Health effects of radon exposure, contribution of epidemiology

Tirmarche Margot
Commissionner
ASN
Authority for nuclear safety and radiation protection
France

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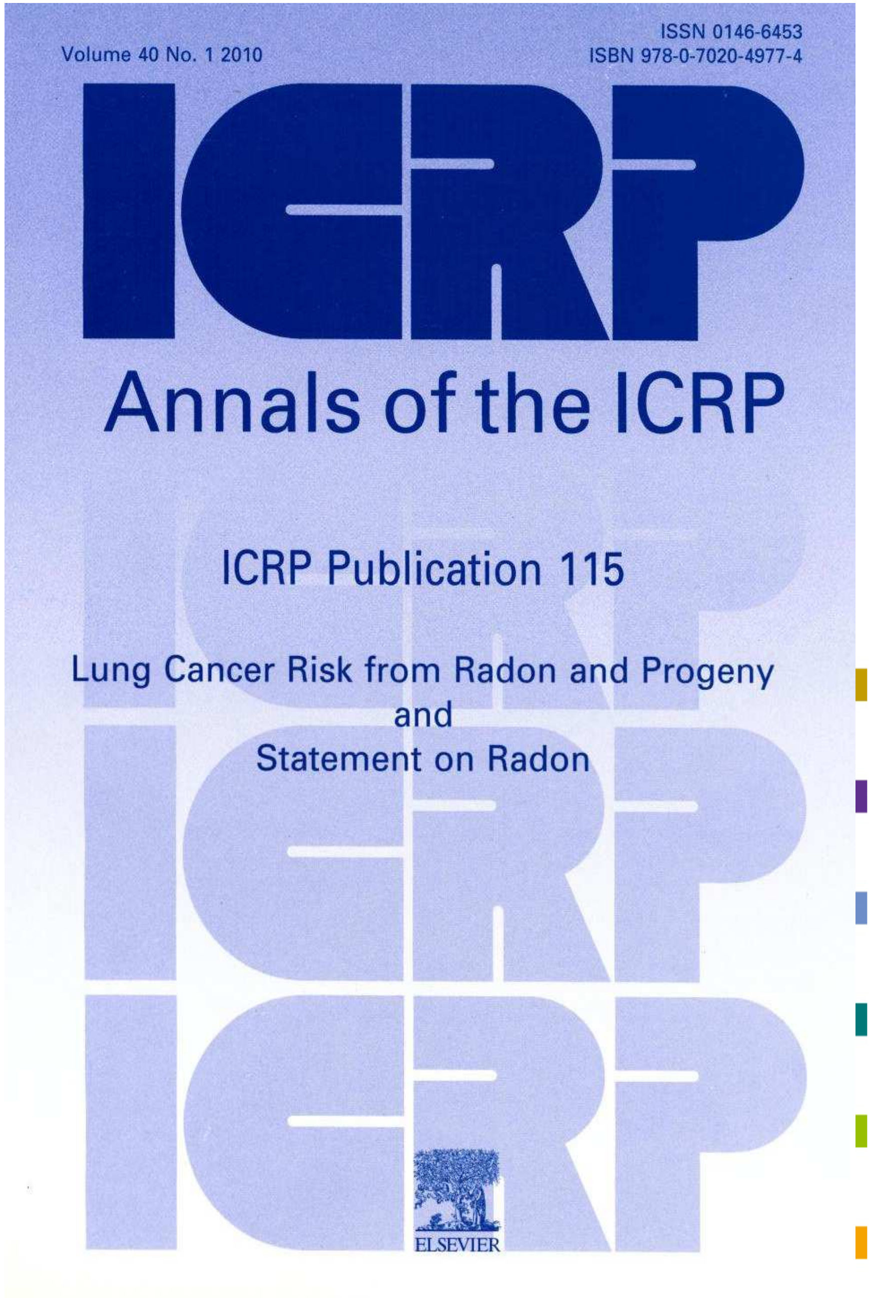
Radon risk assessment

TaskGroup TG64 ICRP C1
Major contribution from

Harrison JD (HPA)
Laurier D (IRSN)
Paquet F (IRSN)
Blanchardon E (IRSN)
Marsh JW (HPA)
Tirmarche M (IRSN)



•Revue of literature (epidemiology + dosimetry of alpha emitters and lung model)

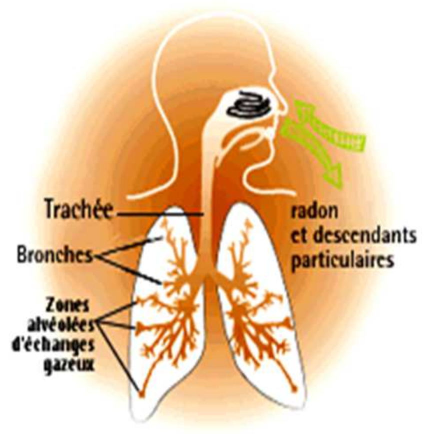
•Lifelong risk calculation

Experience of ICRP C1 taskgroup64:

- Review over last 10-15 years publications (updated /Unscear)
- Selection of epidemiological studies with a good quality of individual exposure
  - to radon decay products (U miners + domestic exposure studies)

Taking account of other concomittant exposures: external gamma exposure, uranium dust, chemicals, tobacco

ICRP C1 taskgroup64: Target organ: lung others?



