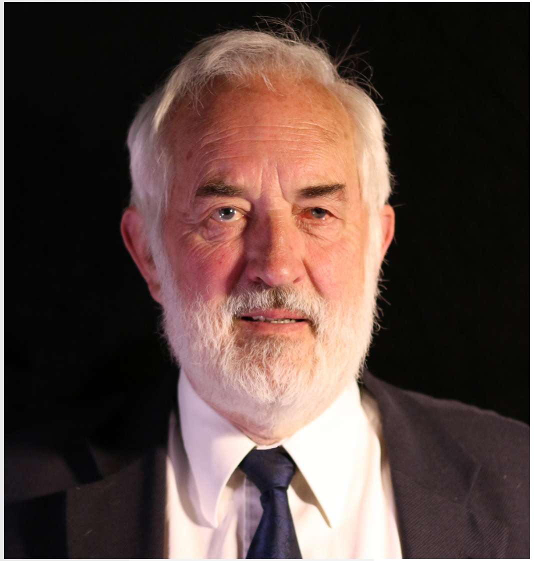
Cancer Risks from Natural Background Radiation and Radon



Dr. Gerry Kendall
Cancer Epidemiology Unit
NDPH, University of Oxford
Gerald.Kendall@ceu.ox.ac.uk

DCEG Radiation Epidemiology and Dosimetry Course 2019

If it’s Natural it must be good for you!

If it’s Natural it must be good for you!

- Adder bite
- Aids
- Aflatoxins
- Alligators
- Angina
- Anthrax
- Arsenic
- Asbestos
- Asteroid impact

Why is this topic important?

Evidence on effects of low-dose radiation

Epidemiology difficult if

- Inadequate power
    - Not enough cases
    - Few induced effects (doses low)
    - Background cancer rates high
- Biases in cases/controls
- Important confounders not measured

