On the Use of Location and Occupancy Factors for Estimating External Exposure from Deposited Radionuclides

M. Tzivaki, E. Waller

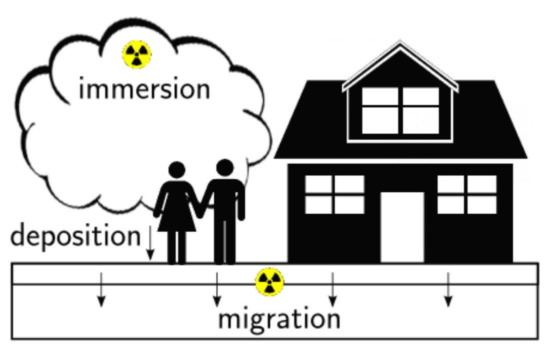
Faculty of Energy Systems and Nuclear Science, University of Ontario Institute of Technology

Abstract

Predicting dose from external exposure due to deposition requires knowledge of the demographic of the affected population concerning habits and housing in order to use appropriate location and occupancy factors. In the newly proposed methodology in the UNSCEAR 2016 report a simplified methodology was proposed. This approach uses one time-independent location factor for indoor occupancy as well as a single occupancy factor that is independent of the age and occupation of the population studied. In this work the two approaches are compared for a variety of population groups and housing types. It was determined that the new simplified methodology overestimates the integrated effective dose over 100 years for both Cs-137 and Cs-134. However an underestimation of the dose can be observed on the short time scales, especially for the shorter lived Cs-134. Additionally the annual dose is significantly underestimated for certain types of buildings for both investigated radionuclides. It can be concluded that, while the simplified methodology can reasonably be applied in urban areas, caution has to be exercised in more complex situations like rural areas.

Introduction

External dose due to deposition:



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

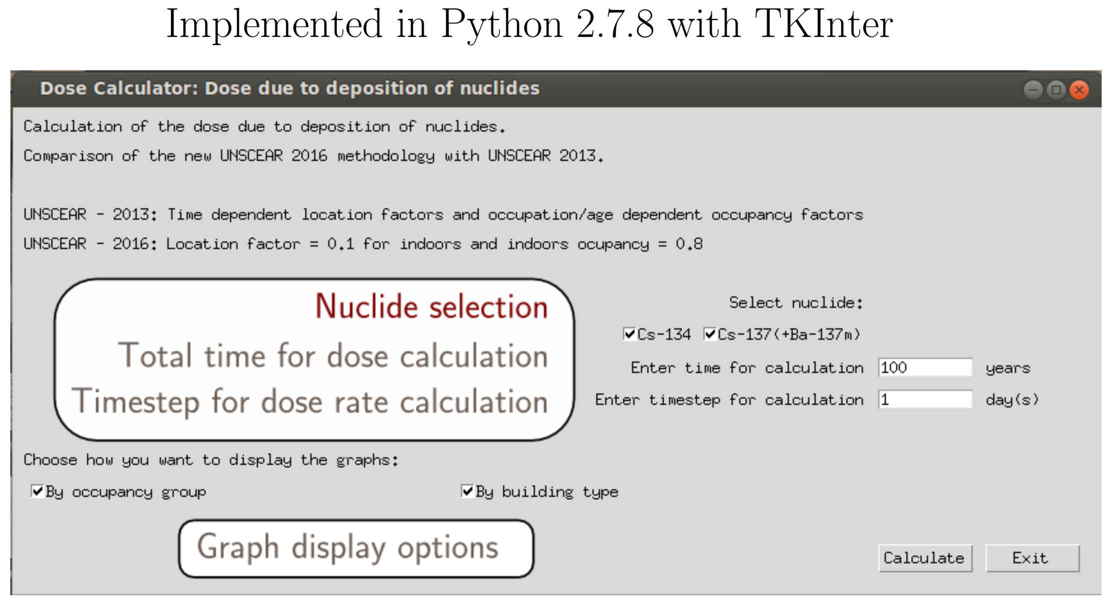
$$\dot{e}_{dep} = \dot{e}_{dep} \int_0^t e^{(-\lambda_i t)} r(t) dt$$

