Geolocation of premises subject to radon risk: methodological proposal and case study in Madrid

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ABSTRACT

Useful information on the potential radon risk in existing buildings can be obtained by combining data from sources such as potential risk maps, the 'Sistema de Información sobre Ocupación del Suelo de España' (SIOSE) [information system on land occupancy in Spain], cadastral data on built property and population surveys. The present study proposes a method for identifying urban land, premises and individuals potentially subject to radon risk. The procedure draws from geographic information systems (GIS) pooled at the municipal scale and data on buildings possibly affected. The method quantifies the magnitude of the problem in the form of indicators on the buildings, number of premises and gross floor area that may be affected in each risk category. The findings are classified by type of use: residential, educational or office. That

information may guide health / prevention policies by targeting areas to be measured based on risk category, or protection policies geared to the construction industry by estimating the number of buildings in need of treatment or remediation. Application of the methodology to Greater Madrid showed that 47 % of the municipalities have houses located in high radon risk areas. Using cadastral data to zoom in on those at highest risk yielded information on the floor area of the vulnerable (basement, ground and first storey) premises, which could then be compared to the total. In small towns, the area affected differed only scantly from the total, given the substantial proportion of low-rise buildings in such municipalities.

1. INTRODUCTION

1.1 Radon as a health hazard

Uranium (U-238), an element present on the planet since it formed, is the head of the natural decay chain of radionuclides that includes radon (Rn-222).

Inhaled radon gas (^{222}Rn) is a well-known carcinogen (IARC 1998) and the leading source of ionising radiation to which the population at large is exposed (UNSCEAR 2000). After pooling epidemiological studies for Europe (Darby et al. 2005), China (Lubin et al. 2004) and North America (Krewski et al. 2006), the World Health Organization estimates that the risk of lung cancer rises 16 % for every extra 100 Bq/m3 in radon concentration (WHO 2009).

Radon is presently acknowledged to be the second leading cause of lung cancer after smoking and the number one cause of lung cancer in non-smokers (WHO 2009), accounting for 3 % to 14 % of cases worldwide. Around 100 000 deaths from lung cancer are attributed to indoor

radon exposure worldwide (Lim et al. 2012) and 21 000 in the United State of America (EPA Environmental Protection Agency 2003).

Other factors such as occupation, premise use profiles, genetics, diet and especially tobacco related habits, are vital to accurately calculating data on lung cancer. (Ruano-Ravina, Figueiras, and Barros-Dios 2003).

1.2 Policy framework

Aware of the implications for public health, in 2013 the European Commission adopted Directive 2013/59/Euratom (European Parliament 2014) setting out the guidelines for legislation to be enacted by EU Member States. The Directive requires Member States to coordinate measures adopted by the authorities involved under 'national action plans', map high-risk areas, establish radon measurement and diagnostic protocols and lay down construction guidelines to mitigate or prevent indoor radon ingress in buildings.

In Spain, radon exposure at the workplace has been regulated since 2011 (BOE 2012) and a maximum recommended level for housing has been set at 300 Bq/m^3 (CSN Spanish Nuclear Safety Council 2012). The national radon action plan is still in the drafting stage, however, although some progress has been made, driven by Directive 2013/59/Euratom. More specifically, a new addition to the Technical Building Code on radon protection measures (prepared and made available for public review and comment in July 2018) would require the adoption of different levels of radon protection in new builds depending on the local radon risk classification. Integrating land use and geolocated cadastral data with radon risk categories would contribute to more effective protection, prevention and risk communication policies and strategies.

1.3 Radon risk maps in Spain.

Spain's Nuclear Safety Council (CSN) made an early attempt to formulate a radon map of the country under its MARNA (Spanish initials for natural gamma radiation map) project (Suarez et al. 2000). MARNA was drawn from 799 440 gamma radiation measurements made at an elevation of 1 m above ground. Using cut-off values of 7.5 and 14 microR/h (19.35x10^{-10} C/kg·h and 36.12x10^{-10} C/kg·.h), the country was divided into three radon risk regions based on empirical linear regression analysis of the relationship between γ–radiation levels and ^{226}Ra content in soils to model indoor radon concentrations using the RESRAD code (Garcia-Talavera San Miguel et al., 2013a).

In the same timeframe, the existing indoor radon measurement database grew substantially under the 10x10 project, coordinated by the University of Cantabria with the Autonomous University of Barcelona (UAB) and the University of Santiago de Compostela (USC) as collaborating institutions (Sainz-Fernandez et al. 2014). By the time the project drew to an end, Spain had a database of over 12 000 radon measurements.

That number was clearly insufficient, however, to formulate a radon risk map based on radon measurements alone. The resolution of such maps logically depends on the number of measurements available. In recent decades, extensive indoor radon surveys have been conducted in a number of countries to narrow geolocation data uncertainties. In the United Kingdom, for instance, over half a million radon concentration readings have been made in dwellings (Health Protection Agency 2009).

