Nordic Nuclear Safety: Research, Operations and Beyond
- Joint NKS-R and NKS-B Seminar, Finlandshuset,
Stockholm, 19-20 January 2022

UNIVERSITY OF GOTHENBURG

RADIOECOLOGICAL TRANSFER FACTORS FOR NORDIC SUBPOPULATIONS FOR ASSESSMENT OF INTERNAL COMMITTED DOSE

Mats Isaksson, prof.
Medical radiation sciences

NKS ECONORMS

- Radioecological transfer factors for Nordic subpopulations for assessment of internal committed dose from atmospheric fallout of radiocaesium

  - Martin Hjellström[1]
  - Mats Isaksson[1]
  - Christopher L Rääf[2]
  - Lavrans Skuterud[3]
  - Håvard Thørring[3]
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Background 1

- Measurements of whole body burden of radiocaesium have for a long time been performed in Finland, Norway and Sweden.
- These data have previously been used to estimate the effective dose (radiation dose) due to fallout from nuclear weapons testing, as well as from the Chernobyl accident, to the populations in the three countries.
- Based on work by Rääf et al., the internal radiation dose from ^{134}Cs and ^{137}Cs, which dominates the long-term dose after fallout, can be modelled by an empirical relation to the regional average of the deposition density (Bq/m^2).

Paper

ECOLOGICAL HALF-TIME AND EFFECTIVE DOSE FROM CHERNOBYL DEBRIS AND FROM NUCLEAR WEAPONS FALLOUT OF ^{137}Cs AS MEASURED IN DIFFERENT SWEDISH POPULATIONS

C. L. Rääf,* L. Hubbard,† R. Falk,† G. Ågren,‡ and R. Vesanen§

INTRODUCTION

Available online at www.sciencedirect.com

ELSEVIER

Science of the Total Environment

Transfer of ^{137}Cs from Chernobyl debris and nuclear weapons fallout to different Swedish population groups

C.L. Rääf, L. Hubbard, R. Falk, G. Ågren, R. Vesanen

Abstract

1. Introduction

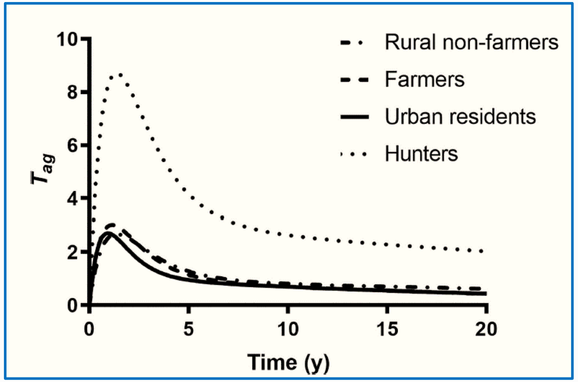
Rääf, C.L., Hubbard, L., Falk, R., Ågren, G., Vesanen, R., (2006). Ecological halftime and effective dose from Chernobyl debris and from nuclear weapons fallout of ^{137}Cs as measured in different Swedish populations. Health Phys. 90(5), 446-458.

Rääf, C.L., Hubbard, L., Falk, R., Ågren, G., Vesanen, R., (2006). Transfer of ^{137}Cs from Chernobyl debris and nuclear weapons fallout to different Swedish Populations. Sci. Total Environ. 367 (1), 324-340.

Background 2

- The *aggregated transfer function* (Bq/kg per Bq/m^2), could be derived for various sub-populations, such as reindeer herders and hunters, reflecting variations in dietary habits.

$$\dot{E} = \chi \cdot A_{esd(county)} \cdot T_{ag(max)} \cdot \left[\left(1 - e^{-\frac{\ln 2}{t_1}(t-t_0)}\right) \cdot c_1 \cdot e^{-\frac{\ln 2}{t_2}(t-t_0)} + c_2 \cdot e^{-\frac{\ln 2}{t_3}(t-t_0)}\right]$$



- The model has recently been used in a scenario-based study by Isaksson et al. and was found to agree with empirical data from the Bryansk region in Russia.


