Development of a software for visualizing the effect of location and occupancy factors when calculating external exposure from deposited radionuclides

Margarita Tzivaki

University of Ontario Institute of Technology

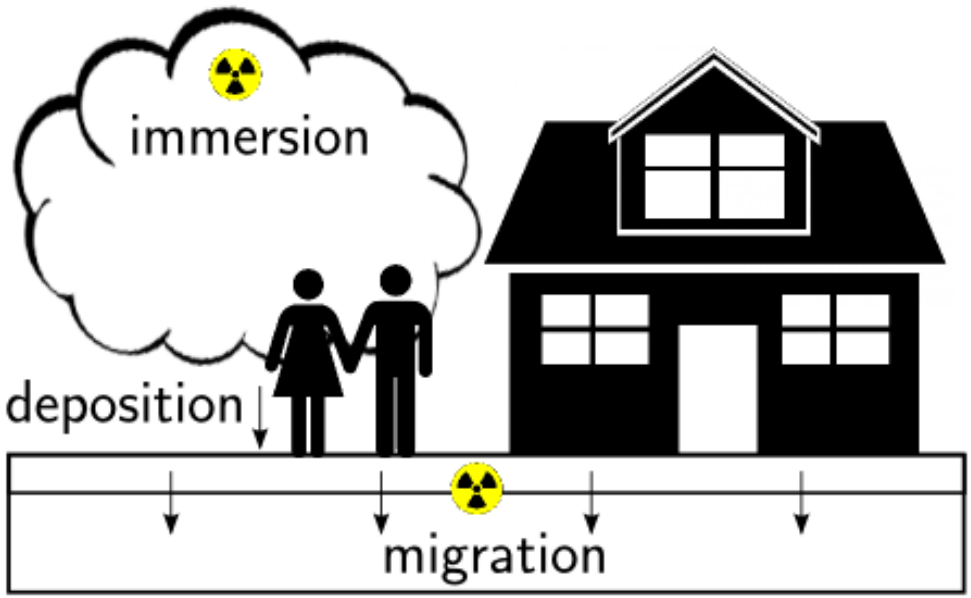
Faculty of Energy Systems and Nuclear Science

June 6, 2017

Introduction

External dose:

1. Dose due to immersion
2. Dose due to deposition



General considerations

- Nuclide decay
- Exposure geometry
- Population habits (location and occupancy)

External dose due to deposition

$$e_{dep} = \dot{e}_{dep} \int_0^T e^{(-\lambda_i t)} r(t) dt$$

$$r(t) = p_1 exp\left(-\frac{ln2}{T_1} t\right) + p_2 exp\left(-\frac{ln2}{T_2} t\right)$$

- **Dose rate coefficients ($\dot{e}_{dep}$):** infinite mono-energetic plane source [1]
- **Attenuation function ($r(t)$):** migration of nuclides in the soil [2]

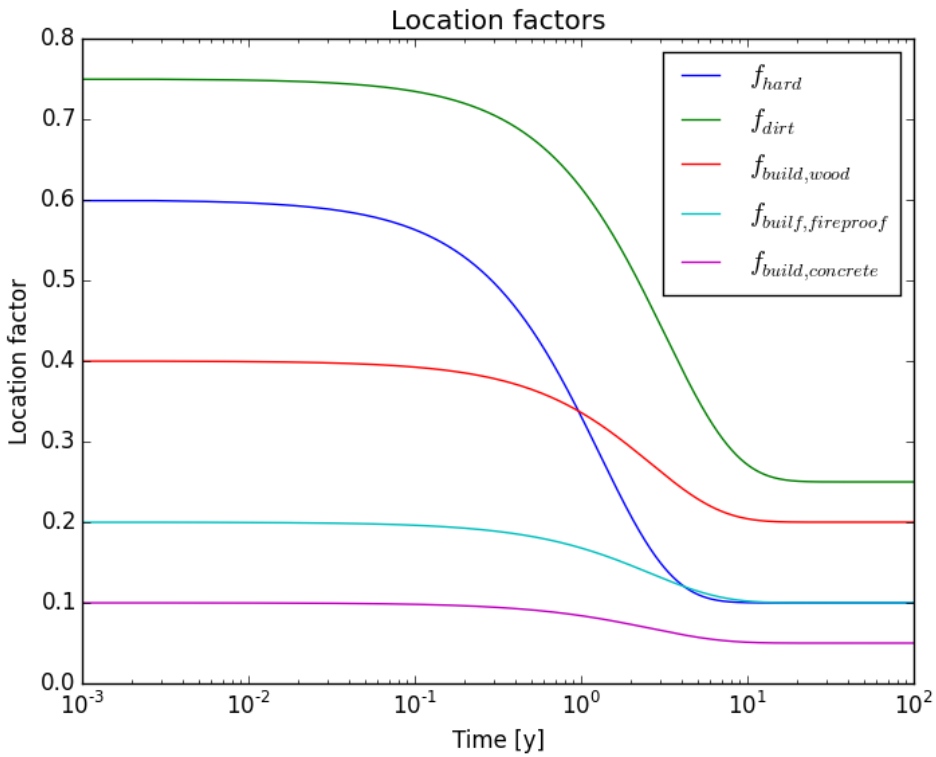
[1] Petoussi-Henss, N., et al. "Organ doses from environmental exposures calculated using voxel phantoms of adults and children." *Physics in medicine and biology* (2012)

[2] Golikov, V., et al. "External exposure of the population living in areas of Russia contaminated due to the Chernobyl accident." *Radiation and environmental biophysics* (2002)

Location factor

Accounts for the impact of individual's location [3]

1. Paved surfaces f_{hard}
2. Unpaved surfaces f_{dirt}
3. Buildings f_{build}
   - concrete
   - wood, fireproof
   - wood



[3] Golikov, V., et al.

