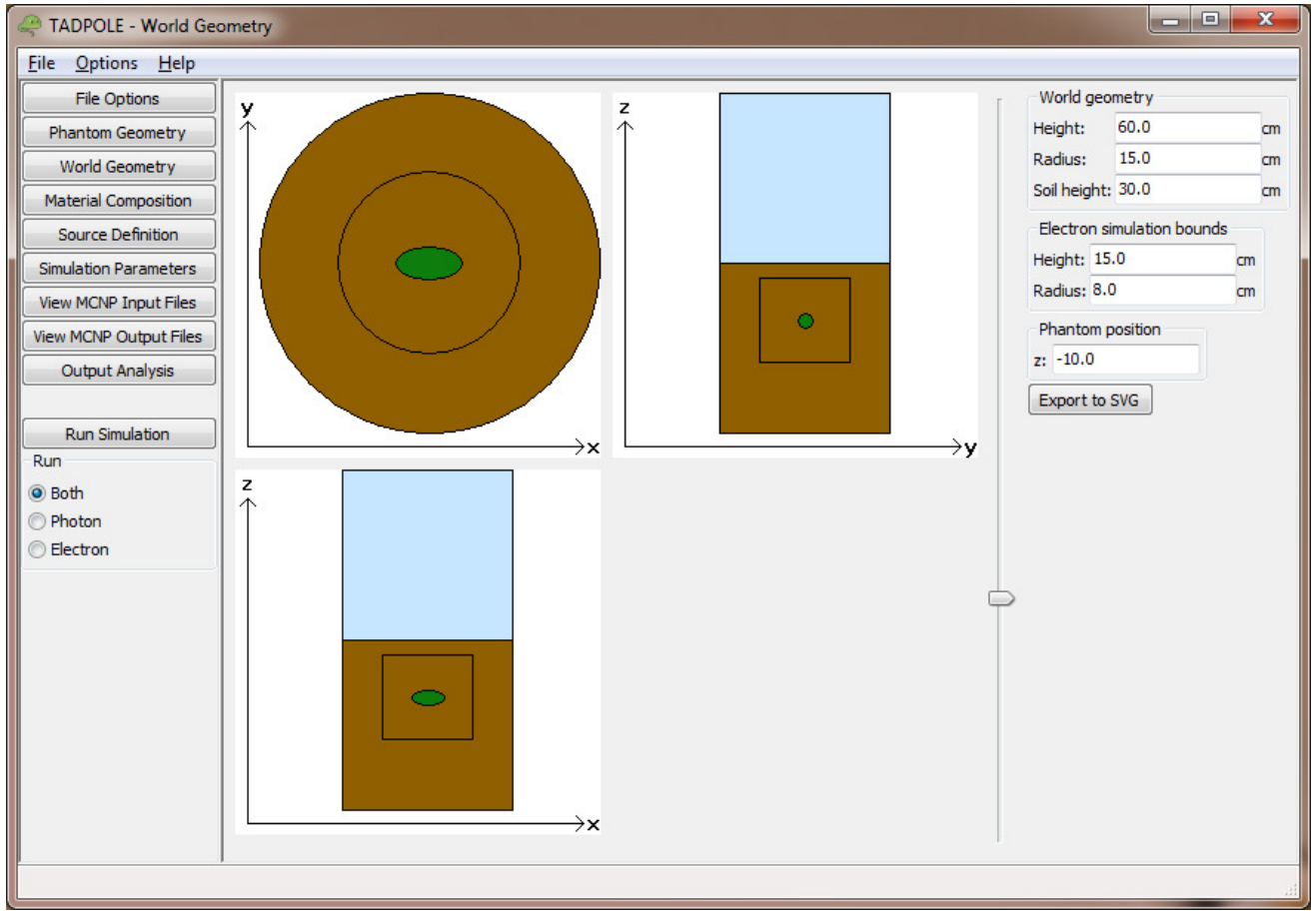
TADPOLE: world geometry menu



The size of surrounding and upper medium, and position of the organism

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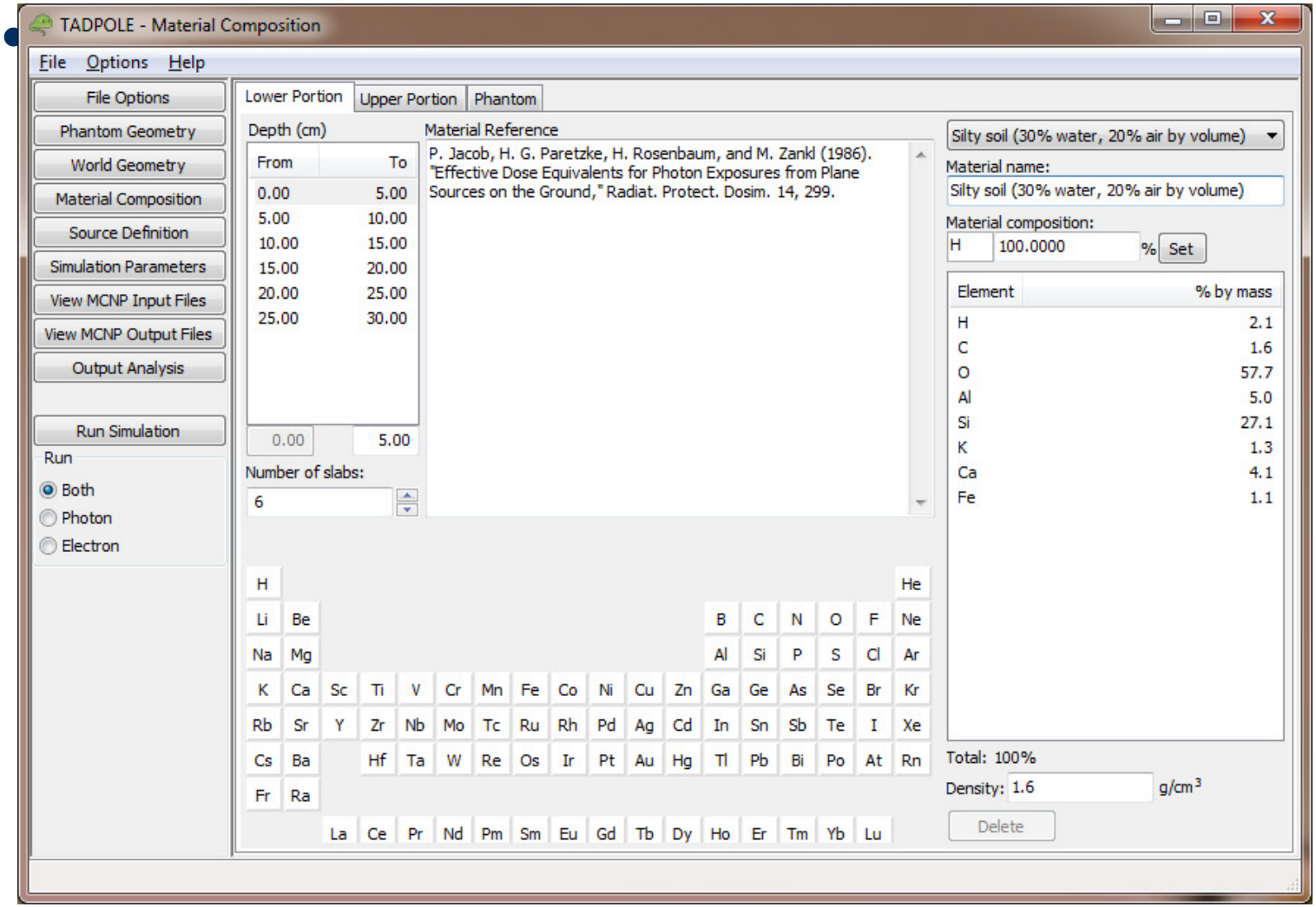
TADPOLE: material composition menu