PLOS ONE

RESEARCH ARTICLE

Modelling the effective dose to a population from fallout after a nuclear power plant accident—A scenario-based study with mitigating actions

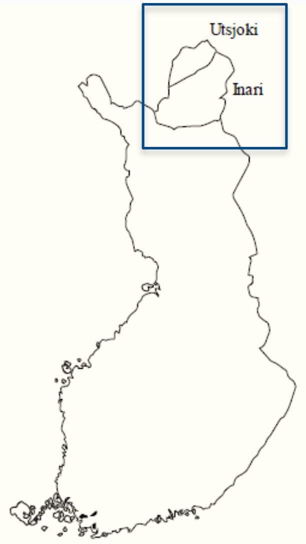
Abstract

Isaksson, M., Tondel, M., Wålinder, R., Rääf, C. (2019). Modelling the effective dose to a population from fallout after a nuclear power plant accident—a scenario-based study with mitigating actions. PlosOne.; 14(4):e0215081. https://doi.org/10.1371/journal.pone.0215081

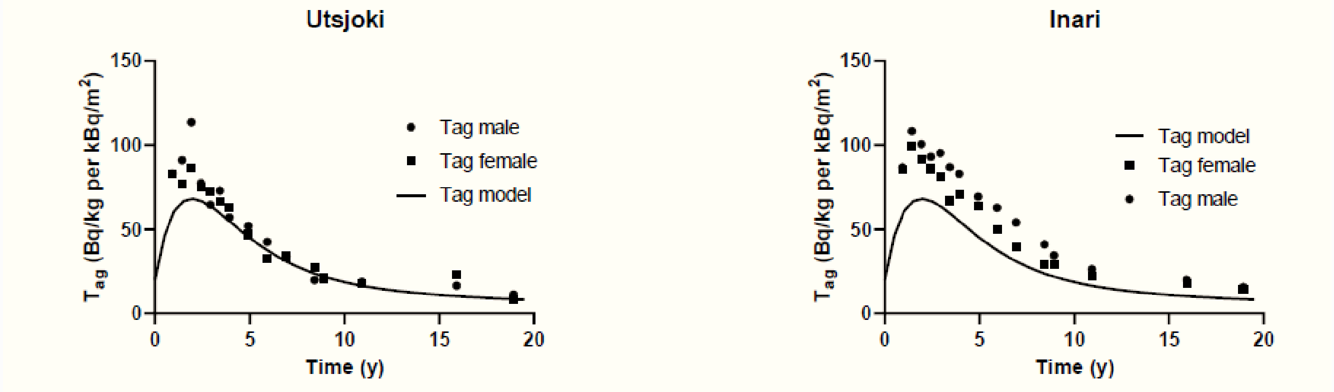
Methods

- Data from measurements of whole body activity of ^{137}Cs and deposition density (Bq/m^2) were compiled from Finland, Norway and Sweden.
- Where possible, partitioned into sub populations representing reindeer herders, hunters, farmers, rural non-farmers and urban residents.
- The model for internal radiation dose was applied to the data from the three Nordic countries.

Results – Finland 1

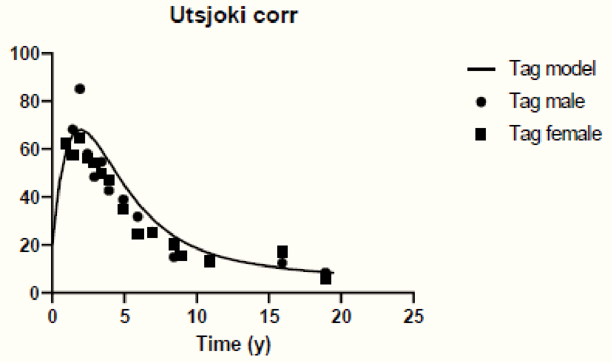


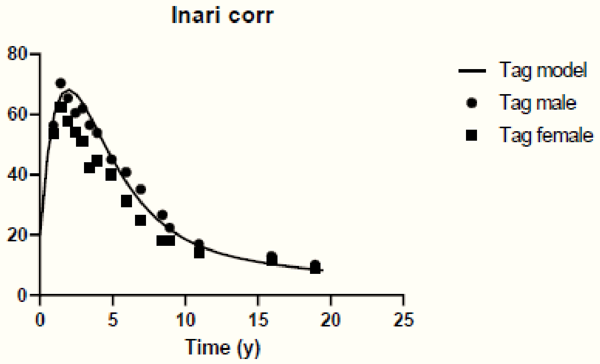
- Calculated T_{ag} compared to model with parameters for Swedish reindeer herders