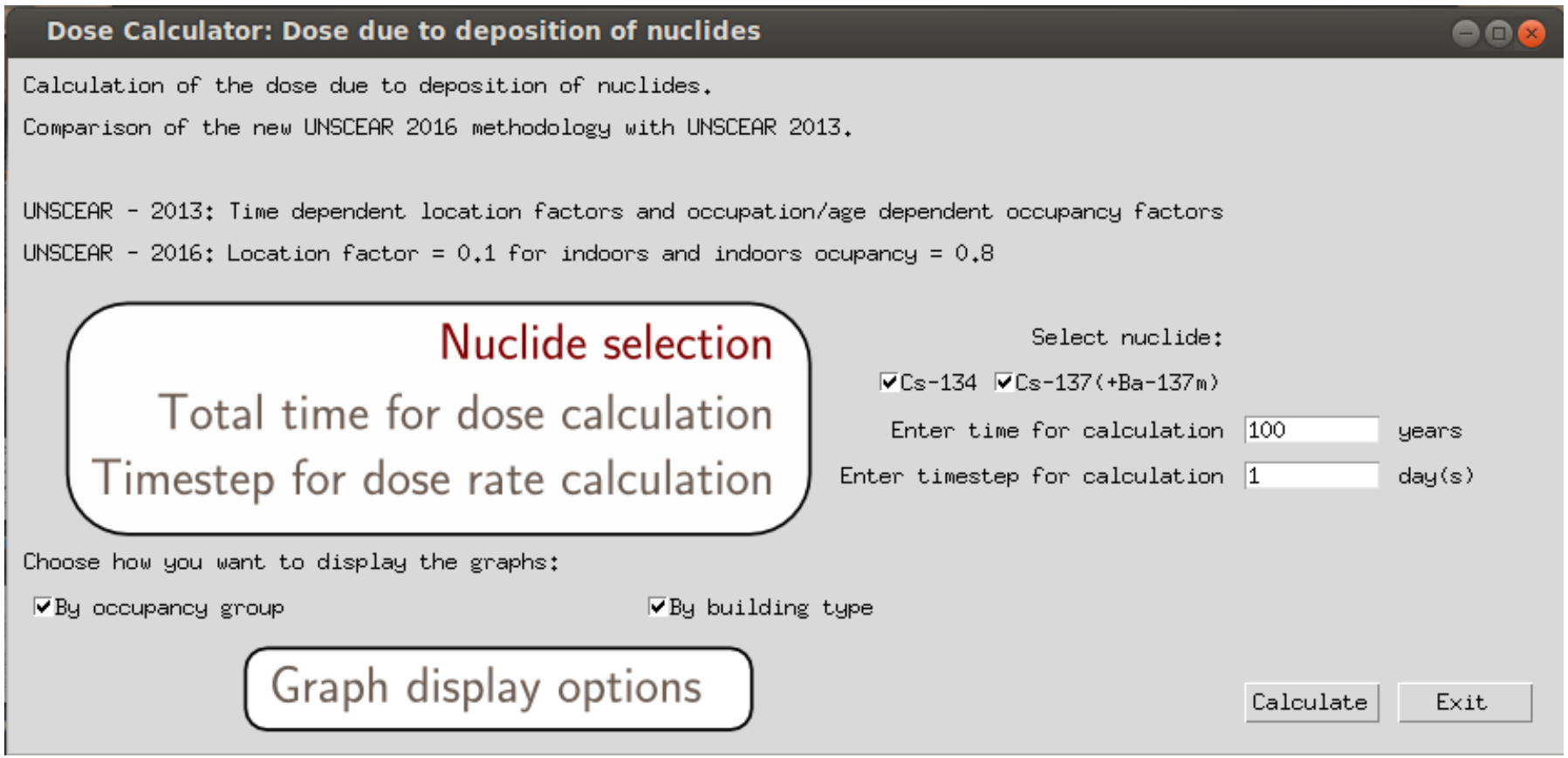
Occupancy factor

Describes the time spent by a certain population group member in a location [4].

