Identification and delineation of radon areas in Austria

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Austrian Agency for Health and Food Safety (AGES), Radon and Radioecology

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Background

Implementation of EU-BSS in Austrian legislation

Medical Radiation Protection Ordinance
idF BGBl. II Nr. 353/2020

Radiation Protection Act 2020
BGBl. I Nr. 50/2020

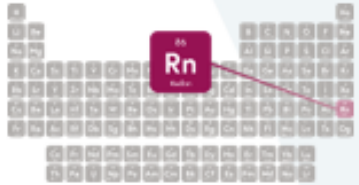
StrSchG

General Radiation Protection Ordinance 2020
BGBl. II Nr. 339/2020

Radioactive Waste Shipments Ordinance 2009
idF BGBl. II Nr. 331/2020

Ordinance on Interventions 2020
BGBl. II Nr. 343/2020

Radon Protection Ordinance
BGBl. II Nr. 470/2020

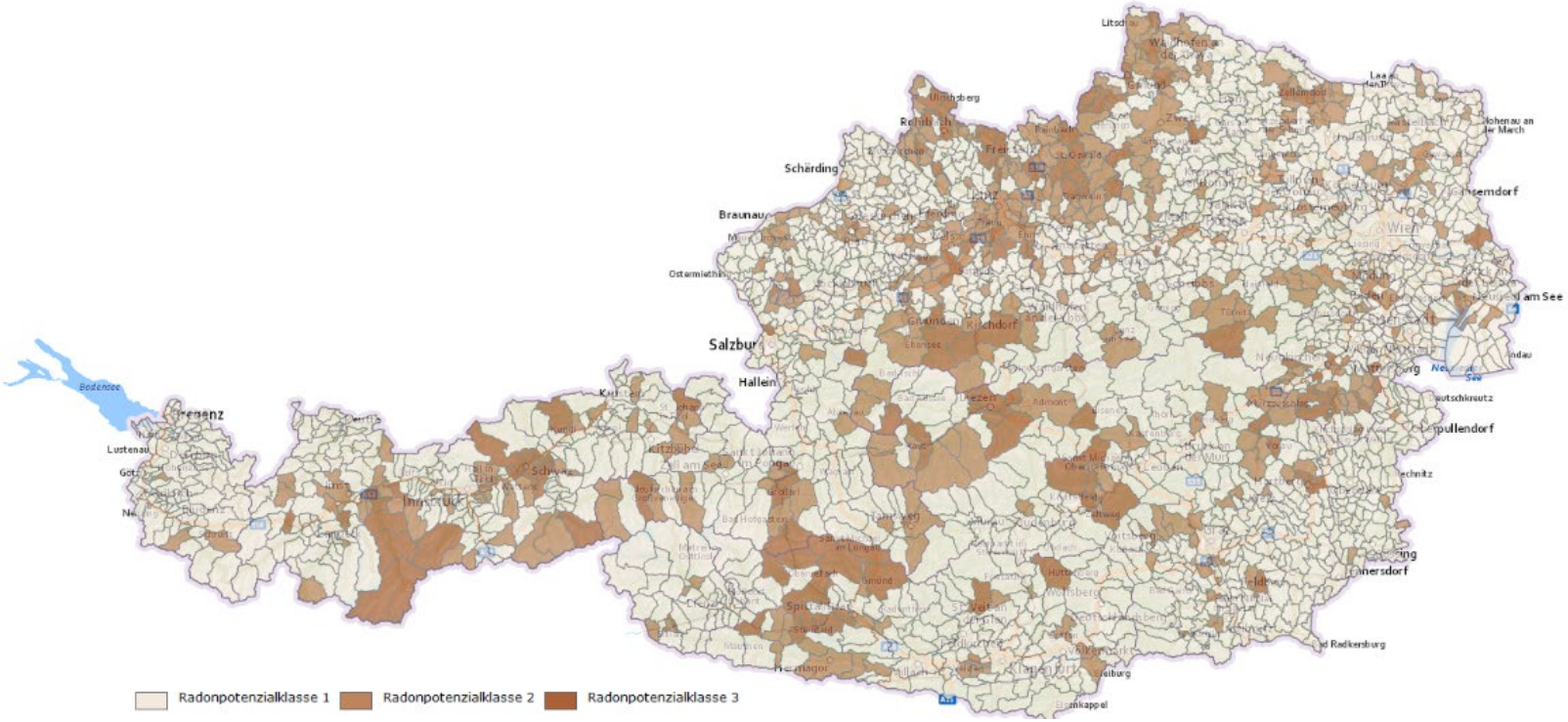


RnV

Reference: BMK

Background

Austrian Radon potential map (ÖNRAP 1, 1992-2004)



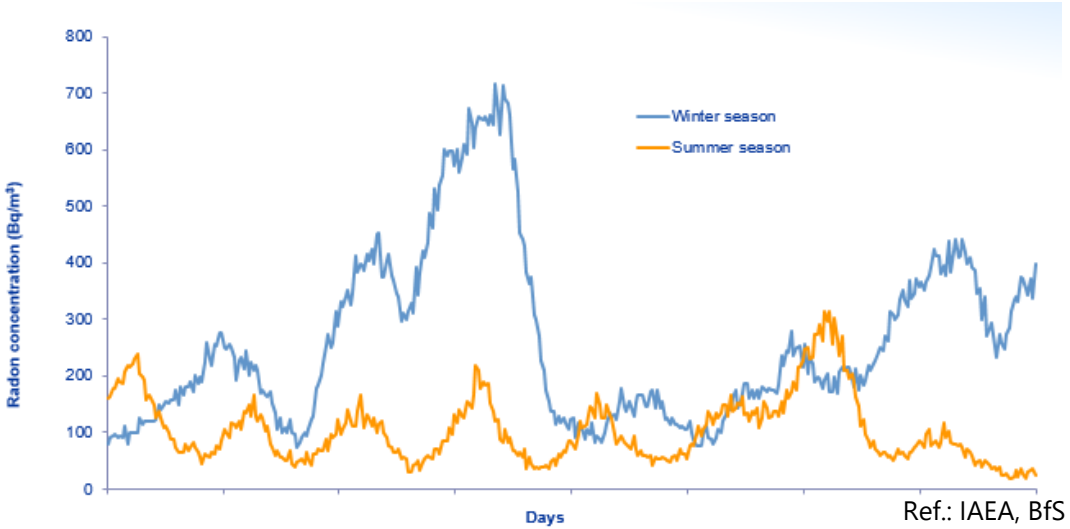
BUT:

- > 10 years old
- Small number of dwellings per municipality (3-5) (about 9,000 dwellings in total)
- Different measurement systems used (charcoal, electrets, track etch)
- Maximum measurement time 3 months, > 50% short term (few days)

Design of the new Austrian indoor radon survey

ÖNRAP 2 (2013 – 2019)

- Purpose: Reliable delineation of radon priority areas
- Geograhpically-based survey
  - All populated areas should be uniformely covered with measurements
- One single measurement method:
  - Track etch detectors
  - 6 months (half winter, half summer time)
  - 2 rooms (preferably ground floor or lowest inhabitated floor)

