Possible ways to Radon Map of Europe – from input data to result

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Abstract

The paper deals with the purposes of future European radon map-atlas and types of data available for its construction. The map should be targeted to radioprotection awarness of citizens as well as to radioprotection and health bodies to focus their activities to areas of enhanced radon potential. The tested cross border comparison between Oberpfalz (Germany) and Tachov (Czech Republic) regions has confirmed the usefulness of GIS application in expressing the soil gas and indoor radon data on the basis of administrative NUTS(5) units, which can be the unifying and basic element for the future European radon map based on easily accessible GIS information. However the variety of methods used in national radon programmes requires the development of new unified scientific methods characterizing the geographically confined area of administrative units from the radon point of view. The present research studies of soil gas, radiometric and indoor Rn data relationships support this way of radon risk mapping activities.

Introduction

When we are thinking about European Radon Map, we should answer mainly following questions:

1) Do we really need that Radon Map ?
2) In which way can we prepare it ?
3) In which way should it help us ?

The answer for the first question is relatively simple - Yes. The results of various researches show that radon is a hazard to be taken seriously. The study of the effect of radon on the risk of lung cancer (Darby et al. 2004) has concluded that there is a strong evidence of an association between the radon concentration at home and lung cancer and that indoor radon accounts for about 9% of deaths from lung cancer and about 2% of all deaths from cancer in Europe. Recent studies have opened even the wider effects of radon to human health (Groves –Kirby et al. 2006). If we are able to prepare the Radon Map, which could be useful for responsible people – professionals, municipalities – for the distribution of the indoor radon detectors, for efficiently detecting areas at which higher concentrations of indoor radon frequently occur, it would be certainly welcomed (Neznal and Hulka 1997)
The answers for the second and third question are much more complicated. The base is almost clear, i.e. the predominant source for elevated indoor radon values is the soil gas. The methods for measuring both – indoor and soil gas concentrations – are well developed. In the European countries different approaches for the classification of the radon risk exist. Both values may be used for mapping purposes – e.g. in Great Britain (Miles et al. 2005) and Switzerland (Piller and Johner 1998) the indoor radon, in the Czech Republic (Neznal et al. 2004, Barnet et al. 2005) and Germany (Kemski et al. 1999, Klingel et al. 2001) the soil gas radon. Mapping techniques and input parameters for an European Radon Map are from today's point of view highly variable and should be discussed using scientific and

administrative practical necessities. The result should be an easily understandable map, valuable for all countries and helping us to define the radon risk of people living in different areas. The variable building structure of dwellings must be considered. We have dwellings of different age, dwellings of various types and from various materials, with cellars or without them, people living in basements or on ground floors. Finally there are climatic factors and their influence on typical ventilation and social habits (e.g. North Europe x Mediterranean region).

Available input data

Four basic types of data are available for radon risk maps construction.
Environmental radiological data are available mostly as **radiation maps** resulting from airborne measurements or from exploration purposes. Mostly a differentiation in the uranium and thorium part of dose is possible. The relation between uranium in the ground and the soil gas radon potential is not very strict, but may be used where no soil gas measurements exist.
In only some countries **soil gas measurements** are available. They are performed by different methodics and there is no doubt that countrywide radon characterizations cannot be done by some new large soil gas Rn measurement campaigns. Rather it must rise from comparison of existing results and partial testing the datasets in the bordering areas with respect to find the common radon geostatistical characters.

Indoor radon data are usually a product of nationwide programmes directed by radioprotection bodies which means (or should mean) better consistency of datasets. Each datum represents one quantity (mostly average indoor Rn concentration) related to time interval of measurement. The advantage of these data in the interstate relations can be found in similarity of used method (mostly track-etch detectors). Also the topographical localization for relating data to GIS coordinates can be simply done using the administrative data connected to radon data (owner, address, house number, municipality etc.). The disadvantage of the data lays in a great number of factors influencing the resulting value (meteorological, users´ habits, building characters and age of house etc.). These disadvantages can be eliminated by preference of long term measurements and proper registration of these different influencing factors during the short term measurements with an unified questionnaire. It should also be state of the art to use only long time measurements as input values for mapping purposes. The purpose of indoor radon measurements – to give the average indoor Rn value for the particular house – simplifies the computerized processing the databases and supports the geostatistical modelling in not yet measured areas. The indoor data can be easily divided after the accepted action levels which enables to characterize the studied areas into radon prone – radon nonprone areas (Lehmann et al. 2002), to use the probability calculations or to orient the state financed efforts to limited areas. All the time it must be taken into consideration that the main purpose of indoor measurements is the radioprotection of citizens. The outstanding aim is to detect the particular houses exceeding a given radon level and in the resulting phase to remediate them or to give clear advises for remediation procedure.