Building Type	O.F. outdoor worker	O.F. indoor worker	O.F. Child 1-year	O.F. Child 10-years
Paved Surface	0.2	0.05	0.1	0.05
Unpaved Surface	0.1	0.05	0.1	0.1
Wood, 1-3 storey	0.7	0.9	0.8	0.85
Wood, 1-3 storey, fireproof	0.7	0.9	0.8	0.85
Concrete, multi-storey	0.7	0.9	0.8	0.85

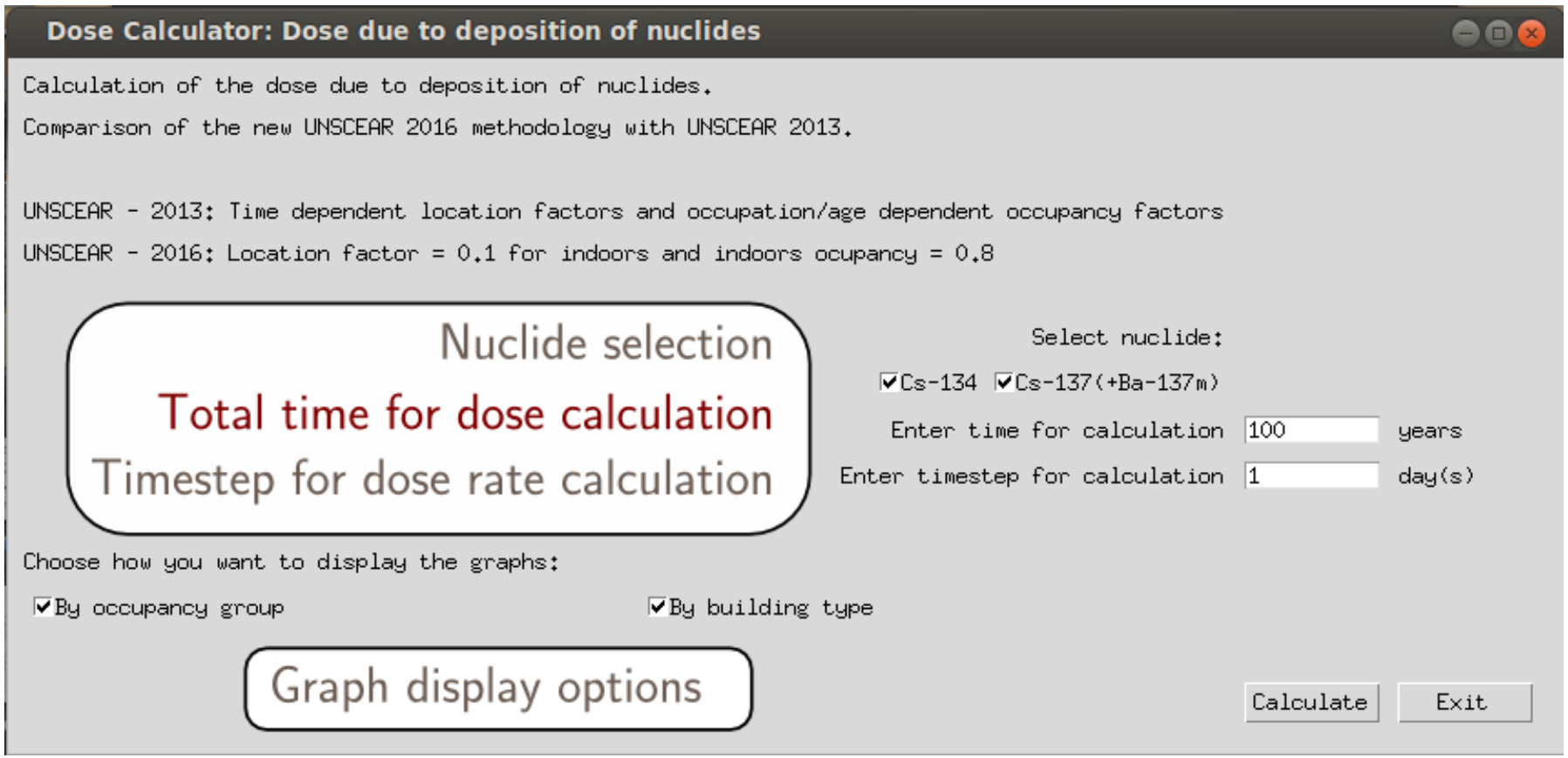
[4] United Nations Scientific Committee on the Effects of Atomic Radiation. "UNSCEAR 2013 Report Volume I. Report to the general assembly scientific annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami." United Nations (2014)

User Interface[5]



