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Ethics and Justification in Radiation Protection

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Justification in the law enforcement among the population, the example of residential radon

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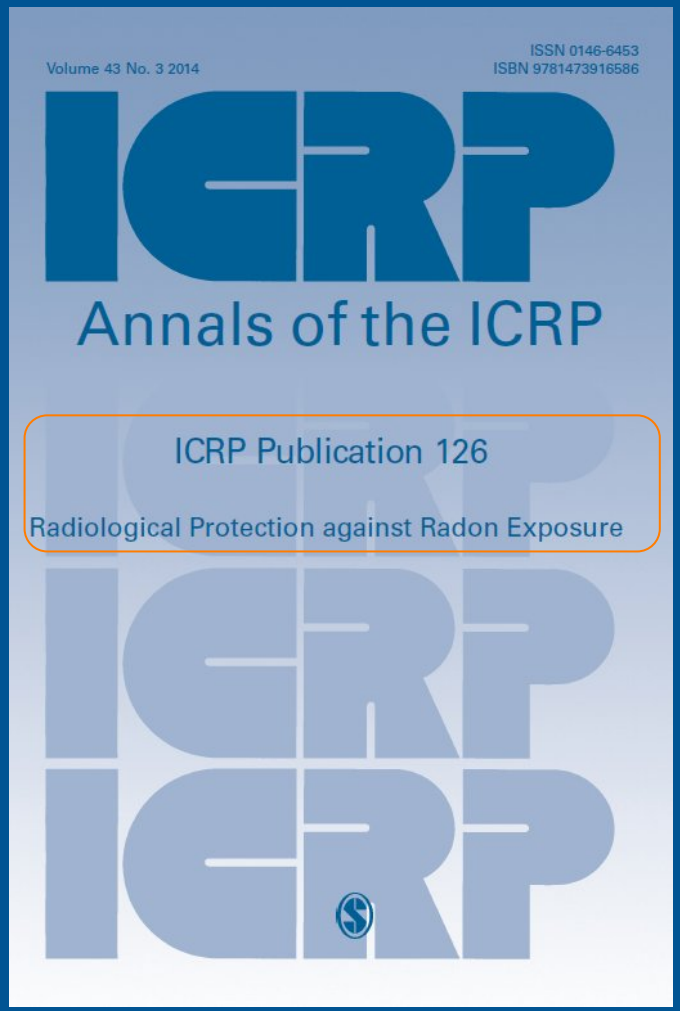
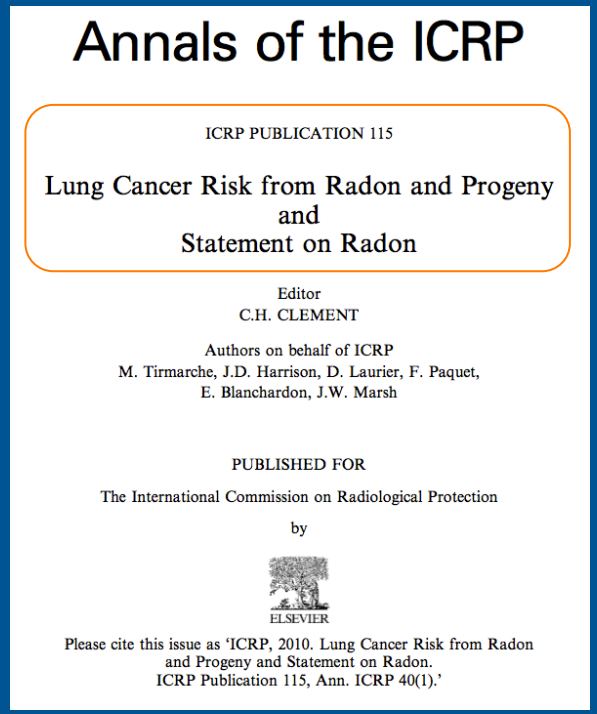
Justification for radon in dwellings: the main reference documents (+ ICRP-103)





