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Radiation Protection

Investigating a redistribution of naturally occurring radioactive material (NORM) in dwelling walls

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First part will be discussed in the 5-minute presentation
Second part is display material only – but highly interesting nevertheless. ;)

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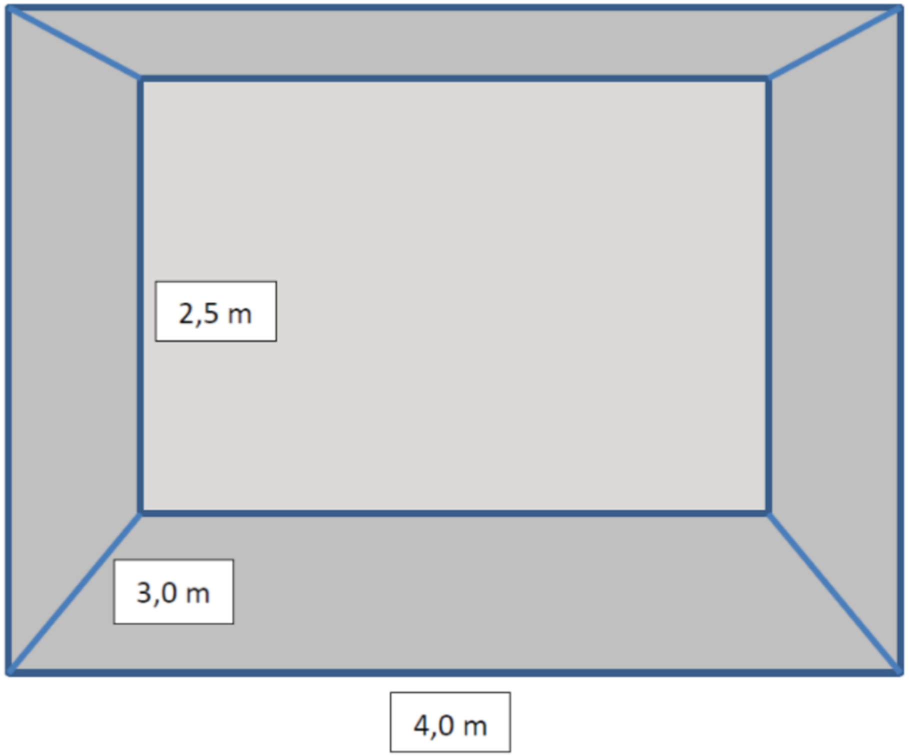
Model room

Dose at a point in a dwelling:

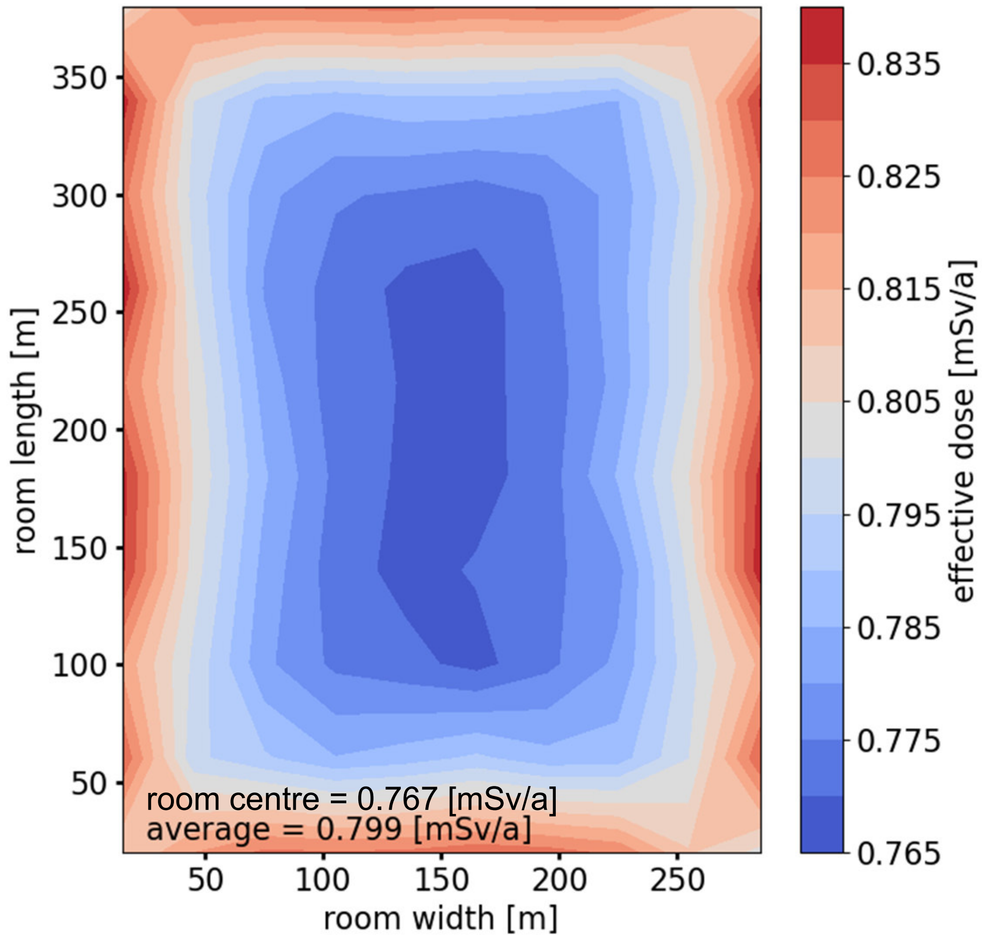
$$D = 5.77 * 10^{-13} * C * \rho \sum_i E_i \gamma_i \frac{\mu_{En}}{\rho_i} \iiint_{wall} \frac{B_i \exp(-\mu_{i,c} s)}{4\pi l^2} dxdydz$$