Topics to cover

- Background radiation

  Natural and other

- Radon and Lung Cancer

  Radon and lung cancer in miners

  Radon and lung cancer in homes

- Natural background and other cancers

  High Natural Background Areas

  Register based studies of childhood cancer

The field is huge. This is an overview with pointers to literature

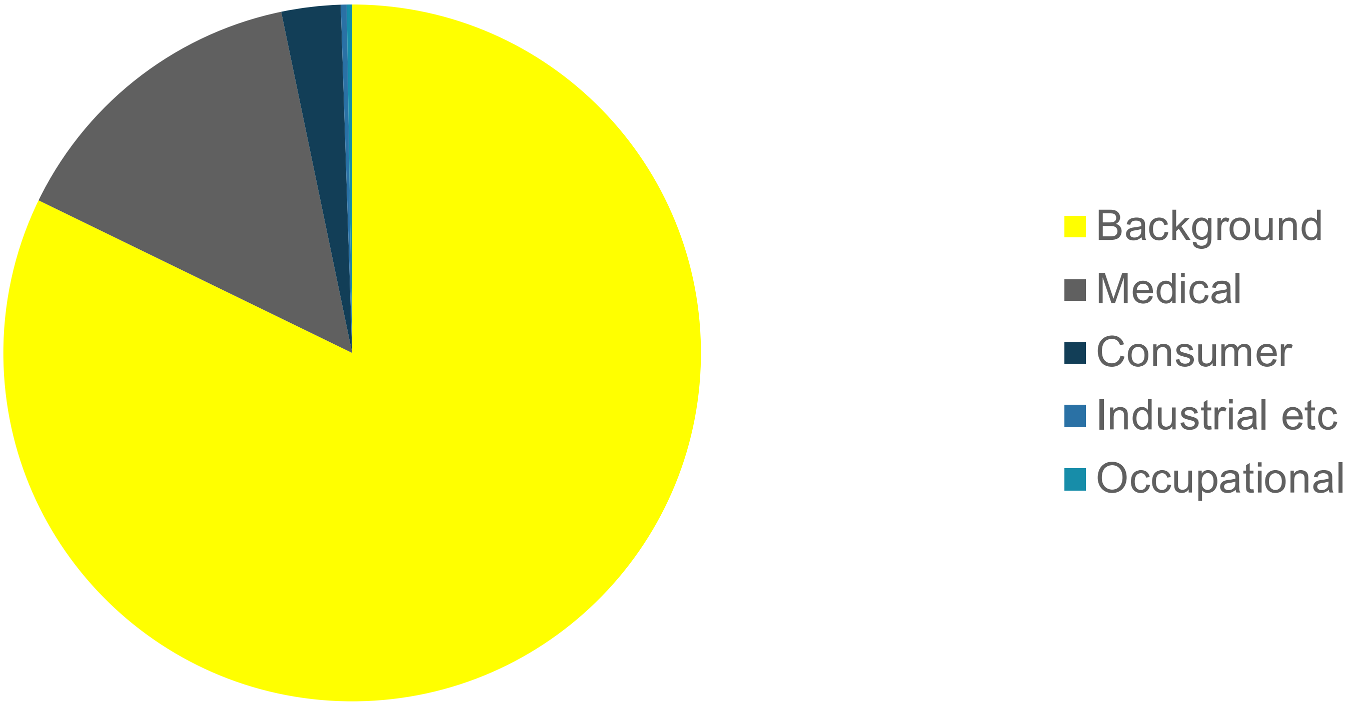
Radiation Exposure of the US Population

NCRP Report 93 (1987)
Exposures in early 1980s Mean 3.6 mSv pa

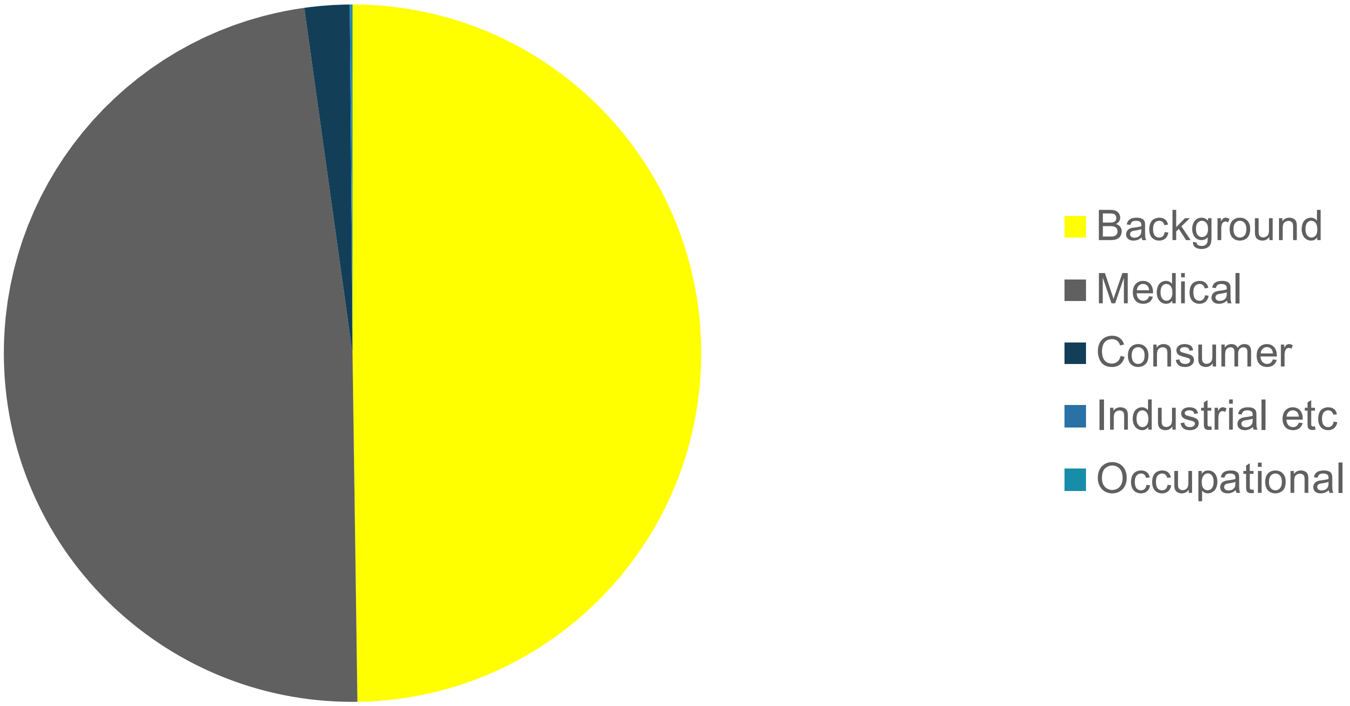
NCRP Report 160 (2009)
Exposures in 2006 Mean 6.2 mSv pa

