

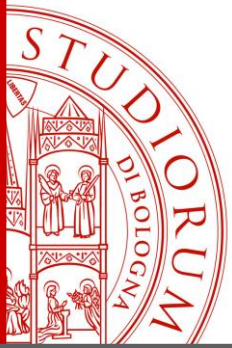
Radiation protection issues in the excavation of road and railway tunnels

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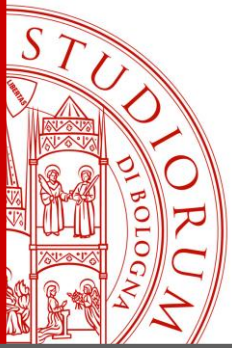
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- In road and railway tunnel excavation personnel is exposed to natural radiation.
- Exposure can have varying degrees of significance, as NORM content may vary by more than an order of magnitude depending on local lithology
- As far as radon is concerned, depending also on features of more distant bedrocks involved in radon convection
- Permeability of rock formations can also vary widely from rock to rock, playing also a key role in radon exhalation.



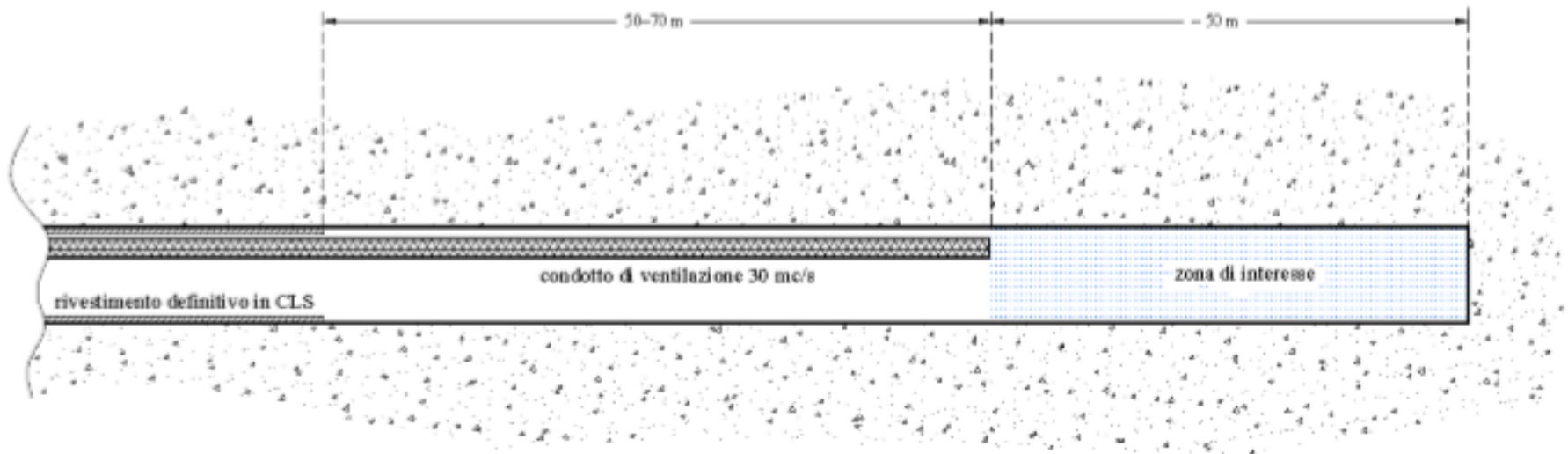
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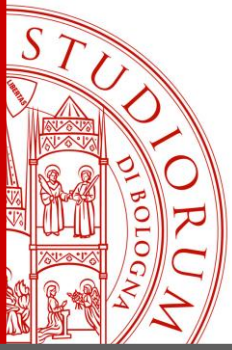


- It is of interest to develop a method to predict radon levels to characterize the work area.
- Drill cores are invariably taken before excavation begins, for a preliminary assessment of the geology involved
- The method proposed here for predicting radon levels is based on NORM and exhalation measurements in drill core samples, and on the geometry of the tunnel to be excavated
- An experimental campaign is under way on a railway tunnel under construction in northwestern Italy:
- Preliminary results will be presented and predicted values compared to experimental measurements



Typical structure of a tunnel under excavation



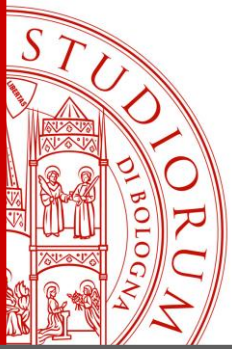


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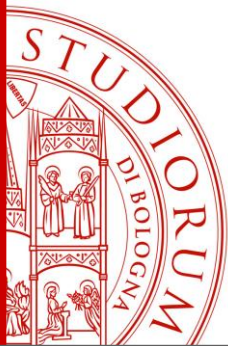
- The tunnel under evaluation has a section of 80 m^2 , approximately circular
- Air is blown at a rate of $30 \text{ m}^3/\text{s}$ through a duct ending 50 m before the tunnel bottom
- The interesting area, where workers are found, is then 4000 m^3
- This yields an estimate for the ventilation rate: 27 h^{-1}
- Excavation proceeds at a rate of 1 m every 8 h, so $80 \text{ m}^3/\text{h}$ of excavation material are produced.
- The actual timing is as follows: material is produced during 2 h, removed in the following 3 h then consolidation work is conducted for the next 3 h



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- An average presence of 25 m³ of excavation material is considered in the following
- The work area is mainly the last 10 m, that is also the most affected by the excavation front area
- The scenario considered here is the 800 m³ cylindrical volume comprised of the last 10 m of tunnel, surrounded by the walls and facing the front surface, and containing 25 m³ of excavation material
- Samples were taken from 2 locations: “Valico sud” and “Bypass”. Results in the following will refer to those two sets of samples