with build-up factor B after Berger-Model



CEN/TR 17113

Effective dose at half room height with
$[C_{Ra}, C_{Th}, C_K]$ = [80, 80, 800] Bq/kg



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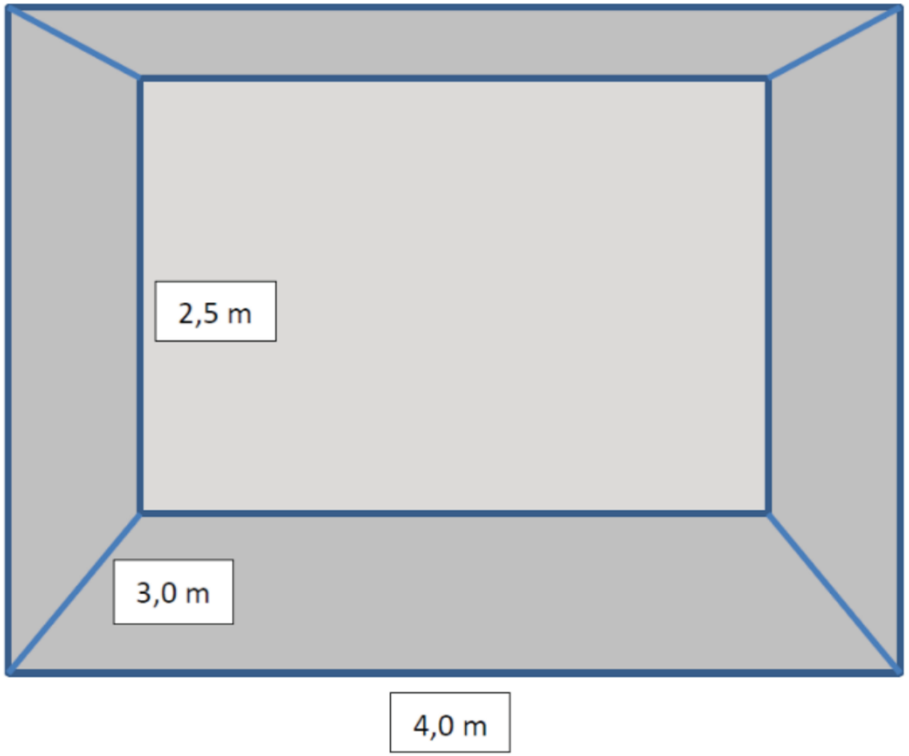


Room centre:

* Index formula (Markkanen, 1995)