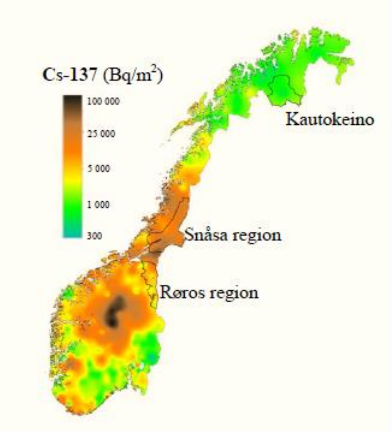
Results – Finland 2

- Calculated T_{ag} based on Chernobyl derived ^{137}Cs compared to model with parameters for Swedish reindeer herders

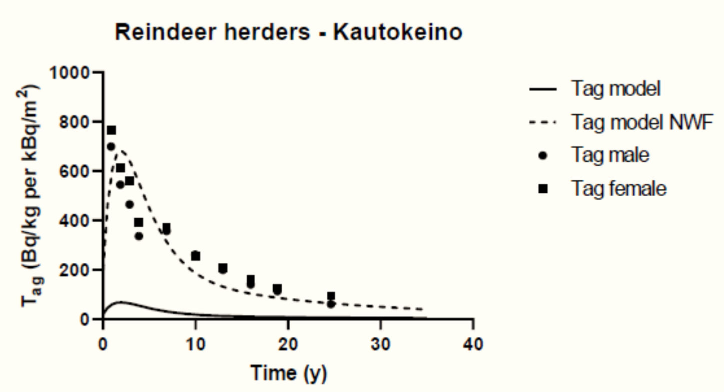




Results – Norway 1

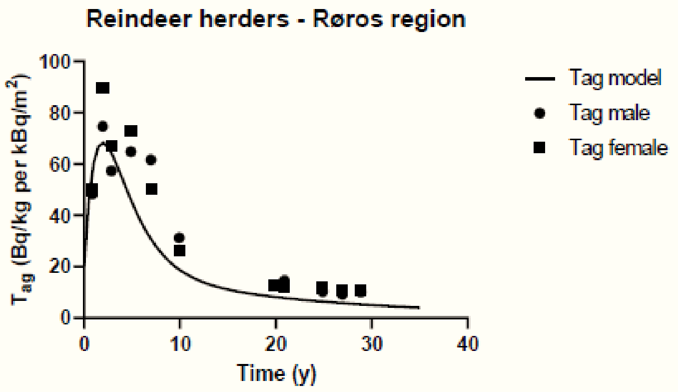


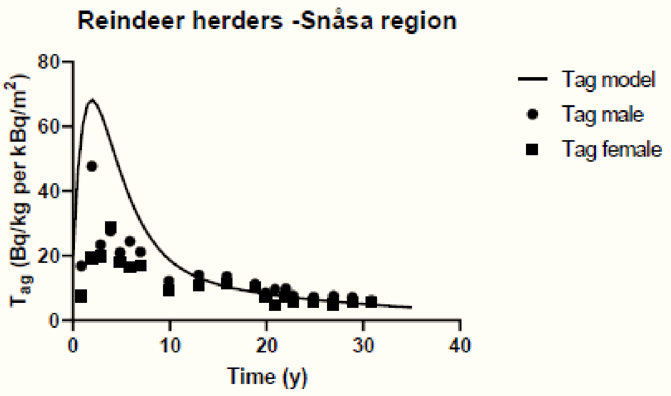
- Deposition data in is based on an average value from 4 soil samples per municipality in June 1986.
  – Limitations on precision and spatial variability compared to data from Sweden and Finland
- Larger contribution to body burden from NWF in Kautokeino leading to model underestimating calculated T_{ag}
- Good agreement when model parameters from Härjedalen, Sweden, is used



Results – Norway 2

- Calculated T_{ag} compared to model with parameters for Swedish reindeer herders
- Calculated T_{ag} in Snåsa region reflect extensive countermeasures



