# QUEST OF PROXIES FOR INDOOR RADON RISK : BELGIAN EXPERIENCE

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# Proxy for indoor Rn risk:

Property well-correlated to indoor Rn that could contribute to the prediction of the level/class of indoor Rn risk in areas where no or very few indoor Rn data are available.

Proxies are usually assumed to exist on the basis of simple concepts…

Indoor Rn
<migration of soil Rn (permeability)
< (sub)soil Rn < (sub)soil Ra < (sub)soil U
< geology, geochemistry, pedology
> terrestrial gamma doserate

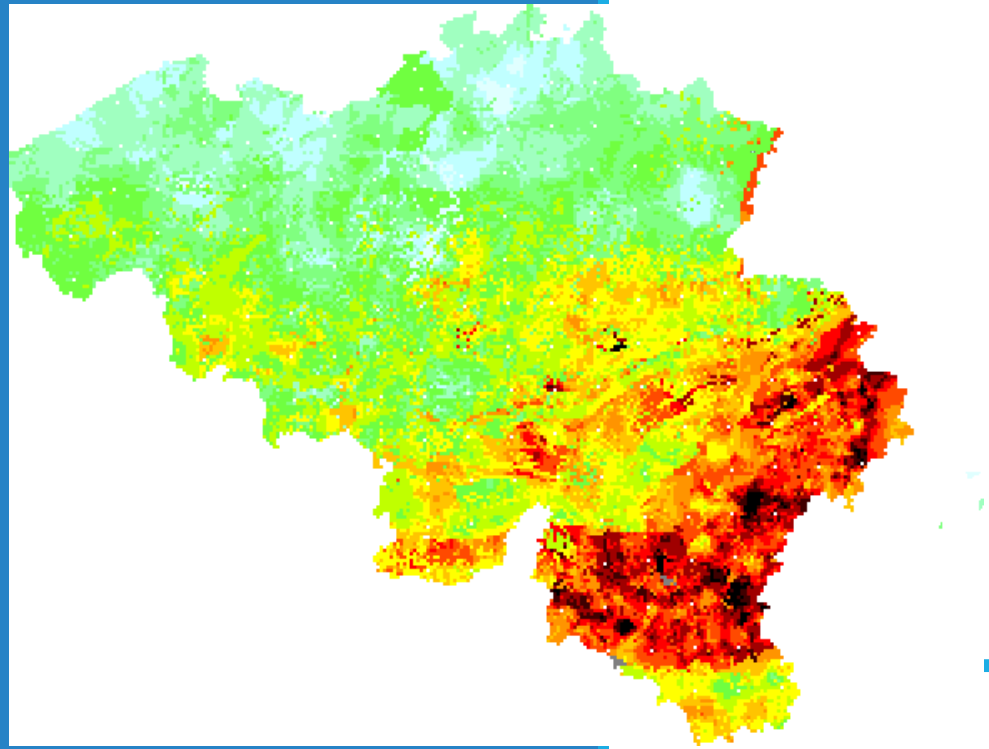
… but nature is not always simple,

it is essential to control their mutual correlations.

# Contents

1. Belgian context
2. Available databases
3. Summary of Ardenne results (variability within an affected area)
4. Data treatment – co-location
5. ANOVA (geology, lithology, soil class and texture)
6. Correlations between co-located variables
7. Data grouped by geology or soil class
8. Discussion

# 1. Belgian context



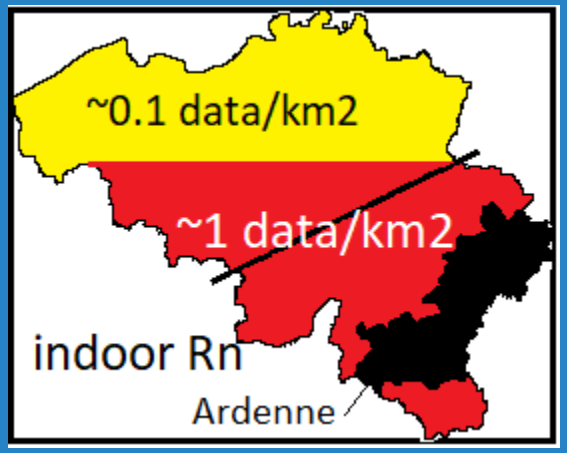
Map of indoor radon risk:

Moving median of nearest 20 indoor Rn data in same geological unit

North: not Rn-affected, except few hot spots
Mainly Meso-Cenozoic, thick soils

South: Rn-affected, except few cold areas
Mainly Paleozoic, thin stony soils

# 2. Available databases




*Georeferenced datasets*

*Indoor radon:* Walloon region ~1 data/km$^2$

Flemish region ~0.1 data/km$^2$

*Soil gas radon and permeability:*

*FANC:* Ardenne > 1 data/km$^2$, ISIB: all Belgium ~0.003 data/km$^2$

*Soil K, Th, U/Ra:* ~500 data used to calibrate airborne data

*Airborne survey of K, Th, U:* 100m x 100m grid

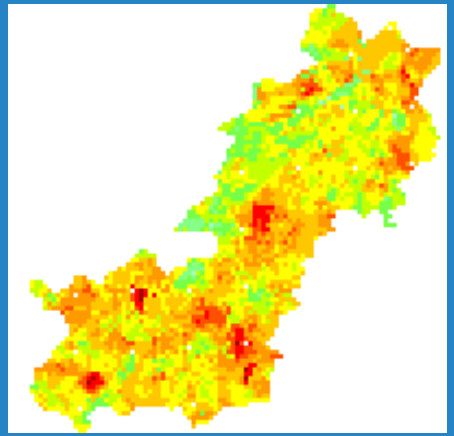
*Terrestrial gamma dose rate:*

379 data + calculated values from airborne data.

*Qualitative information*: geological, lithological and pedological information available for each data.

*In red: used in present work (whole Belgium)*

Ardenne: Indoor Rn map
(median of 20 nearest data)



# 3. Ardenne: no correlation

*Synthesis (presented in Verbania IWEANR 2017)*

**High variability** within this main affected area:
Smoothed indoor Rn: 45 Bq/m$^3$ < local median < 450 Bq/m$^3$ (fig)
Smoothed soil gas Rn: 16 kBq/m$^3$ < local median < 106 kBq/m$^3$
Smoothed permeability: 0.5 µm$^2$ < local median < 16 µm$^2$

**BUT**

**Good homogeneity** of geology, lithology, soil type

**No correlation** between smoothed values of

**Indoor Rn**

**Soil gas Rn**

**Permeability**

**Geogenic Rn potential (Barnet-Neznal)**

**Soil U (airborne)**

The factor governing the variability is still not identified

# 4. Data treatment

1. Calculated "Rn potential" and terrestrial gamma doserate

$$RP = \frac{[Rn]-1}{-log_{10}K-10}$$

*[Rn],kBq/m³ K,m²*

*TGDR=12.91*[K]+2.46*[Th]+5.7*[U]*

*[K],% [Th],ppm [U],ppm*

2. Mathematical transformation to get approximately normal distributions

Indoor Rn: logarithm
Permeability: logarithm
Soil gas Rn: cubic root
Radon potential: fourth root

3. Co-location at the coordinates of scarce ISIB soil data

Indoor Rn: smoothing (moving median)
Airborne data: interpolation

# 5. Analysis of variance

| Variable | Geology | Lithology | soil class | Texture |
|---|---|---|---|---|
| Number of classes | 12 | 8 | 9 | 6 |
| Smooth Ln(indoor Rn) | 66 % | 57 % | 61% | 24 % |
| Airborne K | 40 % | 30 % | 45 % | 39 % |
| Airborne Th | 47 % | 44 % | 65 % | 47 % |
| Airborne U | 41 % | 37 % | 50 % | 43 % |
| Calculated TGDR | 47 % | 42 % | 59 % | 46 % |
| Soil gas Rn ^1/3 | 36 % | 31 % | 15 % | 5 % |
| Log permeability | 56 % | 53 % | 29 % | 13 % |
| Rn potential ^1/4 | 39 % | 28 % | 29 % | 17 % |