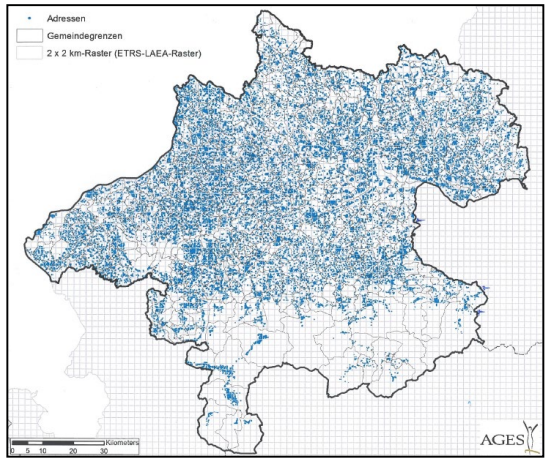


Ref.: IAEA, BfS

Design of the new Austrian indoor radon survey

Selection of measurement points (dwellings)

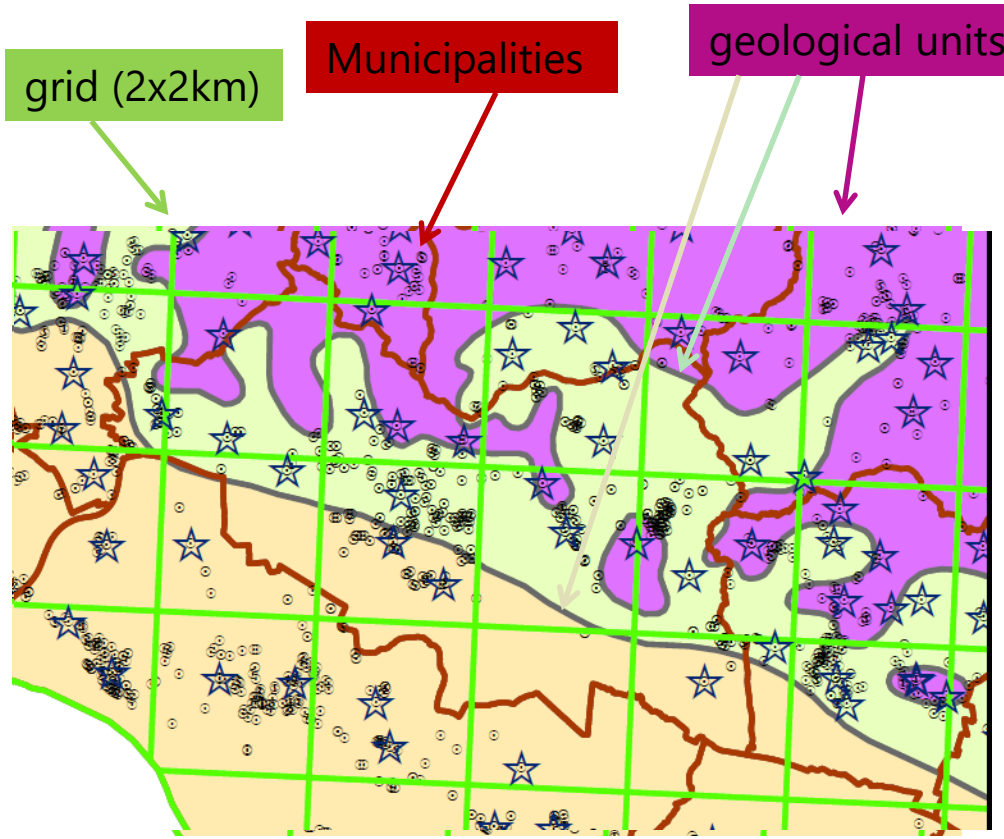
- Data basis for selection of dwellings:
  - Members of voluntary fire brigade
  - 360,000 members - 4% of population



- At least 1-3 dwellings per 2x2 km grid cell
  - depending on heterogenity of geology
- At least 12 dwellings per municipality
  - selected 15-20 (anticipate loss, non-return)

dwellings of fire brigade members

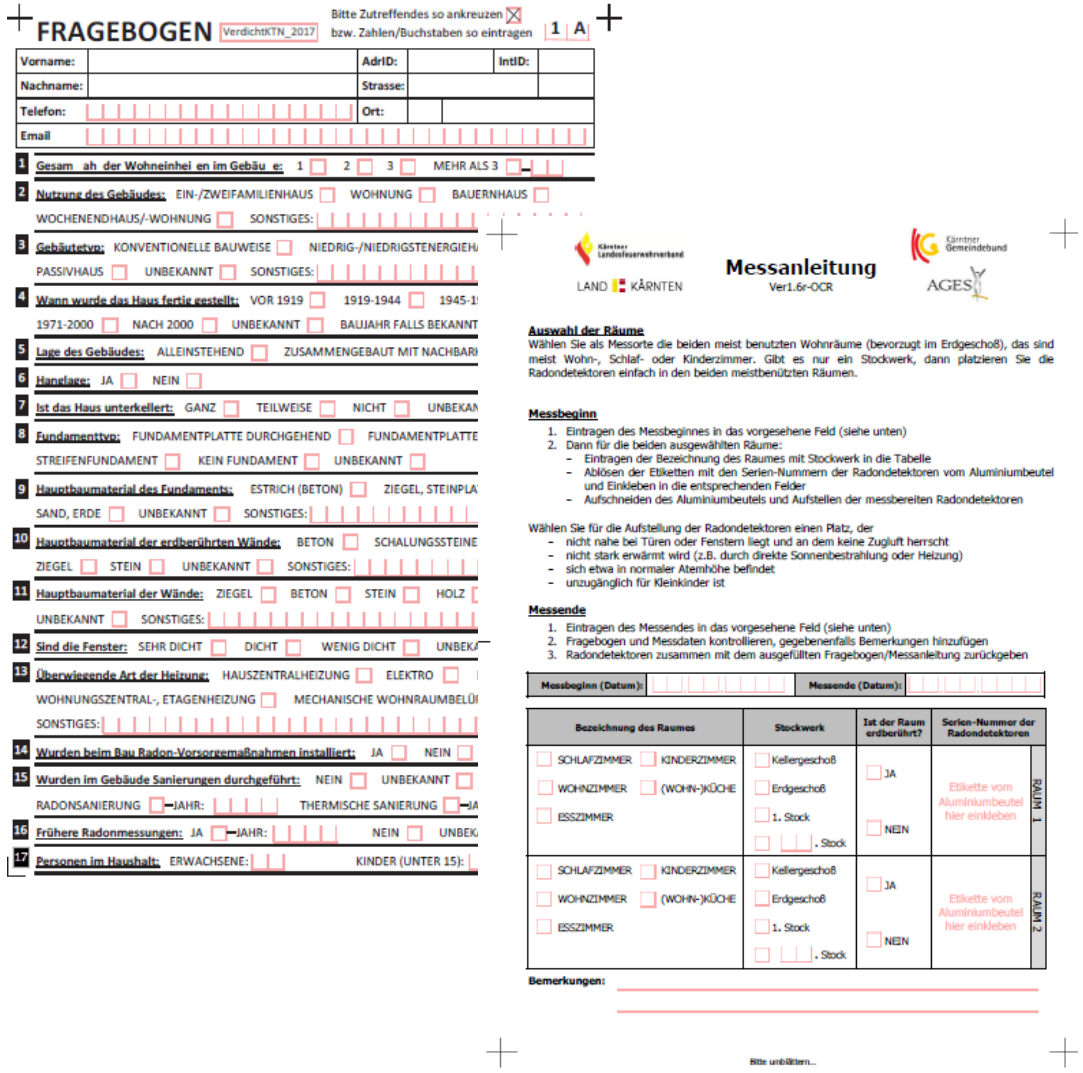
selected dwellings



Design of the new Austrian indoor radon survey

Questionnaire and Distribution of detectors

- Questionnaire
  - building characteristics, living habits
- Organisation of measurement campaign and distribution of detectors/questionnaires via (local) voluntary fire brigades