Effective doses in milli Sv (mSv)
NB Exposures may be to only part of body

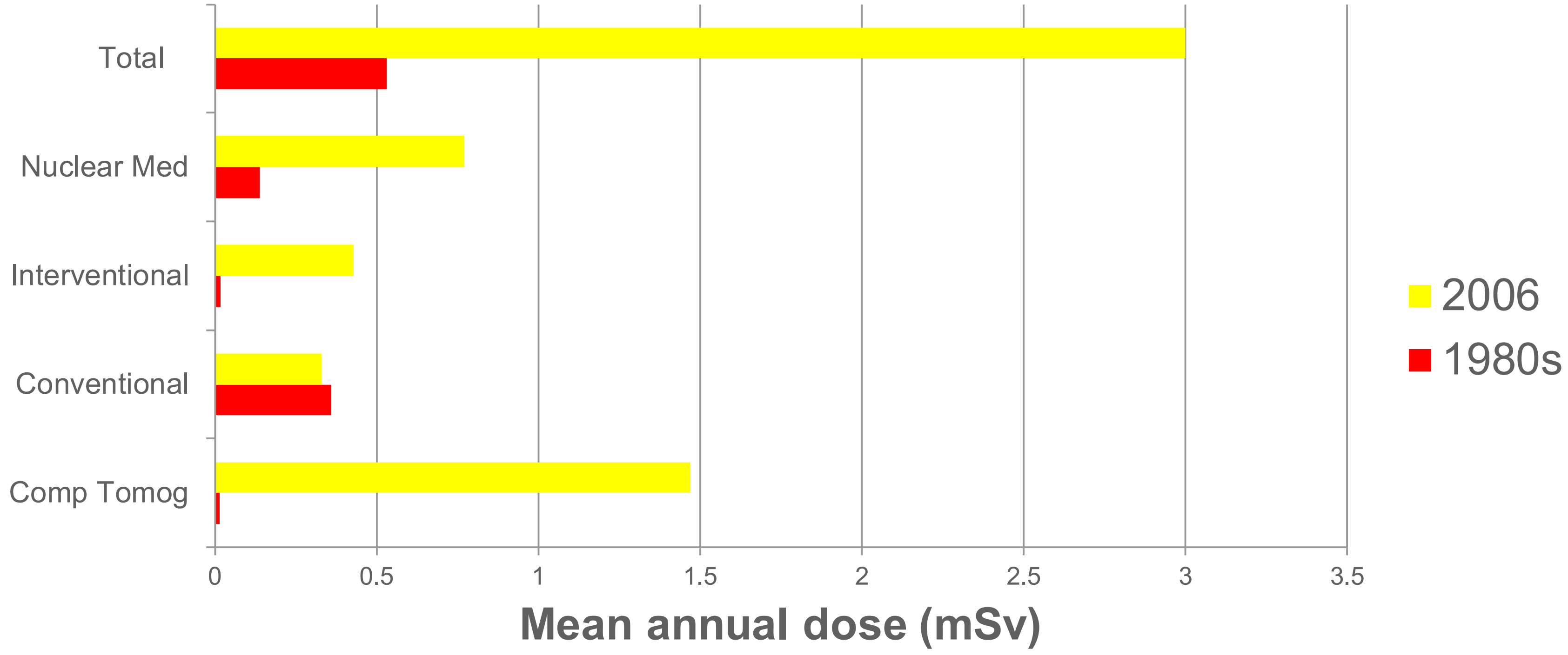
US mean exposure early 1980s.   Total 3.6 mSv