The **geological data** are usually based on vectorised geological maps. All states of Europe dispose of the geological maps in different scales and different coordinate systems. If vectorised and prepared for GIS applications these maps strictly divide the rock types after lithology which influences most the radon characters of particular units – polygons. The advantage of primary geological data in maps is the long lasting (up to 150 years) scientific experience of rock types classification based on mineralogical, structural, geochronological and chemical research. The differences in coordinate systems can be solved using the GIS tools. More disputable are the differences in scales which has the direct influence on the detailness of geological and lithological information. However the present achievements in international geological mapping projects show that the way of consensus in the classification terminology of bordering lithogeological units can be found.

The least complicated data for construction of radon maps are already existing **topo GIS administrative data** for municipalities (polygons of cadastres, centroids of municipalities and of houses etc). These data are already available for EU administrative (also on internet – GfK Macon, but not for free), for scientific purposes the data can be found in national Statistical Offices, results of censuses, Cadastral bureaus etc. As for practical experience, these data are best prepared for GIS processing. .

How can these different types of data come together? For our opinion the geological units can be characterized by specific values resulting from existing radiation or soil gas data. Each single soil gas Rn measurement can be characterized by a number – e.g. the volume activity of Rn in $kBq.m^{-3}$, which seems at present to be the strongest unifying element of all different methods of radon risk determination. This single number can be used either as an characteristic description of a geological unit or as an input parameter for more advanced geostatistical calculations (interpolation).

The administrative data can serve as a nationally comparable „frame" for expressing the radon characters of a studied area.

Provoking possibilities of using the results from EU radon risk map

1. To make a nice wallpaper in a very generalized scale to decorate the walls of research and public institutions - nonsense

2. To make an radon map of EU countries expressing the latest achieved results of soil gas, indoor data and/or their combination in the user convenient scale – cartographical task

3. To focus the research efforts on the development of new methods for the characterization of NUTS5 units with respect to an European unified classification of the radon risk. The main purpose should be a useful help for radioprotection bodies and local health authorities to increase public awarness of the radon problem and to identify regions with higher radon levels. This could be, related to the construction types of buildings, the number of houses exceeding a given action level in each NUTS5 unit.

The last purpose is without any doubt the only meanigful purpose from the three ones mentioned above. It can be achieved by using the existing scientific knowledge and already developed software solutions to link the different data and methodical approaches into a combined database – GIS system (e.g. like in Germany). The „frame" for expressing the research results can be found in already existing administrative topodata which are the most unified for Europe up to now. Consequently, the radon risk map will be mostly used by people familiar with administrative units divisions.

Test of geology – indoor Rn relationship in Oberpfalz (Germany) and Tachov (Czech Republic) regions

An example of this approach is illustrated on the cross - border study of two districts in the Czech Republic (Tachov – eastern part) and Germany (Oberpfalz – western part). In both areas the long-term indoor radon measurements were performed during the independent state radon programmes (in Oberpfalz 723 data and Tachov district 632 data). The distribution of the Tachov district indoor values is despite similar soil gas radon concentrations shifted more to higher values (tab. 1), which can be explained by the worse building state of the Czech houses (Barnet 2004). The similar difference was found in the 90ths between new and old German states (Kemski et. al. 2004). Up to now this difference has been significantly reduced due to improved building regulations.