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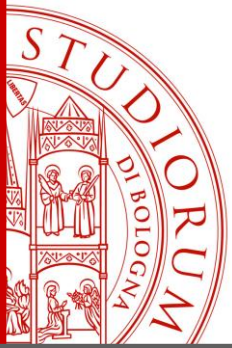


Physical characteristics of the rock samples

	surface	volume	mass	density
Valico sud	0.0135 m ²	9.48*10 ⁻⁵ m ³	0.3 kg	3164.82 kg/m ³
Bypass	0.0247 m ²	2.52*10 ⁻⁴ m ³	0.75 kg	2676.19 kg/m ³

NORM concentrations

	C(Ra)	C(Th)	C(K)
Valico sud	22 Bq/kg	29 Bq/kg	490 Bq/kg
Bypass	38 Bq/kg	41 Bq/kg	621 Bq/kg



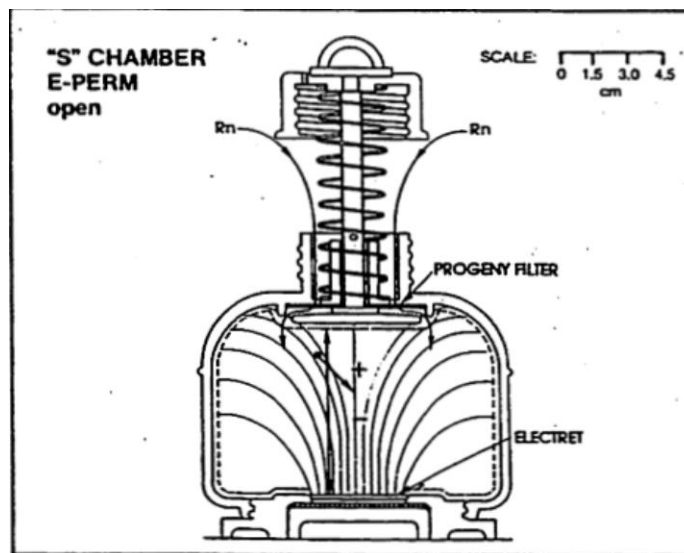
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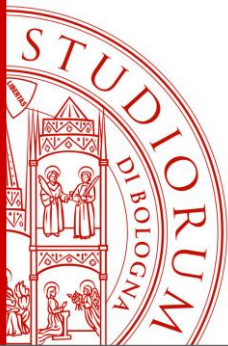


- Rock samples were cut into a simple geometry, to assess exact exhaling surface
- The remains were used to measure NORM content of the two bedrock types
- Measurements were made on a HPGe, coaxial, a model PROFILE by Ortec
- Energy range 20-2,000 keV, relative efficiency 20%, FWHM 1.9 keV @1332.5 keV
- Secular equilibrium ^{226}Ra - ^{238}U was assumed in spectrum analysis with Gamma Vision, likewise for the isotopic ratio ^{235}U - ^{238}U



- Exhalation was measured on an e-Perm electret system, following the protocol by Kotrappa
- the samples were closed in radon-tight container with an electret chamber and measured for 15 days.





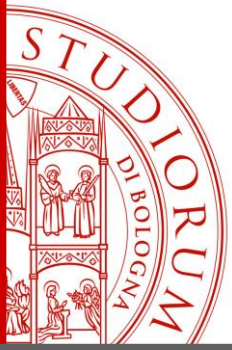
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- Measurements were repeated twice, yielding consistently the essentially same results

Exhalation

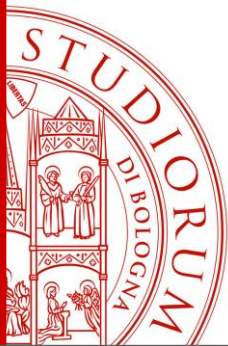
	Emission	surface	exhalation
Valico sud	$7.9 \cdot 10^{-7}$ Bq/s	0.0135 m ²	0.2110 Bq/h-m ²
Bypass	$1.1 \cdot 10^{-6}$ Bq/s	0.0247 m ²	0.1560 Bq/h-m ²



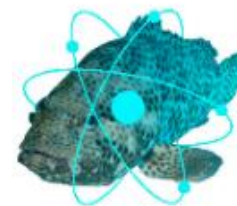
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- A special treatment needed to be given to the excavation material, for which it is impossible to know the actual surface offered.
- An estimate was made comparing it to spherical pebbles of a few cm of diameter, and correcting for irregularity in a “wild guess” fashion
- In the end the following concentrations were calculated, both with simple analytic formulas and with RESRAD-BUILD
- An experimental assessment was also conducted: 4 dosimeters were positioned in either location, during the Christmas recess.
- Ventilation was off at Valico sud. It was started for one hour a day at Bypass.
- The results will now be presented for Valico sud

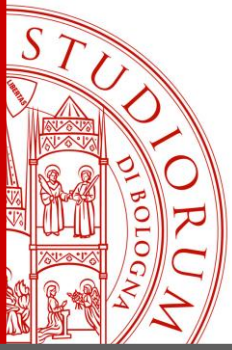


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Results for Valico sud

Radon concentration expected value		
	No material	W/excav. mat.
Analytic	11 Bq/m ³	130 Bq/m ³
RESRAD	12 Bq/m ³	97 Bq/m ³
experimental	<10	No data



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Conclusions

- The idea seems promising, as results are in the right ball game
- Further work needed on the excavation material
- Need for a dedicated experimental setting: tunnel at rest (no ventilation, no workers therefore) with appropriate quantity of excavation material
- Experimental setting at rest for at least 2 weeks, to permit build-up



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