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

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

Calculation Software

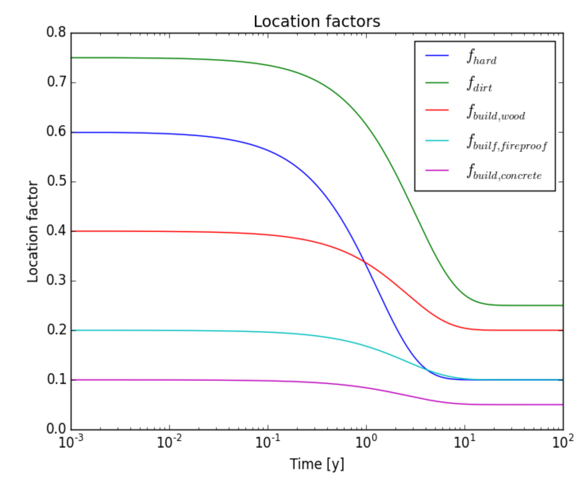
Implemented in Python 2.7.8 with TKInter



UNSCEAR 2013 and 2016 - Reduction factors

UNSCEAR 2013 [3]

Location factor: Accounts for the impact of individual's location



- Paved surfaces
- Unpaved surfaces
- Buildings: concrete, wood (fireproof), wood

Occupancy factor: Describes the time spent by a certain population group member in a location.

- Adult (indoor and outdoor worker)
- Child (10 years)
- Infant (1 year)

UNSCEAR 2016 [4]

Location factor:	Occupancy factors:
0.1 indoors	0.8 indoors, 0.2 outdoors

Potential issues:

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

Inputs - Example

Adult indoor worker living in a 1-3 storey fireproof wood house:

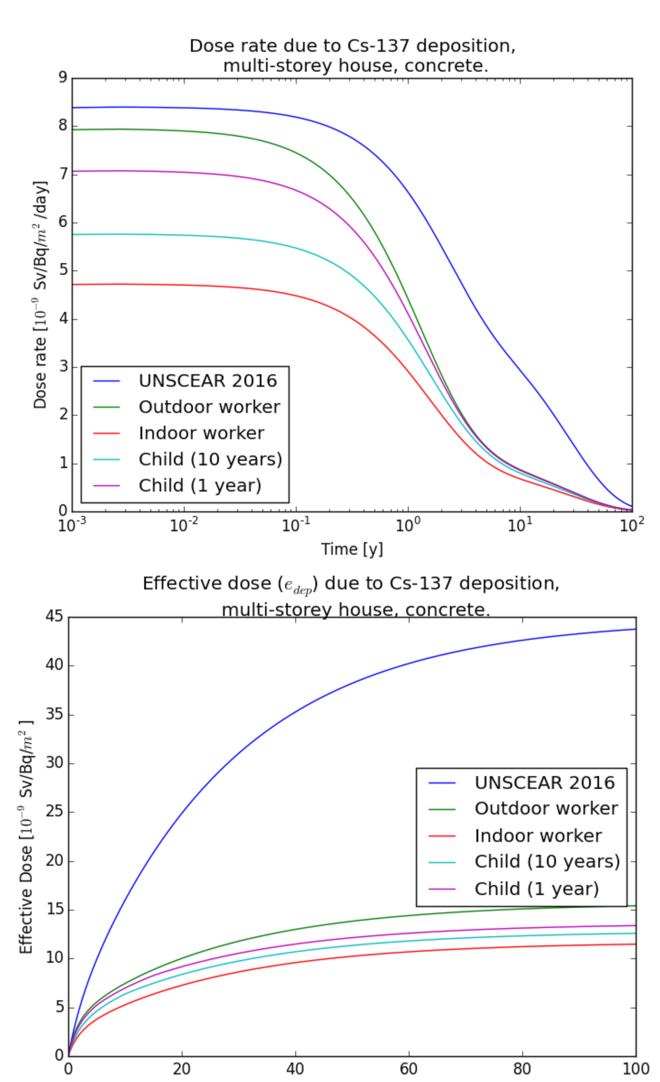
$$e_{dep,UNSCEAR2013} = 0.9 \cdot \sum_0^{100} e_{dep}(t_i) \cdot f_{build}(t_i) + 0.05 \cdot \sum_0^{100} e_{dep}(t_i) \cdot f_{dirt}(t_i) + 0.05 \cdot \sum_0^{100} e_{dep}(t_i) \cdot f_{hard}(t_i)$$