	MEAN			**MAX**	
	Bq.m*-3			**Bq.m*-3**	
	Tachov	**Oberpfalz**		**Tachov**	**Oberpfalz**
Quaternary	197	84		237	112
Carboniferous	182	107		197	154
Proter. -Lower Palaeozoic	178	160		225	220
Paragneiss	214	128		259	161
Orthogneiss	197	134		234	156
Plut.inter.-bas.	199			235	
Granit	238	225		292	283

Tab. 1 – The mean indoor radon concentrations in Tachov and Oberpfalz regions after the bedrock geology

As a background for data expressing the borders of administrative units NUTS5 were used in the Czech Republic and postal codes areas in Germany (*Note: NUTS5 borders are available in both countries but not for free download. For a future international project all data could be expressed on NUTS5 or NUTS4 borders*). The best available geological map overlapping the territory of the Czech Republic is the geological map of the Bohemian massif 1 : 500 000, even if the detailed geological maps are available in both bordering areas. The problem of scale dependancy of geological information is discussed in more details in Kemski et al., 2006. The indoor data were expressed using the ArcGIS „average with spatial location application“ which enables to characterize the particular area with single quantity – average of indoor radon values. From fig. 1 it is obvious that the administrative units with enhanced indoor radon values fit to geology – the extent of granitic bedrock after the geological map of the Bohemian massif
1 : 500 000.

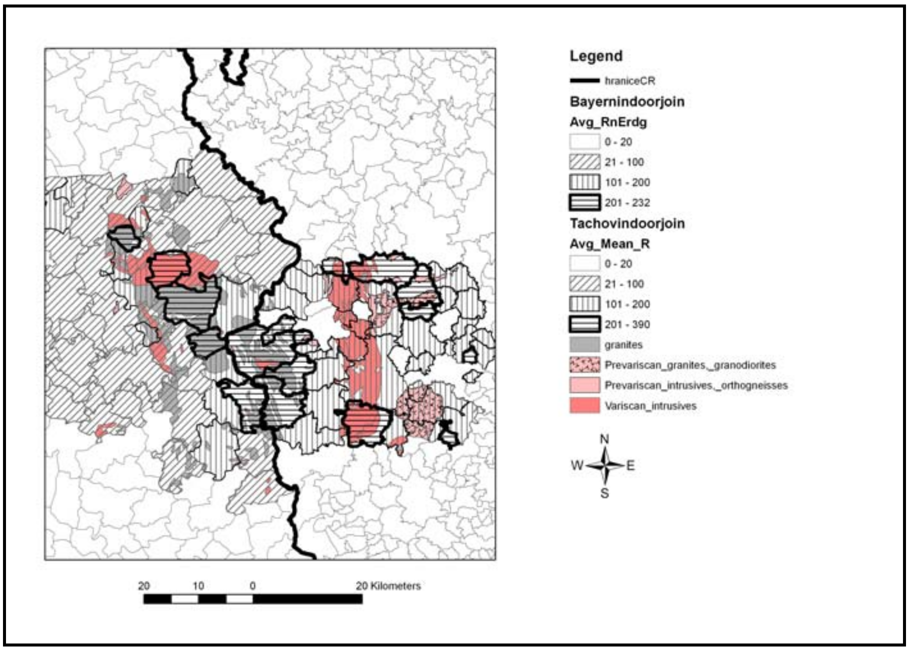

Fig. 1 – The mean indoor Rn concentrations (Bq.m^{-3}) in Oberpfalz – Tachov regions. The administrative or postal units exceeding indoor Rn mean 200 Bq.m^{-3} are situated mostly on granitic bedrock.

This is not very surprising. From our investigations during the last decade we know very well that granites are related with high risk areas (Barnet 2004a,b, Barnet et al. 2005). In case of geological bodies with distinct boundaries and administrative units, fitting clearly to these bodies, the use of both parameters is very effective, even across the state borders. Problems will arise if the geological units are large and of inhomogeneous character, like in some sedimentary covers, and the differences occur not in the geological map but mainly in the soil gas radon distribution. This again will find some response in the indoor values. As an example the soil gas values for the German part are mapped in 500 x 500 m grid (Kemski et al, 2005) (fig. 2). Even in the granitic bodies a variation of the radon source is clearly visible. This information should be used, if geologically based expertise is not convincing to the radon problem.