FRAGEBOGEN VerdichtKTN_2017

Bitte Zutreffendes so ankreuzen ☒
bzw. Zahlen/Buchstaben so eintragen 1 A

Vorname:		AdrID:		IntID:	
Nachname:		Strasse:			
Telefon:		Ort:			
Email					

1 Gesam ah der Wohneinhei en im Gebäu e: 1 ☐ 2 ☐ 3 ☐ MEHR ALS 3 ☐

2 Nutzung des Gebäudes: EIN-/ZWEIFAMILIENHAUS ☐ WOHNUNG ☐ BAUERNHAUS ☐
WOCHENENDHAUS/-WOHNUNG ☐ SONSTIGES:

3 Gebäutetyp: KONVENTIONELLE BAUWEISE ☐ NIEDRIG-/NIEDRIGSTENERGIEH
PASSIVHAUS ☐ UNBEKANNT ☐ SONSTIGES:

4 Wann wurde das Haus fertig gestellt: VOR 1919 ☐ 1919-1944 ☐ 1945-1
1971-2000 ☐ NACH 2000 ☐ UNBEKANNT ☐ BAUJAHR FALLS BEKANNT

5 Lage des Gebäudes: ALLEINSTEHEND ☐ ZUSAMMENGEBAUT MIT NACHBAR

6 Hanglage: JA ☐ NEIN ☐

7 Ist das Haus unterkellert: GANZ ☐ TEILWEISE ☐ NICHT ☐ UNBEKAN

8 Fundamenttyp: FUNDAMENTPLATTE DURCHGEHEND ☐ FUNDAMENTPLATTE
STREIFENFUNDAMENT ☐ KEIN FUNDAMENT ☐ UNBEKANNT ☐

9 Hauptbaumaterial des Fundaments: ESTRICH (BETON) ☐ ZIEGEL, STEINPLA
SAND, ERDE ☐ UNBEKANNT ☐ SONSTIGES:

10 Hauptbaumaterial der erdberührten Wände: BETON ☐ SCHALUNGSSTEINE
ZIEGEL ☐ STEIN ☐ UNBEKANNT ☐ SONSTIGES:

11 Hauptbaumaterial der Wände: ZIEGEL ☐ BETON ☐ STEIN ☐ HOLZ ☐
UNBEKANNT ☐ SONSTIGES:

12 Sind die Fenster: SEHR DICHT ☐ DICHT ☐ WENIG DICHT ☐ UNBEKA

13 Überwiegende Art der Heizung: HAUSZENTRALHEIZUNG ☐ ELEKTRO ☐
WOHNUNGSZENTRAL-, ETAGENHEIZUNG ☐ MECHANISCHE WOHNRAUMBELÜ
SONSTIGES:

14 Wurden beim Bau Radon-Vorsorgemaßnahmen installiert: JA ☐ NEIN ☐

15 Wurden im Gebäude Sanierungen durchgeführt: NEIN ☐ UNBEKANNT ☐
RADONSANIERUNG ☐ JAHR: THERMISCHE SANIERUNG ☐ JA

16 Frühere Radonmessungen: JA ☐ JAHR: NEIN ☐ UNBEK

17 Personen im Haushalt: ERWACHSENE: KINDER (UNTER 15):

Kärntner Landesfeuerwehrverband
LAND KÄRNTEN

Messanleitung
Ver1.6r-OCR

Kärntner Gemeindebund
AGES

Auswahl der Räume
Wählen Sie als Messorte die beiden meist benutzten Wohnräume (bevorzugt im Erdgeschoß), das sind meist Wohn-, Schlaf- oder Kinderzimmer. Gibt es nur ein Stockwerk, dann platzieren Sie die Radondetektoren einfach in den beiden meistbenützten Räumen.

Messbeginn
1. Eintragen des Messbeginnes in das vorgesehene Feld (siehe unten)
2. Dann für die beiden ausgewählten Räume:
   - Eintragen der Bezeichnung des Raumes mit Stockwerk in die Tabelle
   - Ablösen der Etiketten mit den Serien-Nummern der Radondetektoren vom Aluminiumbeutel und Einkleben in die entsprechenden Felder
   - Aufschneiden des Aluminiumbeutels und Aufstellen der messbereiten Radondetektoren

Wählen Sie für die Aufstellung der Radondetektoren einen Platz, der
- nicht nahe bei Türen oder Fenstern liegt und an dem keine Zugluft herrscht
- nicht stark erwärmt wird (z.B. durch direkte Sonnenbestrahlung oder Heizung)
- sich etwa in normaler Atemhöhe befindet
- unzugänglich für Kleinkinder ist

Messende
1. Eintragen des Messendes in das vorgesehene Feld (siehe unten)
2. Fragebogen und Messdaten kontrollieren, gegebenenfalls Bemerkungen hinzufügen
3. Radondetektoren zusammen mit dem ausgefüllten Fragebogen/Messanleitung zurückgeben

Messbeginn (Datum):		Messende (Datum):	

Bezeichnung des Raumes	Stockwerk	Ist der Raum erdberührt?	Serien-Nummer der Radondetektoren
☐ SCHLAFZIMMER ☐ KINDERZIMMER ☐ WOHNZIMMER ☐ (WOHN-)KÜCHE ☐ ESSZIMMER	☐ Kellergeschoß ☐ Erdgeschoß ☐ 1. Stock ☐ . Stock	☐ JA ☐ NEIN	Etikette vom Aluminiumbeutel hier einkleben — RAUM 1
☐ SCHLAFZIMMER ☐ KINDERZIMMER ☐ WOHNZIMMER ☐ (WOHN-)KÜCHE ☐ ESSZIMMER	☐ Kellergeschoß ☐ Erdgeschoß ☐ 1. Stock ☐ . Stock	☐ JA ☐ NEIN	Etikette vom Aluminiumbeutel hier einkleben — RAUM 2