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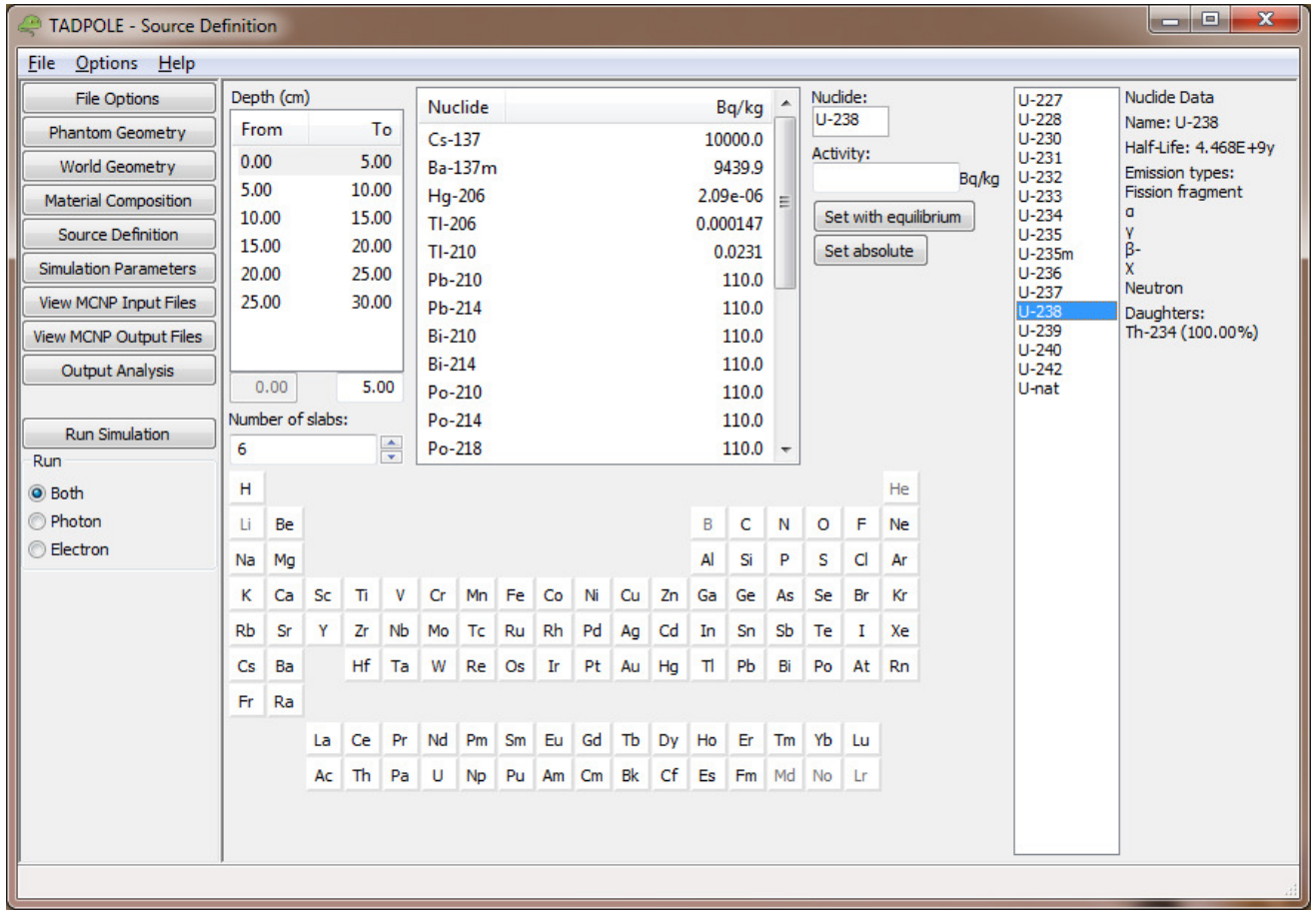
TADPOLE: source definition menu



