10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

Radon and geology in Spain: Past, present and future

Fuente Merino, I; Sainz Fernandez, C.; Gutierrez Villanueva J.L.; Quindos Lopez, L.; Quindos Poncela, L.S.

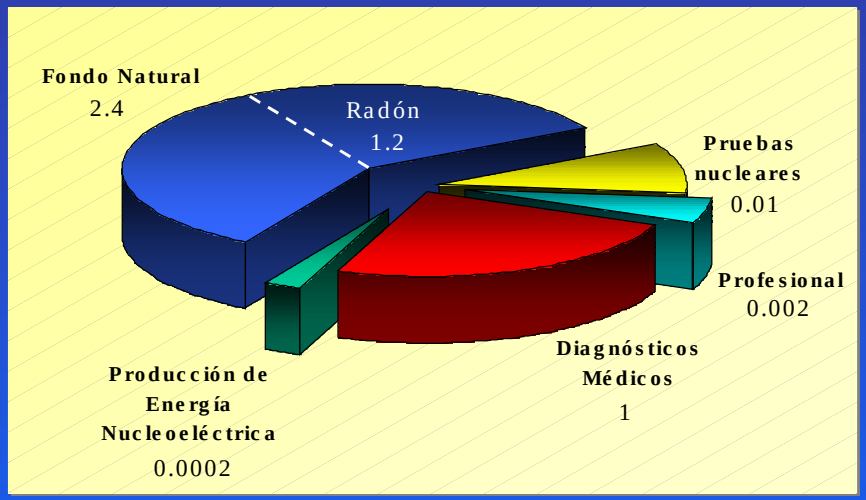
Radon Group

Universidad de Cantabria

Santander, Cantabria, Spain

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA



^{222}Rn

Noble gas

MAIN SOURCE OF RADIATION

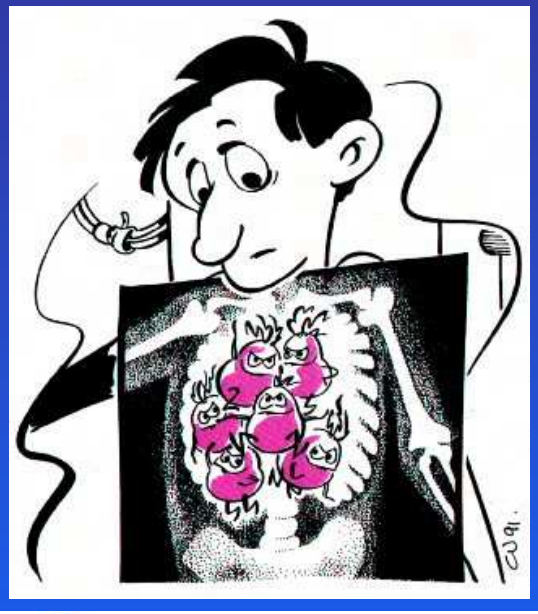
$T_{1/2}$ = 3.82 d

Emisor alfa (5.49 MeV)

SOURCES and transport mechanisms

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA



Il radon è inquadrato al secondo posto, dopo il fumo, come causa per l'insorgenza di tumori polmonari.
(foto: Radon, Ufficio federale d. sanità pubblica di Berna, CH).

RADON PROGENY INHALATION

LUNG CANCER RISK
Others ?

Increase in risk of lung cancer:

16% por 100 Bq/m3 95% CI (5, 31)

after correction for the dilution due to random year-to-year variability in residential radon concentrations, as well stratification for study, age, sex, broad region of residence within study, and detailed smoking history. (Darby el al. 2006)

INTERNATIONAL RADON PROJECT (WHO, 2005 - 2009)

UNIVERSIDAD DE CANTABRIA

RADON CONCENTRATION MAY PRESENT VARIATIONS

- **OF 3 ORDERS OF MAGNITUDE**
- **FROM ONE BUILDING TO ANOTHER**
- **FROM ONE AREA TO ANOTHER**

… SO MEASUREMENT CAMPAINGS ARE ESSENTIAL

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....

RADON MEASUREMENTS : MAIN RESULTS FROM THE NATIONAL SURVEY (1989-1991)

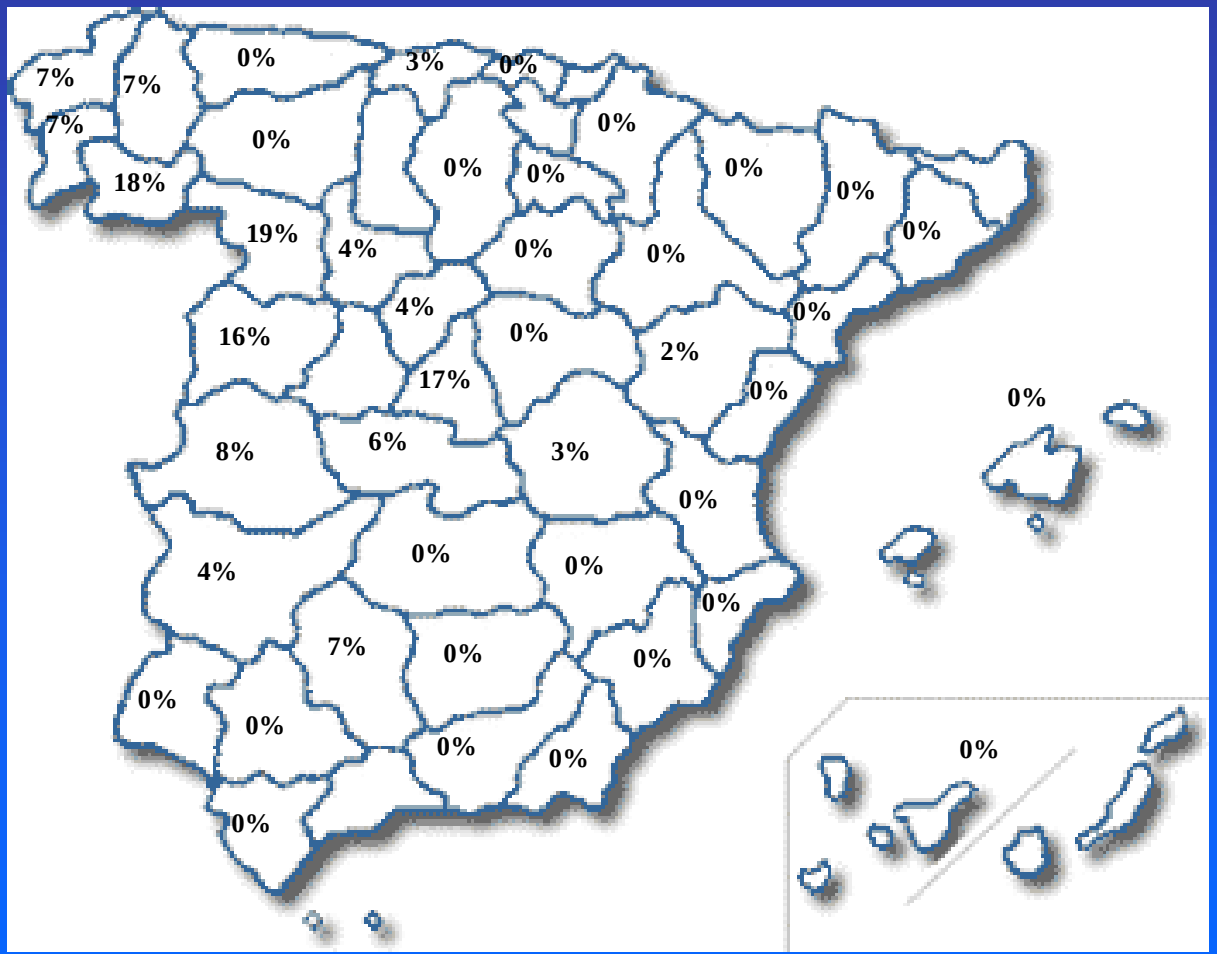
- NUMBER OF DWELLINGS SURVEYED: 2,000
- ABOUT 500 CITIES AND VILLAGES
- POPULATED WEIGHTED GEOMETRIC MEAN 45 Bq/m^3; G.S.D.:2.7
- PERCENTAGE OF DWELLINGS ABOVE 400 Bq/m^3 : 2%
- HIGHEST VALUE: 15,400 Bq/m^3

AREAS WITH HIGH RADON INDOOR VALUES HAVE BEEN IDENTIFIED, IN THE CENTER AND THE WEST OF THE COUNTRY

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....