Annals of the ICRP

ICRP PUBLICATION 115

Lung Cancer Risk from Radon and Progeny
and
Statement on Radon

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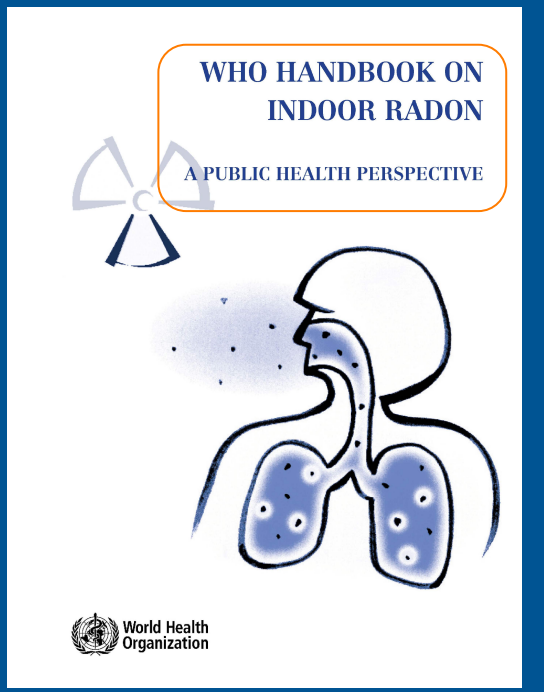


Justification for radon in dwellings: the ICRP position

Justfication: any decision that alters (including reduction of) the radiation exposure situation should do more good than harm.

(65) The Commission considers that there are many arguments which provide broad justification of the implementation of national radon protection strategies. These include:

- radon is a significant source of radiation exposure, and is the second cause of lung cancer in the general population after smoking;
- radon exposure can be controlled, as feasible techniques exist to prevent and mitigate high indoor radon concentrations; and
- a radon protection strategy can have positive consequences on other public health policies such as indoor air quality and non-smoking policies. Reducing the radon concentration contributes to mitigate the health effects of tobacco.

From ICRP publ. 126 (Radiological Protection against Radon Exposure) (2014)

Justification for radon in dwellings: the risk of lung cancer

- Risk evidence: the risk of lung cancer due to radon exposure has been demonstrated and evaluated by means of many large epidemiological studies, conducted on miner cohorts and on populations exposed in dwellings.
- Individual risk: the risk level corresponding to common radon exposures is high and considerably higher than that of most other exposures to ionizing radiation:
  - For a 50-y exposure at 100 Bq/m^3, lung cancer risk is ~ 10^{-2}
- Collective risk: radon is present (although at different concentrations) in ~all the dwellings => public health issue (WHO)

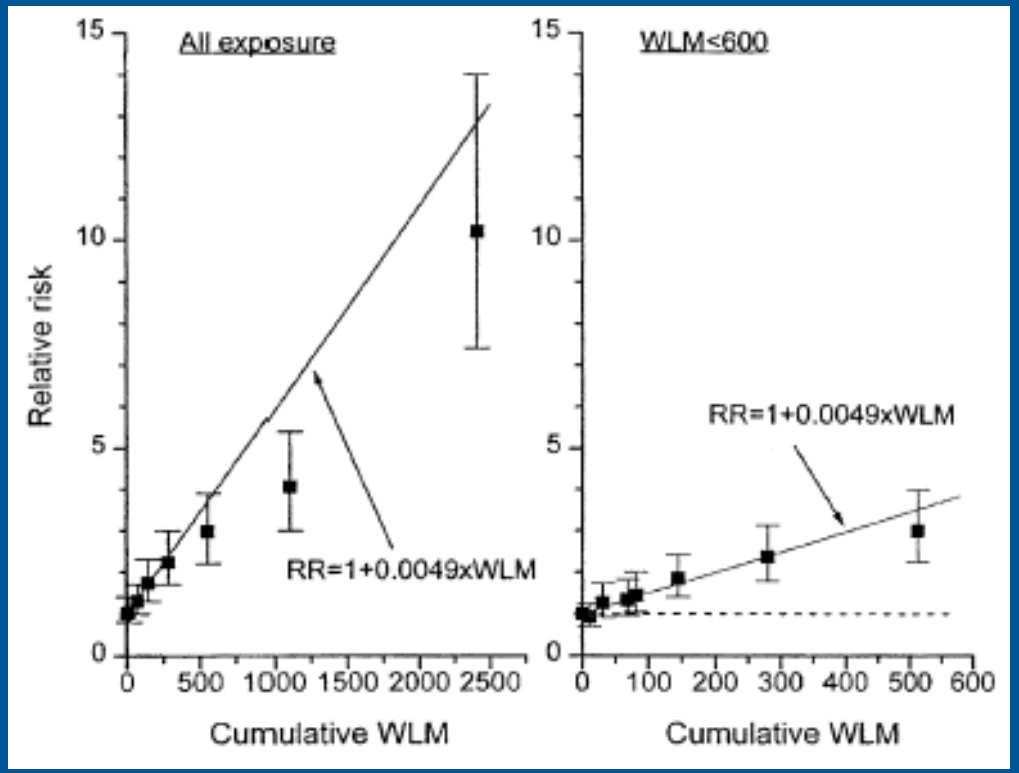
Risk evidence: comparison of cohorts used for risk estimates