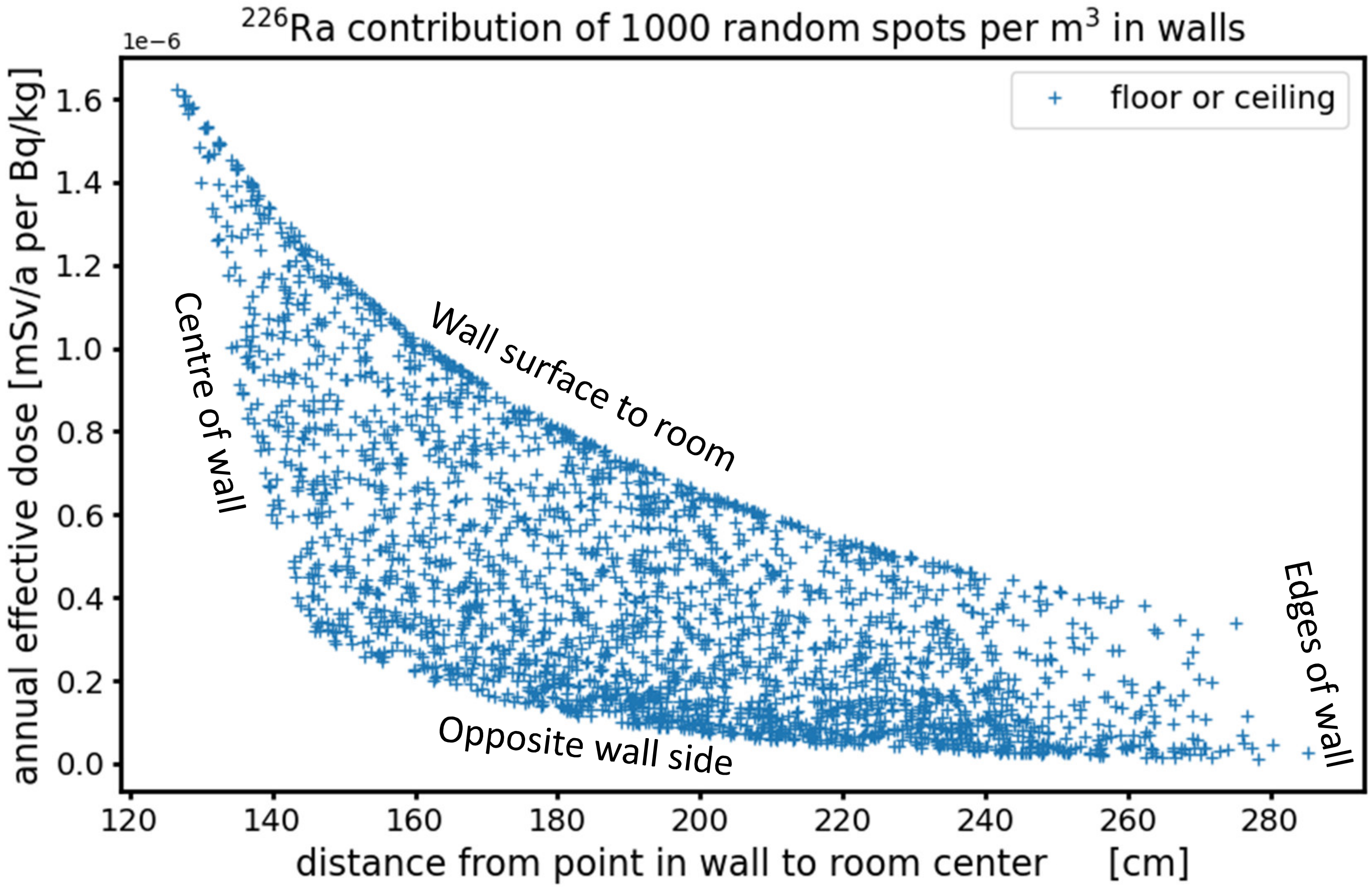
$$I = \frac{C_{^{226}\mathrm{Ra}}}{300} + \frac{C_{^{232}\mathrm{Th}}}{200} + \frac{C_{^{40}\mathrm{K}}}{3000}$$

* Quadratic index formula (CEN/TR 17113)

$$D = \begin{bmatrix} [281 + 16.3\rho d - 0.0161(\rho d)^2] * C_{^{226}Ra} \\ [319 + 18.5\rho d - 0.0178(\rho d)^2] * C_{^{232}Th} \\ [22.3 + 1.28\rho d - 0.00114(\rho d)^2] * C_{^{40}K} \end{bmatrix} * 10^{-6}$$

D: dose at room midpoint
d: wall thickness
ρ: building material density
C: activity concentration

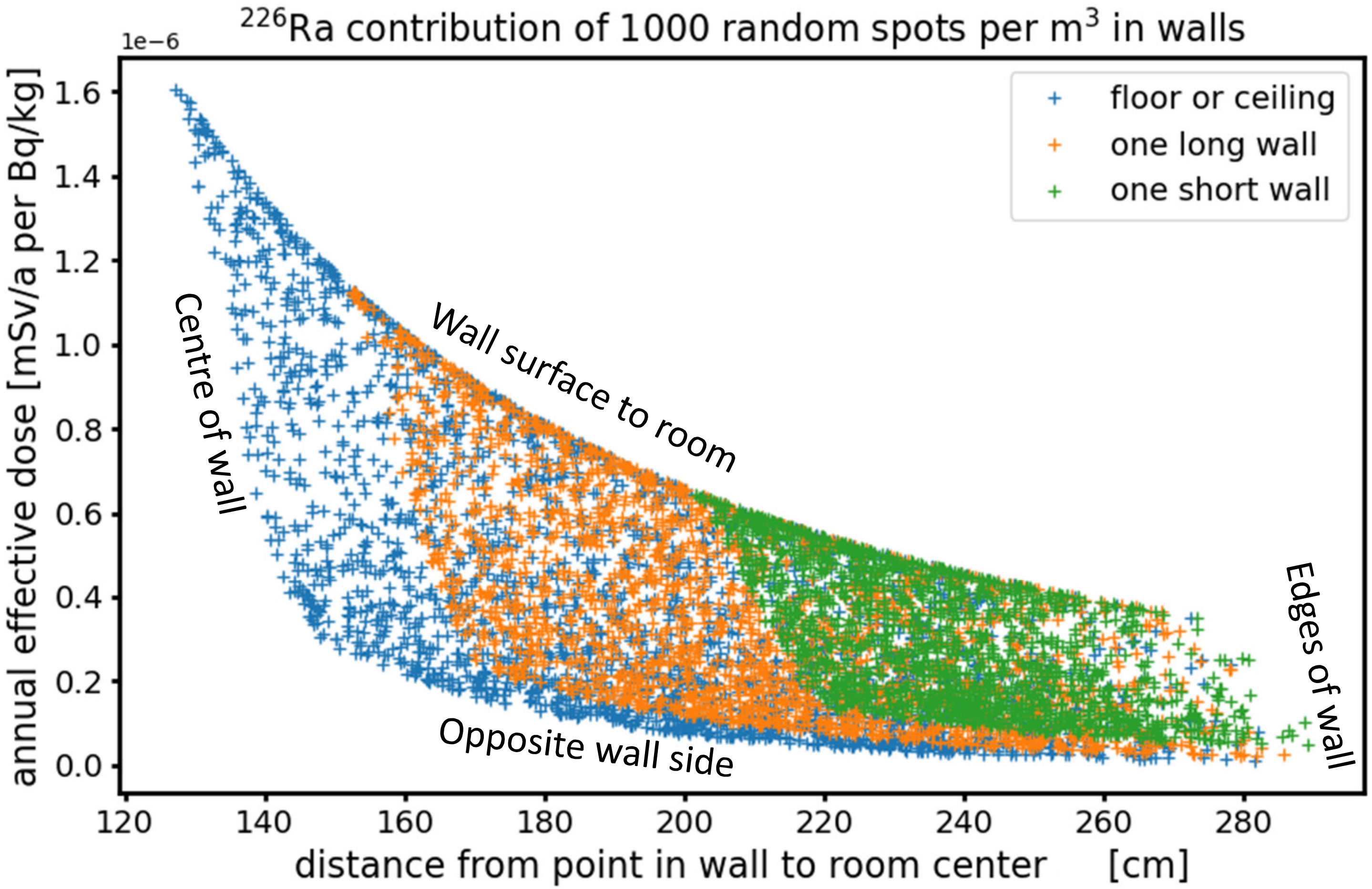
Wall contribution to dose at room centre