$$e_{dep,new} = 0.8 \cdot 0.1 \cdot \sum_0^{100} e_{dep}(t_i) + 0.2 \cdot \sum_0^{100} e_{dep}(t_i)$$

Parameter	UNSCEAR 2013	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

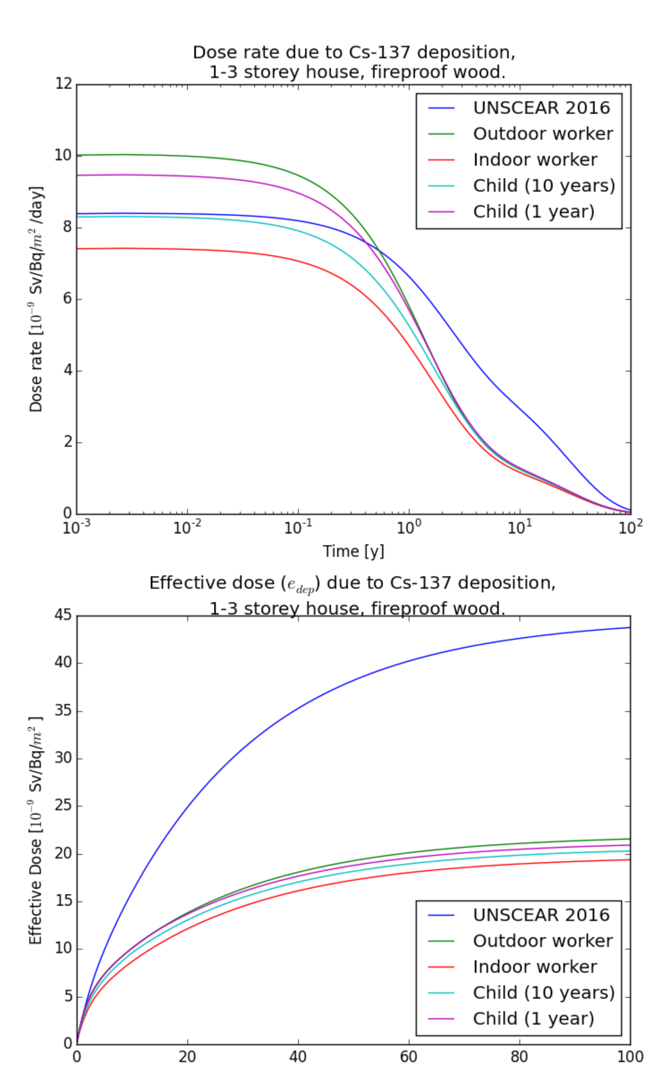
Comparison

Concrete housing:



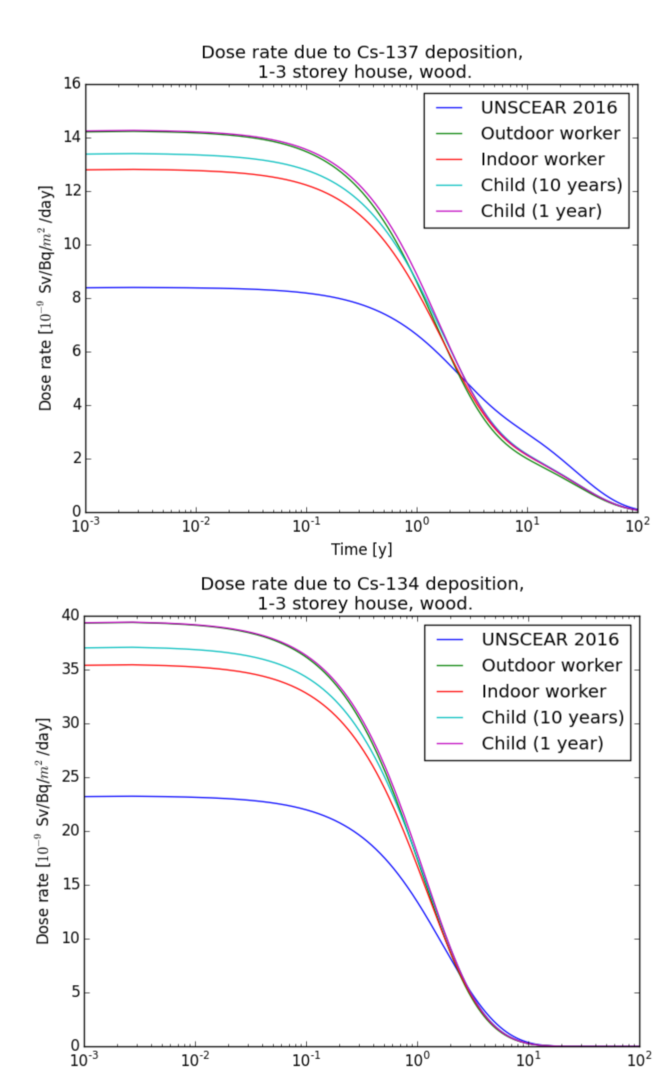
Overestimation of the dose and dose rate in all cases.

Fireproof housing:



Overestimation of the total dose. Potential underestimation of the dose rate in the first year in selected cases.

Wood housing:



Underestimation of the dose rate in the first year of exposure more severe in the case of a short-lived radionuclide.

Conclusions

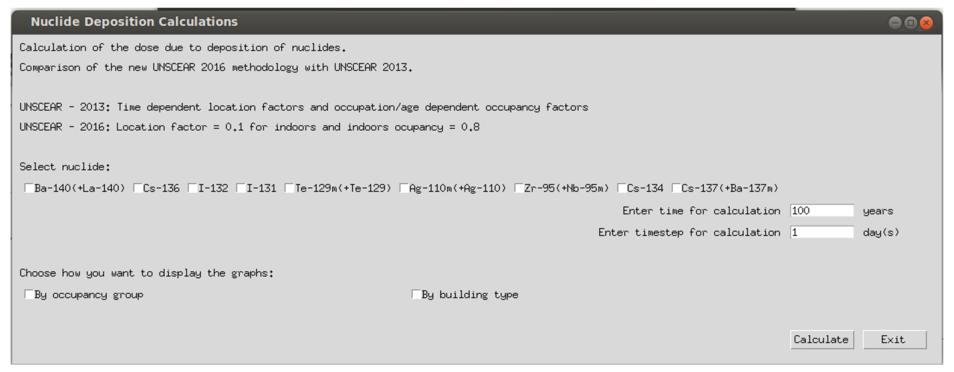
- Overestimation of dose for t =100 years, more pronounced for longer lived nuclides.
- Underestimation of the dose rate in the first years, more pronounced for shorter lived radionuclides.

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

- **Overestimation by a maximum of 50%**
- **Underestimation no more than 10%**

Future work

- 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



References

[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)

[3] 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)

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

Funding

NSERC CRSNG

UNENE University Network of Excellence in Nuclear Engineering

Contact

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

ed.waller@uoit.ca
Ed Waller
Faculty of Energy Systems and Nuclear Science
University of Ontario Institute of Technology