Many epi studies on radon exposure in mines (slides 5-6) and in dwellings (slides 7-9)

	Follow–up period: range and average	Number of persons	Person-years	Number of excess cancers (and % of all cancers)	Dose or exposure: average and range	Average duration of exposure	Radiation type
Survivors of Hiroshima and Nagasaki	1950–1990 31.8 y	86 572 52 113 > 5 mGy 36 459 < 5 mGy	2.44 x 10^6	500 solid cancers (4.8 %) + 150 leukemias (50%)	0.24 Gy (0.01–6.0)	~instaneous	gamma (+ neutrons)
11 cohorts of miners (of underground mines)	1943–1991 17.2 y	68 000	1.15 x 10^6	**~1100 lung cancers** **(40 %)**	162 WLM (0–3200) ~ 0.8 Sv	5.7 y	**alpha** (+ gamma)

Risk evidence: pooled analysis of miner studies

- The lung cancer risk in mines increases with radon exposure (the increase is statistically significant for intermediate-high exposures).



(from Lubin et al., 1995)

Evidence confirmed by more recent studies at lower exposures.

(e.g. Tomacek et al 2008, "Lung Cancer in French and Czech Uranium Miners: Radon-Associated Risk at Low Exposure Rates and Modifying Effects of Time since Exposure and Age at Exposure")

Risk evidence: Pooled analyses of residential epi studies

	Cases	Controls	RR (95% CI) 100 Bq/m^3
2 Chinese studies (2004)	1028	1974	1.13 (**1.01**–1.36)
only complete (25y) Rn meas.	464		1.32 (**1.09**–1.88)
13 European studies (2004-5)	7148	14208	1.08 (**1.03**–1.16)
corrected for Rn exp. uncertainty	7148	14208	1.16 (**1.05**–1.31)
7 North-American studies (2005)	4081	5281	1.11 (1.00–1.28)
only complete (25y) Rn meas.	1621	2323	1.21 (**1.03**–1.50)