In Spain, a hybrid method was designed, combining indoor radon measurements with other co-related variables (García-Talavera et al. 2013b); in particular, gamma radiation and lithostratigraphic information was combined with the available indoor radon measurements to produce the country's radon potential map (https://www.csn.es/mapa-del-potencial-de-radon-

en-espana). Similar hybrid approaches using geological parameters (Miles and Appleton 2005; Drolet et al. 2014), soil gas radon (Cinelli et al. 2015) or uranium content in bedrock (Ielsch et al. 2017) have been proposed, used and compared (Chen and Ford 2017) (Watson et al. 2017). Methods have also been put forward recently to enhance the resolution of Europe-wide radon risk maps for the European Atlas of Natural Radiation (Ciotoli et al. 2017).

The present exercise combines Spain's radon potential map with urban and building data from official records and regional radon risk classifications to formulate indicators usable for radiological protection studies and mitigation policies.

That 1:200 000 scale radon potential map (https://www.csn.es/mapa-del-potencial-de-radon-en-espana) classifies regions by indoor radon potential concentration on a five-point scale defined in terms of the 90th percentile. In an area classified in the highest risk category, '5_P90 > 400 Bq/m^3', for instance, 90 % of the buildings would have levels lower and 10 % higher than 400 Bq/m^3. In the Madrid region shown in Figure 2, risk was found to be highest (orange shading) in the mountains where the terrain is predominantly granitic (Hercynian geosyncline).

2. OBJECTIVE

This proposal constitutes an innovative approach to depicting housing-related data from population census and cadastral records on building use and urban land occupancy. By cross-referencing the Information on potential radon risk by geographic location with data from other sources, the proposal aims to describe the details constituting the human and building fabric in a given area affected by radon, i.e., the number and type of premises built in the area and the number of inhabitants involved.

The ***risk* indicator** is a variable parameter that specifies the number of premises in each potential radon risk category (defined in terms of radon concentration) in a given geographic area. It contains information on the number of dwellings or other premises affected, the gross floor area involved, the number of occupants at risk and type of use, i.e., residential, office, or non-commercial (medical, cultural, educational).

The scope of the study was limited to the Region of Madrid, and in particular to the 10 most heavily populated municipalities located in the geographic areas of highest risk with a view to establishing search guidelines and routines that can be applied to studies of other Spanish regions as needed.

The findings, which adopt the form of indicators, may serve different purposes, as follows.

- Health. To determine the magnitude of the health problem by risk category and geographic area and estimate the ***number of individuals possibly at risk*** by concentration bracket. Health authorities could base their prevention programmes on such prior studies.

- Construction industry. To estimate the ***floor area (in square metres)*** in need of mitigation, broken down by type of use. This would raise building market awareness of the challenge confronted in terms of diagnosis, dimensioning or design and implementation of corrective measures. It would also be useful for industry-related authorities who could determine the scope of the support for users of buildings in need of abatement and draft guidelines geared to solving the construction-related technical problems by geographic area.

- Insurance industry. To address the implications of inhabiting geographic areas where risk has not been mitigated. Authorities in some countries recommend pre-property purchase testing for radon concentrations (EPA Environmental Protection Agency. 2018), in much the same way as others, Spain among them, subject such transactions to the existence of energy efficiency certificates.

3. METHOD

The procedure implemented consisted in cross-referencing:

(1) data on potential risk by type of terrain, identified in the Spanish Nuclear Safety Council's potential radon risk map (CSN 2017) and

(2) data on urban land, population and habitable premises in contact with the terrain, further to the criterion set out below on vulnerability to radon ingress.

Radon is the result of the spontaneous disintegration of radium 226, present in soil, rock and water in concentrations that vary with terrain geology (Quindós-Poncela 1995). The surface exhalation rate, in turn, depends on the permeability of the soil overlying the substrate containing the gas (Neznal et al. 2004). Whilst construction products may also contribute to indoor radon concentrations due to the radon present in their raw materials, research has found such amounts to be on the order of only 5 Bq/m^3 to 20 Bq/m^3 (Roserens et al. 2000). The assumption adopted here that the terrain is the sole source of radon risk and diffusion and advection the only transport mechanisms was consequently regarded to entail only a minor error. In light of the foregoing, vulnerability was deemed highest in premises where the envelope is in contact with the terrain, i.e., the lowest storeys:

- basement storeys
- ground storeys
- first storeys, although not directly in contact with the source, possibly subject to high concentrations due to air convection from the storeys below.

Measurement campaigns in Madrid, Barcelona (Baixeras et al. 1997) and the region of Galicia (Lorenzo-González et al. 2017) showed that concentrations above 50 Bq/m^3 are unlikely in higher storeys.

The flow chart for the method proposed is shown in Figure 1.