Wall thickness = 0.2 m
Density = 2350 kg/m3

Similar plots for all other points in room available!

Wall contribution to dose at room centre



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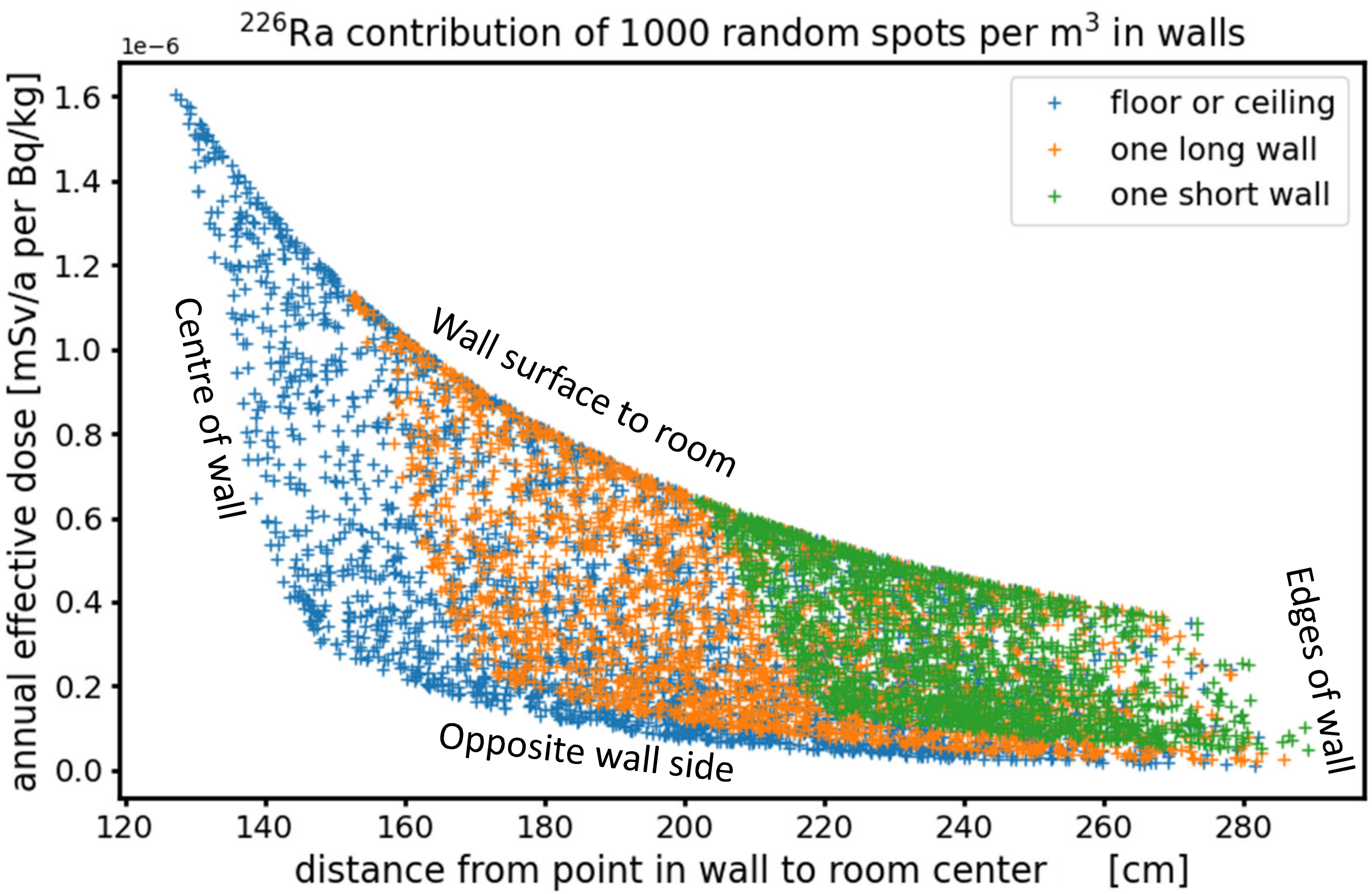