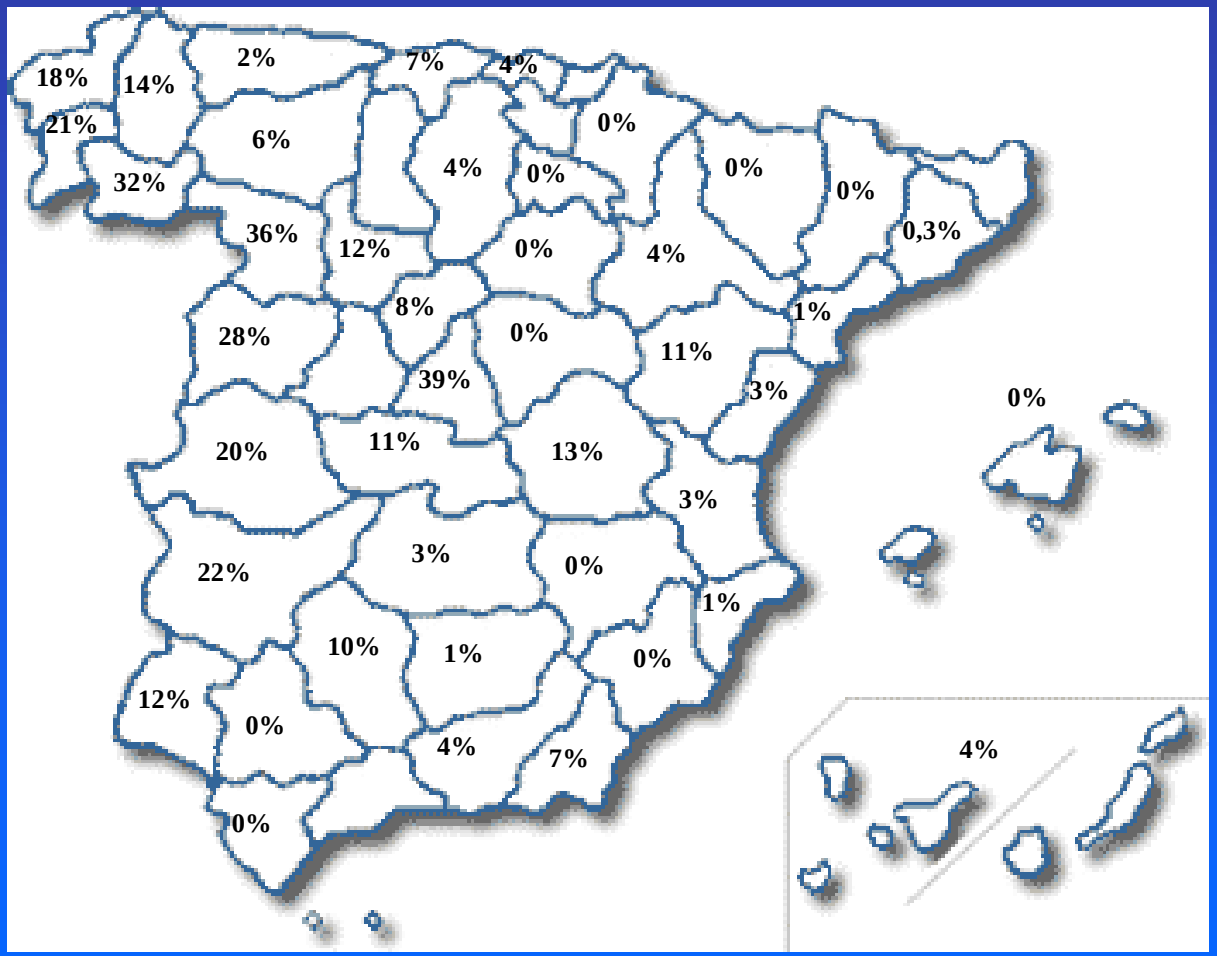


> 400 Bq/m³

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....



> 200 Bq/m³

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....

NATURAL RADIATION MAP (MARNA Project) (1991-)

- AN ONGOING PROJECT THAT IS BEING CARRIED OUT BY THE CSN , THE URANIUM NATIONAL COMPANY, SOME UNIVERSITIES AND AUTONOMOUS COMUNITIES.
- CURRENTLY IS IN THE LAST PHASE. THIS PROJECT PROVIDES US MAPS OF THE COUNTRY WHERE THE ZONES WITH DIFFERENT GAMMA RADIATION LEVELS ARE SHOWED.

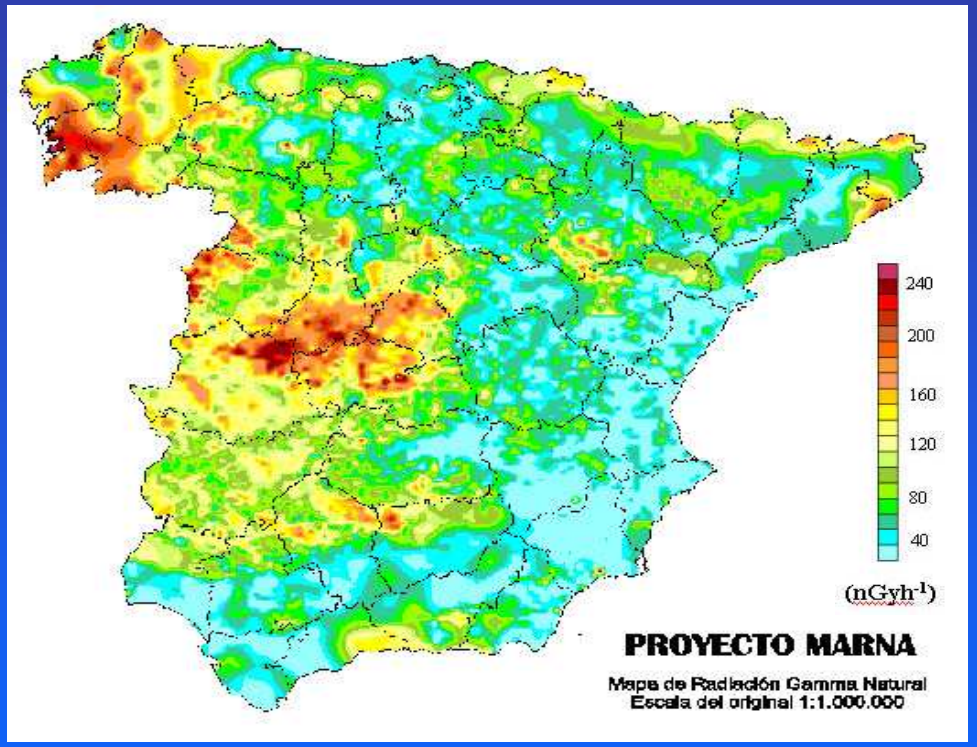
1.500.000 nationwide terrestrial gamma radiation values

1320 nationwide activity concentration data of ^{40}K, ^{226}Ra, y ^{232}Th in soil.

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....



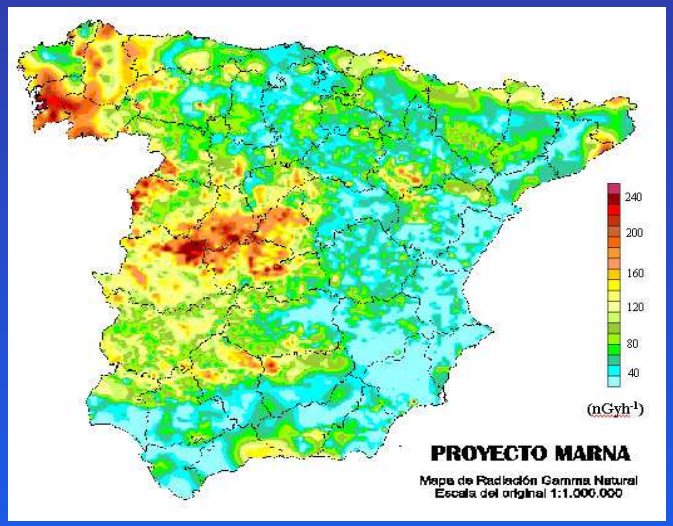
"NATURAL GAMMA RADIATION MAP (MARNA) AND INDOOR RADON LEVELS IN SPAIN"

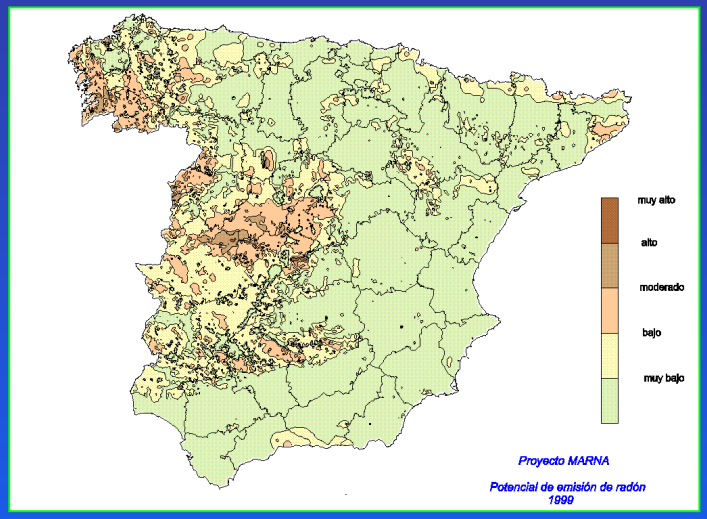
Environment International, 29 (8), 1091-96, 2004

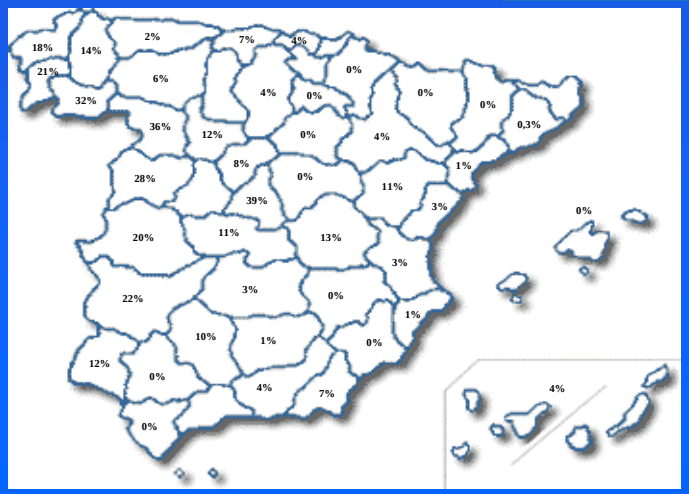
10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....