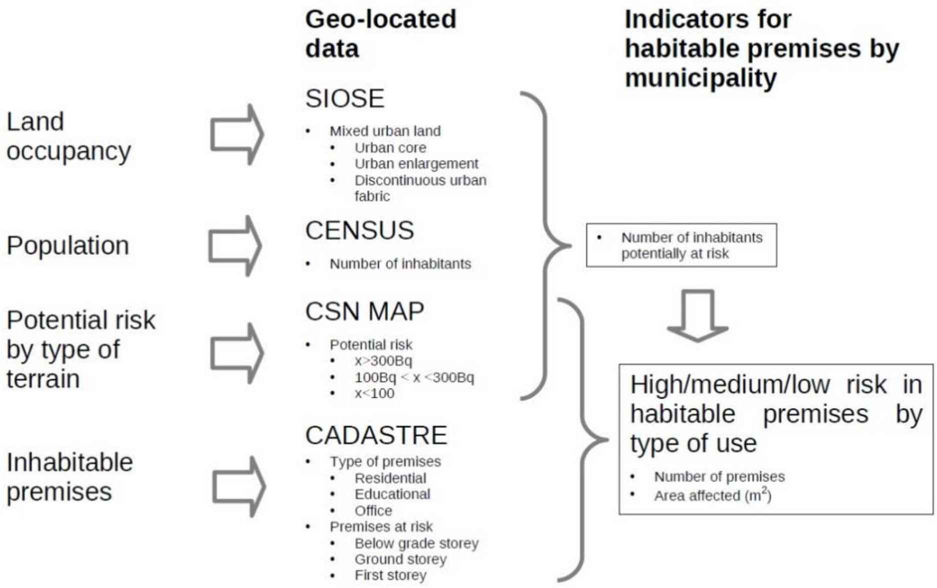

Figure 1. Flow chart for method proposed

In this study the method proposed was implemented on a municipal scale. Population, urban land and inhabited premises were drawn from the following sources.

- Census. Population and Housing Survey 2001 (Instituto Nacional de Estadistica 2001).

This quantitative measurement of the population residing in Spain by autonomous region and province is broken down by basic demographic characteristics such as sex, year of birth, age, nationality and country of birth. The 2001 survey was chosen over the more updated 2011 edition because it contains more detailed data on population location by building storey.

- SIOSE. Sistema de Información sobre Ocupación del Suelo de España (Dirección General del Instituto Geográfico Nacional 2011). This database of land occupancy in Spain integrates region-

and nation-wide information on a scale of 1:25 000. It contains geo-referenced information on area of urban-occupied land, type of cover (classification by biophysical properties such as urban, farm or forest land) and land use (characterisation by present socio-economic purpose such as industrial, commercial or recreational).

The case study discussed in the first part of the article includes the artificial land categories labelled mixed urban (city cores, enlargements and discontinuous urban fabric), industrial (structured industrial estates, non-structured industrial sites, isolated industrial facilities), office (retail and offices, hotel complexes) or non-commercial (Institutional, health, education, penitentiary, cultural, governmental facilities). Land used for recreational facilities, camp sites, cemeteries, places of worship, sport grounds, golf courses and urban parks were excluded.

- Cadastre. Cartographic and property data (Dirección General del Catastro, n.d.).

This administrative registry, managed by a body under the aegis of the Ministry of the Treasury and Civil Service, describes the physical, legal and economic characteristics of real property, with information on location, cadastral reference, area in square metres, building height, use, cadastral value and cadastral ownership, as well as graphic representations.

The filters applied to the databases were adapted to the criteria on habitable premises possibly at risk of hazardous radon concentrations. The output included: (1) inhabitants by urban centre, with a list of municipalities ranked by population affected; (2) area in square metres of urban construction on terrain at risk; and (3) number of premises and the respective gross floor areas affected in each municipality, broken down by use (here, for the 10 municipalities at highest risk).

The procedure applied is described below.

Stage 1: Classification of municipalities by degree of vulnerability (municipal scale)

This stage consisted in the following sub-stages.

- Classification of urban land in geographic areas at risk. Square metres of urban land affected based on land occupancy data (source: SIOSE (Dirección General del Instituto Geográfico Nacional 2011)) and maps showing risk by type of terrain (source: CSN (CSN Spanish Nuclear Safety Council. 2017)).
- Selection of municipalities with largest number of inhabitants at risk based on square metres of urban land affected and population by municipality (source: 2001 census (Instituto Nacional de Estadistica 2001)).
- Formulation of provincial scale map and statistics on radon risk.

Stage 2: Detailed study of municipalities at highest radon risk (building scale)

Vulnerable premises in urban areas where radon risk is highest were identified and classified by use with a procedure that compiles public cadastral data on the municipalities involved. The information collected was drawn from two open data sources:

- Cadastral alphanumerical information: unprotected data on property units identified in terms of their cadastral references, including location, primary use and built area (m^2).
- Vector cartography: spatial distribution by municipality identified by cadastral reference and height code to detect radon-vulnerable premises.

Berkeley Software Distribution open source Panda data library software (http://pandas.pydata.org) was used to process the data. This open source library features data structure and high performance, easy to use data analysis tools for the Python programming

language. Cadastral information was applied to build the type-risk matrix for each premise in the database. Three use types, residential, educational and office, and three at risk elevations, basement, ground and first storeys, were defined. The information on spatial distribution was then cross-referenced with the radon risk map to calculate the square metres of inhabitable area at risk by use category.

This approach was an adaptation of the procedure designed to apply cadastral data to assess urban scale building energy loss using the big data analysis methodology described in greater detail in (Martín-Consuegra et al. 2018).

Cadastral data were also used in a master's dissertation (Seisdedos 2016) defended at the Technical University of Madrid.

These stages and sub-stages are discussed in greater detail below.

4. RESULTS

This section describes the results of filtering and cross-referencing in the two stages of the study.