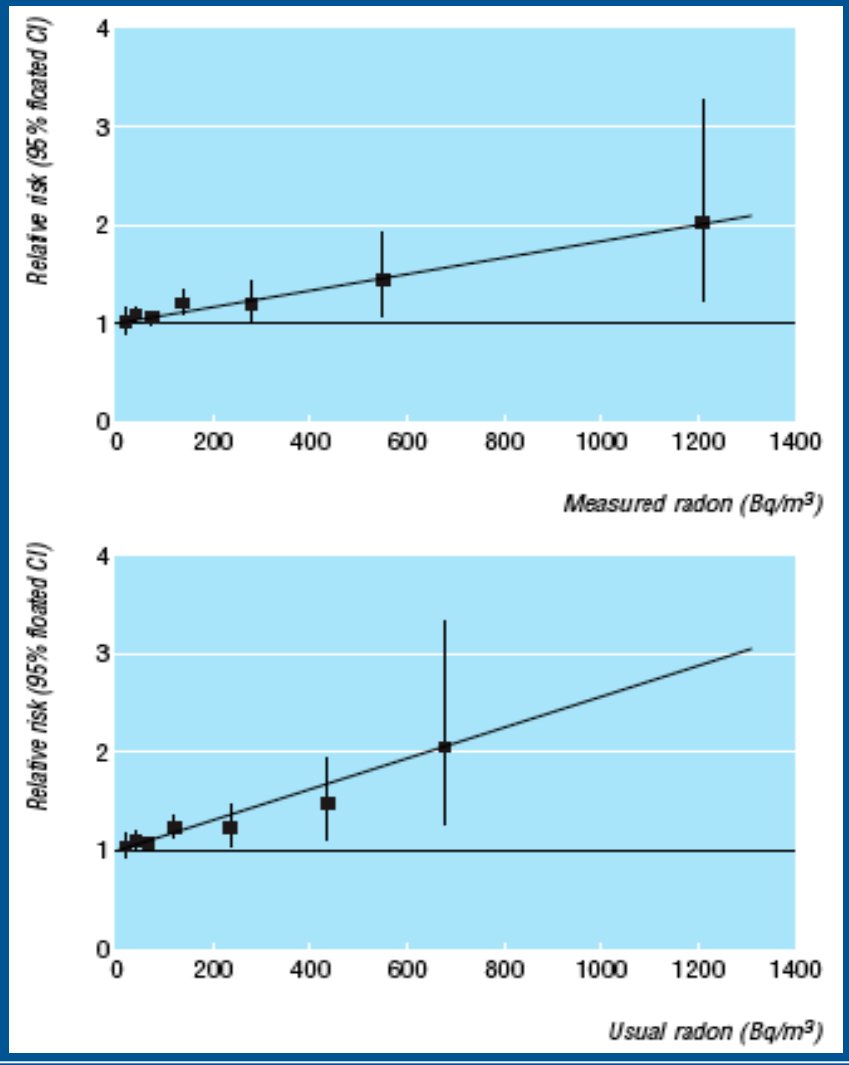
Risk evidence: Eur. pooled analyses of residential epi studies

- Results are homogeneous across the 13 studies
  - contrary to the meta-analysis of 1997
- Strong synergism between radon and cigarette smoking
  - smokers have similar *relative risk* than never smokers (and therefore a much higher *absolute risk*)
- The increase of the lung cancer risk is statistically significant also selecting subjects exposed up to 200 Bq/m^3
  - RR at 100–200 Bq m^{-3} vs <100 Bq m^{-3} = 1.2 (95% CI=1.03–1.30)
- Risk increases linearly with exposure level
  - Non linear models (log-linear, linear-quadratic) do not improve fit goodness
  - Models with threshold do not improve fit goodness
    - A threshold >150 Bq m^{-3} can be excluded (95% CL)

Risk evidence:
Eur. pooled analyses of residential epi studies

ERR=8.4%
per 100 Bq/m^3

Accounting for exposure errors:
ERR=16%
(+ ~100%)
per 100 Bq/m^3



Errors proportional to exposure

(from European pooling, Darby et al., BMJ, 2005)

Individual risk: Absolute risk evaluations

- The cumulative risk of lung cancer up to 75 years of age is estimated for lifelong non-smokers as 0.4%, 0.5%, and 0.7% for radon activity concentrations of 0, 100, and 400 $Bq\,m^{-3}$, respectively. The cumulative risks of lung cancer by 75 years of age for lifelong smokers are close to 10%, 12%, and 16% for radon activity concentrations of 0, 100, and 400 $Bq\,m^{-3}$, respectively (Darby et al., 2005, 2006). Cigarette smoking remains the most important cause of lung cancer.

From ICRP publ. 126 (Radiological Protection against Radon Exposure) (2014)

(31) As a result of this review, the Commission recommended, in its Statement on Radon, a detriment-adjusted nominal risk coefficient for a population of all ages (mixed adult population of non-smokers and smokers) of 8×10^{-10} per $Bq\ h\ m^{-3}$ for exposure to radon-222 gas in equilibrium with its progeny (ICRP, 2010).

This corresponds to a risk of 2.2×10^{-4} for 1-y exposure to 100 Bq/m^3 of Rn concentration in dwellings.

Individual risk: Effective doses for exposures in dwellings

- The effective doses due to exposure to 300 Bq/m^3 of radon concentration in dwellings is (using ICRP 2009 dose coefficient) about 10 mSv/y.
- This is quite higher than typical doses for radiation workers.
- For radon concentrations >600 Bq/m^3, the dose limits for radiation workers (20 mSv/y) are exceeded.
- Despite the log-normal distribution, in many countries several thousands of persons are exposed to such levels.