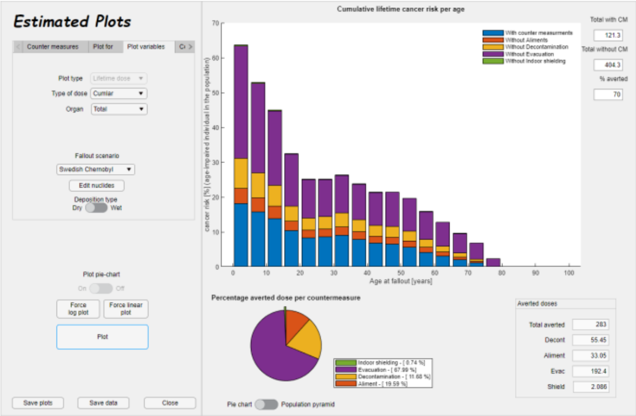


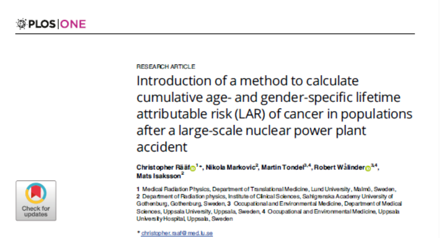
Conclusions from ECONORMS

- During this work, it has become evident that the existing data can be analysed to a greater extent than has been possible within the frames of this project.
  - For example, comparing the aggregated transfer functions, $T_{ag}(t)$, calculated from Finnish and Norwegian data with models parameterized using Swedish data, the agreement was found to be heavily dependent on the estimated deposition.
- The issue of modelling uptake of caesium from the food chain, based on ecological half-life or $T_{ag}(t)$, in areas where there are reminiscences of previous fallout occasions of the same extent as the present fallout, has to be further investigated.
- Modelling is a useful tool to check our state of knowledge and reveal gaps in data, which have to be considered in case of future fallout events.
- This also emphasizes the need for maintaining continuous time-series of measurements on atmospheric deposition as well as the body-burden in various populations, especially among those known in advance to be sensitive to radioecological transfer of fission products.

Further modeling – LARCalc

- LARCalc: a tool for dose and risk assessment for RN-events, and assessment of mitigating actions
  - Christopher Rääf, Mats Isaksson, Simon Jansson, Jonathan Sundström




PLOS | ONE

RESEARCH ARTICLE

Introduction of a method to calculate cumulative age- and gender-specific lifetime attributable risk (LAR) of cancer in populations after a large-scale nuclear power plant accident

Christopher Rääf[1]*, Nikola Markovic[2], Martin Tondel[3,4], Robert Wålinder[3,4], Mats Isaksson[2]

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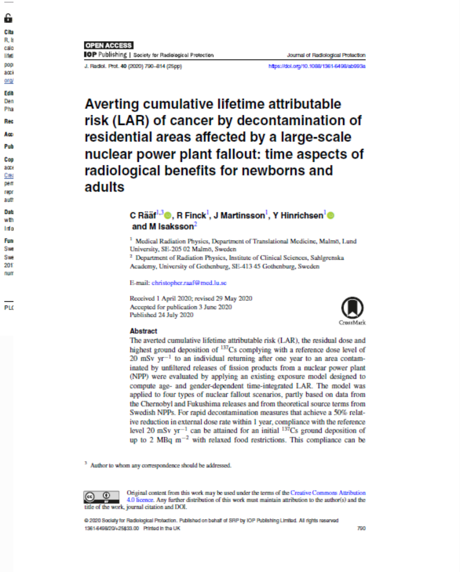
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IOP Publishing | Society for Radiological Protection — Journal of Radiological Protection

J. Radiol. Prot. 40 (2020) 790–814 (25pp) https://doi.org/10.1088/1361-6498/ab993a

Averting cumulative lifetime attributable risk (LAR) of cancer by decontamination of residential areas affected by a large-scale nuclear power plant fallout: time aspects of radiological benefits for newborns and adults

C Rääf[1,3], R Finck[1], J Martinsson[1], Y Hinrichsen[1] and M Isaksson[2]

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CrossMark

Abstract

The averted cumulative lifetime attributable risk (LAR), the residual dose and highest ground deposition of ^{137}Cs complying with a reference dose level of 20 mSv yr^{-1} to an individual returning after one year to an area contaminated by unfiltered releases of fission products from a nuclear power plant (NPP) were evaluated by applying an existing exposure model designed to compute age- and gender-dependent time-integrated LAR. The model was applied to four types of nuclear fallout scenarios, partly based on data from the Chernobyl and Fukushima releases and from theoretical source terms from Swedish NPPs. For rapid decontamination measures that achieve a 50% relative reduction in external dose rate within 1 year, compliance with the reference level 20 mSv yr^{-1} can be attained for an initial ^{137}Cs ground deposition of up to 2 MBq m^{-2} with relaxed food restrictions. This compliance can be