Percentage of the variance explained by the classification

# 6. Correlation between co-located variables

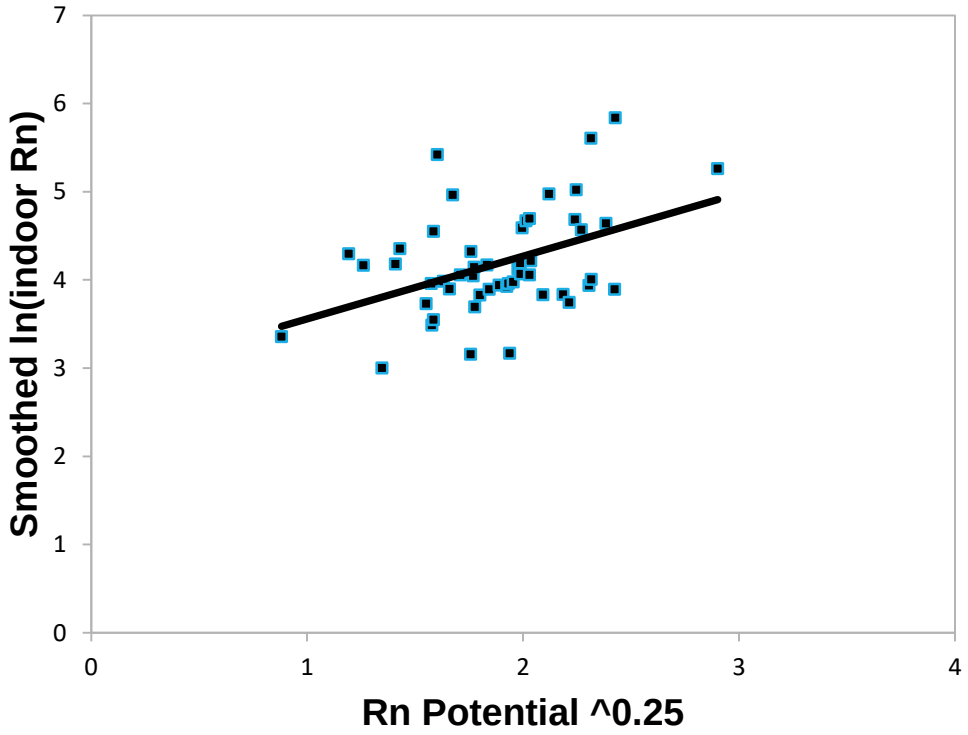
HE2B ISIB

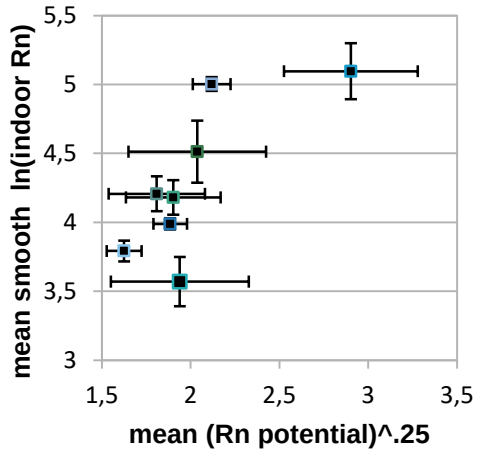
## Pearson correlation coefficients - co-location at soil data points or [on km grid]

| | Soil gas Rn^1/3 | Log Perm | Rn pot ^1/4 | soil K | Soil Th | Soil U | TGDR |
|---|---|---|---|---|---|---|---|
| **Smooth ln indoor Rn** | **0.32** | 0.22 | **0.44** | 0.30 [0.42] | 0.41 [0.53] | **0.23** [0.41] | 0.38 [0.51] |
| **Soil gas Rn^1/3** | * | -0.35 | *(0.73)* | 0.35 | 0.37 | 0.37 | 0.41 |
| **Log Soil permeability** | * | * | *(0.35)* | -0.38 | -0.37 | -0.30 | -0.39 |
| **Rn potential^1/4** | * | * | * | 0.14 | 0.32 | **0.26** | **0.27** |
| **Airborne soil K** | * | * | * | * | 0.89 [0.86] | 0.54 [0.64] | *(0.93)* |
| **Airborne soil Th** | * | * | * | * | * | 0.61 [0.73] | *(0.96)* |
| **Airborne soil U** | * | * | * | * | * | * | *(0.77)* |