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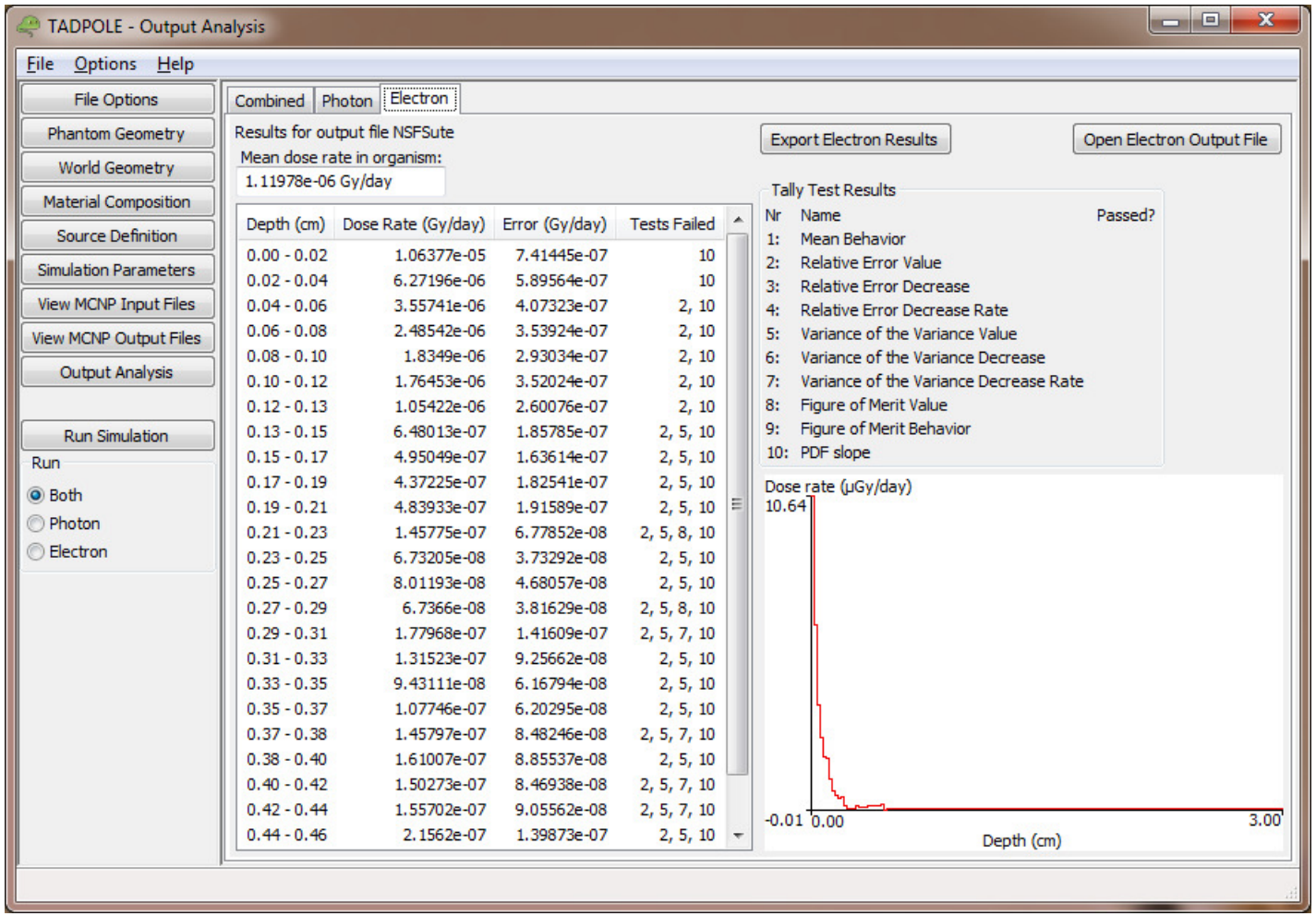
TADPOLE: output analysis menu



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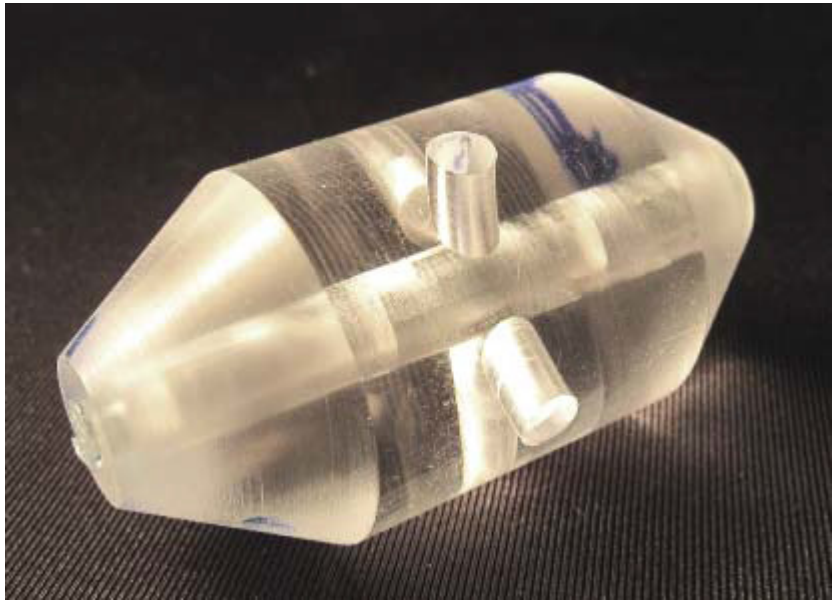
Verification experiment 1: laboratory measurement

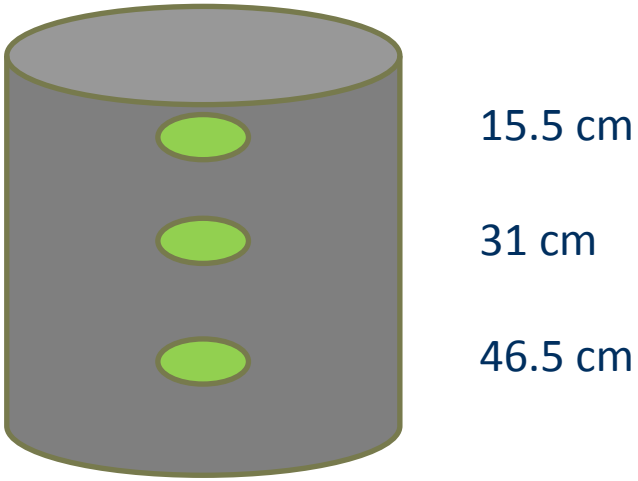
- To verify calculations with TADPOLE
- Frog-phantoms of PMMA with TLDs were prepared



Verification experiment 1

- The frog-phantoms were positioned at three different depths in a homogeneous medium of KNO_3

  in a steel barrel with a radius of 28.35 cm, 62 cm high
- 12 dosimeters placed at different depths
- Activity conc. of ^{40}K in medium was 12 100 ± 350 Bq/kg.
- The exposure lasted 50 days.