10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....

RADON MEASUREMENTS:

REGIONAL SURVEYS

.- NUCLEAR POWER STATIONS

.- OLD URANIUM MINING

.- LOS ARRIBES DEL DUERO

.- SIERRA DE GUADARRAMA

.- VILLAR DE LA YEGUA

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....

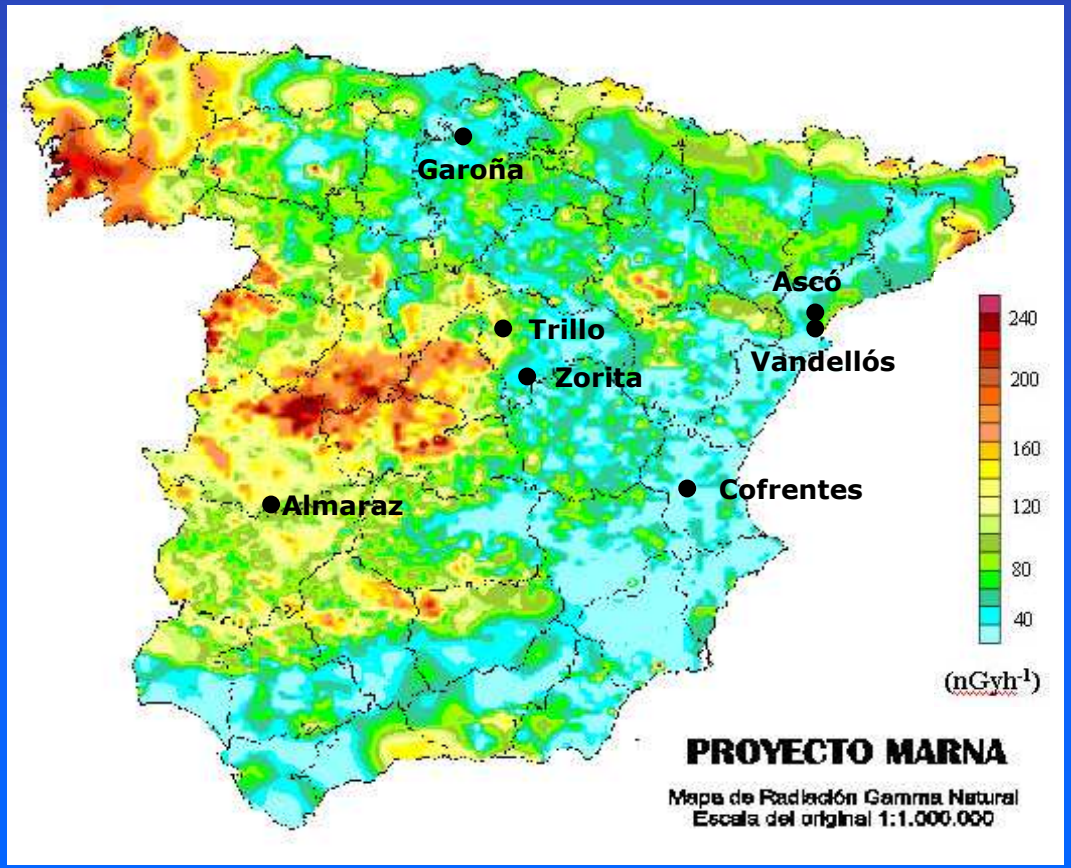
RADON MEASUREMENTS: REGIONAL SURVEYS

.- NUCLEAR POWER STATIONS

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

NATURAL RADIATION EXPOSURE IN THE VICINITY OF SPANISH NUCLEAR POWER STATIONS
Health Physics, Vol 85(5), 594-598,2003



UNIVERSIDAD DE CANTABRIA

NATURAL RADIATION EXPOSURE IN THE VICINITY OF SPANISH NUCLEAR POWER STATIONS

Health Physics, Vol 85(5), 594-598,2003

Table 2. External gamma radiation (outdoors).

		Almaraz	Asco Vandellos	Cofrentes	Garoña	Trillo	Zorita
External gamma radiation (outdoor) (nGy h^{-1})	Geometric mean	79.8	38.1	30.3	31.5	36.2	32.5
	G.S.D.	1.6	1.5	1.5	1.4	1.5	1.5
	Range	36.0–211.0	18.9–83.6	9.2–73.2	16.2–66.7	10.8–69.4	8.7–62.2
	Arithmetic mean	88.9	40.9	32.7	33.4	38.6	34.8
	A.S.D.	44.6	16.4	12.9	11.8	13.3	12.1

Table 3. External gamma radiation (indoors).

		Almaraz	Asco Vandellos	Cofrentes	Garoña	Trillo	Zorita
External gamma radiation (indoor) (nGy h^{-1})	Geometric Mean	119.1	46.1	36.6	38.5	52.5	42.9
	G.S.D.	1.6	1.5	1.4	1.4	1.5	1.4
	Range	54–313.1	22.2–97.4	20.3–82.1	20.6–82.2	17.2–100.1	17.2–87.1
	Arithmetic mean	133.2	49.4	39.1	40.8	55.9	45.0
	A.S.D.	67.5	19.6	15.2	14.4	19.1	14.0

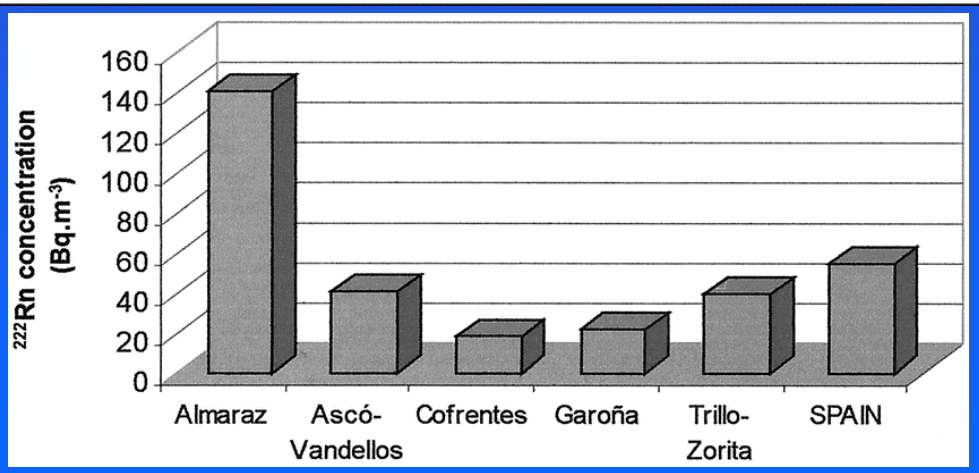
10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

NATURAL RADIATION EXPOSURE IN THE VICINITY OF SPANISH NUCLEAR POWER STATIONS
Health Physics, Vol 85(5), 594-598,2003

Table 1. Radon concentrations (Bq m^{-3}).

	Almaraz	Asco-Vandellos	Cofrentes	Garoña	Trillo	Zorita
Geometric mean	93.9	31.8	13.8	22.6	34.5	30.2
G.S.D.	2.4	2.1	2.1	1.6	1.8	1.7
Range	22.0–640.0	8.0–214.0	5.0–61.0	9.0–50.0	12.0–116.0	12.0–62.0
Arithmetic mean	141.9	42.5	17.9	24.9	41.3	36.2
A.S.D.	147.0	40.4	14.3	11.3	26.1	15.2



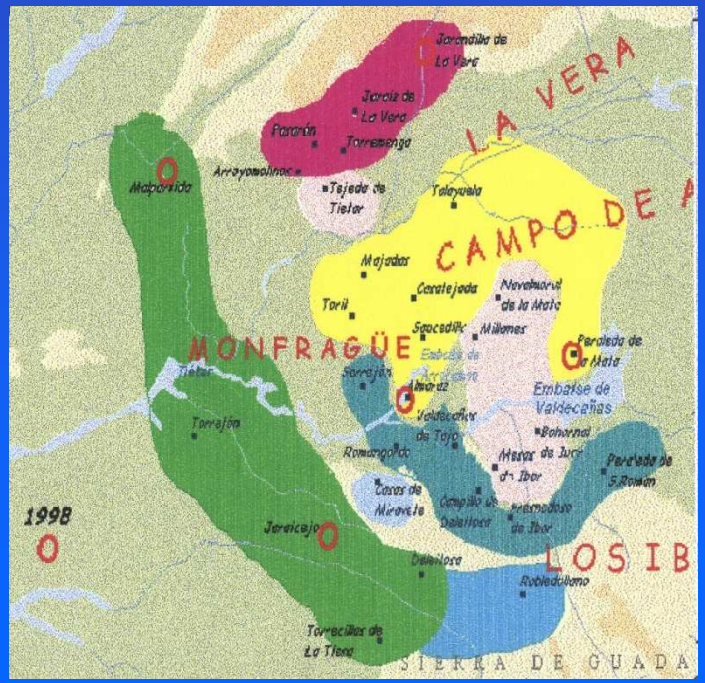
3% of houses > 400 Bq/m³

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

"NATURAL RADIATION EXPOSURE IN THE VICINITY OF THE SPANISH NUCLEAR POWER STATIONS. SPECIFIC STUDY OF CAMPO ARAÑUELO (CÁCERES, SPAIN)"