Individual risk: Comparison with radon in workplaces

- Occupancy in dwellings is usually quite higher than in workplaces (about 3 times higher).
- Radon concentration during workplace occupancy (daytime) is usually lower than during dwelling occupancy (evening, night, early morning).
- Therefore exposures (=> doses and risks) are much higher in dwellings than in workplaces.
- Despite this, regulations (including Directive 2013/59/Euratom) tend to give more stringent requirements for radon in workplaces than for radon in dwellings (see also slides 19-21).

Collective risk: Proportion of LCs due to radon in dwellings

- The proportion of all lung cancers linked to radon is estimated to lie between 3% and 14%, depending on the average radon concentration in the country and the method of calculation.

Regione	Casi osservati	Numero di casi stimati			Percentuale dei casi osservati		
		Stima puntuale	Intervallo di confidenza (95%)		Stima puntuale	Intervallo di confidenza (95%)	
Abruzzo	558	**49**	16	88	**9%**	3%	16%
Basilicata	219	**10**	3	19	**5%**	1%	9%
Calabria	665	**26**	8	48	**4%**	1%	7%
Campania	2 822	**372**	128	642	**13%**	5%	23%
Emilia - Romagna	2 886	**190**	62	346	**7%**	2%	12%
Friuli - Venezia Giulia	775	**106**	37	182	**14%**	5%	23%
Lazio	3 121	**499**	175	841	**16%**	6%	27%
Liguria	1 212	**69**	23	128	**6%**	2%	11%
Lombardia	5 718	**862**	301	1 464	**15%**	5%	26%
Marche	764	**34**	11	63	**4%**	1%	8%
Molise	108	**7**	2	13	**6%**	2%	12%
Piemonte	2 816	**280**	94	496	**10%**	3%	18%
Puglia	1 706	**131**	43	237	**8%**	3%	14%
Sardegna	746	**69**	23	124	**9%**	3%	17%
Sicilia	2 054	**109**	35	201	**5%**	2%	10%
Toscana	2 231	**159**	52	289	**7%**	2%	13%
Trentino - Alto Adige	401	**35**	12	62	**9%**	3%	16%
Umbria	455	**39**	13	69	**8%**	3%	15%
Valle d'Aosta	69	**5**	1	8	**7%**	2%	12%
Veneto	2 808	**238**	79	428	**8%**	3%	15%
Italia	**32 134**	**3 237**	**1 087**	**5 730**	**10%**	**3%**	**18%**

Once justified, how to optimise Rn exposure reduction?

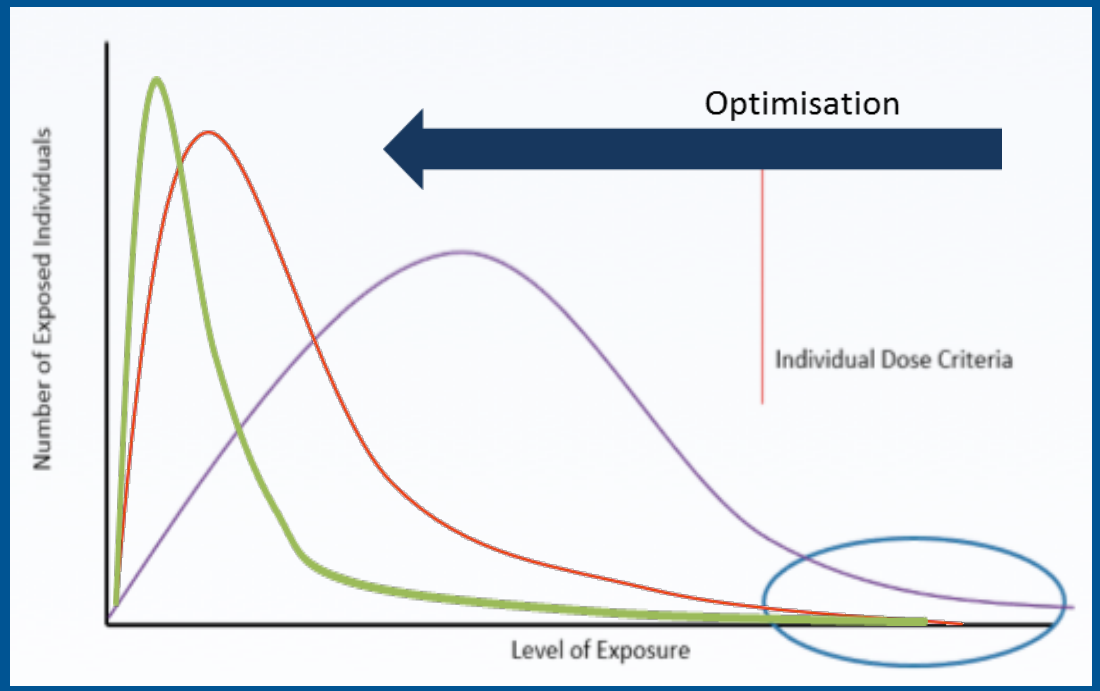
- Optimisation in Eur-BSS (based on ICRP-103)