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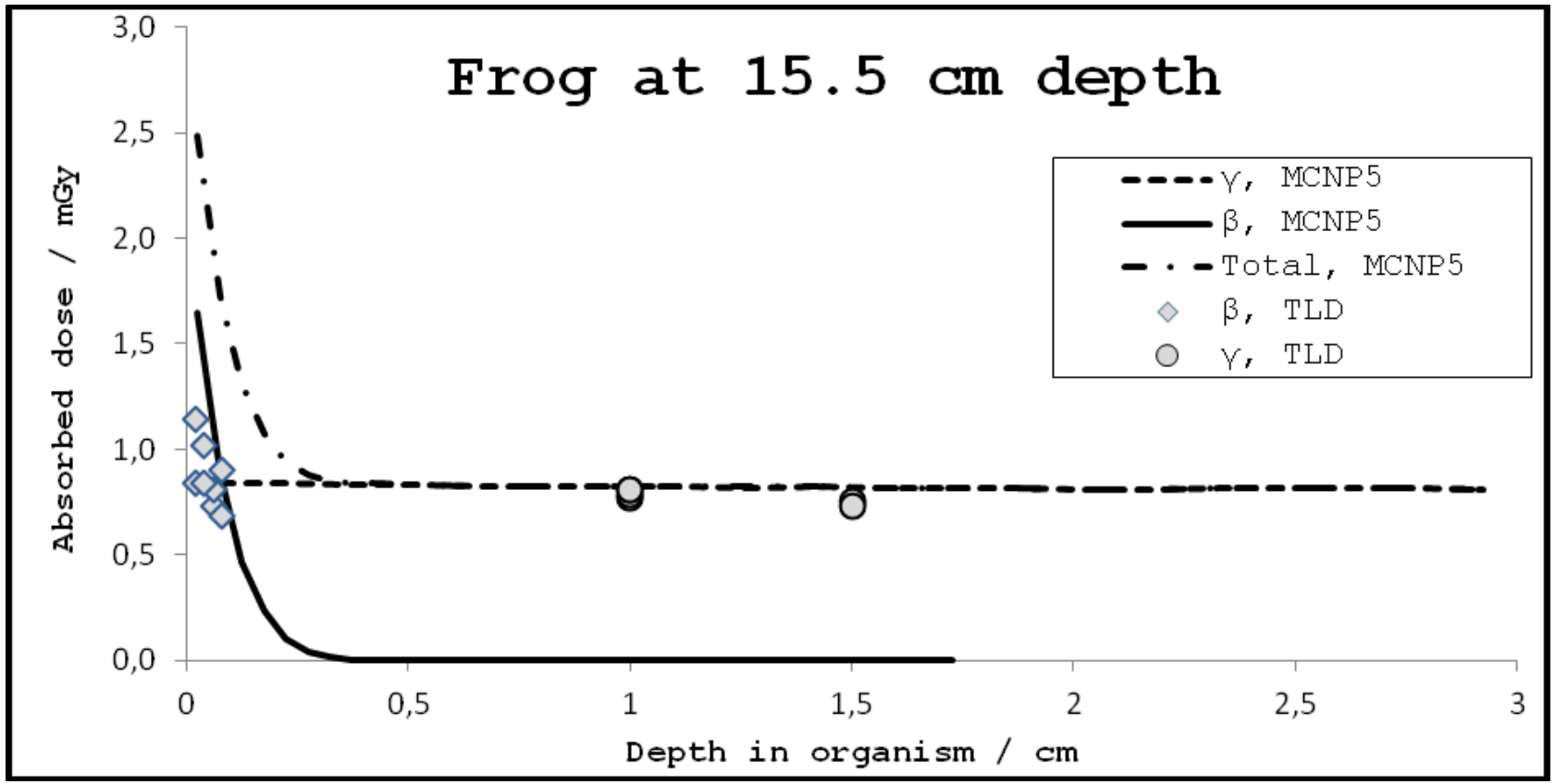
Verification experiment 1: Results



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Verification experiment 2: field measurement

- The study site was a wetland area in Utnora, Sweden, that have receive fallout of ^{137}Cs from the Chernobyl accident in 1986.
- Four frog-phantoms and two worm-phantoms of PMMA with TLDs were prepared.

- The frog-phantoms were placed at 3, 5, 10 and 15 cm depth and the worm-phantoms were placed at 5 and 10 cm depth.