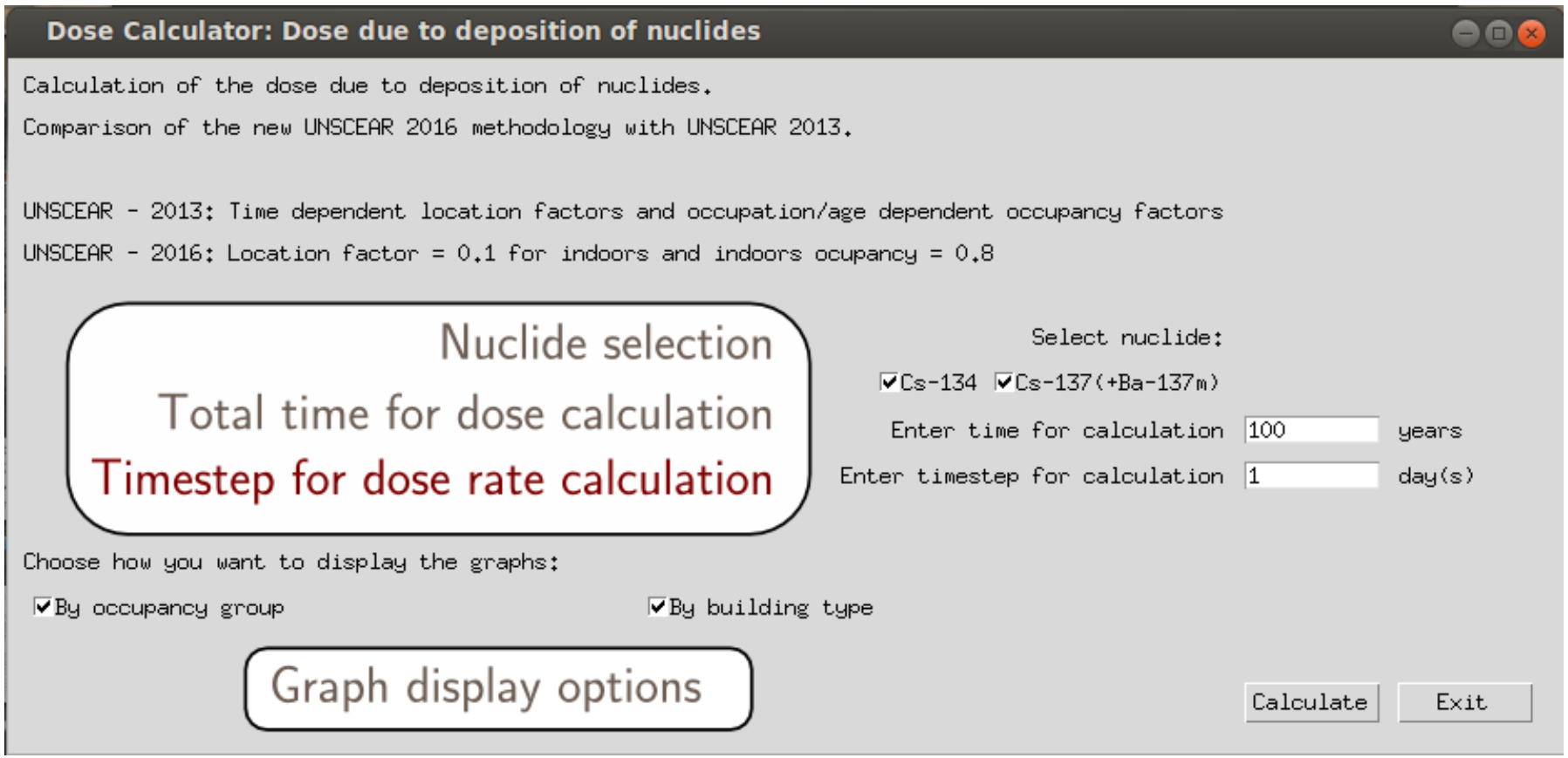
[5]Implemented in Python 2.7.8 with TKInter

User Interface[6]



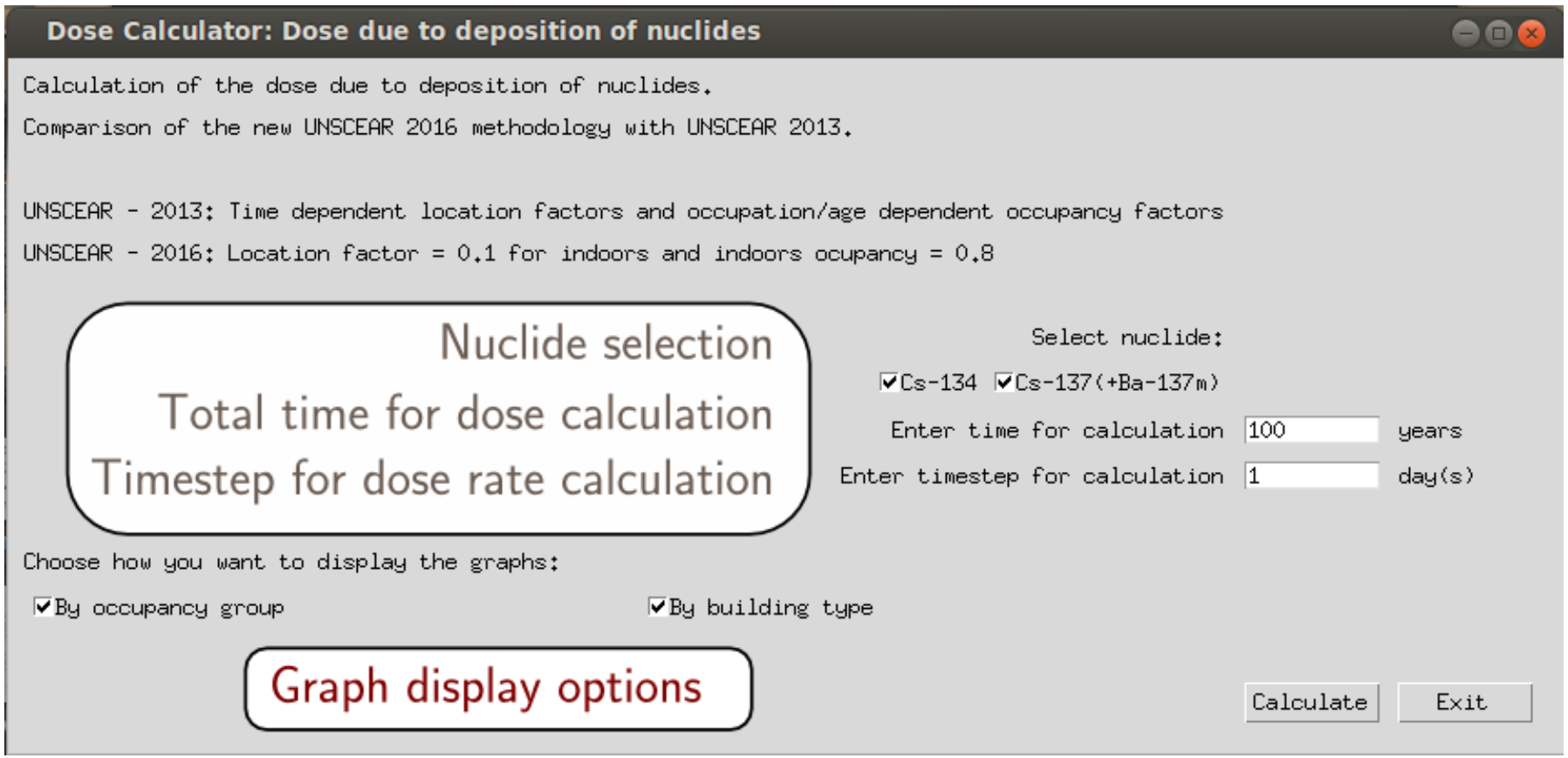
[6]Implemented in Python 2.7.8 with TKInter