- If Cancer risk related to dose at target organ : lung, bone marrow, others….in mGy per year (dose rate) or cumulated over life ?
- Is it possible to take in account separate effects of alpha emitters and external gamma exposure (in miners studies)
- How should be modelised their influence on final risk, if both exposures are concomittant or separated over time period (initiator, promoter….)
- Is dosimetry on organ level influenced by concomittant smoking
- Quality factor of 20 ?
- Is comparison of cancer risk (lung cancer risk) from alpha emitters with H and N lung cancer risk possible ?

Large Experience on international level from cohorts of uranium miners

Individual annual exposure to radon decay products in WLM *ambiant measured indivdiual exposure of radon daughters in eq with radon gas multiplied by duration* ;

A large number of studies, with individual assessment of exposure to external gamma, internal radon decay products and to uranium long lived dust :

Modelisation of time dependancy (dose rate effect, time since exposure, age at exposure)

Separate analysis for smokers and non-smokers,

Synthesis under WHO, BEIR 6,and ICRP115 :

good agreement when comparing results from miners and from general population

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Management of risk :

for domestic exposure: through Bq /m^3

for occupational exposure : workers - /uranium miners

Radon
Major results during recent years

- Risk observed after exposure to low annual exposure (coherence of results from occupatioal and domestic exposure)
- How is risk declining with time since exposure (important for risk communication and risk management)
- Intercation with tobacco: risk communication different for nonsmokers or for smokers ?

Czech-French joint model

EC FP5 project
« Uminers + Al data »

(Tomasek et al. Rad Res 2008)

Combined analysis of low exposed miners

Name-place	Country	Type of mine	Follow-up period	Nb miners	Nb lung cancer deaths	Cumul expo WLM	Person-years	ERR per 100 WLM
West Bohemia	Czech Republic	Uranium	1956-95	5002	449	57	133 521	
CEA-AREVA	France	Uranium	1946-94	5098	125	37	115 261	
Combined				10 100	574	47	248 782	1.6 [1.0 - 2.4]

- Agreement with a linear model
- **ERR ↘ with Time Since Exposure**
- ERR ↘ with Age at Exposure
- no inverse exposure rate effect

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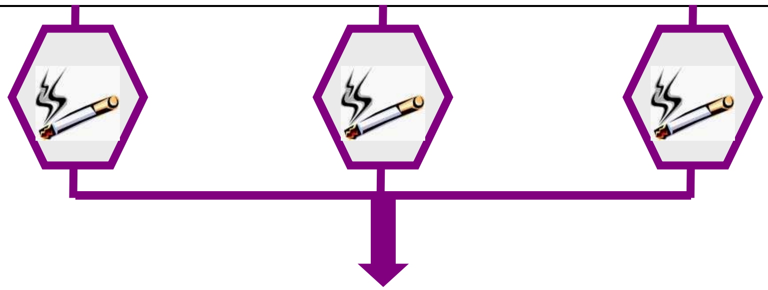
Pooled nested case control study

	France	Czech Rep.	Germany	Total
Cases / controls	100 / 500	672 / 1491	704 / 1398	1476 / 3389
Cases / controls with smoking information	60 / 310	672 / 1491	314 / 691	1046 / 2492
	Leuraud et al, Health Phys 2007	Tomasek, Rad Prot Dosim 2011	Schnelzer et al, Health Phys 2010	

European cohort of uranium miners Alpha risk project

	France	Czech Republic	Germany	Combined Cohort
Population	5086	9979	35084	50149
Follow-up period	1946 – 1999	1952-1999	1955-1998	1946 – 1999
Person-years	153 047	262 507	908 661	1324 215
Follow-up duration	30.1	26.3	25.9	26.4
Attained age (y)	58.9	56.6	48.6	51.2
Number of deaths	1467	3947	4519	9933