Journal of Environmental Radioactivity, Vol 79, 347-54, 2005



10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

"NATURAL RADIATION EXPOSURE IN THE VICINITY OF THE SPANISH NUCLEAR POWER STATIONS. SPECIFIC STUDY OF CAMPO ARAÑUELO (CÁCERES, SPAIN)"

Journal of Environmental Radioactivity, Vol 79, 347-54, 2005

STUDY	A.M. (Bq/m^3)	G.M. (Bq/m^3)	PERCENTAGE >200 Bq/m^3	PERCENTAGE > 400 Bq/m^3	Nº OF MEAS.
TOTAL CAMPO ARAÑUELO	87.6	65.7	7.2	2.7	349
NORTHERN ZONE	168.6	113.9	23.6	9.0	55

La Vera: 6 mSv/y

La Vera, 9 % of houses > 400 Bq/m^3.

Jarandilla: 25 mSv/y

30 % of houses > 400 Bq/m^3.

UNIVERSIDAD DE CANTABRIA

SPAIN: WHAT WE KNOW .....

RADON MEASUREMENTS: REGIONAL SURVEYS

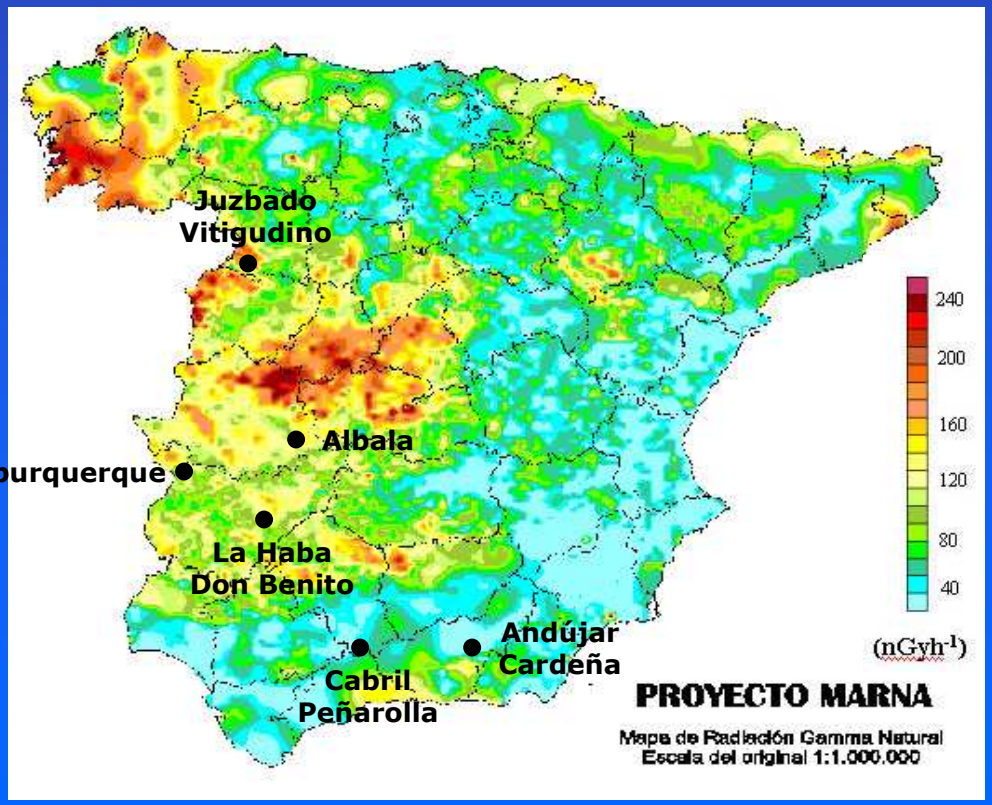
.- OLD URANIUM MINING

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

POPULATION DOSE IN THE VICINITY OF OLD SPANISH URANIUM MINES

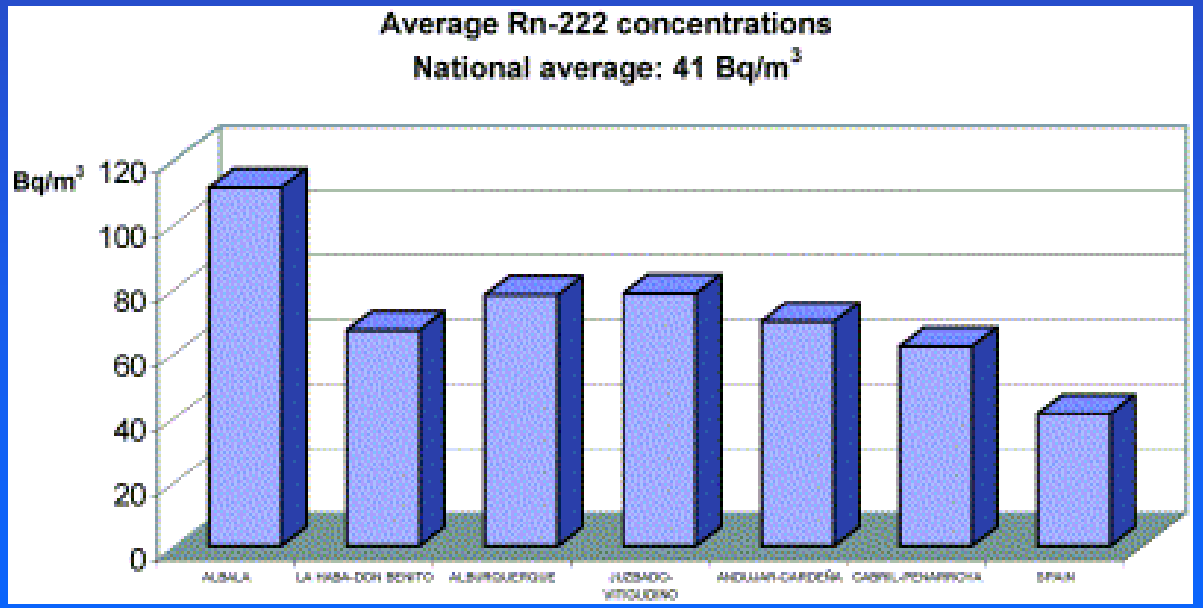
The Science of th Total Environment, vol 329, 1-3, 283-288, 2004



UNIVERSIDAD DE CANTABRIA

POPULATION DOSE IN THE VICINITY OF OLD SPANISH URANIUM MINES

The Science of th Total Environment, vol 329, 1-3, 283-288, 2004



UNIVERSIDAD DE CANTABRIA

POPULATION DOSE IN THE VICINITY OF OLD SPANISH URANIUM MINES

The Science of th Total Environment, vol 329, 1-3, 283-288, 2004

	Arithmetic mean (Bq m^{-3})	Arithmetic S.D. (Bq m^{-3})	Geometric mean (Bq m^{-3})	Geometric S.D.	Range (Bq m^{-3})	Percentage >200 (Bq m^{-3})
Albala (26)	164.4	159.0	111.2	2.5	31–679	26.9
La Haba-Don Benito (27)	94.3	75.7	66.9	2.4	13–273	11.1
Alburquerque (31)	101.5	84.3	77.9	2.1	18–358	16.1
Juzbado -Vitigudino (58)	116.3	124.9	78.3	2.4	11–627	17.0
Andujar -Cardeña (48)	100.9	99.2	69.6	2.3	14–355	16.7
Cabril -Peñarroya (32)	81.3	61.3	62.0	2.1	12–218	7.4

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

POPULATION DOSE IN THE VICINITY OF OLD SPANISH URANIUM MINES

The Science of th Total Environment, vol 329, 1-3, 283-288, 2004

ZONE	PERCENTAGE > 400 Bq/m^3
ALBALA	14
LA HABA-DON BENITO	6
ALBURQUERQUE	8
JUZBADO-VITIGUDINO	9
ANDUJAR-CARDEÑA	8
CABRIL-PEÑARROYA	5