User Interface[7]



[7]Implemented in Python 2.7.8 with TKInter

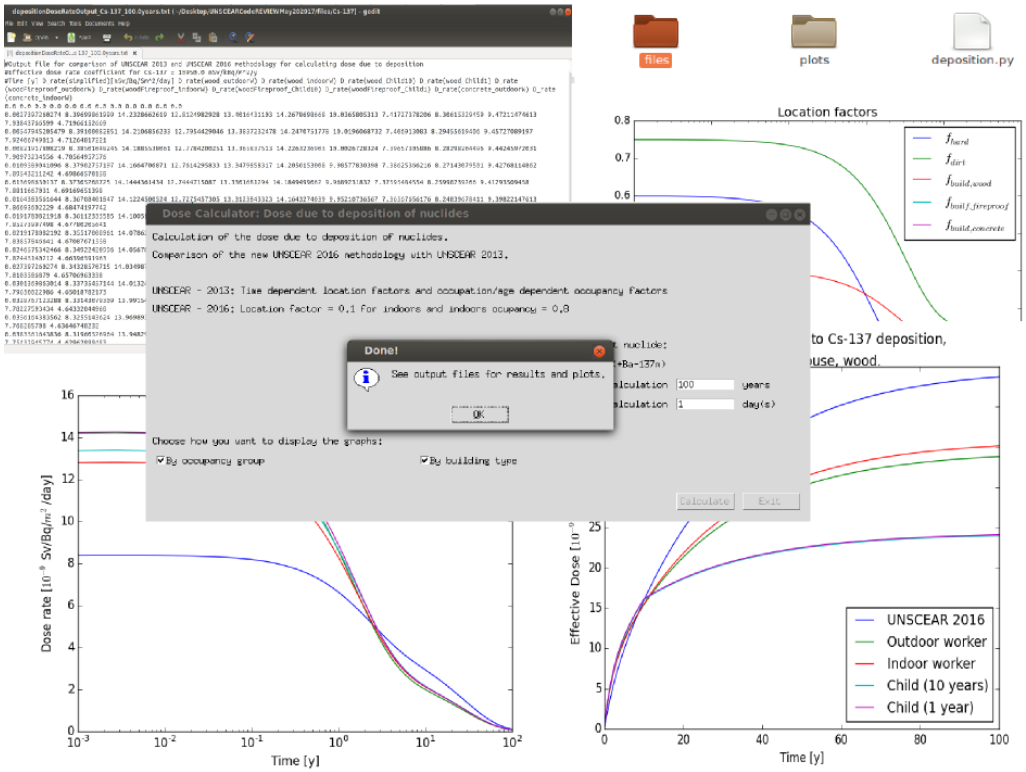
User Interface[8]



[8]Implemented in Python 2.7.8 with TKInter

Calculation and Output

- Location factors development with time
- Space separated text files of dose values
- Time development of effective dose
- Time development of dose rate



UNSCEAR 2016 [9] simplified methodology

Location factor: 0.1 indoors

Occupancy factors: 0.8 indoors, 0.2 outdoors

Potential issues:

- Overestimation of the effective dose for 100 years.
- Underestimation of the dose rate in the short term.

[9] UNSCEAR. Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly and Scientific Annexes A, B, C and D. UNSCEAR 2016 Report. United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations sales publication E.17.IX.1. United Nations, New York, 2017.