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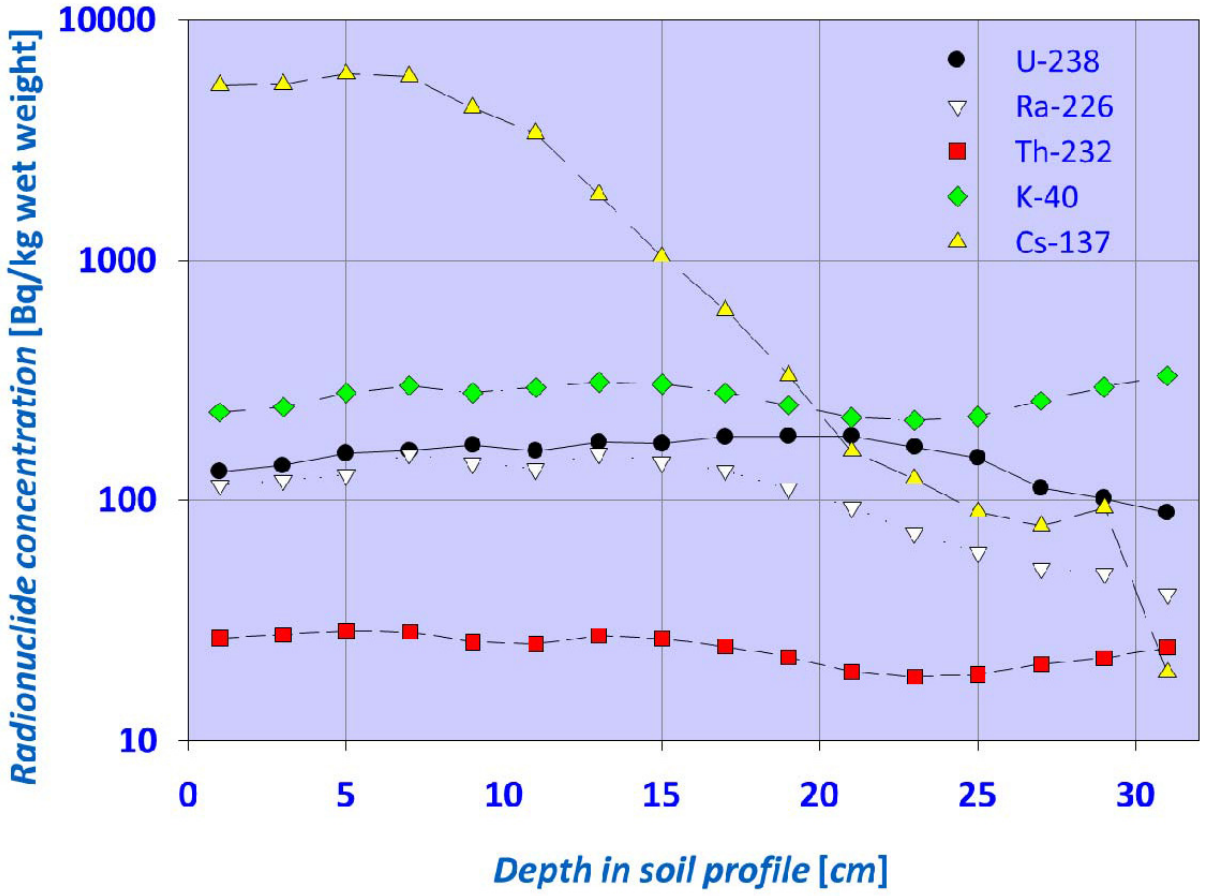
Verification experiment 2: field measurement

- Four soil cores of 10 cm diameter were collected, 1 meter in different directions from phantom positions. Sliced in 2 cm segments down to 30 cm.
- Activity concentrations of main radionuclides ^{137}Cs, ^{40}K, ^{238}U, ^{226}Ra, ^{232}Th were analyzed at Linköping University.
- Material composition of soil were analyzed in the profile by ICP-MS and GC techniques by ALS Scandinavia AB.
- Exposure lasted 200 days over the winter period.

Verification experiment 2: field measurement



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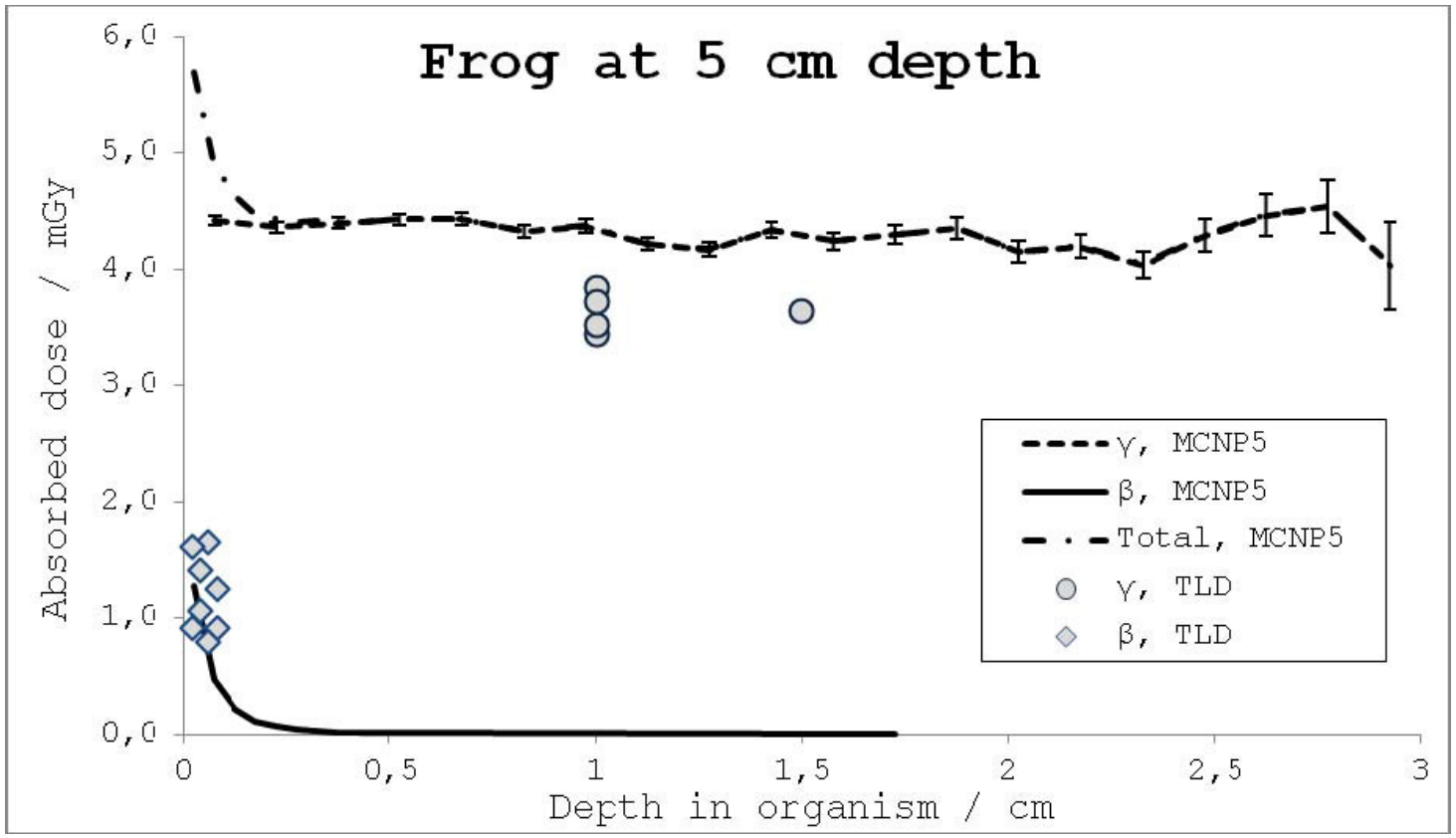
Verification experiment 2: Results

- In TADPOLE the soil cylinder were set to assure at least 75 cm of soil laterally and below the organism.