4.1. Stage 1: Classification of municipalities by degree of vulnerability (municipal scale)

Cross-referencing land occupancy data with the potential radon risk map yielded valuable information about the geographic areas actually occupied and at risk as illustrated for the Madrid area in Figure 2.

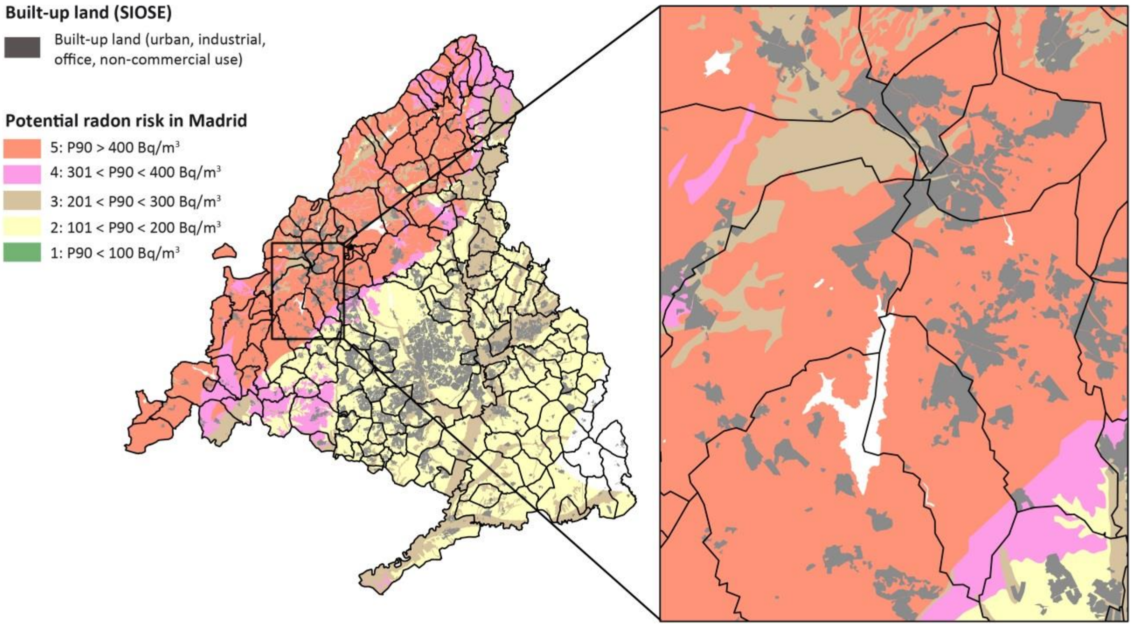

Figure 2. Location of potential radon risk categories in Madrid (CSN) and built-up land (SIOSE) by municipality

The output in this first stage located and quantified the area of the land at risk in each municipality. As noted in the methodology, the 10 municipalities with the largest population at risk were selected for more detailed analysis. That involved calculating the percentage of the area of mixed urban land with a P90 of 4 or 5 (>300 Bq/m^3) relative to the total artificial land cover and determining the number of inhabitants in vulnerable premises (source for ground and first storeys: (Instituto Nacional de Estadistica 2001)). Those findings were used to estimate the proportion of inhabitants at potential risk given in Table 1 for the 10 municipalities at issue.

The indicator ***population affected*** was defined on those floorsas the number of people whose primary residence at the time of the census was in the lower storeys of the dwelling, building or region studied. Height 1 refers to the first above ground storey, normally referred to as the ground storey, and height 2 to the first storey. Municipalities are listed by population affected, in descending order.

Table 1. Pre-selection of 10 municipalities with highest radon risk (>300 Bq/m³) and largest population

Municipality	Total mixed urban land area (m²) **(SIOSE 2011)**	Mixed urban land area with risk 4 or 5(m²) **(CSN map)**	% of urban area with risk 4 or 5	Total pop. (**INE 2001**)	Total pop. in height 1	Total pop. in height 2	Total pop. in heights 1 and 2 (**INE 2001**)	People living in risk areas 4 and 5, at heights 1 and 2.
Las Rozas de Madrid	17 053 830	8 799 795	52	63 056	39 369	8401	47770	24 649
Collado Villalba	6 965 990	6 558 995	94	46 895	15 528	10 625	26 153	24 625
Colmenar Viejo	7 874 901	6 499 142	83	34 576	17 698	7174	24 872	20 527
Galapagar	10 348 202	10 098 892	98	25 342	14 793	5144	19 937	19 457
Torrelodones	7 986 294	7 986 294	100	15 532	12 324	1873	14 197	14 197
Navalcarnero	4 906 372	4 750 942	97	14 316	8375	2290	10 665	10 327
El Escorial	6 685 447	6 009 280	90	10 821	5799	2224	8023	7212
Valdemorillo	8 844 641	8 841 623	100	7091	5810	1114	6924	6922
Alpedrete	4 191 174	3 772 057	90	8438	5724	1545	7269	6542
San Lorenzo de El Escorial	2 452 635	1 823 031	74	12 765	5824	2757	8581	6378

4.2. Stage 2: Detailed study of municipalities with the highest radon risk (building scale)

This stage of the study focused on identifying the premises at risk and the respective gross floor areas at the heights regarded as vulnerable, by use. Whilst the database used (source: (Dirección General del Catastro, n.d.)) contains a wealth of information on real property that may be useful for future research, in this study the search filters were confined to the following.