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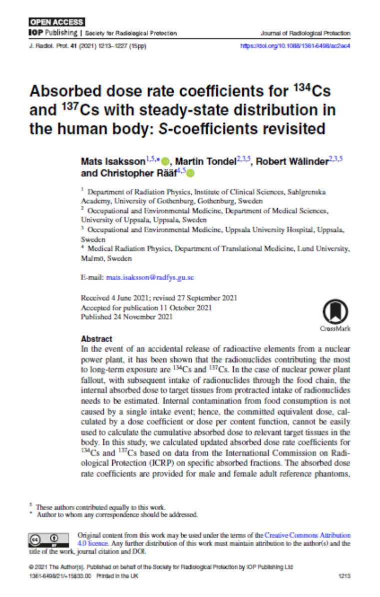
C Rääf et al 2020 J. Radiol. Prot. 40 790

Rääf C, Markovic N, Tondel M, Wålinder R, Isaksson M (2020) Introduction of a method to calculate cumulative age- and gender-specific lifetime attributable risk (LAR) of cancer in populations after a large-scale nuclear power plant accident. PLoS ONE 15(2): e0228549. https://doi.org/10.1371/journal.pone.0228549

Dose assessment

- Using ^{137}Cs as indicator nuclide and nuclide vectors for various RN-events
- Internal tissue and effective dose calculated from T_{ag} and absorbed dose rate coefficients (Isaksson et al, 2021).
- External tissue and effective dose calculated from ICRP 144
- Doses to individuals and populations (age-weighted)
- Asessment of mitigating actions
- Calculation of effective dose and LAR



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IOP Publishing | Society for Radiological Protection Journal of Radiological Protection
J. Radiol. Prot. 41 (2021) 1213–1227 (15pp) https://doi.org/10.1088/1361-6498/ac2ac4

Absorbed dose rate coefficients for ^{134}Cs and ^{137}Cs with steady-state distribution in the human body: *S*-coefficients revisited

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CrossMark

Abstract

In the event of an accidental release of radioactive elements from a nuclear power plant, it has been shown that the radionuclides contributing the most to long-term exposure are ^{134}Cs and ^{137}Cs. In the case of nuclear power plant fallout, with subsequent intake of radionuclides through the food chain, the internal absorbed dose to target tissues from protracted intake of radionuclides needs to be estimated. Internal contamination from food consumption is not caused by a single intake event; hence, the committed equivalent dose, calculated by a dose coefficient or dose per content function, cannot be easily used to calculate the cumulative absorbed dose to relevant target tissues in the body. In this study, we calculated updated absorbed dose rate coefficients for ^{134}Cs and ^{137}Cs based on data from the International Commission on Radiological Protection (ICRP) on specific absorbed fractions. The absorbed dose rate coefficients are provided for male and female adult reference phantoms,

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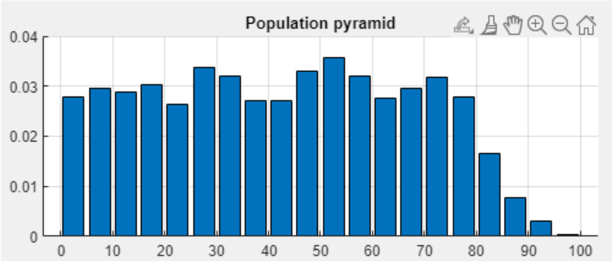
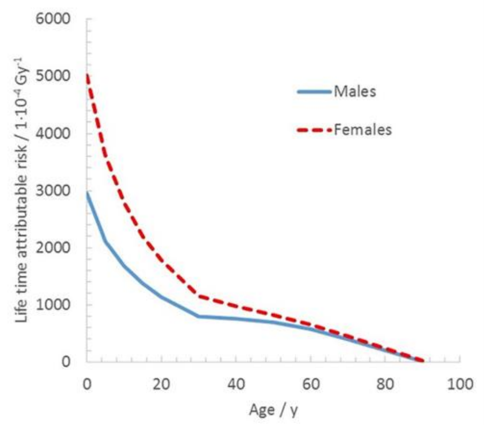