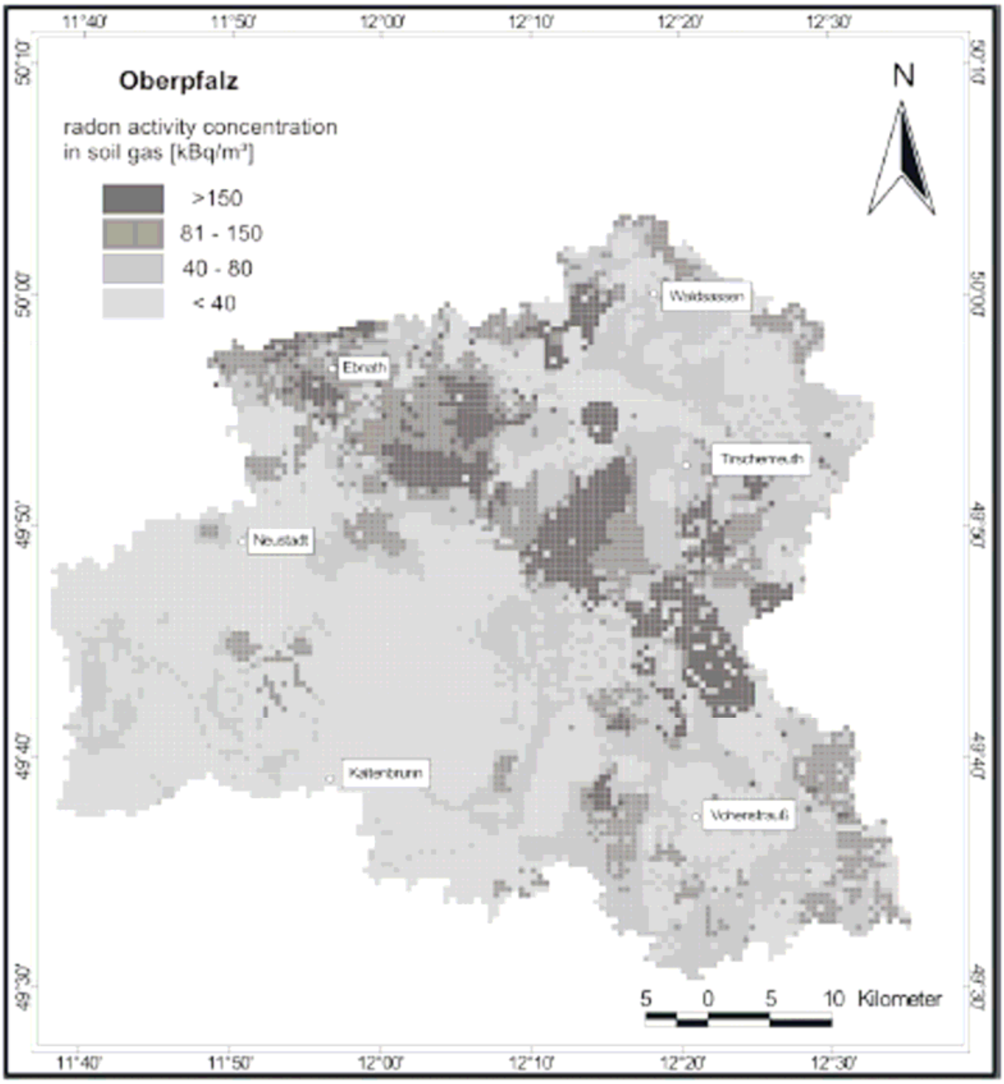

Fig. 2 – Soil gas map of the Oberpfalz region

A clear relation between soil gas and indoor values on the basis of NUTS5 units is shown in fig. 3. This relation is more or less the same for different regions in Germany. The similar relation we have also found by clustering soil gas and indoor radon data to administrative units in the Czech Republic.