- Gross floor area per premise, to establish the size of the premises to be protected.
- Main and detailed use category of premises. Non-inhabited areas (communal areas, warehouses, garages..) were excluded and only three uses were defined: educational, residential and office.
- Location of premises by storey. Premises located in basements and on the ground and first storeys were selected.

The data in Table 2 for the 10 municipalities selected include detailed information on premises built on medium (categories 2 and 3, 100 Bq/m^3-300 Bq/m^3) or high (categories 4 and 5, >300 Bq/m^3) risk terrain, by use.

- No. of premises: number of (office, residential or educational) premises located on basement, ground or first storeys in vulnerable buildings.
- Area affected: The gross floor area of premises at vulnerable heights (the sum of basement, ground and first storeys).
- Total area: sum of the areas in square metres of all the premises in these facilities without filtering for vulnerable heights by way of indication of the proportion of vulnerable premises.

Table 2. Cadastral information showing use and gross floor area of premises affected and total gross floor area: data by municipality for medium (100 Bq/m^3-300 Bq/m^3) and high (>300 Bq/m^3) risk

	EDUCATIONAL			RESIDENTIAL			OFFICE		
	No. premises aff.	Area aff. (m^2)	Total area (m^2)	No. premises aff.	Area aff. (m^2)..	Total area (m^2)	No. premises aff.	Area aff. (m^2)	Total area (m^2)
1-Las Rozas									
MEDIUM	140	80 853	93 484	25 454	2 067 717	3 074 933	1 157	264 070	363 842
HIGH >300 Bq	66	73 567	82 591	16 389	1 601 793	1 903 264	560	95 208	168 751
2-Collado Villalba									
MEDIUM	14	16 038	17 747	1 996	149 741	238 744	52	9 674	9 674

HIGH >300 Bq	94	73 449	90 520	17 905	1 379 833	2 642 044	401	34 371	41 760
3-Colmenar Viejo									
MEDIUM	0	0	0	1 041	129 688	157 243	0	0	0
HIGH >300 Bq	71	62 577	69 374	19 322	1 482 514	2 179 732	607	84 275	89 185
4-Galapagar									
MEDIUM	0	0	0	203	17 353	24 623	5	672	672
HIGH >300 Bq	84	40 680	42 718	17 238	1 477 642	1 885 655	104	8 062	10 563
5-Torrelodones									
MEDIUM	0	0	0	0	0	0	0	0	0
HIGH >300 Bq	67	50 423	58 926	15 467	1 317 899	1 054 630	88	7 774	9 788
6-Navalcarnero									
MEDIUM	0	0	0	0	0	0	0	0	0
HIGH >300 Bq	49	44 507	50 991	12 356	885 581	1 302 960	190	29 106	30 288
7-El Escorial									
MEDIUM	12	10 322	12 441	1 993	161 106	243 927	13	1 244	1 244
HIGH >300 Bq	25	14 308	16 708	7 144	661 338	910 927	33	3 401	3 401
8-Valdemorillo									
MEDIUM	0	0	0	0	0	0	0	0	0
HIGH >300 Bq	5	5 788	5 788	9 717	890 718	936 983	85	7 962	8 342
9-Alpedrete									
MEDIUM	7	2 880	3 883	786	66 751	71 908	6	1 222	1 222
HIGH >300 Bq	52	26 177	26 962	8 117	666 932	821 424	91	7 862	8 683
10-San Lorenzo de El Escorial									
MEDIUM	10	9 107	11 897	2 845	210 699	321 813	73	4 647	4 647
HIGH >300 Bq	29	17 503	29 444	7 897	575 199	927 472	83	6 270	7 487

GIS (geographic information system) applications can be used to process cross-referenced data and visualise the geolocation of the indicators at issue. Here ESRI ArcGIS v10.1 mapping and analytics software (www.esri.com) was used. That mapping tool processed location-based census, SIOSE and cadastral data to identify spatial patterns in radon risk areas, and accurately compute inhabited area by use to establish relationships between the two.

By way of example, Figure 3 shows the area of geolocated habitable premises lying on the basement, ground or first storeys, by detailed use. Laying those data over the radon map identified the premises at highest risk by location and use.