Mats Isaksson et al 2021 J. Radiol. Prot. 41 1213

Effective dose vs LAR

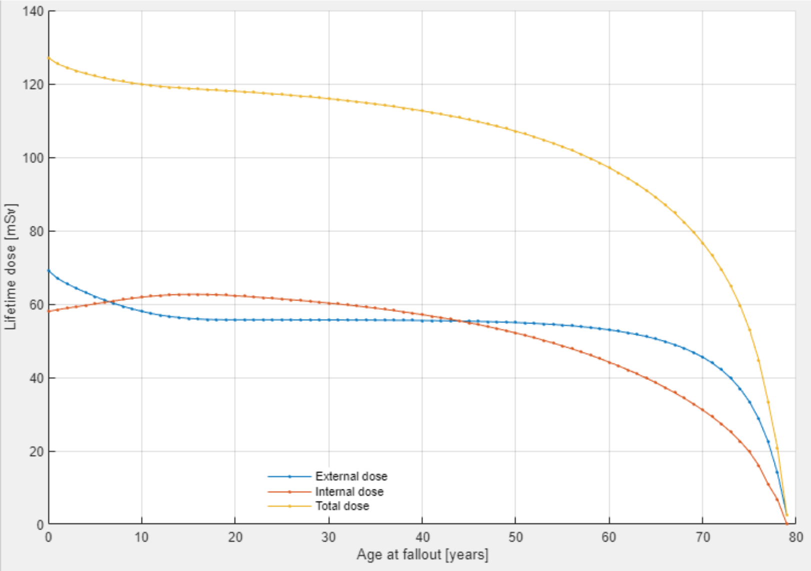
- Effective dose
  - Tissue absorbed dose weighted by radiation type and tissue sensitivity, and summed
  - Mean value for females and males; no age-dependence
  - Detriment can be estimated in planned exposure situations

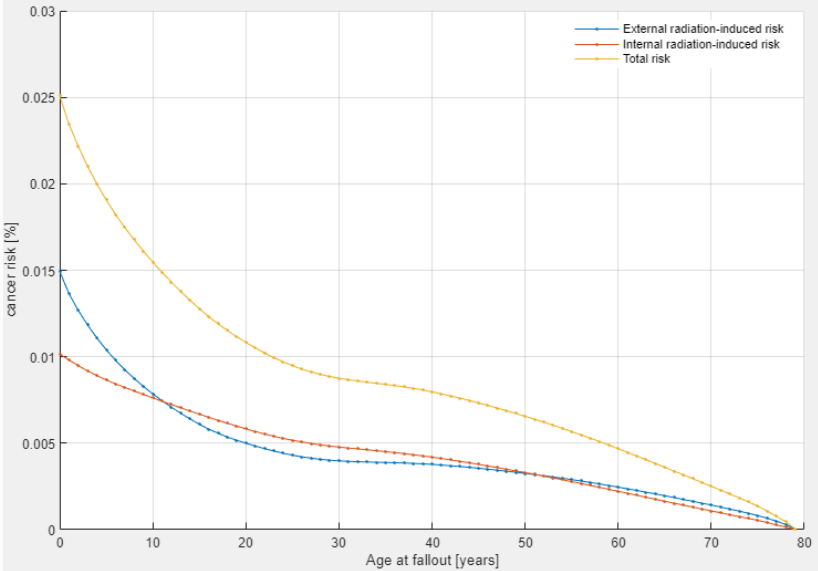
- Life-time Attributable Risk (LAR)
  - Tissue absorbed dose multiplied by sex- and age-dependent LAR-value
  - Probability of cancer incidence can be estimated



Lifetime effective dose vs cumulative LAR (CUMLAR)

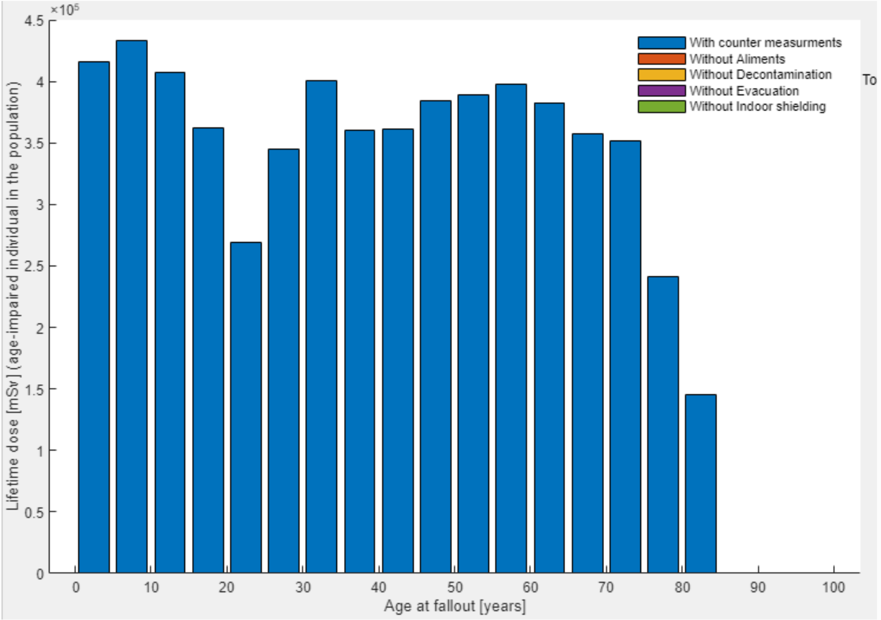
- Integrating contribution from prolonged exposure: ground contamination and body burden