ALL THE AREAS ARE INCLUDED IN THE ICRP 65 CRITERIA FOR RADON PRONE AREA

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

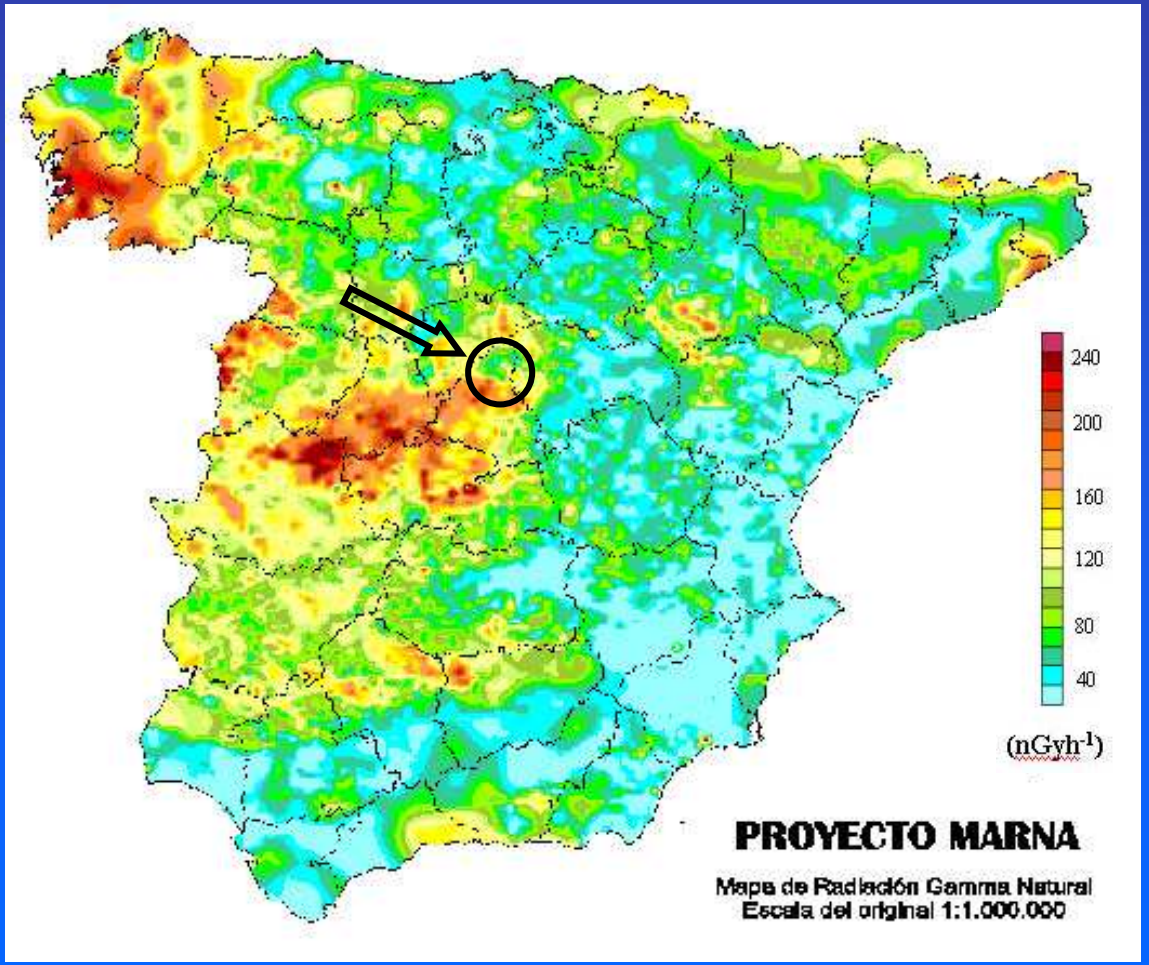
SPAIN: WHAT WE KNOW .....

RADON MEASUREMENTS: REGIONAL SURVEYS

.- SIERRA DE GUADARRAMA

UNIVERSIDAD DE CANTABRIA

SIERRA DE GUADARRAMA



10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

SIERRA DE GUADARRAMA

- First survey (1988-1990)

- 7 % OF HOUSES > 400 Bq/m³
- 28 % OF HOUSES > 200 Bq/m³
- GEOMETRIC MEAN: 122 Bq/m³ G.S.D. :2.1
- HIGHEST VALUE: 1,706 Bq/m³

0.5 million population

- Actual survey (2002-)

- 14 % OF HOUSES > 400 Bq/m³.
- 30 % OF HOUSES > 200 Bq/m³
- GEOMETRIC MEAN: 180 Bq/m³ G.S.D. :1.9
- HIGHEST VALUE: 2,600 Bq/m³

1.5 million population

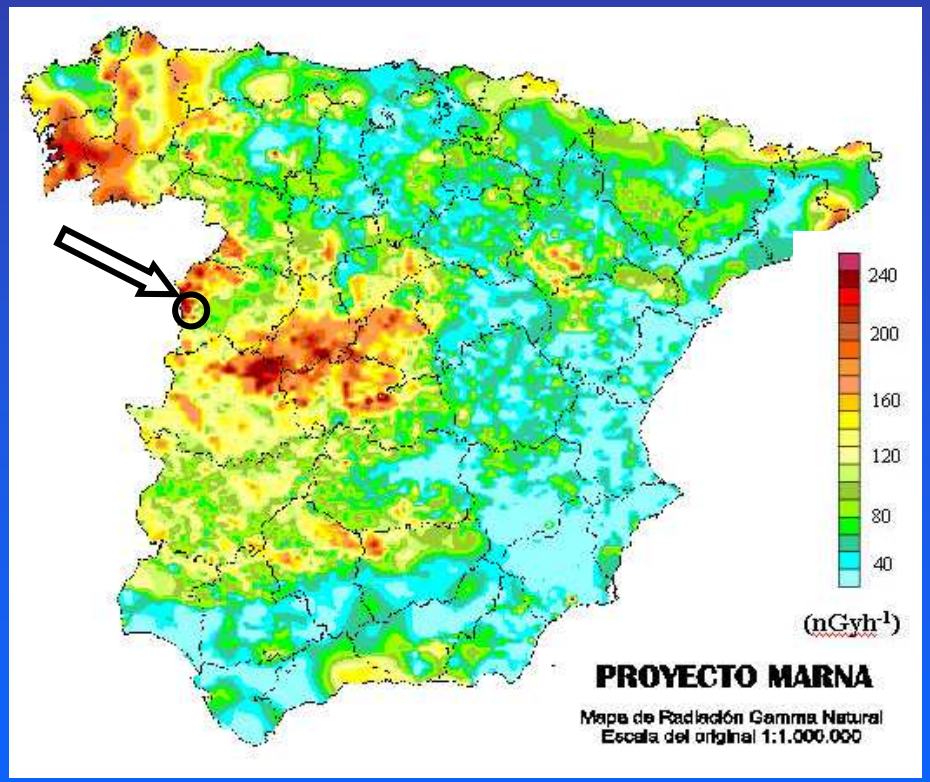
"Lung cancer risk estimations:A comparition between radon prone areas Stei (Romania) and Sierra de Guadarrama (Spain)"

Proceedings of the IRPA Regional Congress for Central and Eastern Europe, Romania, 2007

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

VILLAR DE LA YEGUA



"The Spanish experience on HBRA"

International Congress Series, Vol 1276, 50-53, 2005

UNIVERSIDAD DE CANTABRIA

THE VILLAR DE LA YEGUA TOWN

RADON SURVEYS:

(1988-1990); (1992-1995);(2000-2002) (2004-)

Nº OF MEASUREMENTS: 500

200 POPULATION

MAIN RESULTS:

- GEOMETRIC MEAN: 818 Bq/m^3 G.S.D.: 1.7
- HIGHEST VALUE: 25,160 Bq/m^3
- 75% OF HOUSES > 400 Bq/m^3
- 25% OF HOUSES > 1,000 Bq/m^3
- AVERAGE EXTERNAL GAMMA DOSE RATE: 300 nGy/h
- RADON IN WATER: 1,500 Bq/l

DOSES AS HIGH AS 40 mSv per year

High background radiation areas: The case of Villar de la Yegua village (Spain); Radiation Protection Dosimetry 125,pp. 565 – 567, 2007.

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

EFFECTIVENESS OF REMEDIATION TECHNIQUES

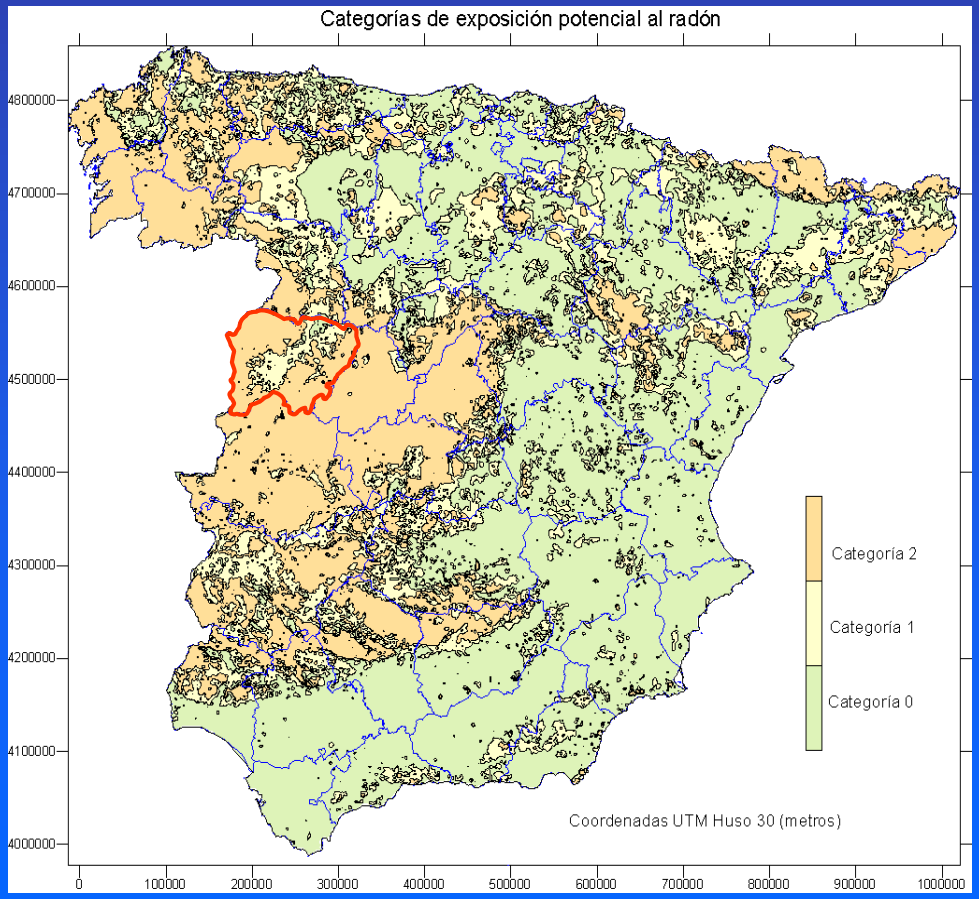
UNIVERSIDAD DE CANTABRIA

Location of the experimental pilot house

POTENTIAL RADON MAPPING

Source:

Spanish Nuclear Safety Council



UNIVERSIDAD DE CANTABRIA

PREVIOUS SOIL STUDY

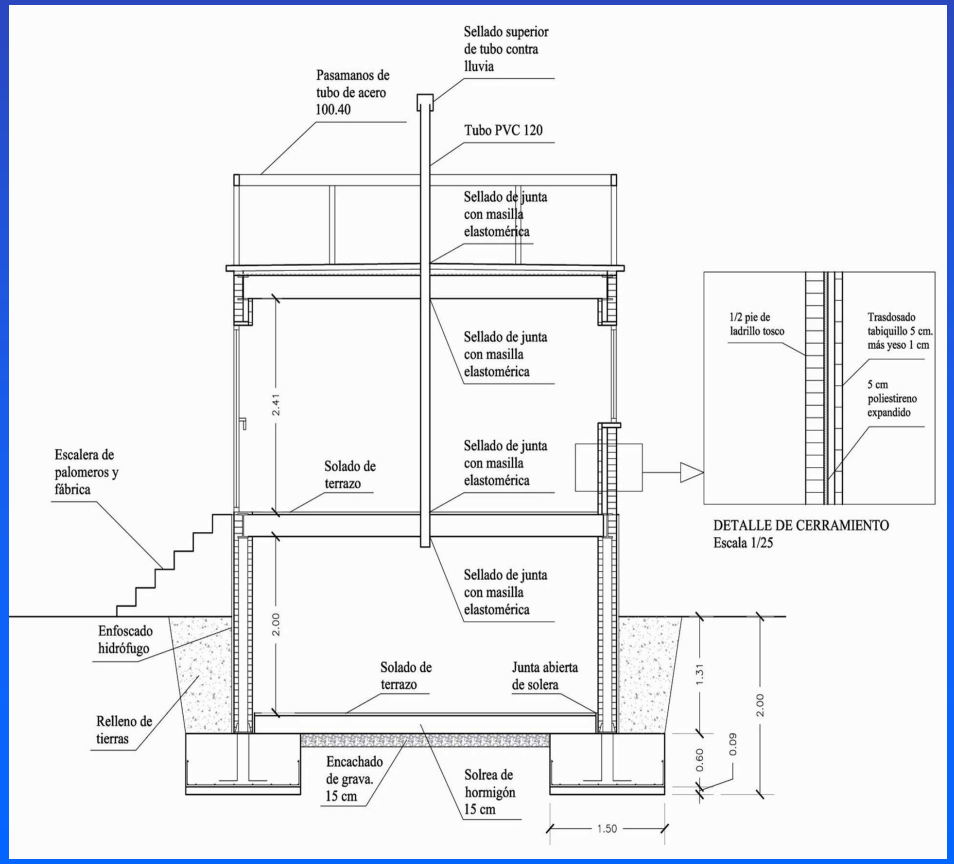
- Determination of radioactive isotopes in soil ► High radium concentration
- Determination of radon in soil at 1 m depth ► AM = 250000 Bq m^{-3} (70000-500000)
- Granulometry and permeability determination ► AM = 10^{-12} m^2 (medium)

HIGH RADON RISK AREA

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

Design of the experimental pilot house



UNIVERSIDAD DE CANTABRIA

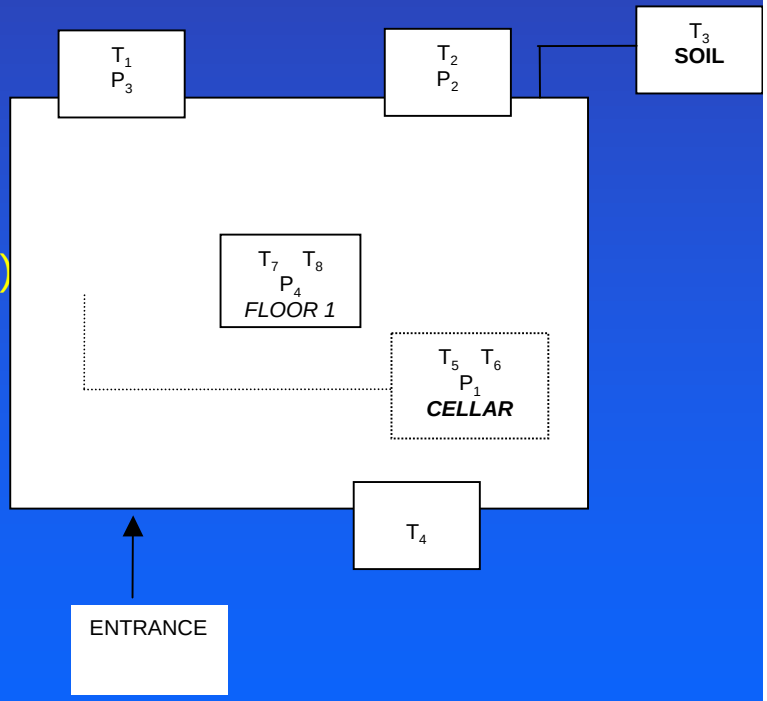
Initial measurements

MATERIAL AND METHODS

- COUNTER LUDLUM
- 8 TEMPERATURE SENSORS (T1 ... T8)
- 4 PRESSURE DIFFERENCE SENSORS (P1... P4)

CONTINUOUS RADON MONITORING:

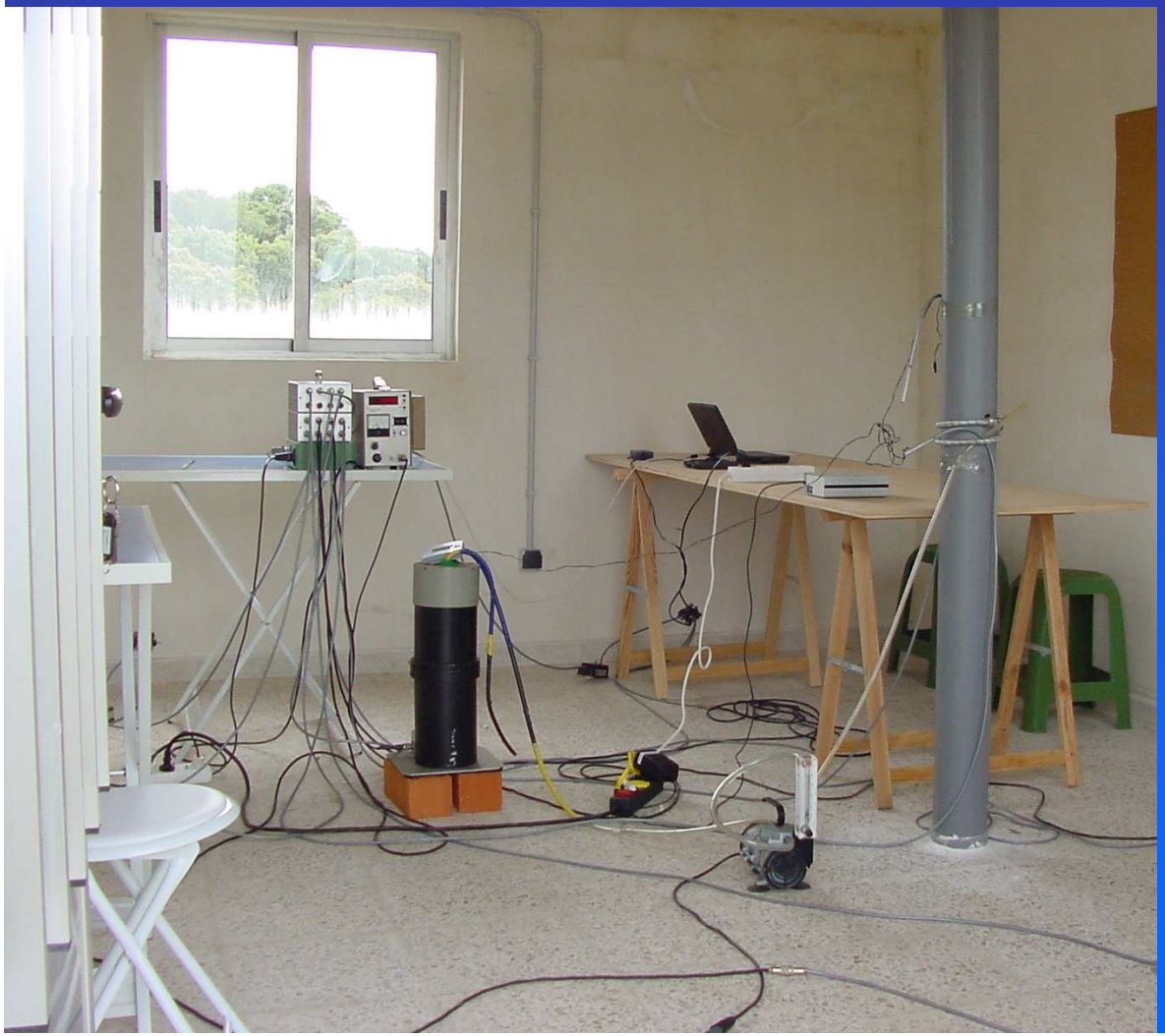
- **2 DoseMan SARAD**
- **2 Radon Scout SARAD**