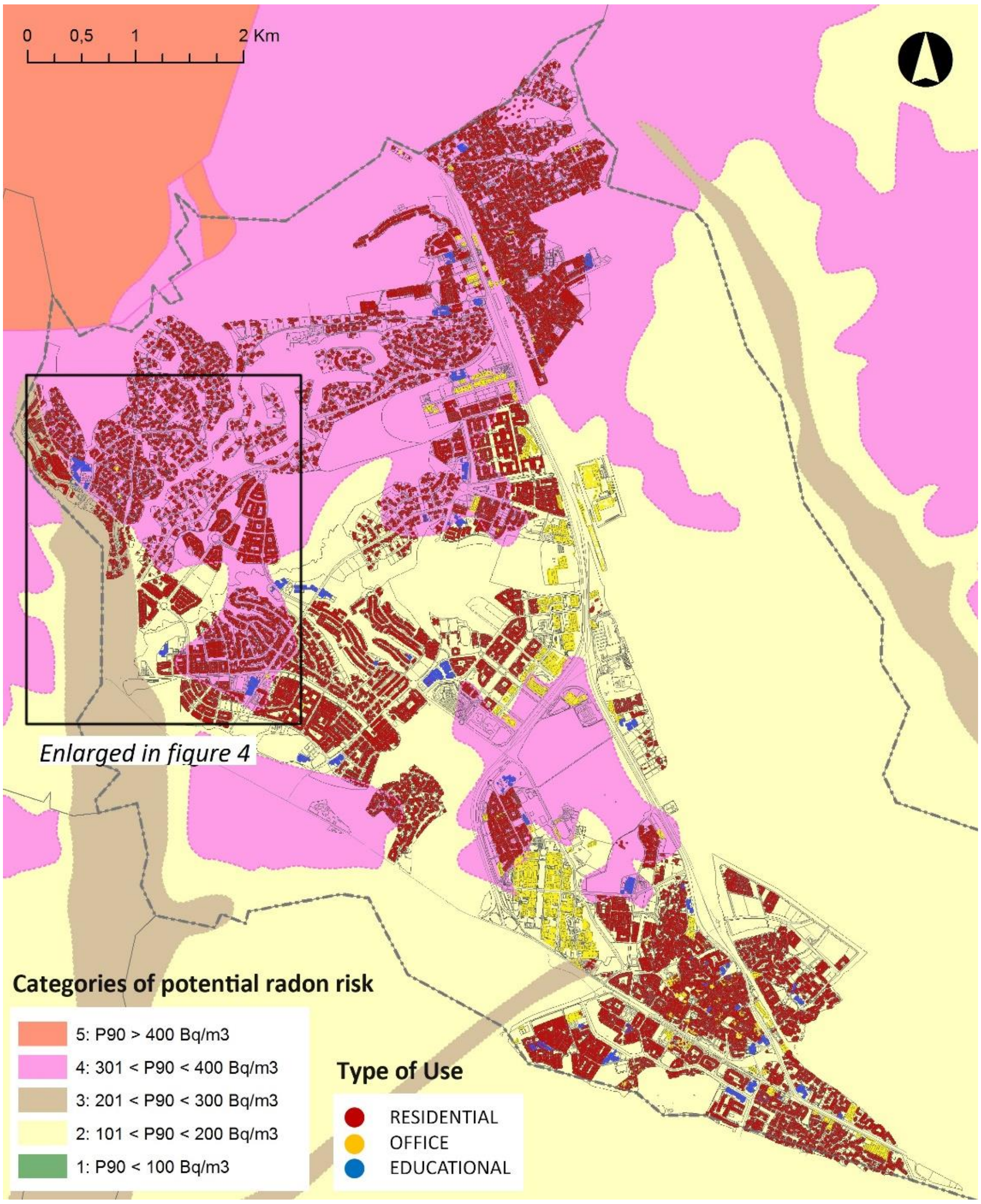

Figure 3. Habitable premises and respective gross floor areas by risk category in Las Rozas

As Figure 4 shows, the software delivered building scale information. That output may nonetheless contain inaccuracies due to the differences in scale in the sources used: whilst the cadastre features building-scale information, the risk map is drawn at a scale of 1:200 000, i.e., with less detail and lower resolution in enlarged views.