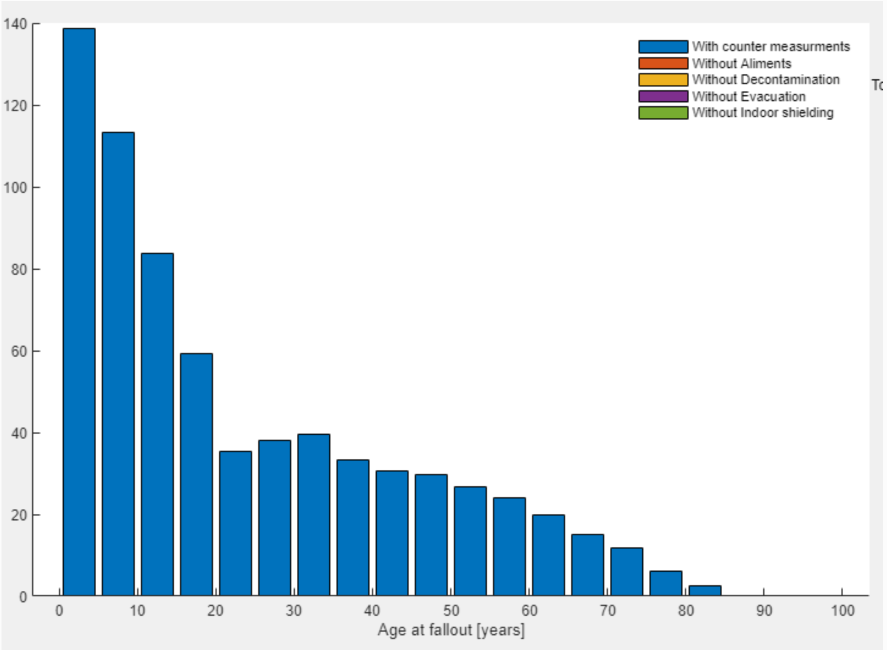


Example: population weighting – Varberg municipality, women

Lifetime effective dose

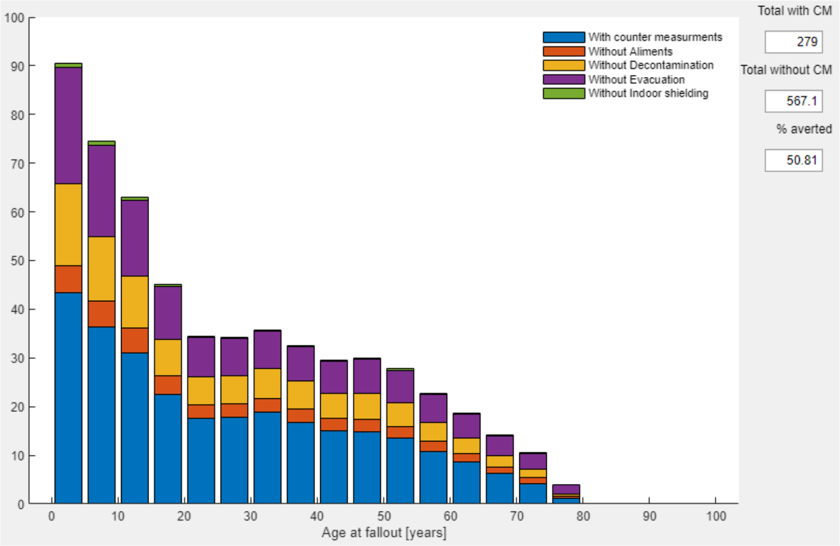


CUMLAR

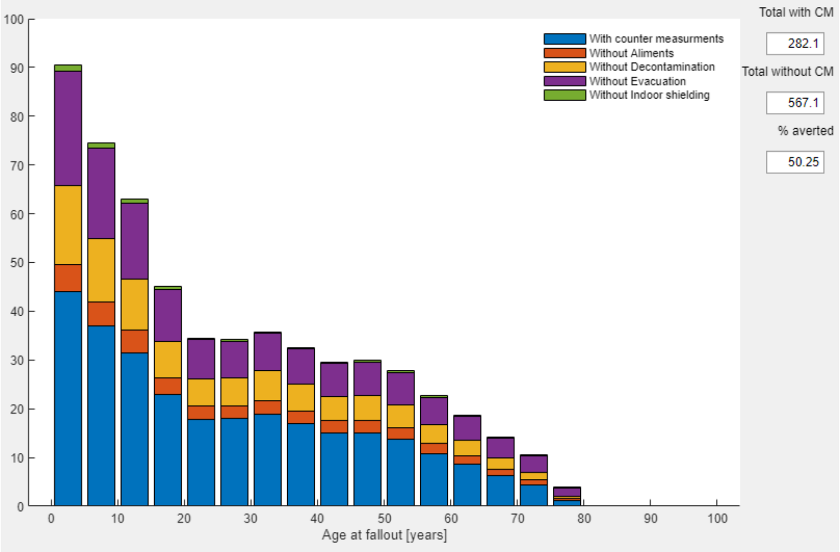


Example: mitigation – Varberg municipality, men

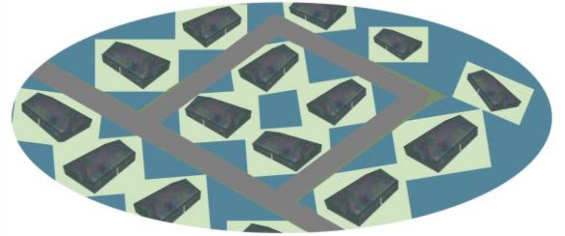
Evacuation 12 mån
Decontamination 40 % efficiency
Indoor stay first 7 days
Food restrictions for 5 years



Evacuation 12 mån
Decontamination 40 % efficiency
Indoor stay first 60 days
Food restrictions for 5 years

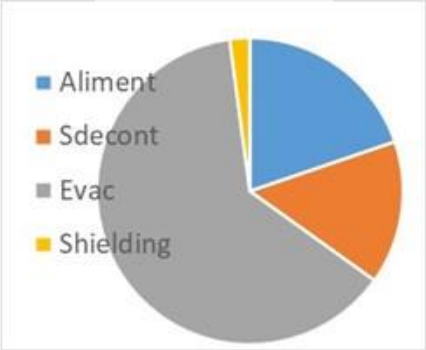


Example: decontamination