1. Belgian context
2. Available databases
3. Ardenne
4. Data treatment
5. ANOVA
6. Correlations between variables

**The measurement of the radon potential at a single site does not allow to predict the local indoor Rn risk**







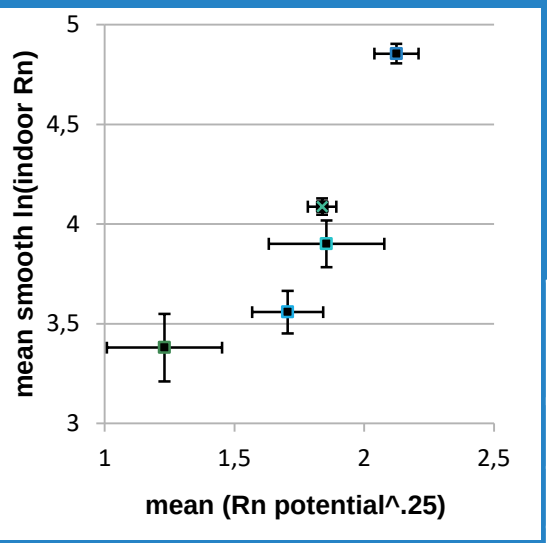

# 7. Data grouped by geology

Pearson correlation coefficients (weighted ~data number)

| Mean values of data | Soil Rn | Perm. | Rn pot. | soil K | Soil Th | Soil U | TGDR |
|---|---|---|---|---|---|---|---|
| ln(indoor Rn) | 0.62 | 0.40 | **0.81** | 0.40 | 0.45 | **0.23** | 0.40 |
| Soil gas Rn^1/3 | * | -0.38 | *(0.78)* | 0.61 | 0.67 | 0.68 | 0.67 |
| Log(permeability) | * | * | *(-0.01)* | -0.42 | -0.49 | -0.66 | -0.52 |
| Rn potential^1/4 | * | * | * | 0.46 | 0.55 | 0.45 | 0.51 |
| Airborne soil K | * | * | * | * | 0.97 | 0.86 | *(0.98)* |
| Airborne soil Th | * | * | * | * | * | 0.90 | *(0.99)* |
| Airborne soil U | * | * | * | * | * | * | *(0.92)* |

Scarce data: only 8 geological units have Rn potential data.

**The mean radon potential of a geological unit seems a good indicator the mean indoor Rn risk.**






# Data grouped by soil class

Pearson correlation coefficients (weighted ~data number)

| | Soil Rn | Perm. | Rn pot. | soil K | Soil Th | Soil U | TGDR |
|---|---|---|---|---|---|---|---|
| Mean ln(indoor Rn) | 0.82 | 0.52 | **0.93** | 0.67 | 0.67 | 0.46 | 0.65 |
| Soil gas Rn^1/3 | * | 0.43 | *(0.94)* | 0.84 | 0.77 | 0.72 | 0.77 |
| Log(permeability) | * | * | *(0.49)* | -0.12 | -0.19 | -0.26 | -0.20 |
| Rn potential^1/4 | * | * | * | 0.79 | 0.74 | 0.69 | 0.74 |
| Airborne soil K | * | * | * | * | 0.98 | 0.98 | *(0.99)* |
| Airborne soil Th | * | * | * | * | * | 0.97 | *(1.00)* |
| Airborne soil U | * | * | * | * | * | * | *(0.98)* |

Scarce data: only 5 WRB soil classes have Rn potential data.

**The mean radon potential of a soil class seems a good indicator of the mean indoor Rn risk.**

# 8. Discussion - 1

**A. CAVEAT**

***Scarce data for soil Rn and permeability: results are indicative, not conclusive***

**B. DEFINITION**

*Local indoor Rn risk described by the median of 20 nearest data with same geology*

**C.**

**A large part of the variability of indoor Rn risk**
**can be related to geology (66%) or to soil class (61%)**

**The remaining variability within an affected area** (Ardenne)
**is not related to soil U, Rn potential, permeability, soil Rn**

**Rn potential at a single site, even several sites within ~10 km$^2$** (Ardenne)
**cannot predict the local level of indoor Rn risk**

# Discussion - 2

**The variability of indoor Rn risk between geological units or between soil classes is well correlated with the mean Rn potential, less with mean soil gas Rn, only poorly correlated with mean soil U**

**This suggests that predictive radon maps based on proxies should use geological units or soil classes as mapping units.**

**In Belgium, soil U is not an acceptable proxy for indoor radon risk.**

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