

## ***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.***

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We thank you for the review of our manuscript and all the constructive suggestions.

Generally comments

-Aim of the study - We are aware that predicting radon is very difficult in this kind of study which includes a large population. We also agree that the use of the word “prediction” was wrong. What we actually wanted to do was to “assign” a radon value to unmeasured dwellings in the Oslo region for later use in an epidemiologic study.

We will therefore modify the aim to the study to:

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“The purpose of this study was to develop a method for assigning inside radon concentration values to unmeasured dwellings in the Oslo region, Norway”.

We are very sorry for not properly presenting the work of Smethurst et al. and will describe it in more detail:

On page 3050:

2.2 Data The Geological Survey of Norway (NGU) and Norwegian Radiation Protection Authority (NRPA) have produced maps of radon hazards in the Oslo region. Smethurst et al. (2008) presented radon maps of awareness level (high or moderate) in the Oslo region. Data on airborne gamma ray spectrometry measurements, bedrock geology and drift geology used in the present study is obtained from this work.

Smethurst et al., 2008 is also refereed in the manuscript:

In the introduction page 3047 line 14 (correlation between geology and uranium)

In the introduction page 3047 line 20 (permeability and uranium)

In the data description page 3050 line 15 (indoor radon measurements in the Oslo region)

In the data description page 3051 line 5 (description of bedrock geology used in the present study)

In the data description page 3051 line 15 (description of radiometric data used in our study)

Smethurst et al, 2008 will also be included on page 3058 line 1-2

-Indoor radon measurements - We agree that radon measurements can be described in a better way. We will add the following text:

Page 3050, line 20

-Type of dwelling and radon measurements - NRPA recommends anyone living in one

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of the three lowest floors above ground level to measure the radon concentration. 98.2 % of the dwellings in the study area (except Oslo) are houses with low-level houses (SSB, 2013). Equivalent present for Oslo are 84.3 %. The most common type of dwelling measured was detached houses with 74.5% of all radon measurements (Table 3).

Table 3. Dwellings style in the Oslo region and number radon measurements Dwellings style (Appendix)

87.1 % of radon measurements used in this study was from low-level houses, 2.7% was from the first three floors of apartment buildings.

91.6% of radon measurements had information on floor level. 99.9% was from below third floor, only 14 radon measurements were made on the third floor and 67 radon measurements were made above third floor, 61 of these were from ground-contact apartments. The radon concentration in ground-contact apartments are similar to those in low-rise residential building located in the same area (Valmari T et al. 2012). The 8.4 % was lacking information on floor level were included because they were made in low-level houses. 66.7% of the radon measurements missing information on floor level were from Oslo. In 2008/2009 a radon survey was performed in Oslo (Helse- og velferdsetaten, 2009). An invitation letter was sent to 40 000 homeowners living on the first three floors in Oslo inviting them to measure radon in the rooms where they spend most of their time. More than 5100 homeowner participated in this campaign.

Valmari T., Arvela H. and Reisbacka H. Radon in finnish apartment buildings. Radiation Protection Dosimetry, Vol. 152, No. 1–3, pp. 146–149. 2012.

Health and Welfare. Survey of radon in Oslo 2008/2009. (In norwegian) <http://www.helseetaten.oslo.kommune.no/getfile.php/bydel%20bjerke%20%28BBJ%29/InterOslo-2008-2009.pdf>

The annual average radon concentration for each dwelling was used in this study. We

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analyzed radon measurements according to which floor and where in the dwelling the measurement was made. Generally the distribution of radon levels in dwellings approximated a log-normal distribution. We analyzed radon values for all municipalities (except Oslo) in different dwelling types including underground, first and second floor. For Oslo the annual average concentration for each dwelling was already calculated by averaging the results of the radon measurements.

The standard Norwegian single family house has a basement. Since 1970 's it has been popular in Norway to share dwellings, single family house with a basement apartment with it's owns independent entrance. Around 10% of singles and single parents in Norway live in a basement flat (Lappegår and Nordvik, 1998). Lappegår and Nordvik (1998) calculated that around 6.5% of all houses in Norway are a basement apartment.

Lappegår T. and Nordvik V. Basement homes in the Norwegian housing market. ISBN: 82-536-0613-3. 1998. (In norwegian) <http://www.sintefbok.no/Product.aspx?sectionId=65&productId=273&categoryId=9>

We analyzed radon measurements made in basements too. 25.5% of the total radon measurements were made in basements. 70.4 % of these were made in main living area, bedrooms and others places where people spend most of their time. 0.8% of the measurements were made in non-living areas. 28.4 % lacked information on type of room. The mean radon value of measurements lacking information on type room was 181.6 Bq. Since radon mean from main living room areas were 186.2 the results was pooled.

-Radon value and apartment building - In section 4.2 methodological limitations page 3059, we describe limitations regarding lack of information on floor number. Sensitivity analysis can be made. We will also perform subanalyses excluding apartment buildings in the later epidemiologic study.

-Multiple radon value in a XY location - In subtitle 2.2.1 we describe the calculation of radon values used in our study. Radon in homes with multiple measurements in several

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rooms was given the average of all radon measurements made in the house. When there were two or more measured residences sharing the same XY location the radon value from the residence with the highest radon mean value was used. We did not use the highest radon measurement in the house, but the residence with the highest mean radon value. It will be explained in a better way under subtitle 2.3.1 page 3052.

1. All dwellings sharing the same coordinate point as a dwelling with at least one measurement got the same radon value or the mean radon value if the dwelling had more than one measurement. If several dwellings shared the same coordinate point the dwelling with the highest mean value in each coordinate point was used to construct buffers.

-Relationship between eU and indoor radon concentration - We did not find a clear relationship between simple eU measurement and simple indoor radon measurement in this material. Smethurst et al. (2008) found that there was a correlation between percentage of dwellings with indoor radon concentrations above the action level of 200 Bqm<sup>3</sup> with equivalent uranium concentration in the study area. Scheib et al. 2006 showed that in England there is a significant correlation between geometric mean (GM) airborne eU and geometric mean (GM) indoor radon in some geological units. We wanted to test this in Norway. We used GM of indoor radon and arithmetic mean (AM) of eU. We found correlation between eU and indoor radon. These are similar results as Scheib et al. 2006 presented in their paper.

Scheib, C., Appleton, J. D., Jones, D. G., and Hodgkinson, E.: Airborne uranium data in support of radon potential mapping in Derbyshire, Central England, in: Radon Investigations in the Czech Republic XI and the 8th International Workshop on the Geological Aspects of Radon Risk Mapping, Prague, edited by: Barnet, I., Neznal, M., and Pacherova, P., Czech. Geological Survey, 210–219, 2006.

[http://nora.nerc.ac.uk/8322/1/AirborneU\\_Cscheib.pdf](http://nora.nerc.ac.uk/8322/1/AirborneU_Cscheib.pdf)

You wrote you have other comments on the manuscript. We look forward to hear from

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them and use them for improving our manuscript.

Appendix

-Table 3. Dwellings style in the Oslo region and number radon measurements -Map of indoor radon measurements -Plott indoors radon value vs eU -Table of Indoor radon values and bedrock geology -Frequency histograms of log-Rn of indoor measurements separated according to site and dwelling type

Please also note the supplement to this comment:

<http://www.nat-hazards-earth-syst-sci-discuss.net/1/C1362/2013/nhessd-1-C1362-2013-supplement.pdf>

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

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