Wall thickness = 0.2 m
Density = 2350 kg/m3

Similar plots for all other points in room available!

Thought experiment:

Would a redistribution of radionuclides (e.g., radionuclide free floor and ceiling – but accordingly higher concentrations in walls) lead to a reduction in the dose at the room centre?

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Wall contribution to dose at room centre

Dose at room centre:

1) Equal act. concentration in walls, floor and ceiling:

   $[C_{Ra}, C_{Th}, C_K]$ = [80, 80, 800] Bq/kg

   → additional annual effective dose: ~ 0.77 mSv/a

2) No nuclides in floor and ceiling, but in walls ($\Sigma N_{1)} = \Sigma N_{2)}$):

   $[C_{Ra}, C_{Th}, C_K]$ = 1.686 * [80, 80, 800] Bq/kg

   → additional annual effective dose: ~ 0.67 mSv/a

→ <u>Dose reduction by ~13%</u>

Wall thickness = 0.2 m
Density = 2350 kg/m3

Similar plots for all other points in room available!

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   → additional annual effective dose: ~ 0.67 mSv/a

→ <u>Dose reduction by ~13%</u>

Attention! Result only valid for room centre in model room. How about dose for room average?
→ see display material

Wall thickness = 0.2 m
Density = 2350 kg/m3

Similar plots for all other points in room available!

Thought experiment:

Would a redistribution of radionuclides (e.g., radionuclide free floor and ceiling – but accordingly higher concentrations in walls) lead to a reduction in the dose at the room centre?

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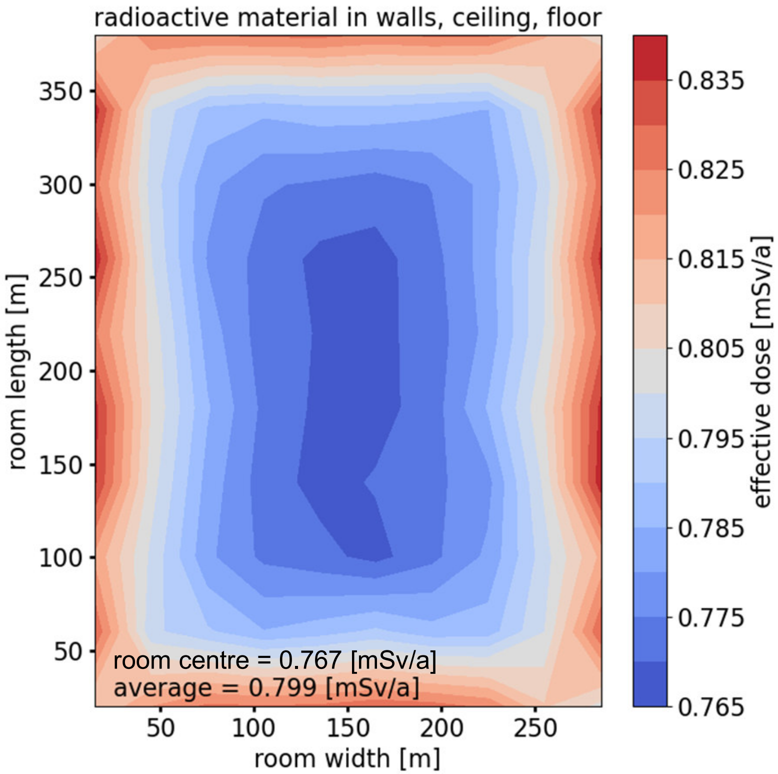
Display Material

How about other places in the room? A 2D application

$[C_{Ra}, C_{Th}, C_K]$ = [80, 80, 800] Bq/kg



Slightly higher dose near the walls compared to room centre.

Dose average of the room is slightly higher than dose at room centre.