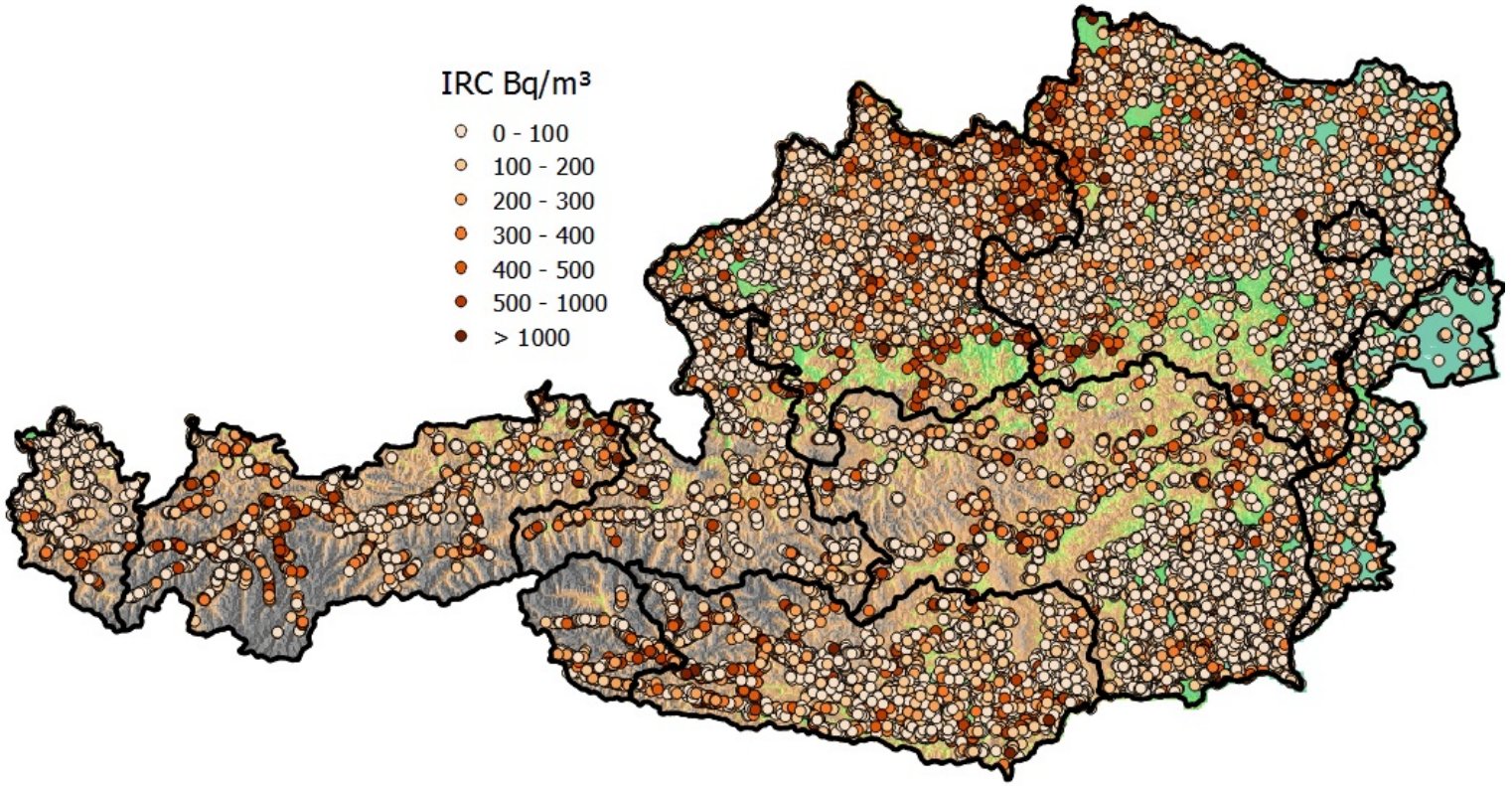
Bemerkungen:

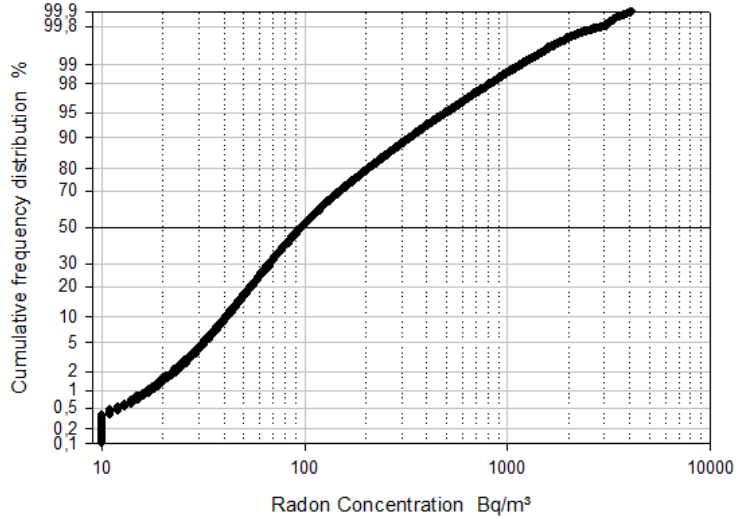
Bitte umblättern...

Results of the Austrian indoor radon survey

Overview

n (meas.)	n (dwell.)	Average return rate	AM [Bq/m³]	Med [Bq/m³]	>100 Bq/m³	>300 Bq/m³	>1000 Bq/m³
46,339	27,834	67%	170	97	49 %	11 %	1 %





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The new Austrian indoor radon survey (ÖNRAP 2, 2013–2019): Design, implementation, results

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Survey design
Geology
Building characteristics

ABSTRACT

The delineation of radon prone areas is one of the central requirements of the European Council Directive 2013/59/EURATOM. It is quite a complex task which usually requires the collection of radon data through an appropriate survey as a first step. This paper presents the design and methodology of the recent Austrian radon survey (ÖNRAP 2, 2013–2019) and its implementation. It details the results of the nationwide survey as well as correlations and dependencies with geology and building characteristics. The paper also discusses the representativeness of the survey as well as advantages and disadvantages of the selected approach.

For the purpose of establishing a new delineation of radon prone areas in Austria we distributed approximately 75,000 passive long-term radon detectors. They were offered to selected members of the voluntary fire brigades and this resulted in about 50,000 radon measurements. Thus, a return rate of about 67% was achieved. The distribution of the radon results closely follows a log-normal distribution with a median of 99 Bq/m^3, a geometric mean of 109 Bq/m^3, and a geometric standard deviation factor of 2.29. 11% of the households show a mean radon concentration above the national reference level of 300 Bq/m^3.

Important data on building characteristics and the location of the measured rooms were collected by means of a specific questionnaire and a measurement protocol that were handed out together with the radon detectors. We were able to identify significant correlations between the indoor radon concentration and geology, the year of construction, and the coupling of the room to the ground (basement yes/no, floor level).

Being a geographically-based and not a population-weighted survey, the comparison of building characteristics with the Austrian census data confirms that rural areas are over-represented in this survey.

As a summary, the selected approach of conducting passive long-term radon measurements in selected dwellings of members of the voluntary fire brigades proved to be an efficient method to collect reliable data as a basis for the delineation of radon prone areas. The next step was to eliminate factors that influence the measured radon concentration through appropriate modelling. Based on the results predicted by the model radon areas are then be classified. This will be presented in a subsequent publication.