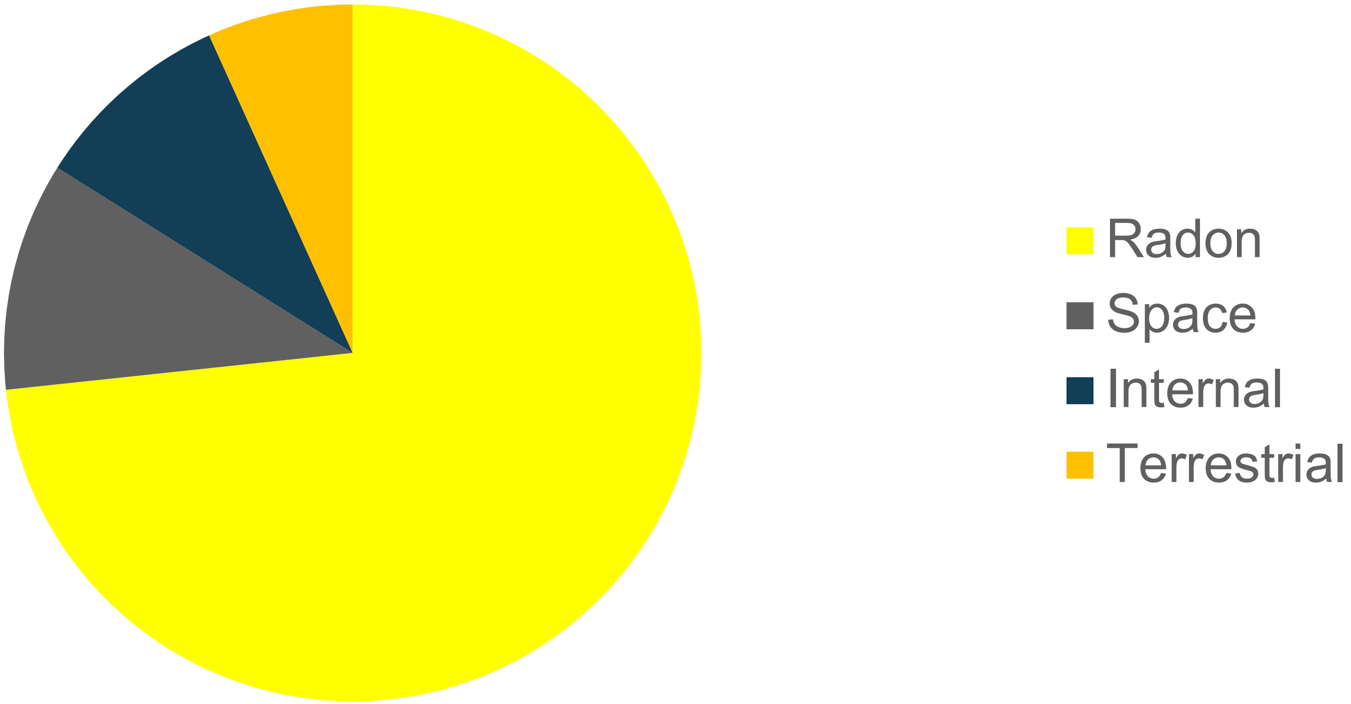
US mean Exposure 2006   Total 6.2 mSv



Medical Exposures 1980s and 2006



Components of effective dose background radiation 2006



Components of effective dose from natural background 2006

Contributions to effective dose (mSv) and interpretation

Radon	2.28	2.28/0.12 = 19 mSv to lung
Space	0.33	whole body
Internal	0.29	~ whole body
Terrestrial	0.21	whole body
Total	3.11	

Components of Natural Background Radiation

Radon (Rn-222) and Thoron (Rn-220)

- Most dose from Decay Products (DP) to respiratory tract

Space

- Cosmic rays (complex at altitude)
- Particles

Terrestrial

- Gamma rays from K-40, U-238, Th-232 etc

Internal

- Radionuclides in food and drink

Measuring Radiation at Ground Level

Radon - Easy to measure [Rn]

Thoron - Not as easy as radon (less important)