Nested case-control study

Lung cancer risk associated to radon exposure and smoking

Cumulative radon exposure (5-year lagged, WLM)	Never smoker	Ex-smoker ≥ 10 y	Ex-smoker < 10 y + current smoker
< 50	**1**	**1.9 (0.8-4.3)**	**7.2 (3.6-14.6)**
50-100	**2.1 (0.8-5.2)**	**3.9 (1.6-9.8)**	**12.0 (5.7-25.2)**
100-200	**2.0 (0.8-5.0)**	**5.0 (2.1-11.6)**	**18.6 (9.0-38.6)**
200-400	**4.9 (1.9-12.5)**	**6.3 (2.6-15.2)**	**21.0 (10.0-44.1)**
≥ 400	**7.1 (2.4-20.6)**	**16.8 (6.8-41.6)**	**36.7 (16.9-279.6)**

WLM: Woking Level Month

Risk increases with both smoking and cumulative radon exposure (submultiplicative model)

Excess relative risk of lung cancer associated to radon exposure

	ERR per WLM (95%CI)
Unadjusted on smoking	0.010 (0.006-0.018)
Adjusted on smoking	0.008 (0.004-0.014)
Among never and long term ex-smokers	0.012 (0.005-0.026)
Among short term ex- and current smokers	0.007 (0.003-0.013)

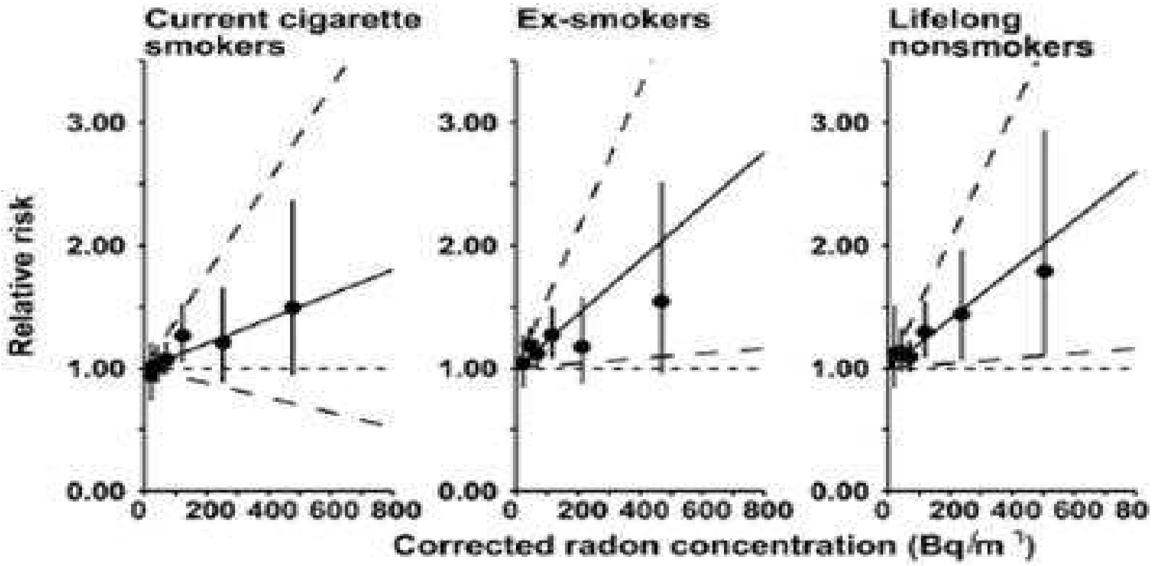
➡ **Risk increases with cumulative radon exposure among smokers and non smokers**

Residential radon and smoking

Residential radon and lung cancer—detailed results of a collaborative analysis of individual data on 7148 persons with lung cancer and 14 208 persons without lung cancer from 13 epidemiologic studies in Europe

(Darby et al, Scand J Work Environ Health 2006)

–Relative Risk of lung cancer according to the time-weighted average residential radon concentration



Pooled residential studies

Indoor data – primary risk coefficients

Joint analysis	Number of studies included	Cases	Controls	Relative risk per 100 Bq m^{-3}	95% CI
Chinese *(Lubin et al., Int J Cancer 2004)*	2	1050	1995	1.13	(1.01-1.36)
European (Darby et al., BMJ 2005)	13	7148	14208	1.08	(1.03-1.16)
North American *(Krewski et al., Epidemiol 2006)*	7	3662	4966	1.10	(0,99-1.26)

Very good coherence of results from different indoor studies

Cumulated Excess Absolute Risk (10^{-4} per WLM) - comparison of miners and indoor models

Mean Population (m+f/asian+euroamerican)

	Beir 6 c	CzFr 2008	Darby 2005
18-59	1.64	1.30	0.73
18-69	3.53	2.72	2.71
18-89	5.58	4.68	7.58

Good agreement of estimated cumulated risk If results of miners are considered under conditions comparable to the selected criteria used in the case control studies considering domestic radon exposure in general population