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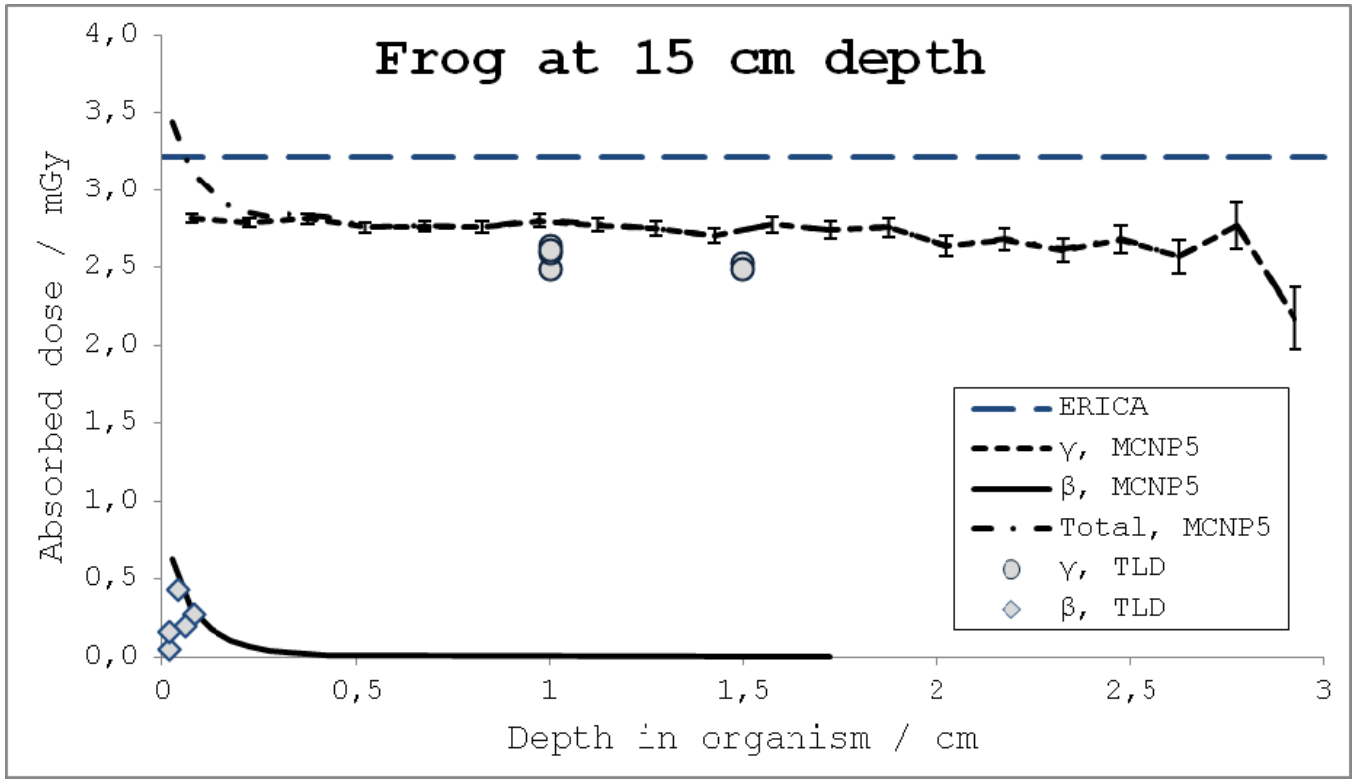
Verification experiment 2: Results

- Calculations with ERICA tool were performed for a frog and a worm positioned at 25 cm depth in 50 cm thick soil. The activity was set to mean of upper 10 cm.