Cosmic - Ionising component easy

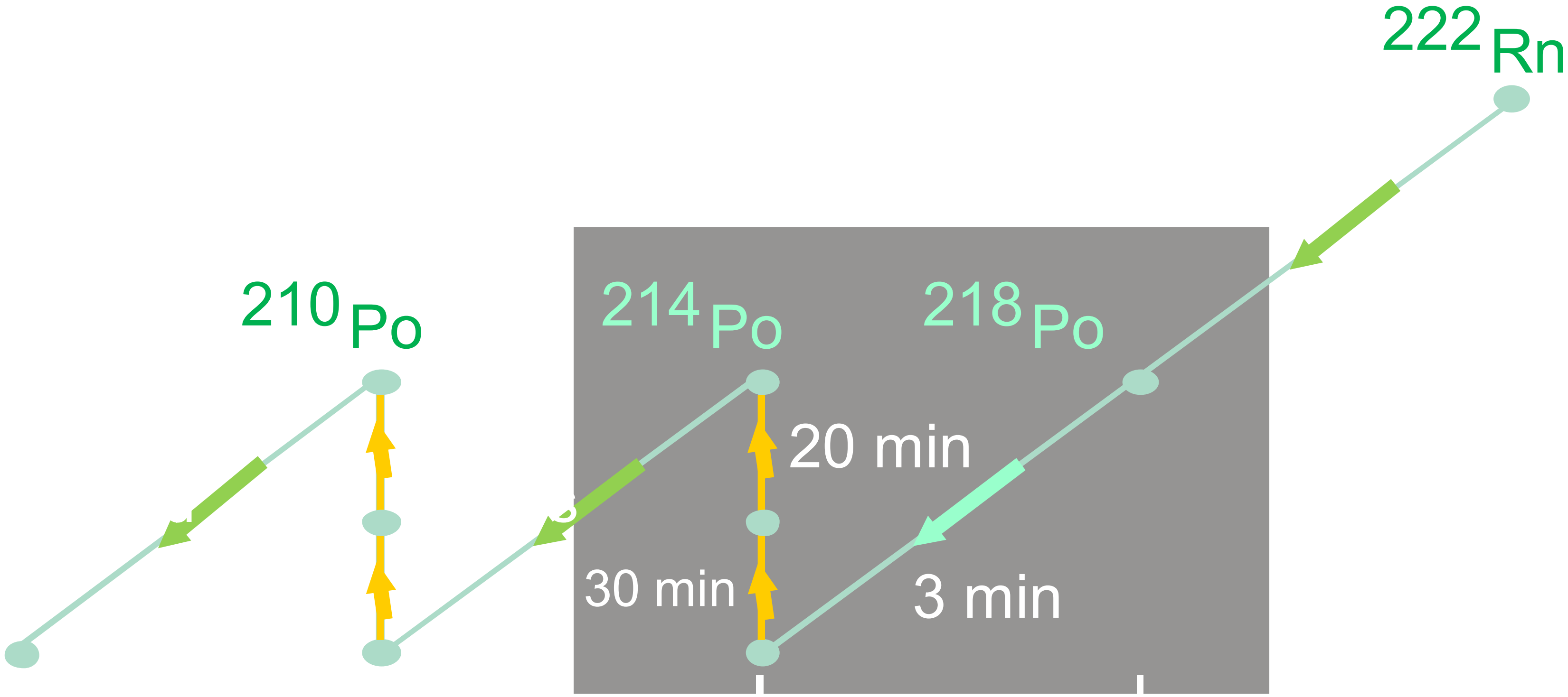
- Neutrons difficult

Terrestrial - Easy

Internal - Difficult (many nuclides)

For epidemiology: Radon, Ionising Cosmic, Terrestrial. Not Internal

Principal Decay Scheme : Radon-222 to Lead-206



Radon Dosimetry

[Rn] is easy to measure (but very variable)

Most dose from Rn decay products (DP) attached to particles

DP emit short-ranged alphas

- Most dose to respiratory tract as deposited DP are being cleared

Dose calculations can be undertaken

- Where are the DP?
- Where are the target cells?

Or you could estimate dose (risk) directly from epidemiology

Working Level Month (WLM)

One WL is conc of short-lived DP in equilibrium with 3,700 Bq/m^3 Rn.

(3,700 Bq/m^3 = 100 pCi/L)

WLM is exposure to one WL for 170 hours.

1 WLM ≈ 10 mSv

Radon and Lung Cancer

Radon (decay products) give much the largest doses to respiratory tract

Epidemiology has detected excess lung cancer following both

- occupational (underground hard rock miners)
- domestic exposure to radon

Several outstanding questions:

- eg how does radon interact with smoking?

Reviews of Radon Miners

Health Effects of Exposure to Radon: BEIR VI.

National Research Council, National Academy of Sciences 1999.

Lubin et al 1995 JNCI 87 817-827 Lung Cancer in Radon-Exposed Miners

UNSCEAR 2006 Volume 2 Annex E

Sources-to-effects assessment for radon in homes and workplaces

ICRP Publication 115 Lung Cancer Risk from Radon (2010)

BEIR VI Report

BEIR VI Models
11 miner studies involving ~68,000 men (2,700 fatal lung cancers)
Two models for lung-cancer risk from radon exposure.
(Exposure, Age, Duration; Exposure, Age, Concentration)
Cigarette smoke and radon - sub-multiplicative synergistic effect.