  Art. 5 (b):

  Optimisation: Radiation protection of individuals subject to public or occupational exposure shall be optimised with the aim of keeping the magnitude of individual doses, the likelihood of exposure and the number of individuals exposed as low as reasonably achievable taking into account the current state of technical knowledge and economic and societal factors.

Optimisation steps for ICRP

1. Identify exposures which warrant specific attention to reduce their magnitude
2. Influence the entire dose distribution and shift exposures towards lower values
3. Reduce inequity



(adapted from Lecomte "Understanding existing exposure situations.", Ann. ICRP June 2016)

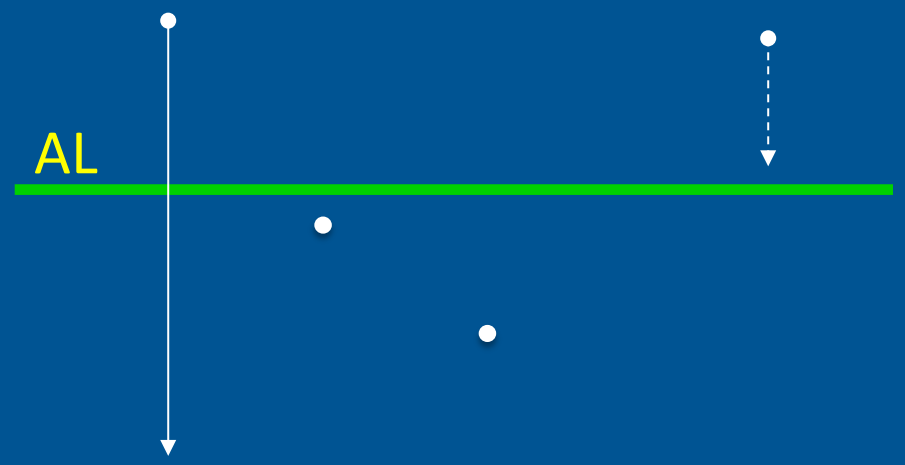
Action Level vs Reference Level for Rn

ICRP 60 + 65 (Dir. 96/29/Euratom)

Interventions

Action level

Optimisation only for levels > AL (no action for levels < AL)

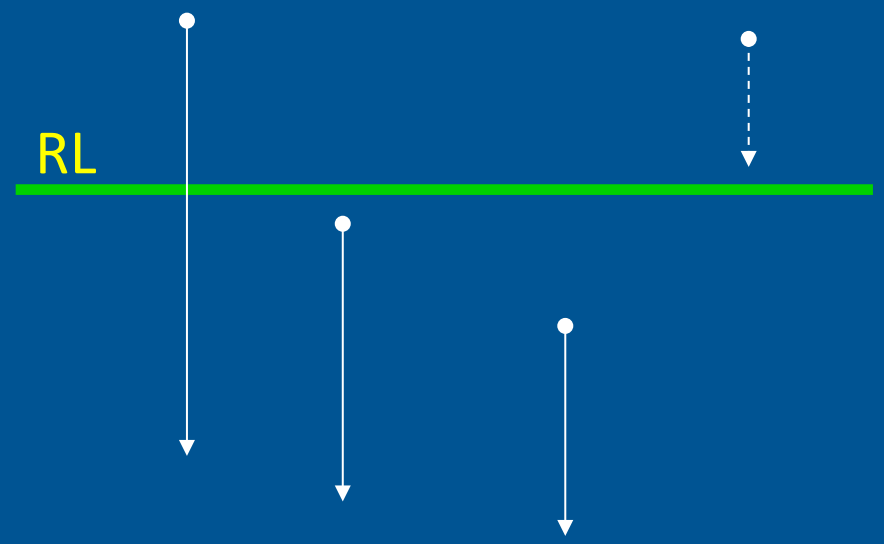


ICRP 103 + 126 (Dir. 2013/59/Euratom)

