Nat. Hazards Earth Syst. Sci. Discuss., 1, C1174–C1183, 2013
www.nat-hazards-earth-syst-sci-discuss.net/1/C1174/2013/

Natural Hazards and Earth System Sciences Discussions

Open Access

NHESSD

1, C1174–C1183, 2013

Interactive Comment

Interactive comment on "Prediction of indoor radon concentrations in dwellings in the Oslo region – a model based on geographical information systems" *by* R. Kollerud et al.

M.A. Smethurst (Referee)

m.a.smethurst@exeter.ac.uk

Received and published: 12 September 2013

General remarks

The general approach to the problem of attempting to predict radon concentrations in unmeasured dwellings from radon measurements made in nearby dwellings is interesting and worthwhile. However, the analysis is let down by utilising indoor data from any type of room in any type of dwelling to predict indoor radon concentrations in unspecified types of rooms in any other type of dwelling. It is likely that much of the variance in indoor radon measurements is due to the radon-dynamics of the dwellings themselves and any radon concentration value that is presented as a prediction of the radon concentration in a specific dwelling without taking any account of this is unsafe. Most studies, wisely, don't claim to predict radon concentrations in individual dwellings, but derive some indication of the probability of a dwelling hosting some significant level of radon contamination.

This issue can be cleared up by simply stating what has actually been done, which is to assign local average radon values to unmeasured dwellings. The probability that the average value is close to the real value is not determined (e.g. 95% confidence limits). Because of a lack of consideration of dwelling factors like how many floors the living area is above the ground, quite a number of the estimates will be misleading or even completely meaningless. Again, if one claims to predict radon levels in individual homes, one has a responsibility to cover this.

Similar work has been carried out by Smethurst et al. in the area, but this strongly overlapping work is not properly represented in the current contribution. Much of the data used in the current study were compiled and used for the same purpose by that earlier study with important findings. These findings are barely discussed in the present contribution. The novelty of the current contribution is not as great as the text implies. The authors observe relationships between geology, airborne eU measurements and indoor radon concentrations. Smethurst et al also did this (first in 2006) but this earlier work, with very significant results, is barely mentioned. The current contribution does not take advantage of the synergic relationship between the different kinds of data. If I understand correctly, the primary product is based on indoor data alone.

The strongest and new element of the present study comes from their use of a far larger data set of indoor radon measurements. The other data were compiled and first presented in the context of radon hazard by Smethurst and co-workers. This large radon data set is perhaps larger than it ought to be because I suspect it includes many data from different types of rooms (with different uses) on different floors of residential buildings. Our much small data set was a subset including only ground floor data from living rooms and bedrooms. The larger data set allows their method to operate at a higher spatial resolution, but as already mentioned the down side is that their average radon values [assigned to unmeasured dwellings] may not be a good guess at the radon levels in the living spaces of those dwellings – which is what you really want.

Recommended action

I think the contribution is interesting but it needs to be introduced and concluded in a way that better reflects its original findings (that are far more modest than claimed in the current version), and how those findings relate to earlier work in the same place (i.e. our work). I don't like the way all indoor data are considered to predict the radon levels in nearby dwellings regardless of dwelling situation, and it will be interesting to hear what other people think about that (I explain this in more detail later). We know why this exercise has been done, but the reason should be spelled out, and also it would be interesting to hear how the authorities might intend to used the radon predictions from this study in future actions. For example, does this information reveal radon affected areas that were previously unknown? What average radon value assigned to unmeasured homes will trigger action from the authorities? (Remember that much of the large local variance/scatter in the actual radon measurements [from dwelling to dwelling –neighbour-to-neighbour] will not be present in the average values assigned to unmeasured dwellings leading to the dangerous illusion of uniformity of contamination in communities). What will happen now that the GIS theme has been generated?

More detailed remarks – sorry about repetition and lack of structure

We must assume that the indoor radon measurements are converted to annual average concentrations. Little is said about them but data set is pivotal in the study. We need to know where they were made in the dwellings, see the log-normal distributions for different floors and room types, get justification that the data from different floors etc can be all used together (I suspect they have different GMs and GSDs.