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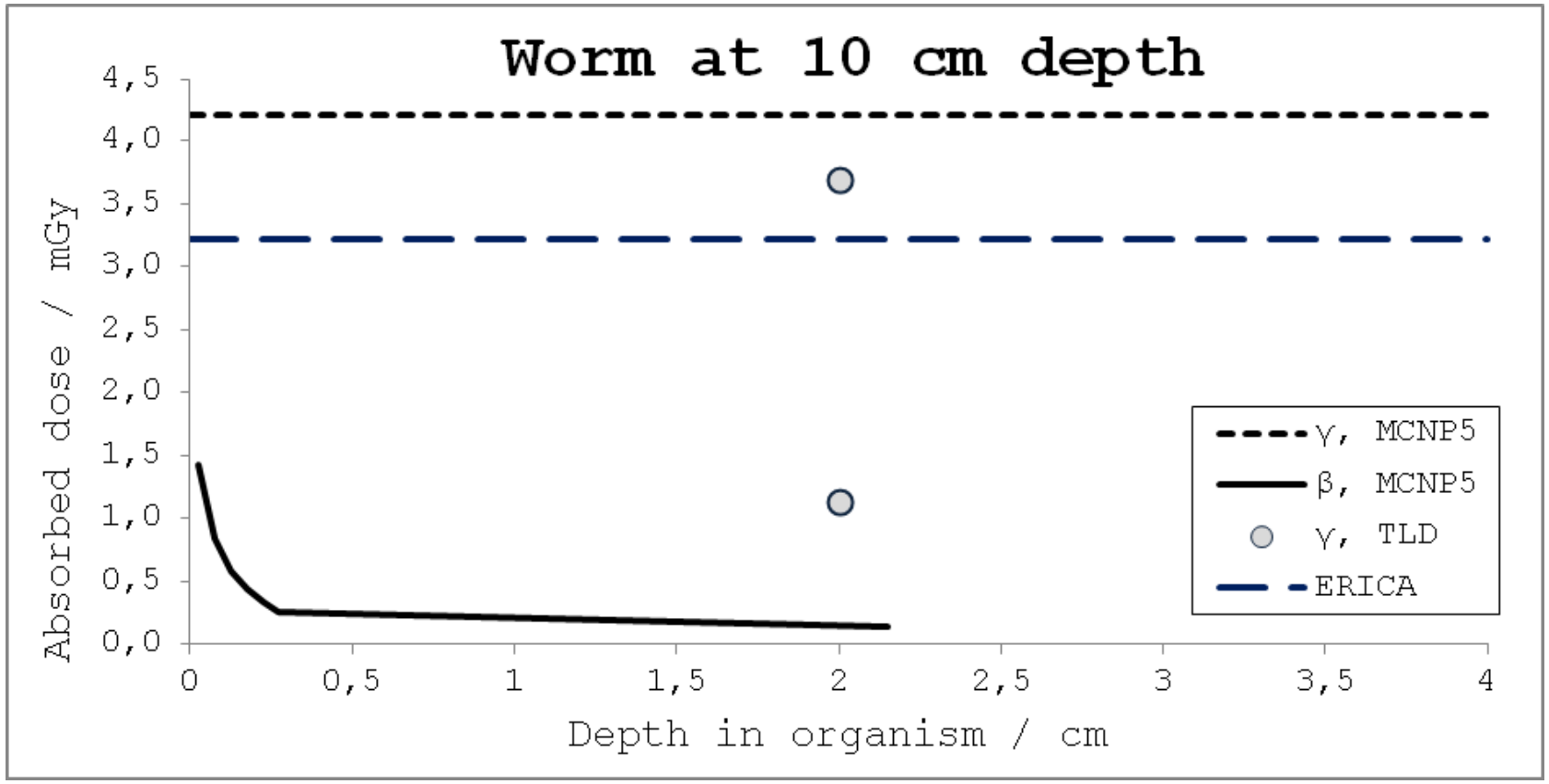
Verification experiment 2: Results



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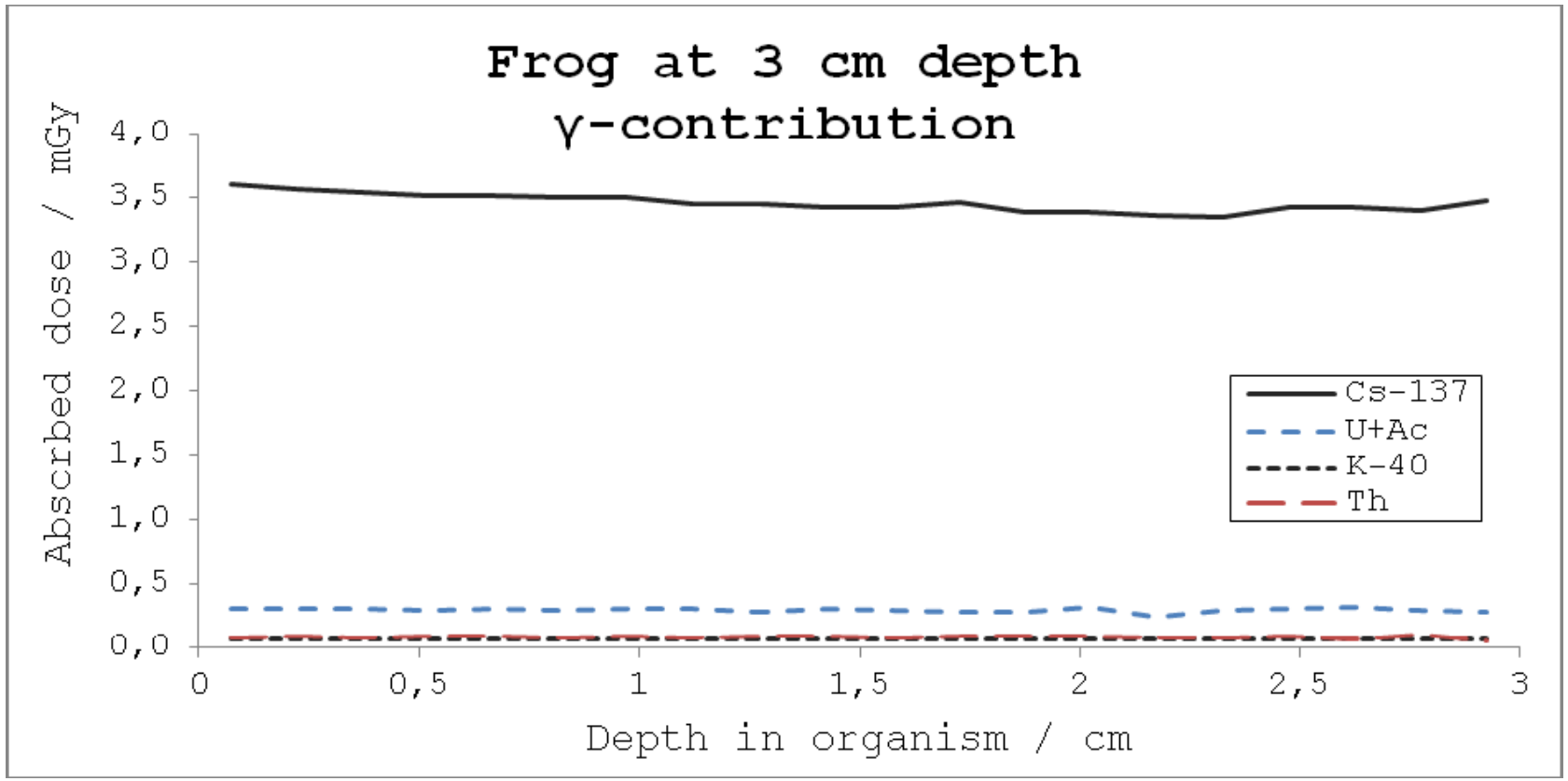
Verification experiment 2: Factors affecting results

- The exposure was performed during the winter period and the sampled soil may not have been characteristic for the whole period, especially concerning water content.
- Secular equilibrium was assumed between ^{226}Ra and ^{222}Rn and its daughters which may overestimate the source term.
- The TLD response may have been affected by the cold conditions.
- The magnitude of post-irradiation fading of the TLD in situ may differ from literature data, obtained in controlled laboratory conditions.