Comparison of Methodologies

Scope

- Test a short and long lived nuclide (Cs-134, Cs-137)
- Test the performance of the new methodology in the long and short term
- Quantify over- and underestimation where applicable

Inputs

Example indoor worker: t= 100 y for 1-3 storey building

Parameter	UNSCEAR 2013	UNSCEAR 2016
Population	adult	adult
Outdoor occupancy [%]	10	20
paved	5	–
unpaved	5	–
Indoor Occupancy [%]	90	80
Location factor outdoors	h_{hard}, f_{dirt}	1
Location factor indoors	h_{build}	0.1

Calculations

Example indoor worker: t= 100 y for 1-3 storey building

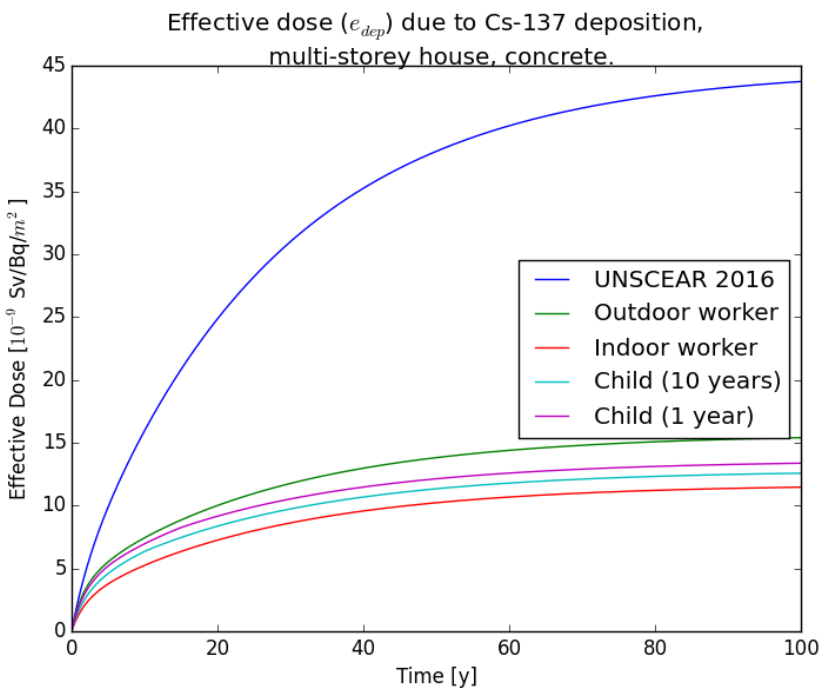
$$e_{dep,UNSCEAR2013} = 0.9 \cdot \sum_{0}^{100} e_{dep}(t_i) \cdot f_{build}(t_i) + 0.05 \cdot \sum_{0}^{100} e_{dep}(t_i) \cdot f_{dirt}(t_i) + 0.05 \cdot \sum_{0}^{100} e_{dep}(t_i) \cdot f_{hard}(t_i)$$

$$e_{dep,new} = 0.8 \cdot 0.1 \cdot \sum_{0}^{100} e_{dep}(t_i) + 0.2 \cdot \sum_{0}^{100} e_{dep}(t_i)$$