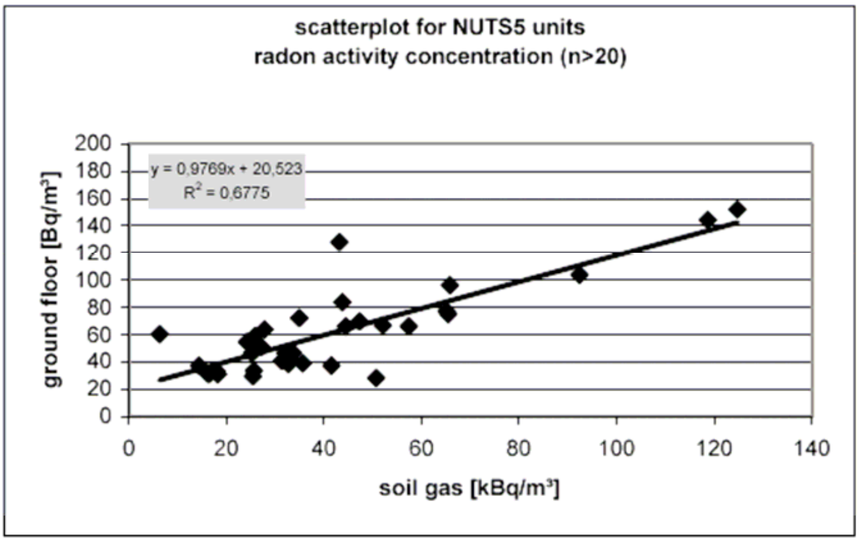

Fig. 3 – Simple regression of soil gas and indoor Rn clustered by German NUTS5 units.

From the selection of data in fig. 4 it is quite clear that houses exceeding 400 Bq.m^{-3} indoor Rn are closely bound to granitic areas and to regions with soil gas concentrations higher than 80 kBq.m^{-3} (and in CZ part also to silicites in Proterozoic – the most eastern values).

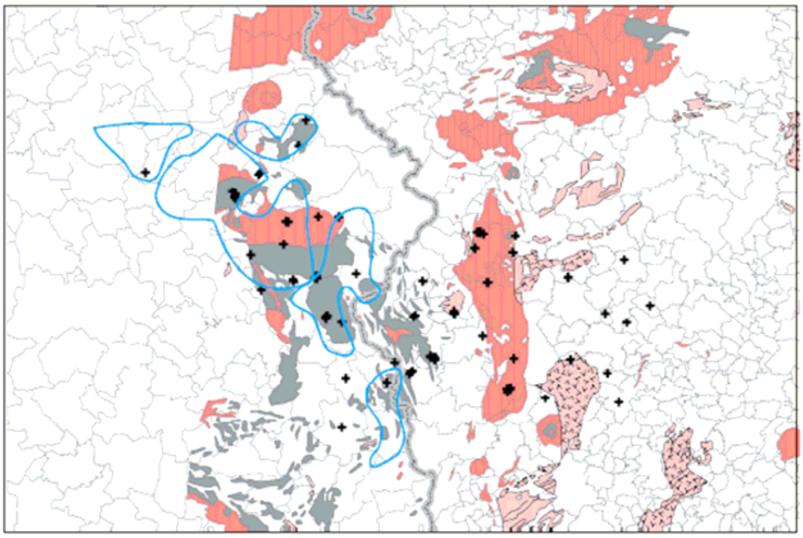

Fig. 4 - Localization of houses exceeding 400 Bq.m^{-3} on granitic bodies in the Oberpfalz (Germany) and Tachov (Czech Rep.) regions. Higher values are also observed in the Czech Proterozoic (most eastern values) . Black lines include soil gas values higher than 80 kBq.m^{-3} in the Oberpfalz.

The regional relationship between soil gas radon and indoor Rn based on the NUTS5 units of the western part of the Czech Republic can be seen from Figs. 5 and 6. The percentage of particular NUTS5 area which is situated on high risk bedrock (after the Czech radon risk classification) was compared to indoor Rn geometric means of NUTS5 units. The increased indoor Rn of granitoid areas (high risk from bedrock) is obvious.