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From the survey to the radon map

Modelling

- Geostatistical Modelling – Generalised Additiative Mixed Model (GAMM)
  - Modelling the results of the Indoor Radon Concentration (IRC) in dependency of explaining factors (based on Borgoni et al., 2014):
    - Building characteristics & living habits
    - Geology
    - Spatial correlation
  - To evaluate influence of variables (building characteristics) → Stepwise forward selection with *5-fold cross validation*

Fixed effects according to the relevant parameters (building characteristics)

Random effect (dwelling)

$$\log(IRC_{ij}) = \beta_0 + \beta_1 z_{ij} + \ldots + \beta_m z_{ij} + s(x_j, y_j) + u_j + \varepsilon_{ij}$$

Intercept (Rn background level)

Smoothing function *(thin plate regression splines)*, spatial intercept

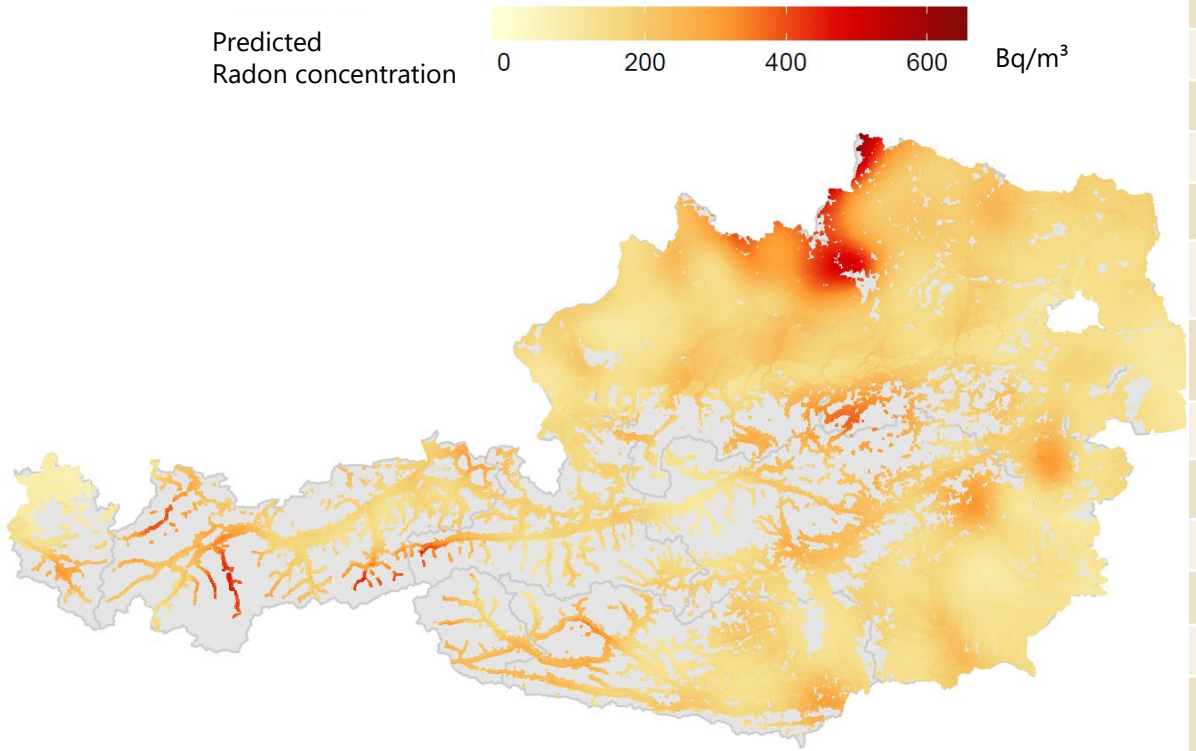
rest variation

Relevant factors:
- earth-boundness
- year of construction
- floor
- geology
- basement
- stone walls
- thermal retrofitted
- usage of building
- number of adults
- low-energy house
- window tightness
- foundation

From the survey to the radon map

Prediction of radon concentration in a reference house

- Prediction of indoor radon concentration (IRC) for reference house on 250 x 250 m grid (Radon potential of the grid cell)
- Definition of reference house has strong impact
- Reference house – representative for requirements for workplaces and for cost-efficient newly built house

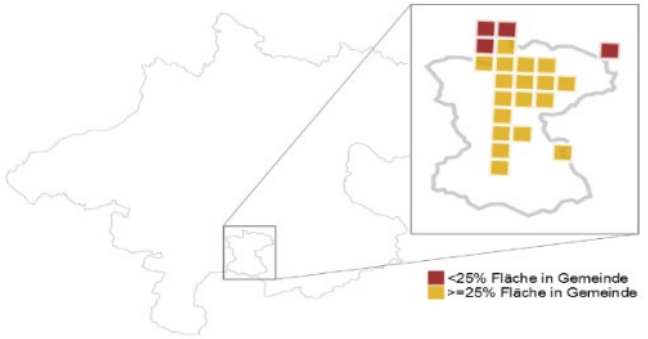


Variable	Characteristic
earth-boundness	yes
year of construction	after 2000
floor	0
basement	no
stone walls	no
concrete walls	no
usage of building	single family house
number of adults	2
low-energy house	no
windows	tight
foundation	full
thermal retrofitted	no
geological unit	assigned by coordinates

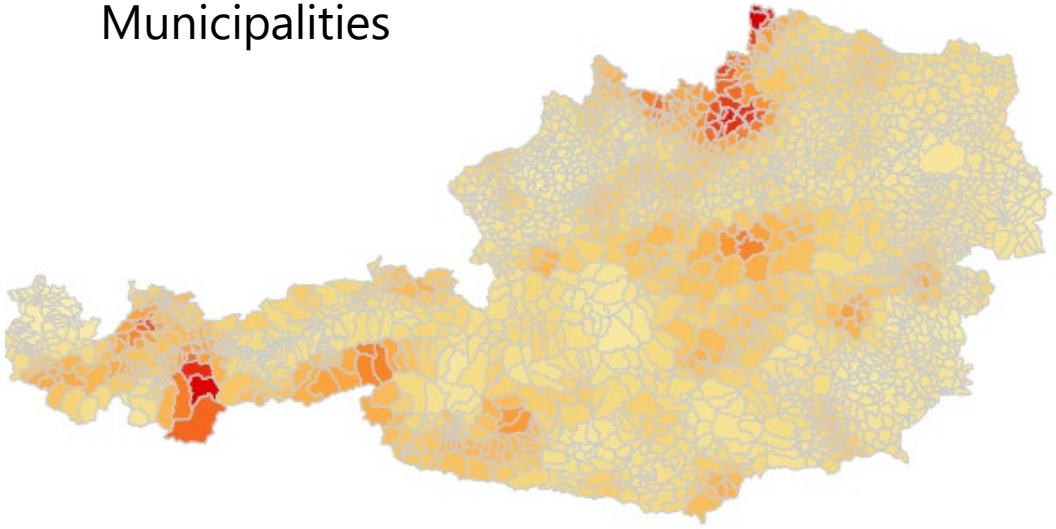
From the survey to the radon map

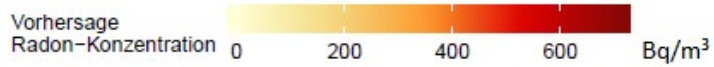
Radon potential of the municipality

- For administrative reasons – radon map for administrative unit (municipalities, districts)
- Radon potential of municipalities/district: average of all predicted IRC of grid cells (250 x 250 m) in the settlement area of the municipality/district