10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

LABORATORY INSTALLED AT THE MODEL HOUSE



UNIVERSIDAD DE CANTABRIA

METEOROLOGICAL PARAMETERS PROVIDED BY A NEARBY STATION

Data were recorded every 10 minutes

- Mean wind velocity (m/s)
- Maximum wind velocity (m/s)
- Mean wind direction (º)
- Mean air temperature (ºC)
- Maximum air temperature (ºC)
- Mean relative humidity (%)
- Mean pressure (mb)
- Mean solar radiation (W/m2)
- Maximum solar radiation (W/m2)
- Accumulated fall (mm)
- Evaporation (mm)
- Battery state (V)

Mean wind speed varied from January 2006 until June 2007 between 0 y 11,6 m/s whereas air temperature between –5,3ºC y +36,1 ºC.

UNIVERSIDAD DE CANTABRIA

Initial measurements (4 months)

CLOSED MODULE

Mean indoor radon concentrations:

42.000 Bq/m^3 in CELLAR (MAX VALUE 120.000 Bq/m^3)
7.000 Bq/m^3 in FIRST FLOOR (MAX VALUE 40.000 Bq/m^3)

- **Increased indoor radon concentrations after heavy rain**
- **No significant influence of wind and temperature**
- **Inverse correlation with athmospheric pressure variations. Main factor**

UNIVERSIDAD DE CANTABRIA

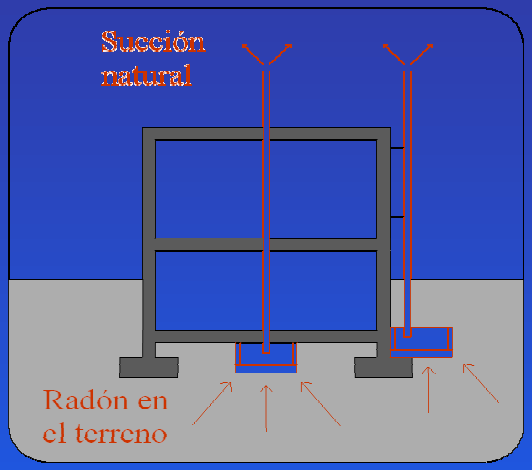
Remedial actions tested

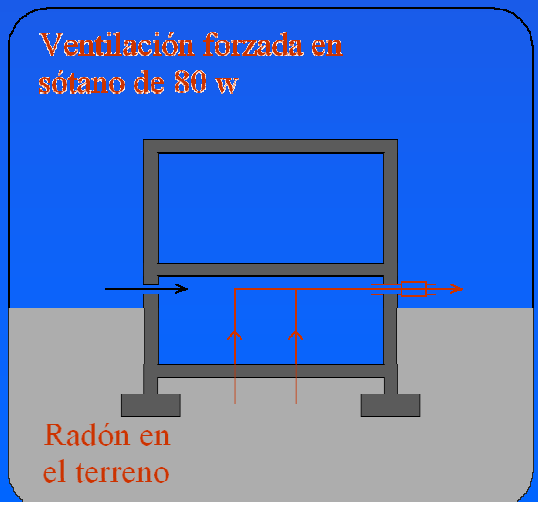
Natural/Forced air extraction from soil with lateral and central pipe

Pressurization/depressurization of air within the soil with central pipe

Crossed ventilation in cellar

Insulation barrier





CENTRAL PIPE
UNDER SOIL

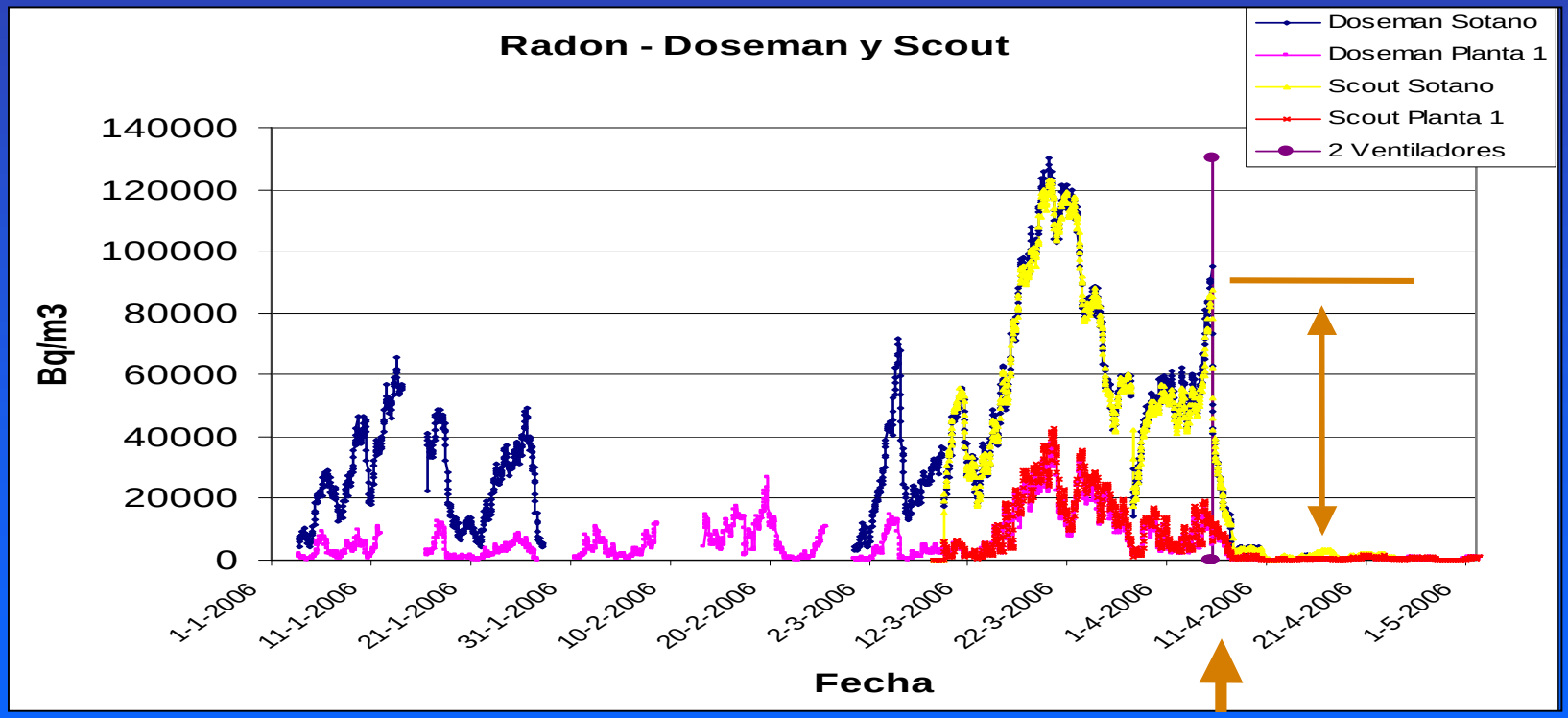

Radon barrier
ETALON
CALtronic 3

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

EFFECTIVENESS

Considerable radon reduction with all actions



MEAN RADON CONCENTRATION REACHED

1.700 Bq/m³ CELLAR

500 Bq/m³ FIRST FLOOR

UNIVERSIDAD DE CANTABRIA

EFFECTIVENESS (mean lowest level reached in Bq m^{-3})