The primary purpose of the exercise is stated as "...develop a method to estimate the radon concentration in each dwelling [in the Oslo region]...” Although the study has produced useful results, it does not fulfil this goal is a practically useful way. The authors are clearly aware that radon concentrations can vary considerably from one part of a dwelling to another and from one dwelling to the next, even though geological conditions around the dwellings might appear to be similar. The physical characteristics of the dwellings and the ways the dwellings are used by their occupants play critical roles in the radon dynamics of the buildings. Therefore, the assignment of actual radon concentrations to individual unmeasured dwellings without any consideration of what kind of dwellings they are is of limited usefulness.

It would appear that all available measurements from dwellings in the region, regardless of what kind of dwellings they are, and where the measurements were made in the dwellings, have been used to estimate the radon concentrations in all unmeasured dwellings. Each unmeasured dwelling is assigned the statistical mean of available radon values from nearby dwellings. A very simple and logical approach at first glance, but weakened in this case by the lack of consideration of where the data come from. For example, one would expect radon measurements to be made on the lower floors of residential high-rise buildings because that is where any radon might be. Seldom will radon from the ground reach beyond the first few floors in any great quantity. If there are some radon measurements available for a local area from the lower floors of high rise blocks (logical) plus a few from single occupancy low buildings, the average of those should not be assigned to an apartment on the 5th or 10th floor of a high-rise. That would be meaningless. This is an extreme example to make a point. Other dwelling properties can be just as significant as floor level.

The study has assigned the same radon value to all unmeasured dwellings with the same XY position. In the tower block case this would mean that apartments on all floors would get the same predicted radon value. It is most likely that radon measurements are made on the lower floors of buildings, so one would expect all unmeasured dwellings on higher floors to be assigned radon values that are far too high. The con-

NHESSD
1, C1174–C1183, 2013

Interactive Comment

sideration of whether the radon measurements are from living areas (bedrooms/living rooms) or non-living areas is also important. It is very unfortunate to include a very high basement measurement (utility/storage area) when estimating the radon level in a nearby unmeasured dwelling when the objective is to map radon where people spend their time.

When multiple radon values are available for the same XY location, the method takes the highest radon value and uses it for that location. This will inevitably introduce a positive bias in the estimates of radon concentrations assigned to unmeasured dwellings. Again, the objective should be to estimate radon concentrations in living rooms and bedrooms while the highest measurements in dwellings are likely to come from basements or other utility areas with limited ventilation.

To conclude the point, the method is assigning smooth statistical mean radon values (and similarly smooth values in the case of prediction from eU) to unmeasured dwellings, taking no account of the radon dynamics of the individual dwellings involved (yes, this is impossible). I therefore suggest that it is unsafe to suggest that the method is able to predict radon concentrations in individual dwellings. Rather, the analysis does say "this dwelling is surrounded by other dwellings with a mean radon value of ??? so it is probable (at an unknown confidence level) that the radon concentration somewhere in this dwelling is something similar"

Contributions by Smethurst et al.

The present study is not as new and novel as it claims to be – this study seems to overlook much of the written contributions of Smethurst and co-workers from the 2000's which collated all of the data sets used in the present study except for the indoor radon data set (which is considerably larger than the one available to Smethurst et al). The first correlations between indoor measurements and eU (from AGRS in the Oslo area) were done by Smethurst and reported in several papers plus a Norwegian Radiation Protection Authority Report (2009:12) entitled "Airborne gamma ray spectrometer mea-

NHESSD
1, C1174–C1183, 2013

surements and radon: The application of airborne gamma ray spectrometry in identifying radon prone areas – an analysis based on measurements in the Oslo region". The classification/simplification of bedrock and drift types in the present contribution was done by us and published in the papers listed below.