Wall thickness = 0.2 m
Density = 2350 kg/m3

Contour plot height at 1.25 m

Thought experiment:

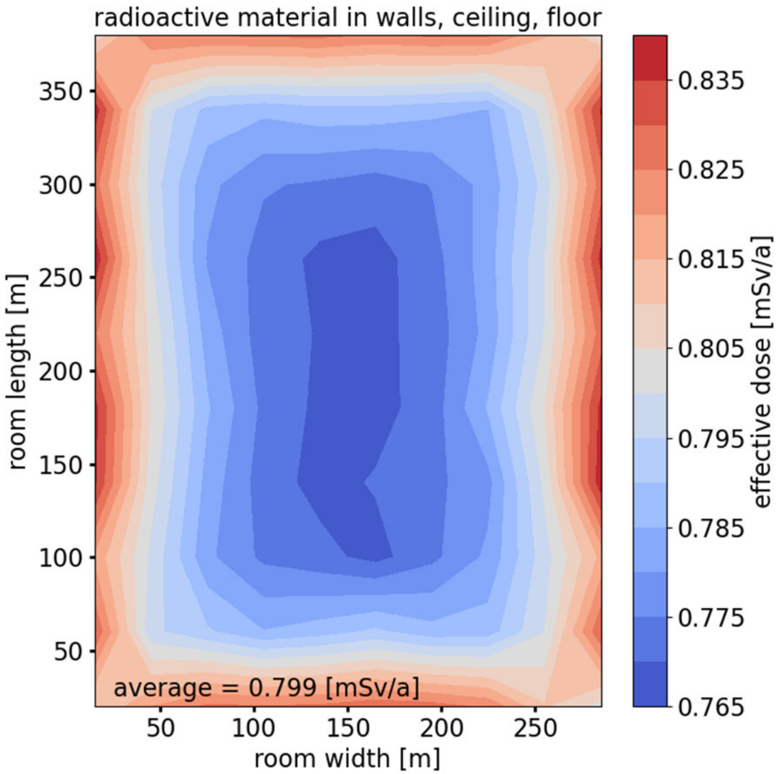
Would a redistribution of radionuclides (e.g., radionuclide free floor and wall – but accordingly higher concentrations in walls) lead to a reduction in the dose at the room centre and room average?

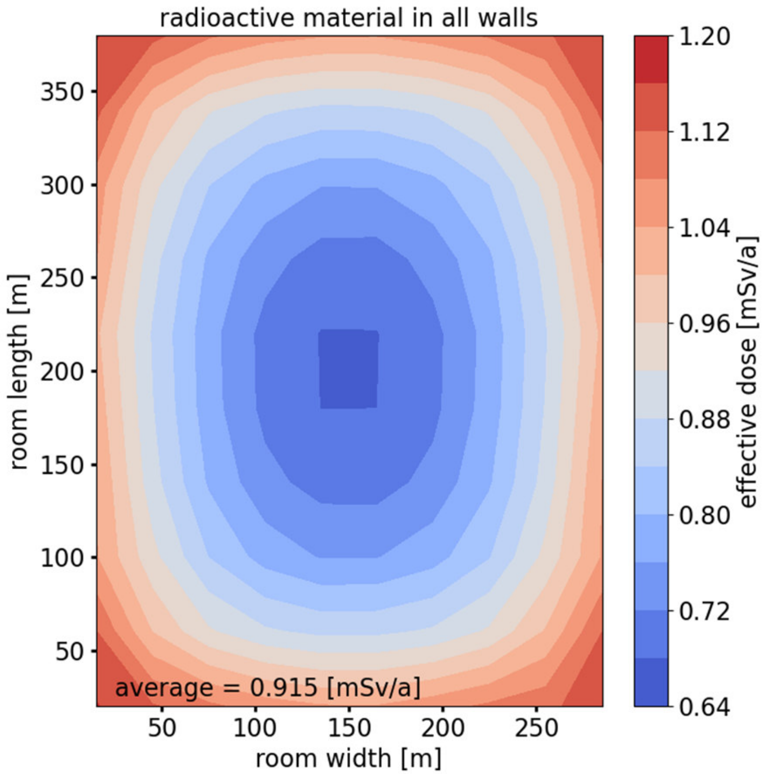
How about other places in the room? A 2D application

Radionuclide redistribution: To maintain the same amount of radionuclides, when floor and ceiling are nuclide-free, walls need 1.686 times higher concentration.

$[C_{Ra}, C_{Th}, C_K]$ = [80, 80, 800] Bq/kg

$[C_{Ra}, C_{Th}, C_K]$ = 1.686*[80, 80, 800] Bq/kg





Wall thickness = 0.2 m
Density = 2350 kg/m3

Contour plot height at 1.25 m

Thought experiment:

Would a redistribution of radionuclides (e.g., radionuclide free floor and wall – but accordingly higher concentrations in walls) lead to a reduction in the dose at the room centre and room average?

How about other places in the room? A 2D application

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To maintain the same amount of radionuclides, when floor and ceiling are nuclide-free, walls need 1.686 times higher concentration.