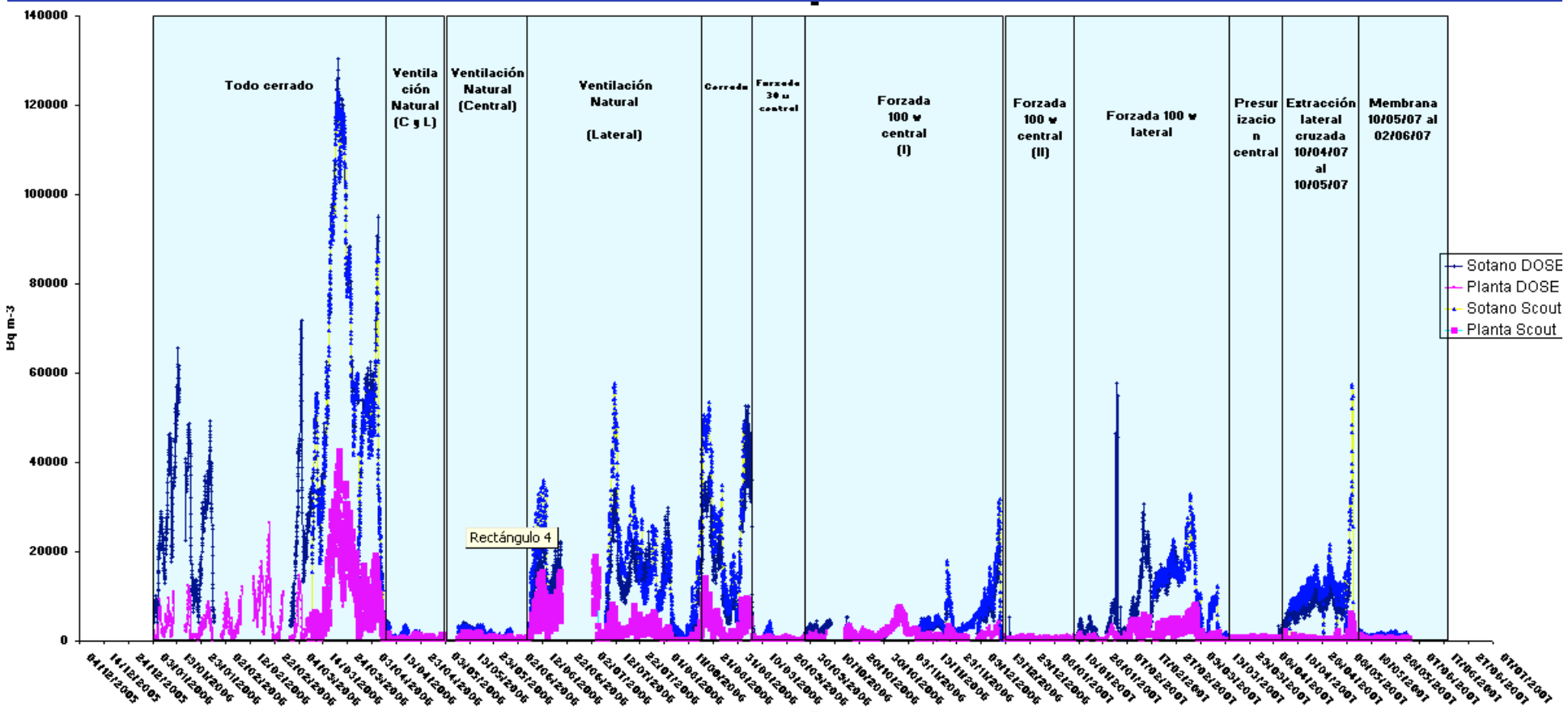
Action	First floor	Cellar
Central natural ventilation	600	1700
Lateral natural ventilation	2300	16000
Central forced extraction	250	400
Lateral forced extraction	700	1300
Central pressurization	400	300
Crossed ventilation	500	7200
Radon barrier	300	1700

Mean lowest level reached in Bq m^{-3}

10th International Workshop on the Geological Aspects of Radon Risk Mapping
September 22 - 25, 2010

UNIVERSIDAD DE CANTABRIA

WHOLE STUDIED PERIOD. 2006 AND FIRST SIX MONTHS OF 2007



UNIVERSIDAD DE CANTABRIA

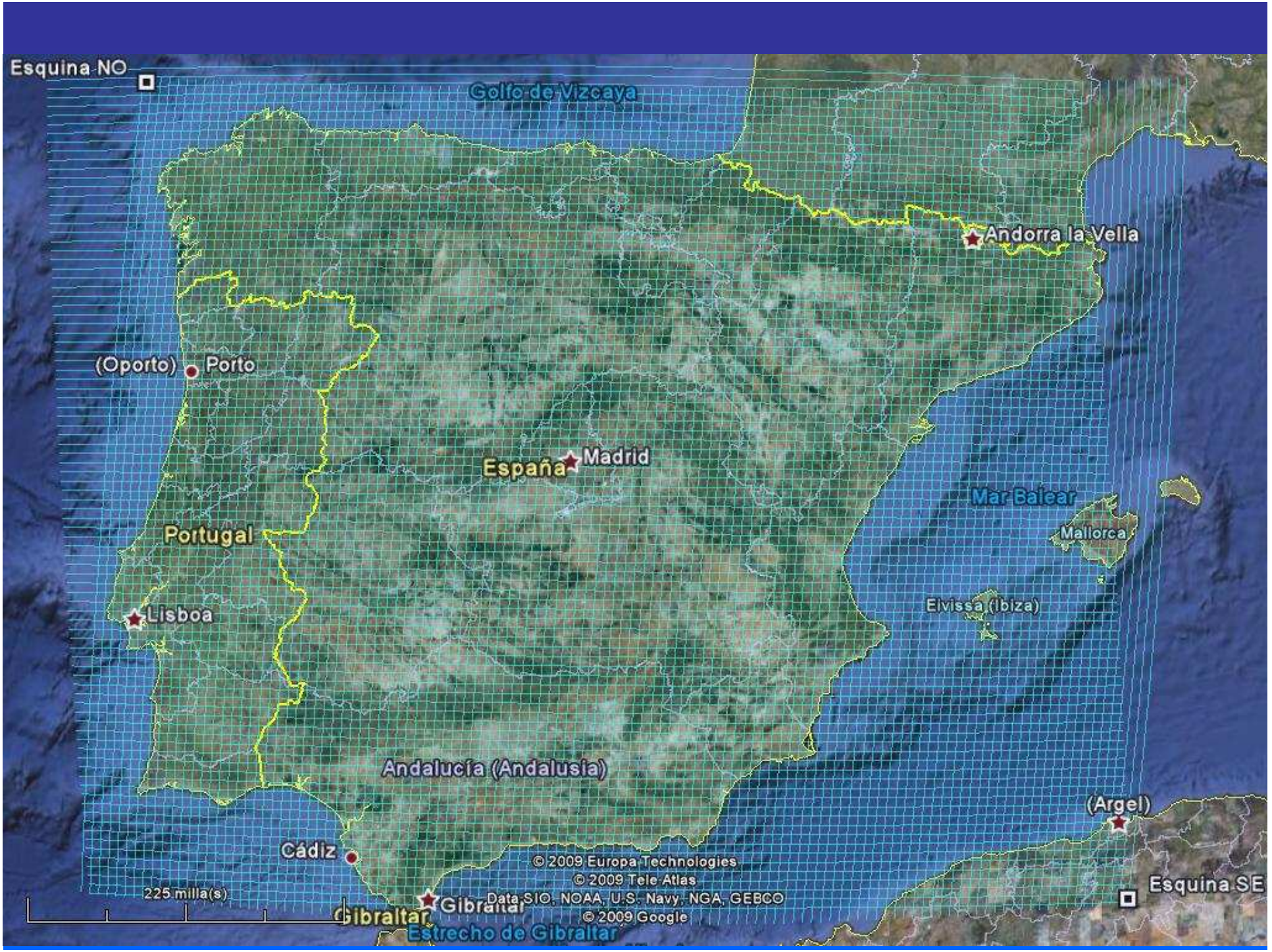
CONCLUSIONS

.- THE RISK COMING FROM NATURAL RADIATION IS VERY DIFFICAULT TO ACCEPT FOR THE AUTHORITIES WHICH FINALLY ARE SUPPORTING THE RESEARCH ACTIVITIES.

.- THE INCLUSION OF RADON AS ANOTHER INDOOR AIR POLLUTANT, IS VERY IMPORTANT BECAUSE THIS MEANS TO BE IN LAW AS A NATURAL WAY.

WHAT ABOUT THE NEXT FUTURE ……..

There is a lack of requirements concerning radon protection in the Spanish legislation for radon in houses BECAUSE in this case only exist a Recomendation 90/143/EURATOM with a design level value of 200 Bq/m^3


Esquina NO
Golfo de Vizcaya
Andorra la Vella
(Oporto)
Porto
España
Madrid
Mar Balear
Portugal
Mallorca
Lisboa
Eivissa (Ibiza)
Andalucía (Andalusia)
(Argel)
Cádiz
© 2009 Europa Technologies
© 2009 Tele Atlas
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Google
225 milla(s)
Gibraltar
Gibraltar
Estrecho de Gibraltar
Esquina SE

We kindly invite you to take part in

INTERNATIONAL INTERCOMPARISON EXERCISE ON NATURAL RADIATION MEASUREMENTS UNDER FIELD CONDITIONS

Organized by the Radon Group (University of Cantabria, SPAIN)

SUMMER 2011

Saelices el Chico
(Salamanca, Spain)

GRUPO RADÓN
Facultad de Medicina
Avda. Cardenal Herrera Oria s/n
39011 Santander
Cantabria (SPAIN)
Phone: +34 942 20 22 07
e-mail: laruc@unican.es

SINCERE THANKS FOR YOUR ATTENTION!