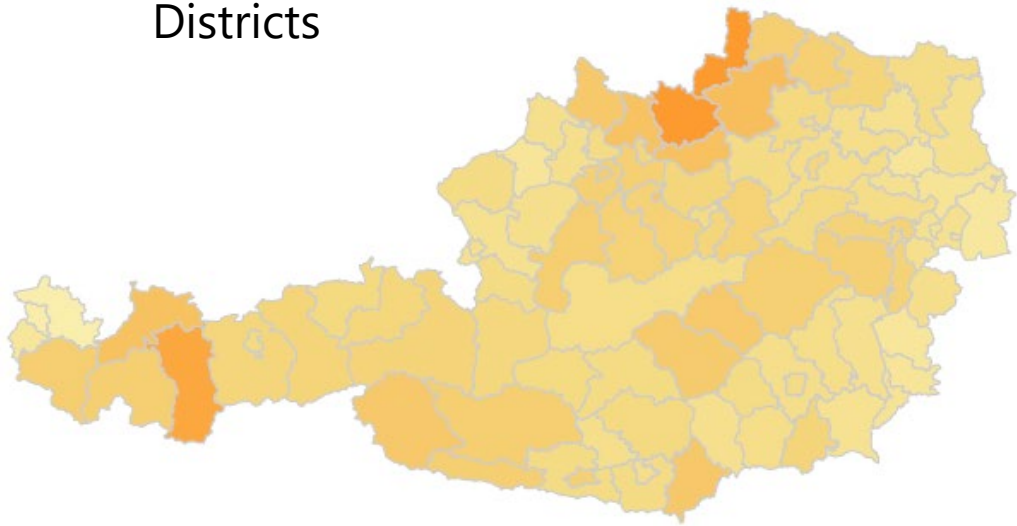


Municipalities





Districts



From the survey to the radon map

Advantages of the Modelling approach

- Characterisation of areas with no or small number of measurements possible
- Takes into account
  - geology
  - building factors – reflecting geogenic radon potential
  - spatial correlations – more homogenic classification possible
- Standard house could be adapted to specific situations
- Predicition of Radon concentration for specific house type for different units (grid, administrative) possible

Delineation of radon areas

Graded approach

- Political discussion, not mainly scientifc; involvement of regional authorities & stakeholders necessary
- Radon measurements at general workplaces needs to be managable; priorisation necessary
- Radon preventive measures very efficient for radon protection – should be done comprehensive
- Effective radon protection in Austria implemented with graded approach and 3 classes:
  - **Radon protection areas**
    - Predicted radon potential of municipality is above 300 Bq/m³
    - Measurements in workplaces (groundfloor & basement) mandatory
    - Preventive measures for new buildings mandatory
  - **Radon prevention areas**
    - Predicted radon potential of district is above 150 Bq/m³
    - Preventive measures for new buildings mandatory
  - Areas with no specific measures necessary (very low radon potential)

Delineation of Radon areas

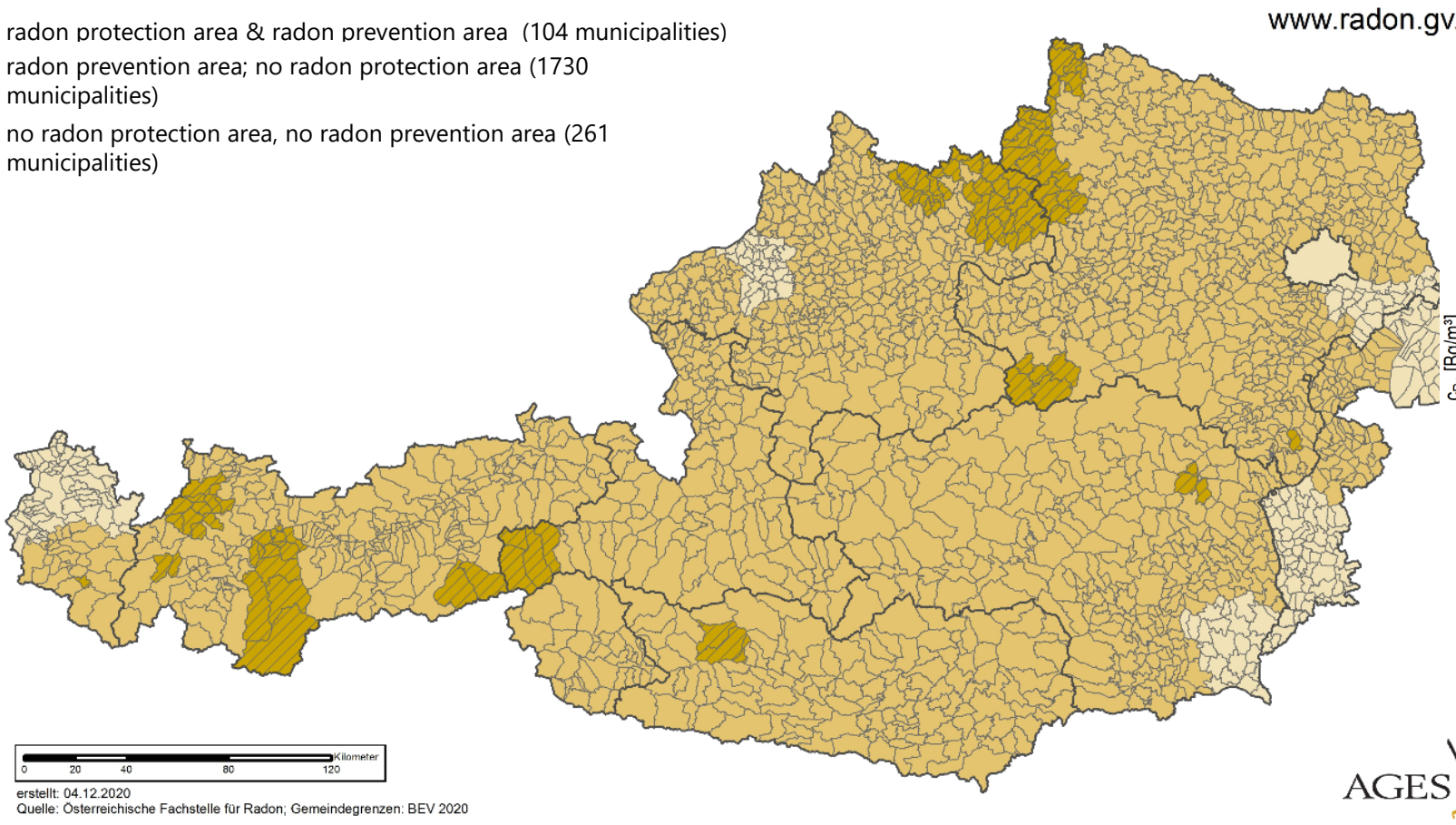
Radon protection areas, Radon prevention areas