Existing exposure situations

Reference level

Optimisation with priority for levels > RL (but also for levels < RL)



(adapted from Lecomte "Understanding existing exposure situations.", Ann. ICRP June 2016)

Optimisation, AL vs RL, Cost/Effectiveness

- For many years optimisation for radon has been considered above an action level (AL) only.
- In 2007 (publ.103) ICRP replaced AL with Reference Level (RL).
- However, the conceptually new RL is often (erroneously) used in the same way as AL.
- Cost/effectiveness analysis show that policies based on AL have a worse cost/effectiveness (and worse effectiveness) compared with policies based on RL (which tend to reduce radon exposure in more situations) (Bochicchio et al, in preparation).

Issues on optimisation of Rn exposure reduction/prevention

- Distribution of radon levels is log-normal => most of the attributable lung cancers are due to exposure to low-medium Rn levels:
  - reducing only high Rn levels has a low global impact (and neglects risk levels which are not neglected for other radiation exposures).
- Although there are areas with average Rn level higher other areas, medium-high Rn levels have been found also in low-average areas (i.e. variation between areas is lower than variation within areas):

=> optimisation should be done in every areas, giving priority to areas with higher average levels (moving from "Rn-prone area" concept to the "Rn-priority area" concept).

Which approach for optimisation in dwellings: recommendatory of mandatory?

- Most of regulations in European countries have a recommendatory approach for radon in dwellings, with large difficulties in finally obtaining radon level reduction in a large fraction of dwellings.
- In transposing the new EU directive, EU Member States may implement a more mandatory approach, although the Eur. BSS require a mandatory approach for workplaces only.
- International BSS (2011) recommend to evaluate both mandatory and recommendatory approach for radon in dwellings
  - e.g. for selected situations, such as rented/sold dwellings, public buildings, bulding codes for new buldings, ...

Which approach for optimisation in dwellings: recommendatory of mandatory?

- Based on the general low effectiveness of the recommendatory approach, some countries (with large experience on radon programs) have moved (or are considering to move) to a more mandatory approach.
  - E.g. Norway:
    - New building regulation (2011): mandatory bulding codes for Rn prevention in new buldings
    - New radiation protection regulation (2014): binding limits for some existing buildings (rented dwellings and public buildings, e.g. schools, kindergartens):
      - action level: 100 Bq/m^3
      - maximum level: 200 Bq/m^3

Protection from radon exposure in dwellings: a unique problem in radiation protection

- Huge number of situations (buildings) to be managed.
- Expertise to reduce/prevent Rn exposure is not included in the typical expertise of radiation protection experts.
- Responsibility (and therefore requirements) can be, in some cases, more difficult (but not impossible) to be managed than in workplaces:

(48) The level of enforcement of actions that are warranted is closely related to the degree of legal responsibility for the situation. The owner of a house may have such responsibilities if the house is rented or sold. An employer has a legal responsibility for the health and safety of the employees. The manager of a school (or the local authority) may have a legal responsibility for the health of the pupils as well as the staff. The same consideration may apply to other public buildings and workplaces. The requirements related to such responsibilities should be commensurate with the wider public health policy in the country.

From ICRP publ. 126 (Radiological Protection against Radon Exposure) (2014)

Few final considerations

- Final goal: to reduce both individual and collective risk, i.e. to reduce lung cancers attributable to radon exposure in dwellings.
- Introducing obligations in dwellings is more and more common (for safety, energy saving, indoor air quality...) and can be (probably should be) introduced also for radon exposure, because recommendations have generally a low effectiveness.
- Regular evaluation of the National Radon Action Plan, based on checks of action effectiveness, is necessary (and required by EurBSS for NRAPs).

Thank you
for your attention

Since Jan 2017, the activities on radon (and on other radioprotection issues) of ISS are carried out within a new department, named:

National Center
on Radiation Protection
and Computational Physics