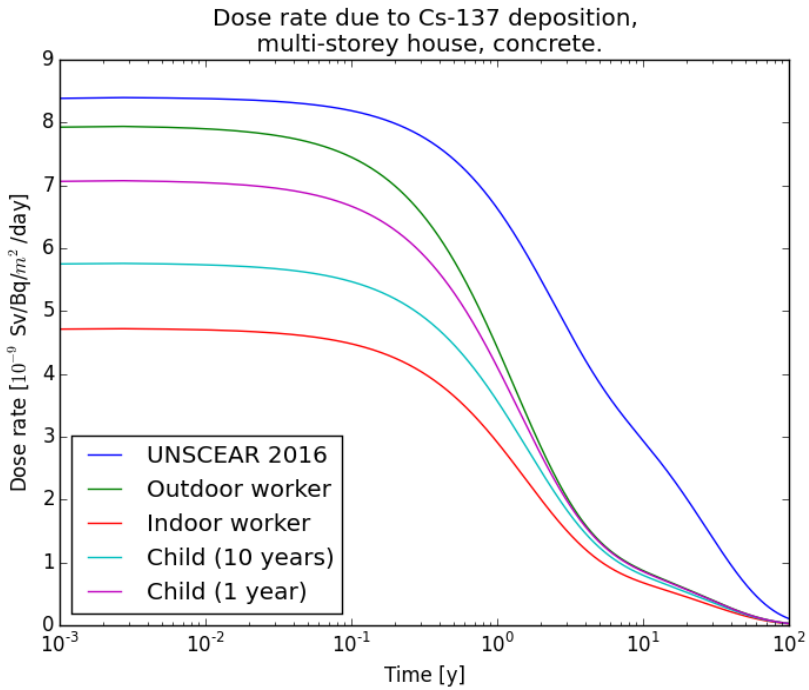
Concrete housing

Overestimation of the dose and dose rate

Integrated Dose



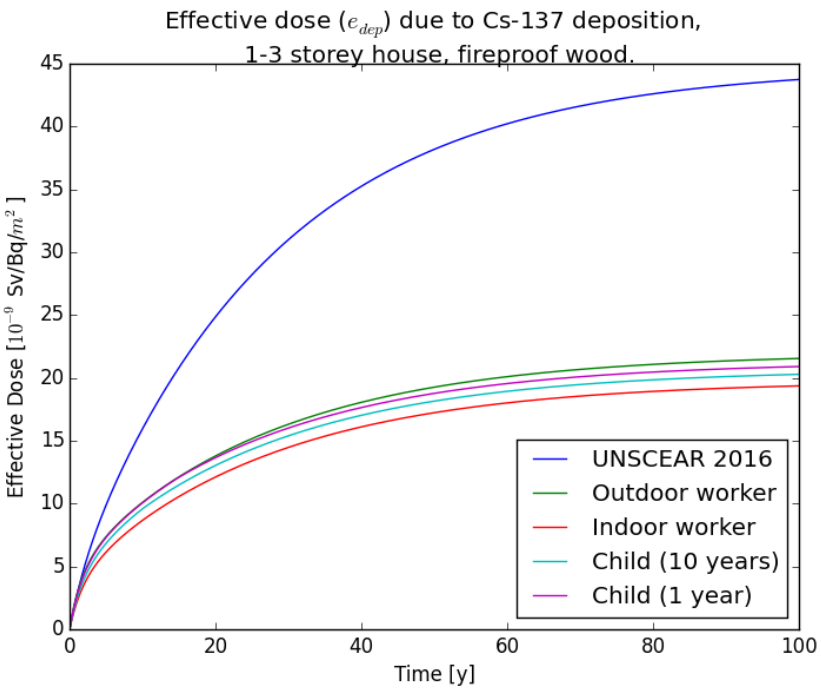
Dose Rate



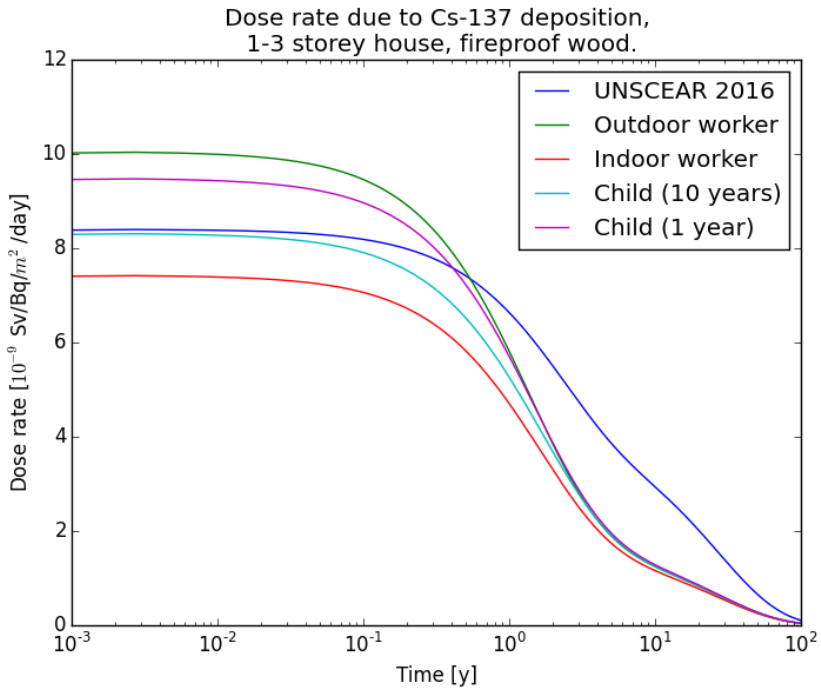
Fireproof housing

Overestimation of the total dose

Integrated Dose



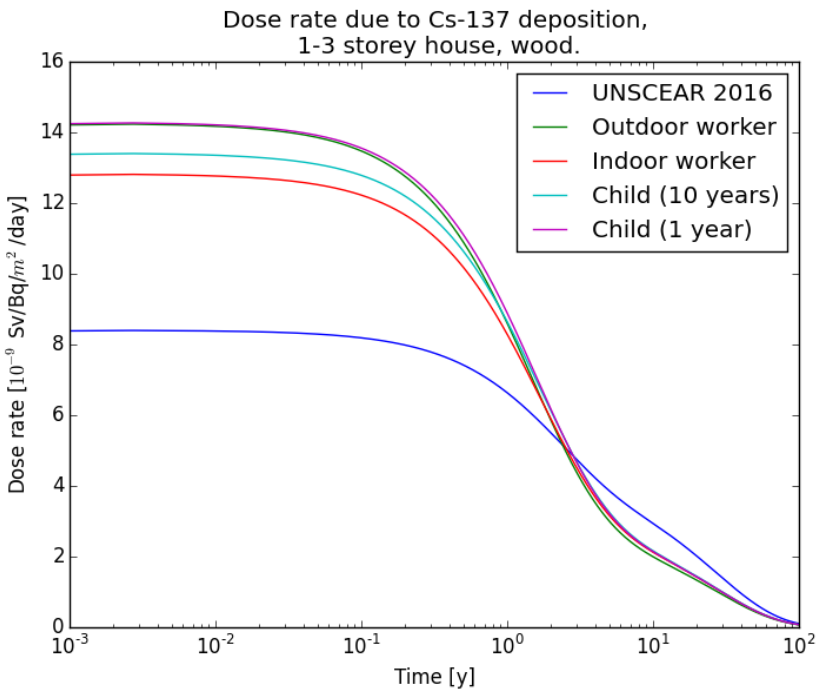
Dose Rate



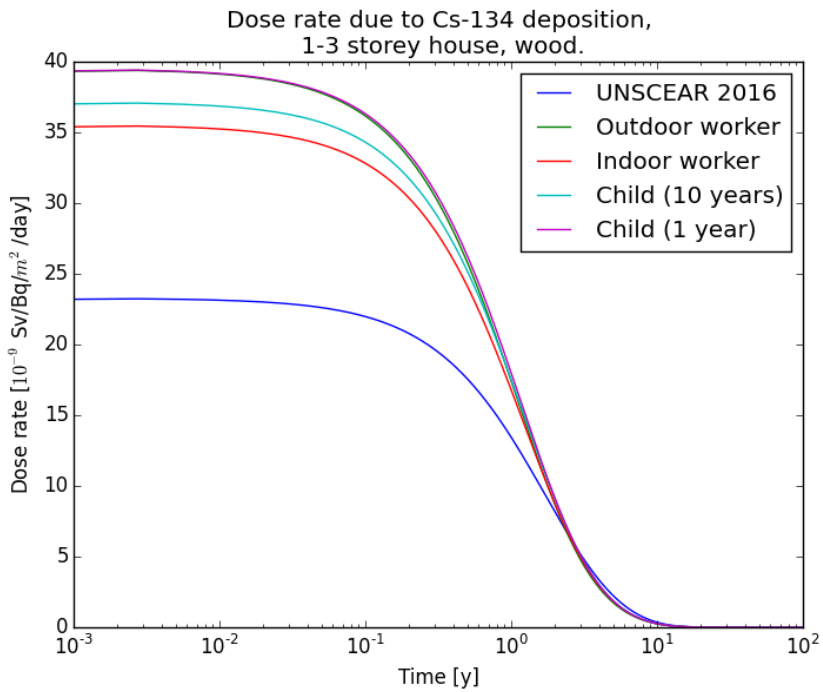
Wood housing

Underestimation of the dose rate

Dose rate Cs-137



Dose rate Cs-134



Summary

Example indoor worker: t= 100 y for 1-3 storey building

Parameter	UNSCEAR 2013	UNSCEAR 2016
Population	adult	adult
Outdoor occ. [%]	20	10
paved	5	–
unpaved	5	–
Indoor occ. [%]	90	80
L.F. (outdoors)	h_{hard}, f_{dirt}	1
L.F. (indoors)	h_{build}	0.1
e_{dep} ^{137}Cs	2.1×10^{-8} Sv/(Bq /m^2)	4.4×10^{-8} Sv/(Bq /m^2)