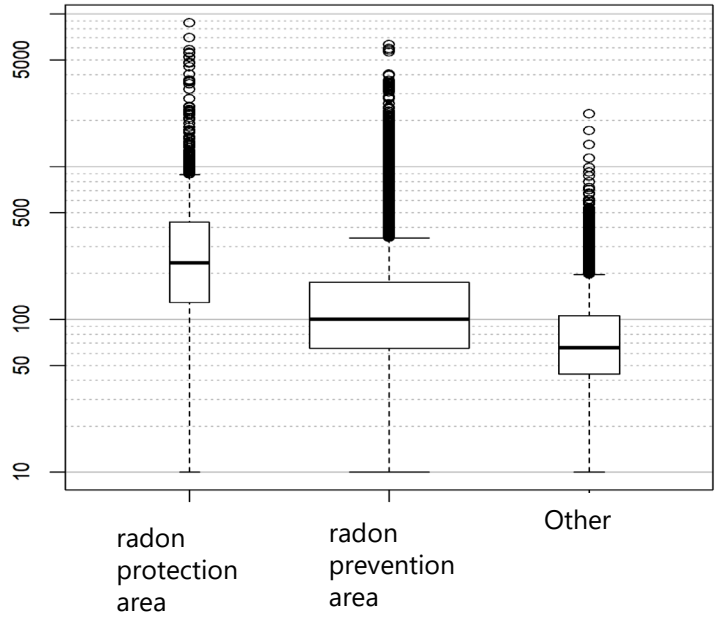
Radon areas in Austria

radon protection area & radon prevention area (104 municipalities)

radon prevention area; no radon protection area (1730 municipalities)

no radon protection area, no radon prevention area (261 municipalities)

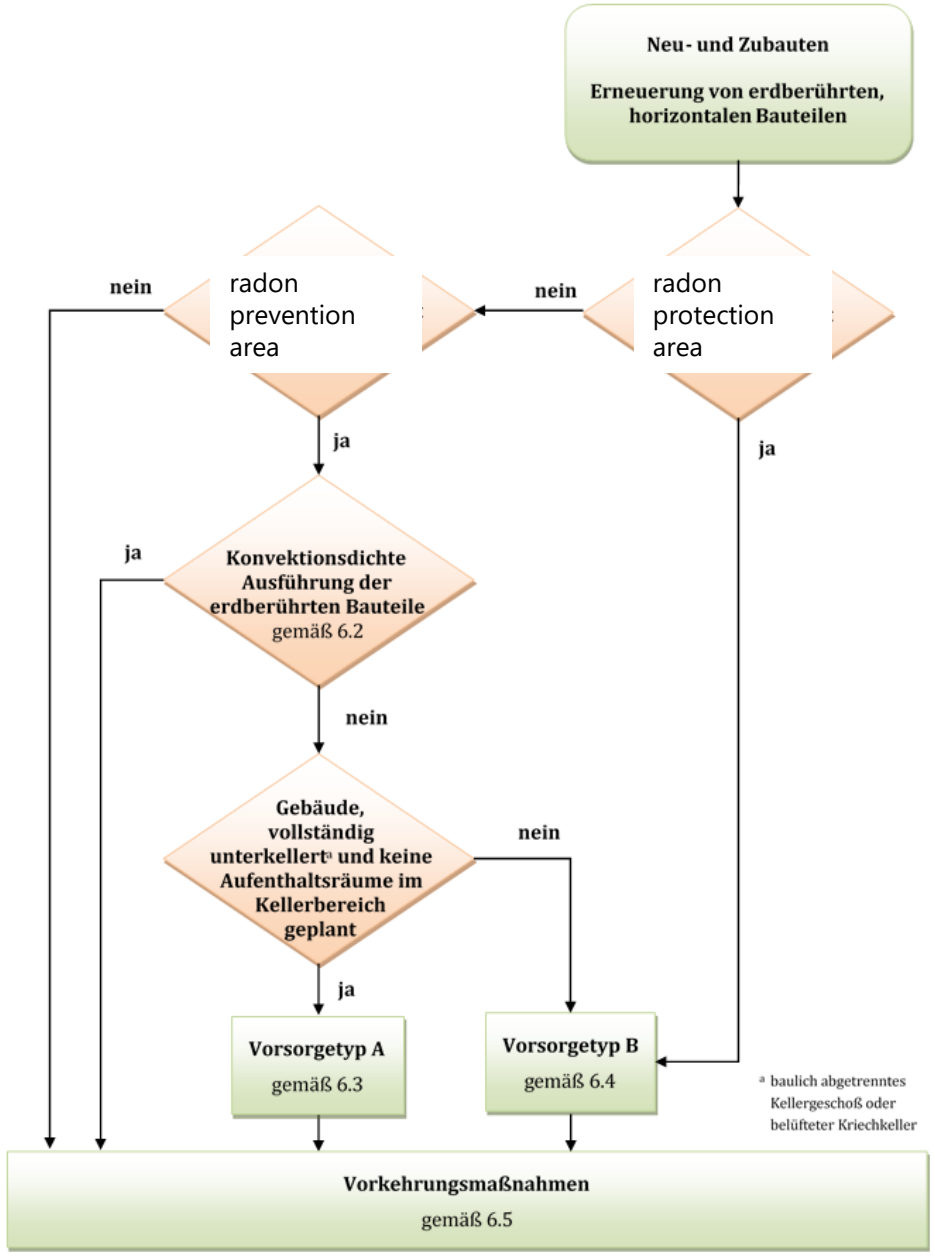




Delineation of Radon areas

Consequences

- Radon at general workplaces:
  - 104 municipalities in radon protection area
  - about 20,000 workplaces
  - Mandatory measurements in workplaces in groundfloor (if no exemption) – 6 months passive measurements
  - about 20 % expected to be > RL
  - about 80-90 % possible to remediate < RL
- Radon preventive measures:
  - New Austrian standard, ÖNORM S 5280-3 (15.7.2021) – graded approach depending on radon areas



Delineation of Radon areas

Communication – List of municipalities in Radon Protection Ordinance, Annex 1

BUNDESGESETZBLATT

FÜR DIE REPUBLIK ÖSTERREICH

Jahrgang 2020	Ausgegeben am 9. November 2020	Teil II

470. Verordnung: **Radonschutzverordnung – RnV**

[CELEX-Nr.: 32013L0059]

B. Als Radonvorsorgegebiete festgelegte Gemeinden:

Burgenland:

Alle Gemeinden mit Ausnahme der Gemeinden in den Bezirken Güssing, Jennersdorf, Neusiedl am See und Oberwart.

Kärnten:

Alle Gemeinden.

Niederösterreich:

Alle Gemeinden mit Ausnahme der Gemeinden im Bezirk Bruck an der Leitha.