It would have been appropriate to discuss the almost completely overlapping work carried out earlier by the NGU and NRPA published in the aforementioned papers. Not only the literature, but radon-related hazard maps were generated and publicised and are still available on the web if I am not mistaken (http://www.ngu.no/no/Aktuelt/2006/049/ (maps in English and Norwegian).

See e.g.

Smethurst et al 2008a. http://dx.doi.org/10.1016/j.scitotenv.2008.09.024

Smethurst et al 2008b. Testing the performance of a recent radon-hazard evaluation in the municipality of Gran, eastern Norway, In Slagstad, T (ed.) Geology for Society, Geological Survey o f Norway Special Publication, 11, pp. 147-156

Smethurst et al 2006. Airborge gamma ray spectrometer measurements and radon. The application of airborne gamma ray spectrometry in identifying radon prone areas – an analysis based on measurements in the Oslo region. Norwegian Radiation Protection Authority, Østerås, 2006.

Airborne Gamma Ray Spectrometry

A clear relationship between eU (same data set) and indoor radon was demonstrated by us and published in 2006 – the relevant findings of this earlier work are barely/not mentioned by the authors. In their abstract and conclusions the authors give the impression their related/similar analysis is completely new for the Oslo area. The only difference is that we compared eU with actual radon measurements while the current work compares it with estimated (and in effect smoothed) model radon values at unmeasured dwellings where weighting will be strongly influenced by the numbers and distribution of unmeasured dwellings (when it would have been logical to test the relationship with actual measurements).

We found that there is not a clear linear relationship between eU and indoor radon concentration (as proposed by the current authors). Rather, that there is a linear relationship between the probability of encountering elevated radon values (e.g. % radon values > Threshold value) and eU (also observed by others elsewhere). I am not convinced that the current authors are right and that we were wrong.

No matter how high ground eU values might be, there will always be some dwellings that can hold radon out of the measured spaces, while other dwellings let radon enter living spaces in amounts proportional to eU, and still more dwellings have other radon dynamics. This is why we frequently observe dwellings with very low indoor radon concentrations even where external eU is very high (see Fig 1 of this comment which is Fig. 7 in Smethurst 2008a - all our indoor measurements were selected from living spaces on the ground floor). I would be surprised if this was not also evident in the larger data set from the current investigation, especially when they might also include data from higher floors in buildings (outside the reach of radon from the ground). I would like to see a simple plot of actual Rn measurements (no buffering) versus eU for their study and compare it with ours.

The authors note a better correlation in alum shale areas. This is because of the far greater range in eU and radon values there and perhaps reduced likelihood that dwellings of any category can hold radon out.

K, eU & eTh

Just a quick note – refer to the nuclides as K, eU and eTh (drop the 'e' in eK). The e stands for "equivalent" (concentration deduce from the detected decay of a daughter nuclide, assuming equilibrium in the decay chain). K decay is detected directly so no e. It could be mentioned that the eU map is derived from the detection of Bi-214 decay – a short-lived radon daughter and therefore a very good measure of radon present in

NHESSD
1, C1174–C1183, 2013

the near surface of the ground. A problem with the mapping method is that radon in near surface soil gas is prone to vary with the weather so small variations in eU maps derived from Bi-214 measurements might be of limited significance. Also, eU maps generated in this ways provide a smoothed indication of the presence of radon in the ground. (Remember the flight lines are mostly 200 m apart and the aircraft travels quite a distance in the 1s it takes to make the measurement. The geochemical picture on the scale of a house footprint is far more complicated.)

AGRS Surveys

Figure 2 – surveys were carried out by the Geological Survey of Norway. A good part of the area (60%) is covered by a survey flown and processed by the company Fugro for the Geological Survey. Also that survey was not helicopter-borne but fixed-wing.