$[C_{Ra}, C_{Th}, C_K] = 1.686*[80, 80, 800]$ Bq/kg

Wall thickness = 0.2 m
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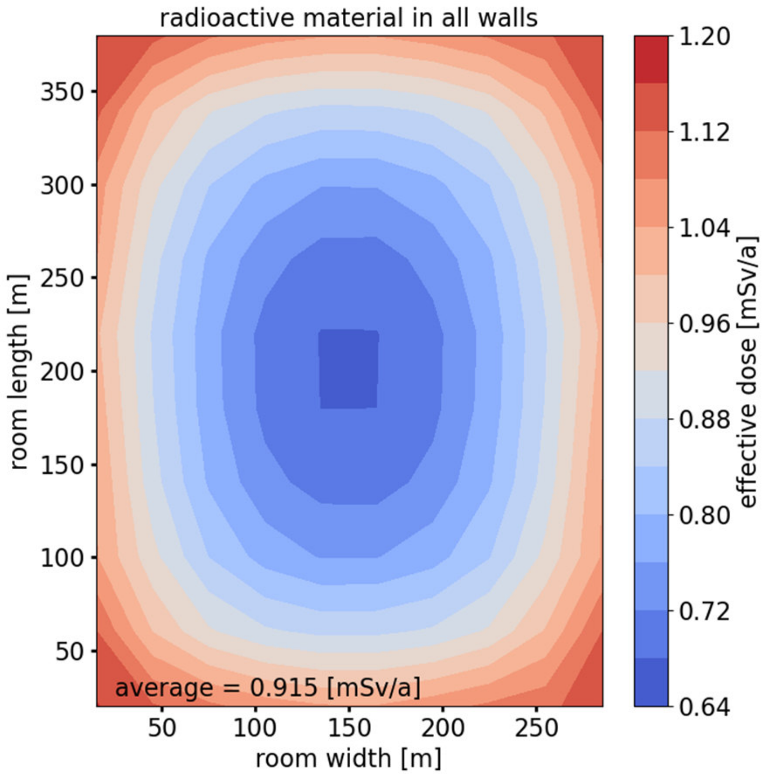
Contour plot height at 1.25 m



- stronger gradient between walls and room centre compared to original scenario

- lower dose at centre but larger at locations close to the walls

- higher average room dose

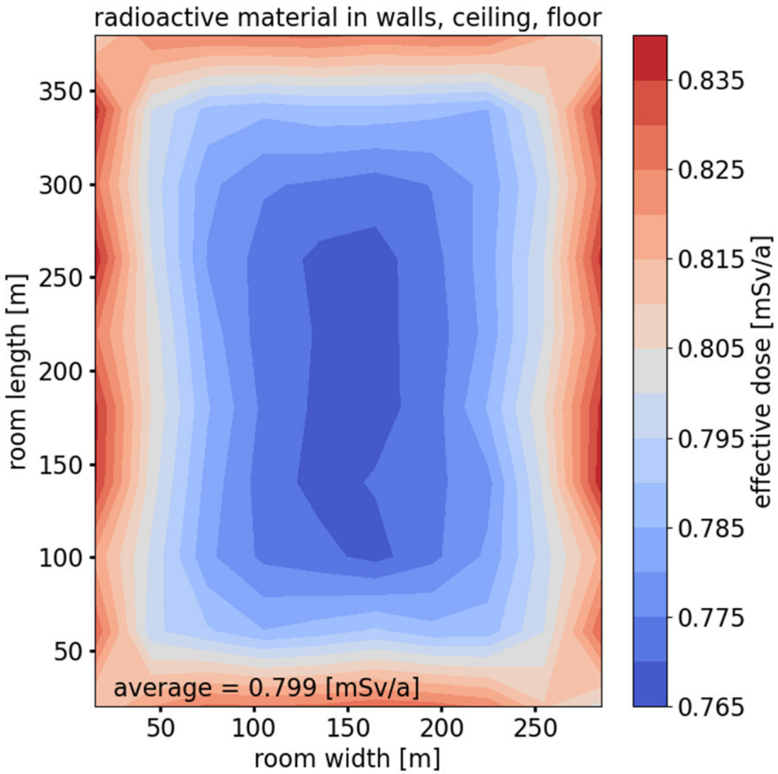
Thought experiment:

Would a redistribution of radionuclides (e.g., radionuclide free floor and wall – but accordingly higher concentrations in walls) lead to a reduction in the dose at the room centre and room average?

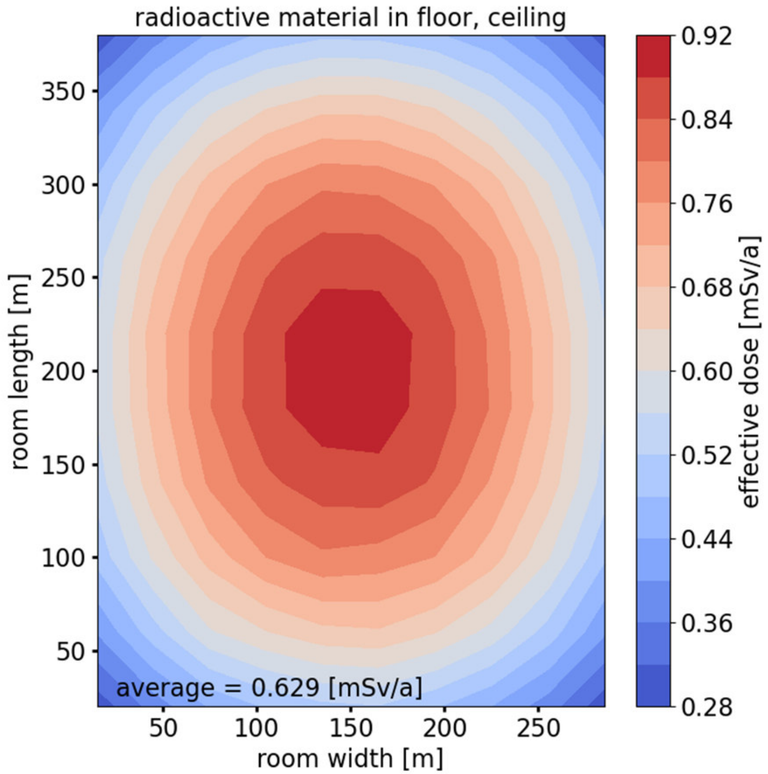
How about other places in the room? A 2D application