Oberösterreich:

Alle Gemeinden mit Ausnahme der Gemeinden im Bezirk Ried im Innkreis.

Salzburg:

Alle Gemeinden.

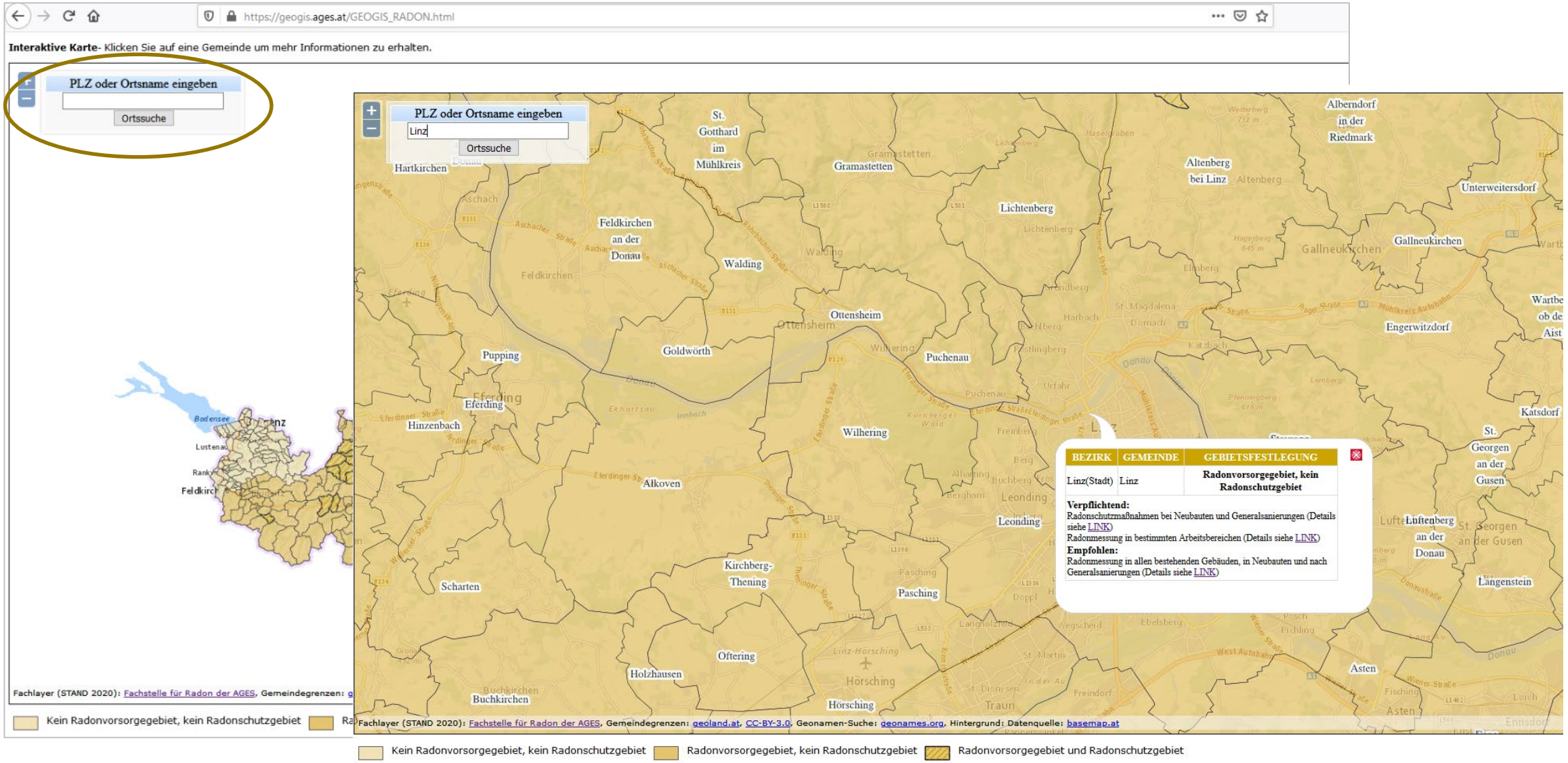
A. Als Radonschutzgebiete festgelegte Gemeinden:

Gemeindename	Gemeinde-kennziffer
Kärnten:	
Mühldorf	20624
Obervellach	20627
Reißeck	20644
Niederösterreich:	
Altmelon	32519
Amaliendorf-Aalfang	30902
Arbesbach	32502

Delineation of Radon areas

Communication – Interactive map

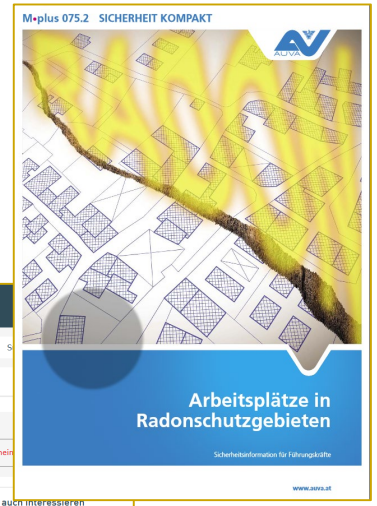
https://geogis.ages.at/GEOGIS_RADON.html

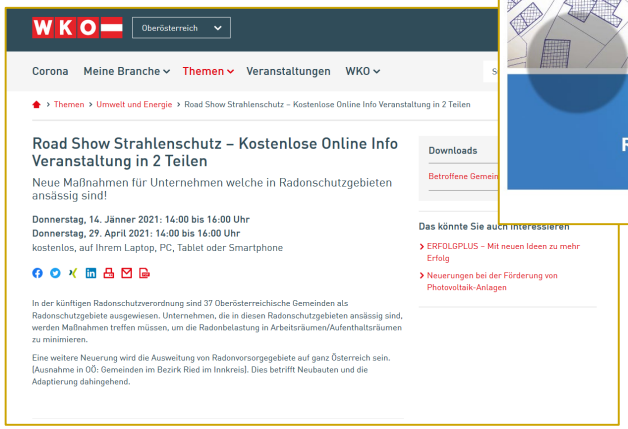


Delineation of Radon areas

Communication - Activities

- Report – for experts & short version for general public (not published yet)
- Information on websites (AGES, BMK, regional authorities)
- „Roadshows“ for employers & co (with regional economic chambers, regional authorities)
- Folders, information campaigns (together with economic chamber, AUVA, regional authorities)
- Presentation of radon map/delineation of radon areas within different stakeholder groups





Conclusions

Delineation of Radon Areas – a lot to take into account

- Should be done in the scientifically best way for the specific situation of data/radon potential/purpose of country
- Map/delineation should be evaluated and adapted regularly
- Not only scientific topic, but also political/economic/etc.
- Many different factors can/need to be taken into account
- Several stakeholders interested/needs to be involved (not always easy process) – clear and open communication good, but can take time
- Good communication of radon areas and necessary measures necessary (employers, building industry, regional & local authorities, population, etc.) – involve trusted/accepted institutions (e.g. labour safety organisation, economic chamber, etc.)
- Measurements and measures recommended also in areas, which are not delineated as radon areas – important message/communication!

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