Assessing the relationships between soil radon concentrations and the occurrence of shallow underground caverns

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Simplified geological map

1 Plio-Pleistocene marine to transitional deposits
2 Sabatini district volcanites
3 Colli Albani district ignimbrites
4 Colli Albani district lavas
5 Alluvial sediments of Tevere River and its tributaries

• Tor Marancia - Valle della Caffarella study area
Map of the artificial cave quarried within the ignimbrites from Colli Albani volcano.
Indoor $^{222}\text{Rn}$ and $^{220}\text{Rn}$ along the cave

![Graph showing indoor $^{222}\text{Rn}$ levels over time with different parts of the cave highlighted.]

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Indoor $^{222}\text{Rn}$ and $^{220}\text{Rn}$ along the cave
Corrections for soil $^{222}$Rn seasonal changes using a permanent station

- March: 1.2
- July: 2.7

$^{222}$Rn at station 1 (kBq/m$^3$)
Corrections for soil $^{220}$Rn seasonal changes using a permanent station.
- **52 kBq/m³**
  Average soil $^{222}\text{Rn}$ on top of the cave

- **36 kBq/m³**
  Average soil $^{222}\text{Rn}$ where the cavern is not present underneath
- **185 kBq/m³** Average soil $^{220}\text{Rn}$ on top of the cave
- **201 kBq/m³** Average soil $^{220}\text{Rn}$ where the cavern is not present underneath
0.31
Average soil $^{222}\text{Rn} / ^{220}\text{Rn}$ on top of the cave

0.21
Average soil $^{222}\text{Rn} / ^{220}\text{Rn}$ where the cavern is not present underneath
Variability of soil $^{222}\text{Rn}$ on top of the cave along the cavern path

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Variability of soil $^{220}\text{Rn}$ on top of the cave along the cavern path

![Graph showing the relationship between rock thickness and soil $^{220}\text{Rn}$ concentration. The equation $y = 199.33x + 76955$ with $R^2 = 0.8625$ is given.]

Decreasing rock thickness

Tufo Lionato

Pozzolane roesse

Increasing rock thickness

![Bar graph showing the soil $^{220}\text{Rn}$ concentration at different stations.]

Soil $^{220}\text{Rn}$ (Bq/m$^3$)
Variability of soil $^{220}$Rn on top of the cave along the cavern path

$y = 199.33x + 76955$
$R^2 = 0.8625$

Tufo Lionato
Pozzolane rosse

Decreasing rock tickness
Increasing rock tickness

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Variability of soil $^{222}\text{Rn}$ on top of a cave in Valle della Caffarella

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Valle della Caffarella cave – Soil Radon (kBq/m³)

Cave entrance: air mixing and dilution

Sinkhole: air mixing and dilution

Max values over the cave middle part

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Max values over the cave middle part

15 m

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Conclusions

• Indoor $^{222}$Rn and $^{220}$Rn concentrations in the cavern depend on the distance from the cave entrance and from the temperature gradient between outside and inside air (changing throughout the year and addressing air flux direction within the cave).

• Shallow underground caverns supply extra $^{222}$Rn to the soil gas sampled some metres on top. This supplementary fraction may enhance radon accumulation in indoor environments placed above, increasing the risk for inhabitants.

• Soil $^{220}$Rn concentration on top of the cave is affected by low indoor thoron content inside the cave and is directly proportional to the rock thickness above the cave roof.
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