e_{dep} ^{134}Cs	1.9×10^{-8} Sv/(Bq /m^2)	1.7×10^{-8} Sv/(Bq /m^2)

Summary

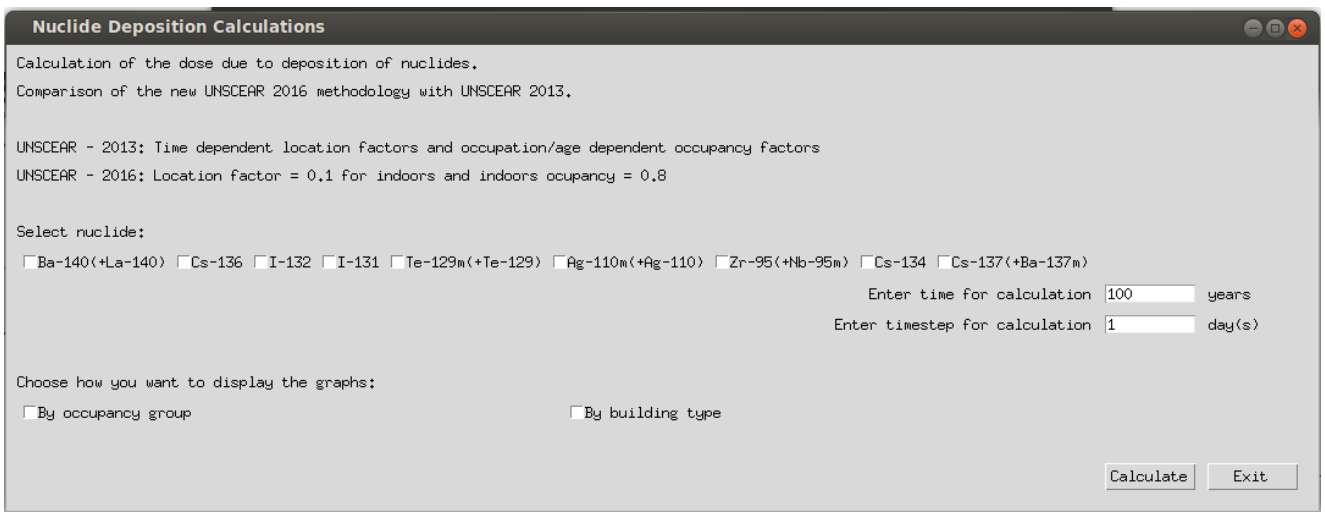
- Overestimation of dose for t =100 years, more pronounced for longer lived nuclides.
- Underestimation of the dose rate in the first years, more pronounced for shorter lived radionuclides.

Generally considered case: 1-3 storey wood house (fireproof)

- Overestimation by 50%
- Underestimation no more than 10%

Future Development

- Implementation of more nuclides
- Effective dose calculation through concentration input of the contamination
- User input: Location and Occupancy factors for comparison
- User input: Dose rate coefficients



Q&A

Thank you!

Contact:
Margarita Tzivaki
Faculty of Energy Systems and Nuclear Science
University of Ontario Institute of Technology
margarita.tzivaki@uoit.net