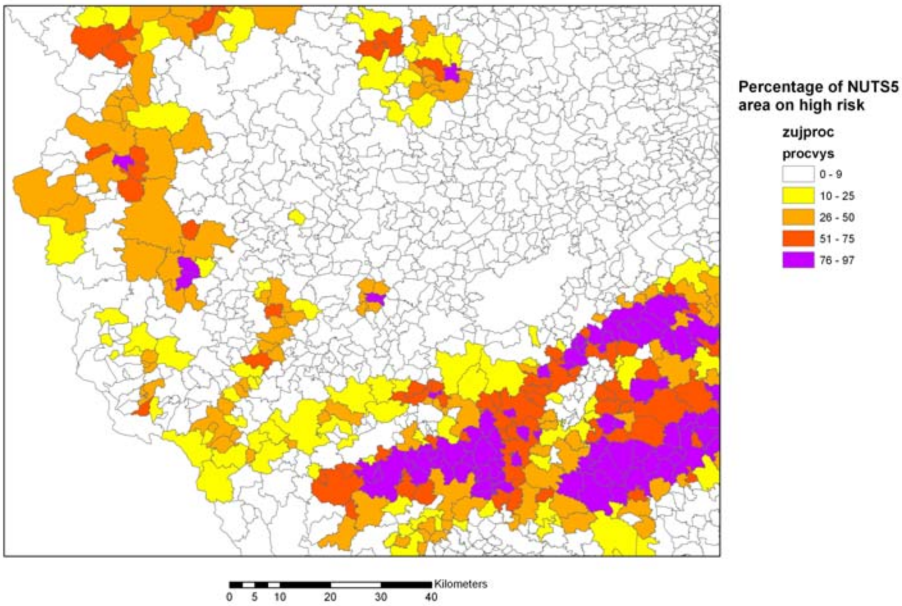

Fig. 5 – The percentage of NUTS5 areas situated on high risk bedrock (W part of CZ).

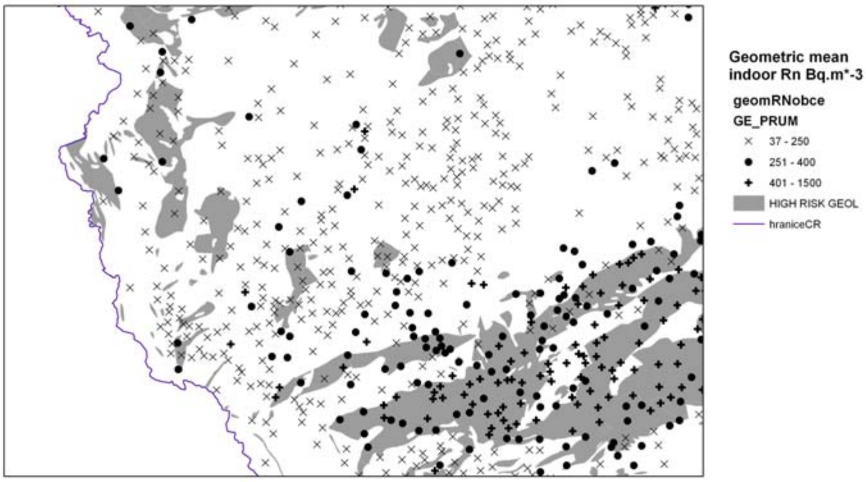

Fig. 6 – Geometric indoor Rn mean in NUTS5 (bound to centroids of municipalities, W part of CZ)

Conclusions

1. The future radon map of Europe should be based on existing data of bedrock radon radiometry and indoor radon research. The relationship of gamma-spectrometry, soil gas radon concentration and indoor radon concentration has been validated in many research studies in all parts of Europe and in various geological environments during past two decades (at least).
2. The geostatistical treatment of the datasets can lead to radon characterization of administrative units. The exact digitized data already exist an they are ready for computer processing.

3. From the radioprotection point of view the administrative units NUTS5 are the most suitable for radon information of citizens and for decision-making of local governmetal authorities concerning the radioprotection.
4. The results of EU radon map should be presented in GIS form to enable an easy access to radioprotection information for citizens. The interest of particular people and pressure generated by them towards the local administrative governments can lead to succesfully targeted radon actions, finding out the houses exceeding the radon action levels and remediating them. These initiatives lead towards the main aim of future EU radon map: To do something for one´s own health.

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