Radionuclide redistribution: To maintain the same amount of radionuclides, when walls are nuclide-free, floor and ceiling need 2.46 times higher concentration.

$[C_{Ra}, C_{Th}, C_K]$ = [80, 80, 800] Bq/kg



$[C_{Ra}, C_{Th}, C_K]$ = 2.46*[80, 80, 800] Bq/kg



Wall thickness = 0.2 m
Density = 2350 kg/m3

Contour plot height at 1.25 m

Thought experiment:

Would a redistribution of radionuclides (e.g., radionuclide free floor and wall – but accordingly higher concentrations in walls) lead to a reduction in the dose at the midpoint?

How about other places in the room? A 2D application

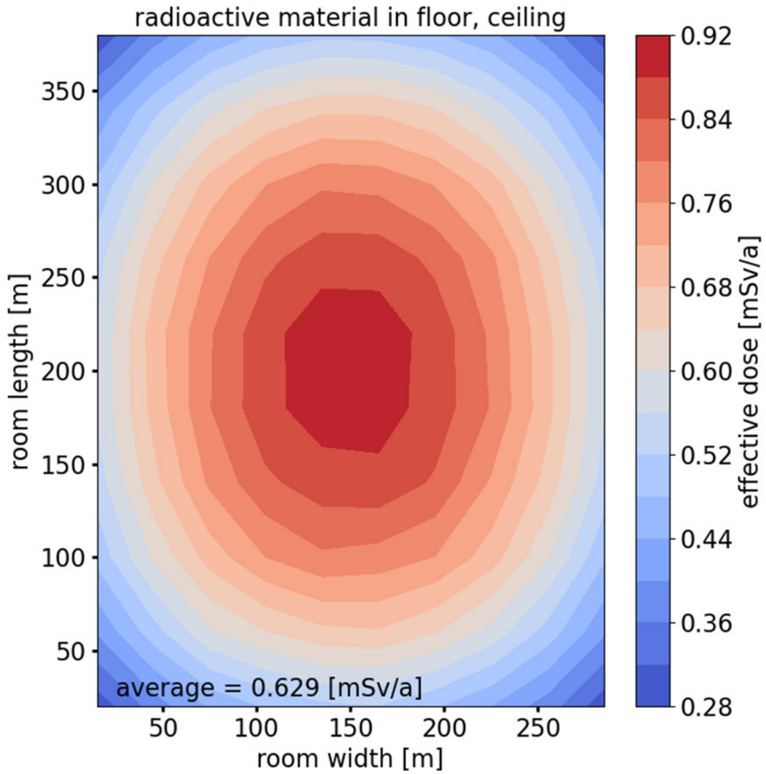
Radionuclide redistribution:

To maintain the same amount of radionuclides, when walls are nuclide-free, floor and ceiling need 2.46 times higher concentration.

$[C_{Ra}, C_{Th}, C_K] = 2.46*[80, 80, 800]$ Bq/kg

Wall thickness = 0.2 m
Density = 2350 kg/m3

Contour plot height at 1.25 m



- inverse and stronger gradient between walls and room centre compared to original scenario

- larger dose at midpoint but smaller dose at places close to the walls

- lower average room dose by 18 %

Thought experiment:

Would a redistribution of radionuclides (e.g., radionuclide free floor and wall – but accordingly higher concentrations in walls) lead to a reduction in the dose at the midpoint?

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To sum up

- a redistribution of radionuclides in walls leads to inverse changes of the dose with respect to room centre and room average

- while for room centres the dose decreases slightly if all radionuclides are in walls and none in floor and ceiling, the room average increases
- a redistribution of radionuclides (into floor and ceiling with radionuclide free walls) leads to a reduced average room dose while the dose at the room centre increases

Potential strategies for reduction of radiation exposure

- currently it seems more appropriate to use building materials with higher radionuclide concentration preferably for floor and ceiling (if possible to choose)
- building material with lower radionuclide concentrations should preferably be used for walls

- next steps: * establishing an index formula for non-uniformly distributed radionuclides in building walls
  * accounting for a second layer of building material