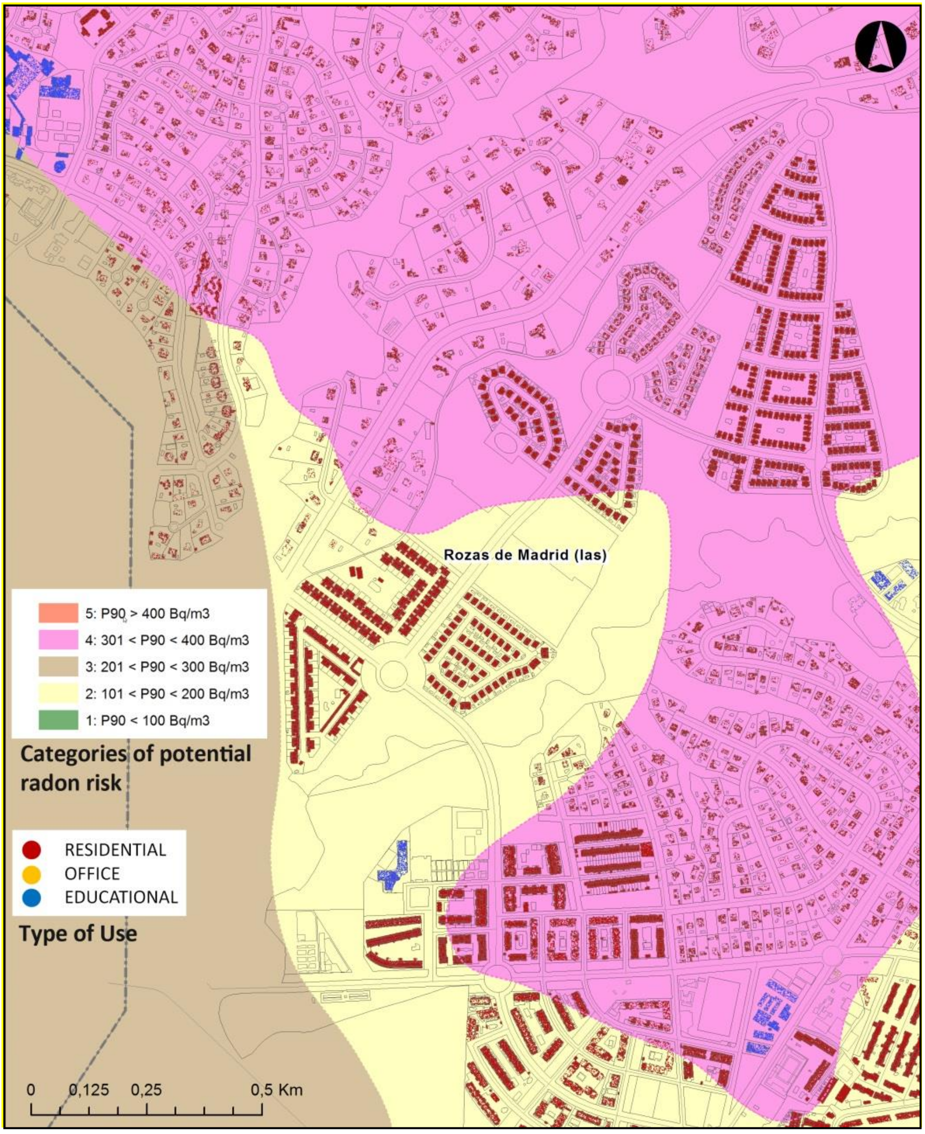

Figure 4. Risk categories for buildings in Las Rozas: neighbourhood scale enlargement

5. DISCUSSION

Cross-referencing census, cadastre and land occupancy data for the geographic areas of potential risk yields indicators that can be used to analyse radon risk from different perspectives.

The percentage of urban land area located on radon risk terrain 4 or 5 (>300 Bq/m^3) by number of municipalities is shown if Figure 5. This bar plot was built from data collected in Stage 1 (see sections 3. Method and 4. Results for further details).

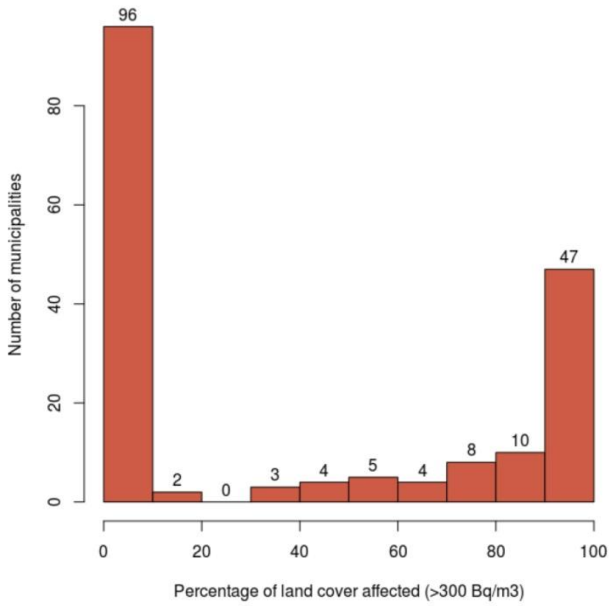

Figure 5. Number of municipalities at medium or high radon risk (>300 Bq/m^3) by percentage of land cover affected

According to Figure 5, 96 municipalities were sited primarily on low risk urban land and 47 on high risk terrain, whereas many fewer were characterised by intermediate percentages of buildings affected. The inference drawn from those findings is that in the Region of Madrid the highest risk is observed in a clearly delimited geographic area.

The area affected in square metres and the number of premises, by municipality and use, are shown if Figure 6, drawn using the data in Table 2.