Correlation with geology and eU

Their correlation between indoor measurements and mapped bedrock geology confirms our earlier findings, as does an apparent lack of correlation with mapped drift geology (more or less a reiteration of Smethurst et al. 2008a Tables 2 and 3 using the same bedrock and permeability assignments). Despite this observation, the digital geology doesn't appear to be used in making any predictions of radon affected areas. Of course the eU map is an expression of the geology and it is closely related to radon concentration in the ground (see Smethurst et al 2008a Figs 8, 9, 10). Despite its correlation with indoor measurements (Fig. 8), this is also not used in any way in locating radon affected areas. The resulting radon predictions seem to be based solely on averages within a search radius. That is useful in itself, but it is disappointing that digital geology and eU maps don't end up affecting the final product.

Tables Statistical tables please

Figures XY plot: Indoor radon values (actual) vs. eU at same location Box-whisker plot: Indoor radon values (actual) vs Bedrock type Map: locations of indoor measurements (contour n if necessary) ?Frequency histograms of log-Rn (or table with GM and GSD): For populations of indoor measurements separated according to site and/or dwelling type (to justify pooling them al together)

Other comments I have quite a number of detailed commentes here and there in the manuscript but at this stage I think it is enough to make the more general observations above.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 3045, 2013.

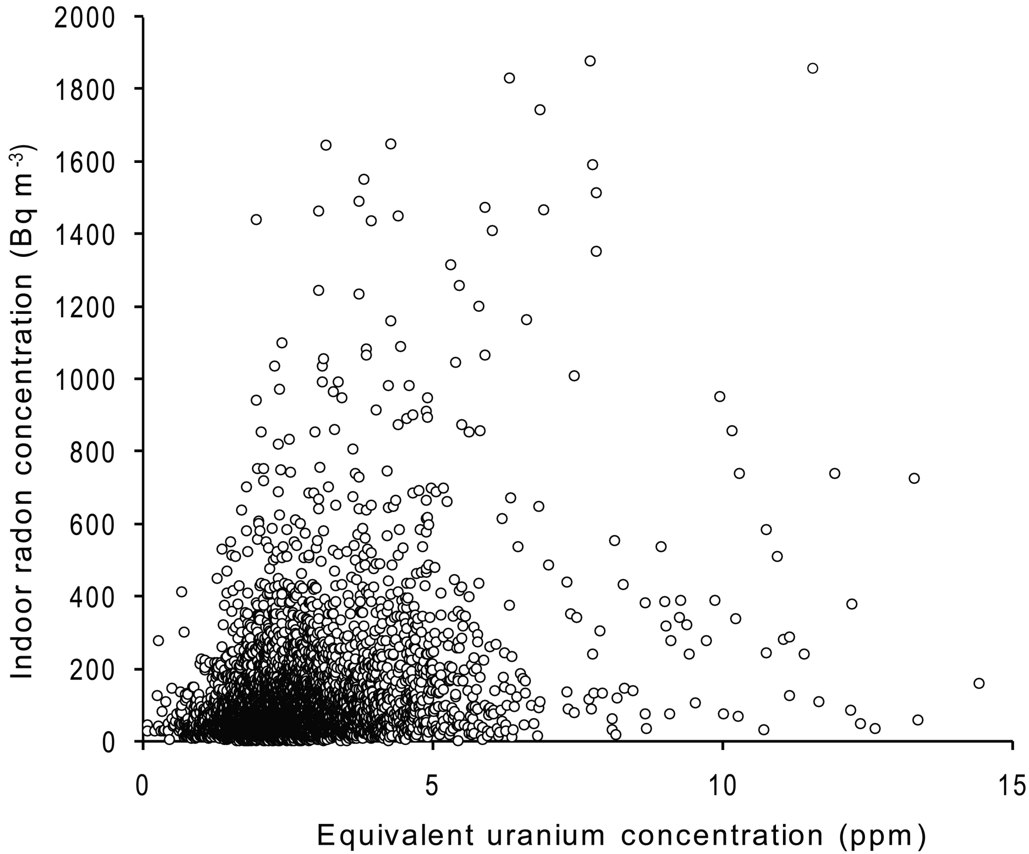

Fig. 1. Smethurst et al 2008a Fig 7 Rn vs. eU

NHESSD
1, C1174–C1183, 2013