Scenario: 0.43 WLM (100 Bq/m3) per y from age 40 to 64

Radon risk other than lung cancer risk- Miner studies

Specific excesses: non-Hodgkin lymphoma, multiple myeloma *(Schubauer-Berigan, AJE 2009)*, kidney (*Vacquier, OEM 2008*), stomach or liver (*Kreuzer, BJC 2008*)
No consistent pattern

German Wismut cohort: exposure risk relationship

- All extra-pulmonary cancers (*Kreuzer, BJC 2008, Walsh, HP 2010*)
  ERR per 100 WLM = 0.014 95%CI=[0.006–0.023]
  linear model with modifying effect of attained age
- Stomach cancer (*Kreuzer et al., ERRS 2010*)
  absorbed dose from radon, long-lived radionuclides and gamma
  ERR/Gy = 1.53 95%CI=[0.23-2.73]
  no more significant after adjustment for arsenic and fine dust exposure

Circulatory system diseases

exposure-risk relationship for cerebrovascular diseases in the French cohort
ERR per 100 WLM = 0.49 95%CI=[0.07–1.23] (*Nusinovici, SJWEH 2010*)
no association in other studies (*Villeneuve, HP 2007; Kreuzer, REB 2006*)

Radon and leukaemia risk – Miner studies

Czech uranium miners (*Rericha, EHP 2006*)

84 leukemia cases

leukemia risk associated with cumulative radon exposure (non-CLL and CLL)

other sources of exposure not considered

German Wismut uranium miners (*Mohner, HP 2010*)

377 leukemia cases and 980 controls

absorbed RBM dose from Rn+RDP, LLR, Gamma + medical X-rays

contribution of radon inhalation to dose = 31%

non significant increased risk above 200 mGy

no difference between CLL and non-CLL

Alpha-Risk European project (*Tirmarche, Alpha-Risk 2010; Tomasek, IRPA 2010*)

69 leukaemia deaths

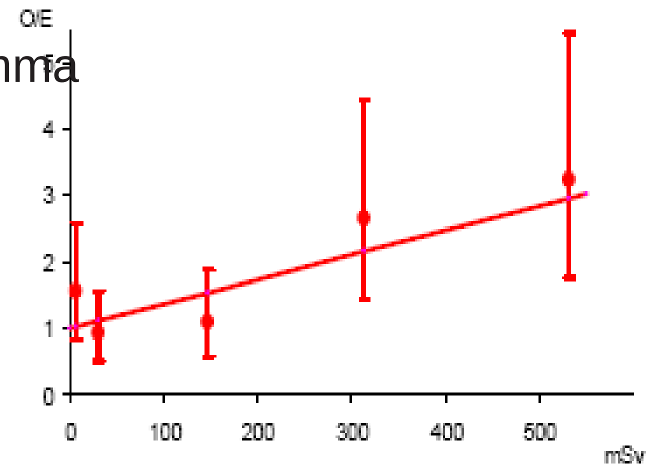
equivalent RBM dose from Rn+RDP, LLR, Gamma (Wr=20 for alpha)

mean RBM dose = 90 mSv

contribution of radon inhalation = 40%

ERR per Sv = 3.7   95%CI=[1.1–8.8]

similar results for CLL and non-CLL



Radon and childhood leukaemia

Several ecological studies suggest an increased risk
(*Laurier HP 2004, Evrard HP 2006, Raaschou-Nielsen, RPD 2008*)

Danish case control study (*Raaschou-Nielsen et al, Epidemiology 2008*)
1153 cases / 2306 controls – children < 15 years old
Radon concentrations estimated through a model –gamma exposure ignored a signifiocant association with acute lymph. leukaemia (ALL)
9% of ALL attributable to radon in Danemark (m=59 $Bq.m^{-3}$)

Case-control study in Great Britain (*Kendall et al, Epidemiology 2012*)
- estimate : natural background radiation may explain 15 to 20% of childhood leukaemia (*Wakeford, Leukemia 2009; Little, JRP 2009; Wakeford, Rad Prot 2010*)

- national case-control study 1980-2006
  27 447 cases / 36 793 controls - < 15 years old

gamma + radon concentration
bone marrow dose calculation

➔ radon contributes for 10% to total bone marrow dose (UK = 20 $Bq.m^{-3}$)

positive association with gamma significative : ERR per mSv = 0.12 IC95% [0.03;0.22]
no significant association with radon : ERR per mSv = 0.03 IC95% [-0.04;0.11]

Childhood leukemia risk ?

- Childhood leukaemia risk in high natural background regions ?
- How to learn more
  - Radon or external gamma exposure ?
    - Comment : natural background radiation = gamma + radon, bone marrow dose mainly influenced by external gamma exposure
    - Adjustment and co-factors is complicated (genetics, in utero exposure…)
    - ➔We should favour research on international level. Necessary for risk communication.

Thanks for your attention