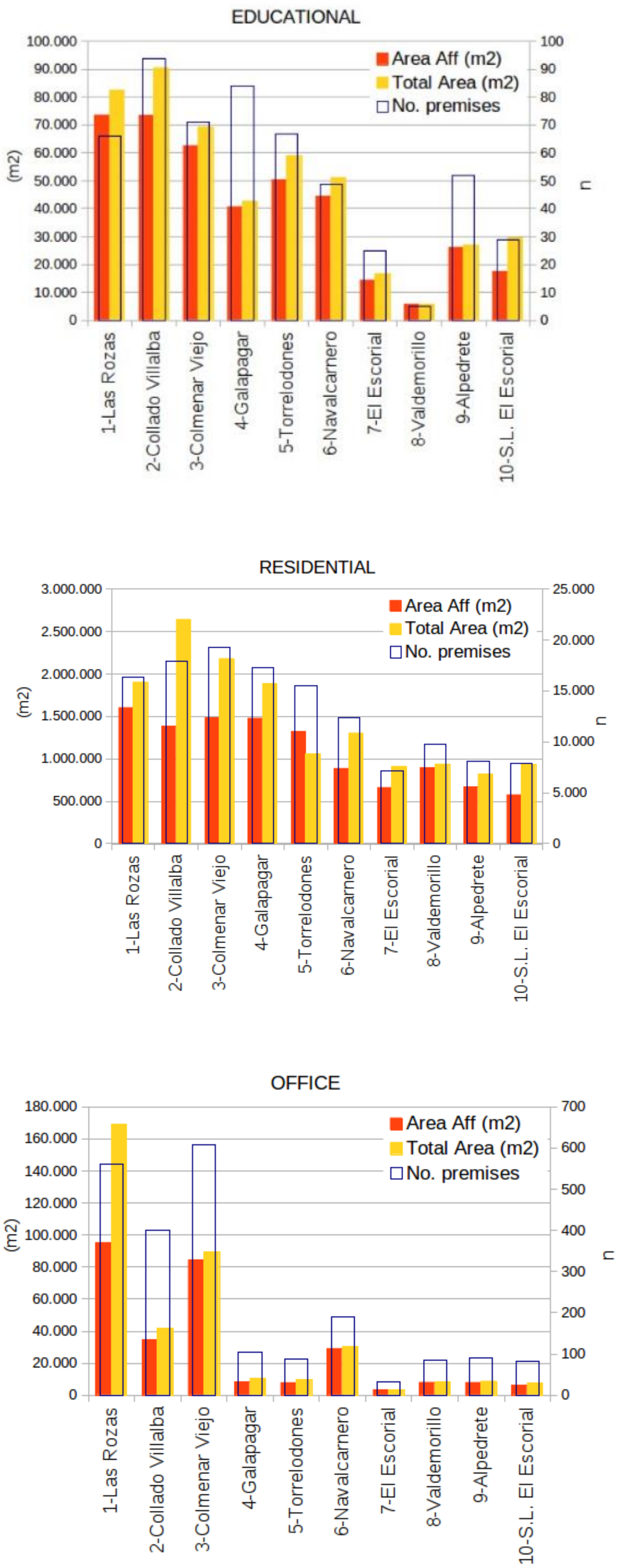

Figure 6. Total area, affected area, and number of premises affected (risk >300 Bq/m3), by use

(a) educational; b) residential; c) office)

Further to the graphs, in municipalities with smaller populations and smaller urban cores, the square metres of total area and area affected are practically the same. The explanation may be that buildings consisting primarily in ground and first storeys, defined here as vulnerable, tend to prevail in smaller towns. The difference between total and affected areas was also observed to be greater in the residential category, perhaps indicating that residential are taller than educational buildings. In the latter, the premises affected may concur with the total number of storeys, typically one or two in schools. Whilst the number of such buildings is smaller than those classified as residential or office, taken individually, their gross floor area tends to be substantially larger. As premises occupied primarily by minors, educational buildings should be regarded as priorities when designing prevention policies.

The accuracy of the results of the detailed study of cross-referenced data may be subject to uncertainties attributable to differences in map resolution. Geographic information systems ensure precise cadastral plot location on the sub-municipality scale. The accuracy of the results therefore depends largely on the capacity of radon risk category maps to precisely define limits on that scale. As these were built with information on a scale of 1:200 000, the inter-area boundaries may be somewhat diffuse. The methodology is therefore subject to a minor error in respect of the precision of the geographic boundaries between risk categories.

Moreover, construction typology, which may substantially modify indoor radon ingress predictions, was not addressed in this study. Other authors (Baeza et al. 2018) showed that construction features have a substantial impact on indoor radon concentration, which may lead to deviation from theoretical estimates. Such inaccuracies could be mitigated by conducting

more detailed analyses of architectural typology and the construction solutions used in foundations based on cadastral information supplemented with sampling data.

7. CONCLUSIONS

The method proposed detects urban areas in which buildings are at risk of radon ingress and classifies them into risk categories. That information can be used, for instance, to define the municipalities affected with a view to preventive measures. When applied to the region of Madrid, the method classified the municipalities by size of the population possibly affected. According to the findings, in more than 70 % of the built land area in 65 of a total of 179 municipalities (Figure 5), at least 10 % of the houses is estimated to have radon levels of over 300 Bq/m^3. A substantial number of the other municipalities (96) is located in low-risk areas (less than 10 % of the built land area classified as risk level 4 or 5), primarily in the southern part of the region. In the remaining 18 municipalities from 10 % to 60% of the built area has risk classification 4 or 5 risk.

Cadastral data on the characteristics and type of buildings in each municipality were included in the analysis. The number of vulnerable (ground and first storey) premises was calculated, along with the habitable gross floor area and use (residential, educational, office). That information was cross-referenced with the risk categories of the terrain on which they stand for mapping purposes. The findings for the 10 municipalities with the largest number of inhabitants living in high radon risk areas were analysed in detail to determine the type of use with the highest rate of occupancy in vulnerable premises. Las Rozas and Collado Villalba were observed to be the municipalities where the number of people likely to be living in homes with radon levels above 300 Bq/m3 was highest. A geographic information platform was used to visualise the neighbourhood-scale data displayed in the article.

The information generated with the method may support decision-making and help identify priority action on the municipal and building scale both, including political measures such as aid for risk prevention in places in greatest need. The indicators sought can be adapted to the objectives of other types of studies such as mentioned in section 2 above and the data available from the sources used.

8. ACKNOWLEDGEMENTS

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