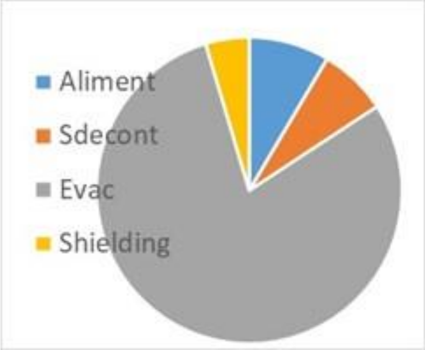


- Assume decontamination of a settlement and relocation 5 years after fallout event
- Which population group benefits most from decontamination, in terms of averted lifetime risk?

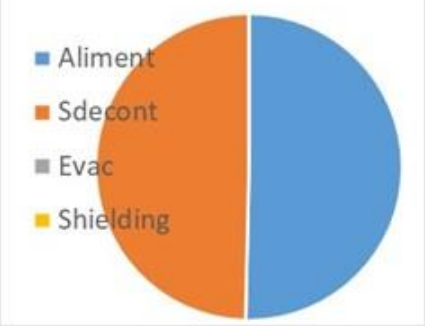
30 y male



Female infant



Female infant
Born 5 y post-accident



Future advances

- ✓ Internal dose modeling including strontium and iodine
- ✓ Dose from inhalation during plume passage
- Dose to future generations, including dose to foetus
- Nuclide vector for fallout from nuclear weapons detonation
- Written manual

Thank you!