Verification experiment 2: Results



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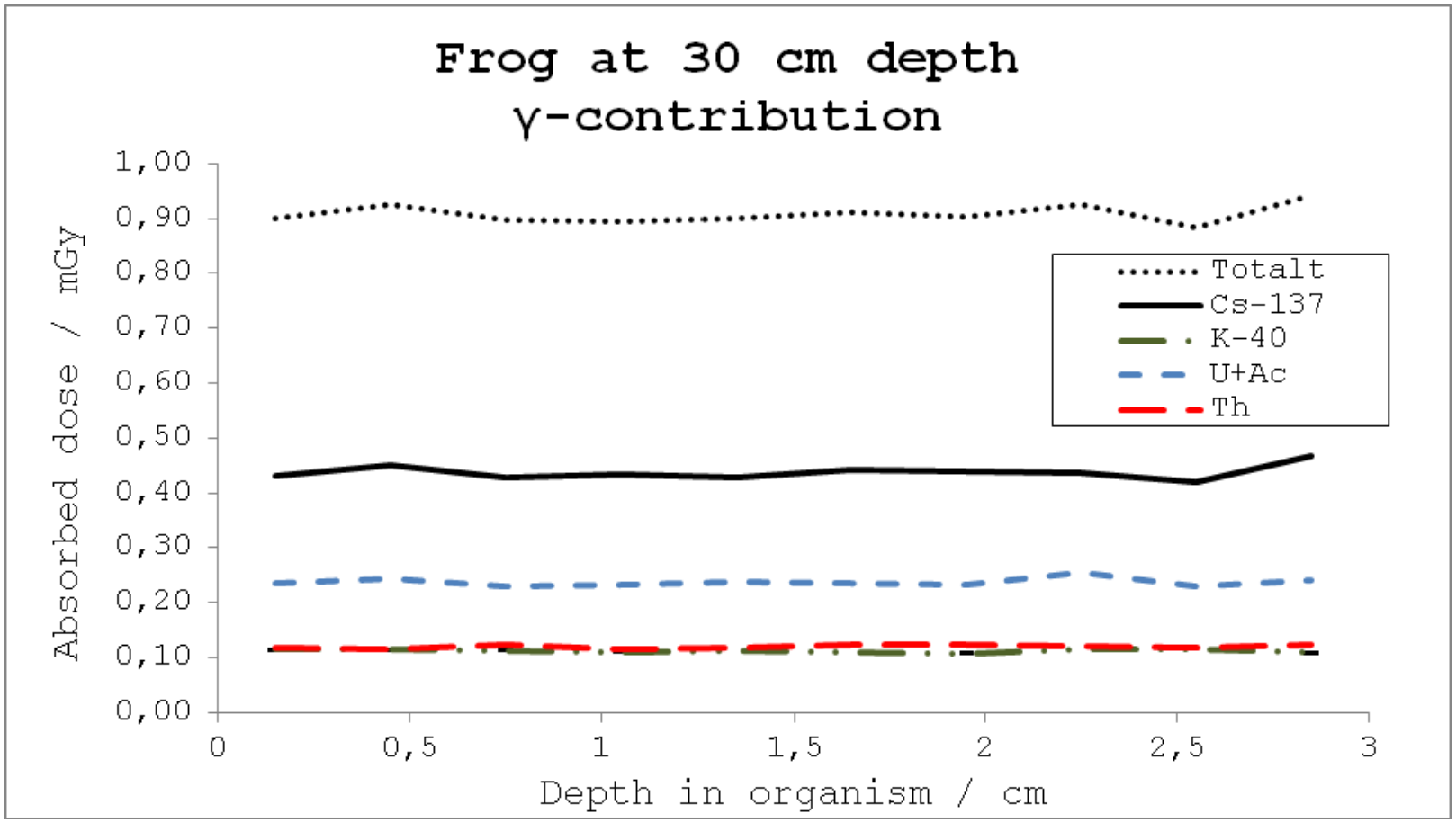
Verification experiment 2: Results



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Conclusions

- A graphical editor TADPOLE was created to facilitate dose calculations with MCNP5. It is designed for site-specific assessment of external doses to wildlife.
- A first verification experiment in the lab resulted in TLD doses to frog-phantoms close to calculated doses.
- A second verification experiment in the field resulted in frog- and worm-phantom measurements significantly different from calculated doses possibly due to insufficient control of environmental parameters during the winter period.
- TADPOLE can be a useful dose model when detailed, site-specific dose assessments are needed (soil profiles, sensitive organs) and has the potential to be extended to also cover internal dose calculations in the future.

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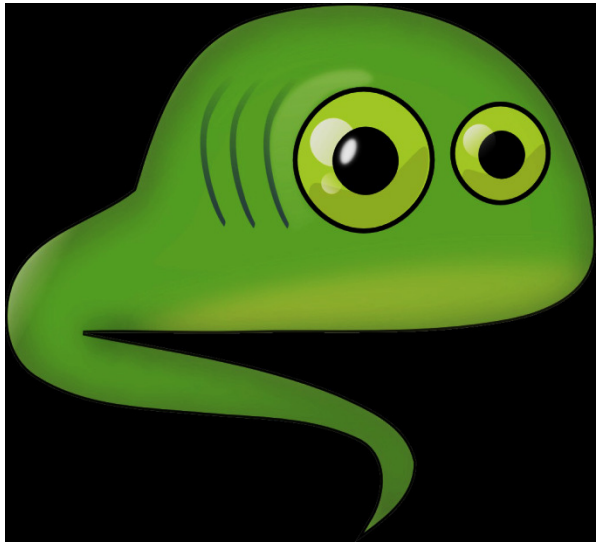
Thank you for your attention!



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