Population estimates of USA lung cancer deaths (1995)
Total fatal lung cancer 157,400 (11,000 never smokers)
Radon-related 15,400 or 21,800 (3,000 - 33,000)

(National Academy of Sciences 1999 BEIR VI Radon)

Lung cancer in radon exposed miners

Study	Observed	Expected	ERR per 100 WLM
Colorado Plateau uranium	327	74	0.42 (0.3, 0.7)
Ontario uranium	282	221	0.89 (0.5, 1.5)
Czech uranium	915	240.8	1.60 (1.2, 2.2)
Swedish iron	79	44.7	0.95 (0.1, 4.1)
Beaverlodge uranium	279	217.8	0.96 (0.6, 1.6)
Port Radium uranium	230	142.7	0.37 (0.2, 0.6)
French	125	83.1	0.80 (0.3,1.4)
Newfoundland fluorspar	206	-	0.47 (0.3, 0.7)
Chinese tin	936	649	0.16 (0.1, 0.2)
Wismut uranium	2 328	NA	0.21 (0.2, 0.2)
	UNSCEAR 2006 Annex E - Table 21		

East German Uranium Miners - Summary

Kreuzer 2015
26,766 miners hired 1960 or later.
ERR 0.013 WLM-1 (CI 0.007 - 0.021).

Kreuzer 2018
58,974 miners <100 WLM
ERR 0.006 WLM-1 (CI 0.003 - 0.010).

Kreuzer 2015 BJC 113 1367-69
Kreuzer 2018 Radiat Res 189 165-176

French and Czech Uranium miners

French and Czech uranium miners exposed to low radon levels (mean cumulative exposure <60 WLM).

95% of annual exposures based on measurements.

Fatal lung cancers O=574, E= 200.

Risk strongly associated with total Rn exposure.

Consistent with BEIR VI estimates using concentration model at exposure rates < 0.5 WL.

Tomasek et al 2006 Radiat Res 169 125-37

Domestic Studies of Radon and Lung Cancer

Many individual studies of domestic of radon in homes and lung cancer.

Three main reviews pooling individual studies

Chinese	Lubin	2004	IJC 109 132-137
European	Darby	2005	BMJ 330 223-229
N American	Krewski	2005	Epidemiology 16 137-45

Domestic radon pooling studies

Joint analysis	No. of studies	Cases	Controls	RR
European	13	7148	14,208	1.08 (1.03–1.16)
N American	7	3662	4966	1.10 (0.99–1.26)
Chinese	2	1050	1995	1.13 (1.01–1.36)
Total	22	11860	21169	1.09 (UNSCEAR)

RR = Relative Risk per 100 Bq/m3 (95% CI)

ICRP 115 table 2.2

Domestic radon pooling studies - Conclusions

- Smoking is the main cause of lung cancer
    - Allowance for smoking is vital in analysis
- Association with lung cancer even in non-smokers
- RR greater after allowance for [Rn] uncertainties
    - European RR 1.08 →1.16
- “World pooling imminent” (ICRP 115, 2010)

Cohen's study of radon and lung cancer

Cohen's ecological study found very strong inverse relationship between mean [Rn] and mean lung cancer rates in US Counties

Cohen 1995 Health Phys. 68 157–174

Puskin found all smoking related cancers show -ve association with Rn, regardless of whether the organ gets a dose from radon.

> "The results indicate that the negative trend previously reported for lung cancer can be largely accounted for by a negative correlation between smoking and radon levels across counties."

Puskin 2003 Health Physics 84 526-532

Natural background and other cancers

Does radon induce cancers other than lung cancer?

Do terrestrial gamma rays (with or without cosmic rays) induce cancer?

Does Radon induce other cancers?

Skin Cancer?
Doses possibly non-trivial.   Epidemiology difficult and inconclusive

Gastric Cancer?
Dose from Rn in water possibly non-trivial. Some evidence from epidemiology but inconclusive

Epidemiological studies of miners find no evidence of other adult cancers (Darby 1995 JNCI 87 378-384)

Childhood Cancers?

UNSCEAR 2008 Annex E

Does Radon induce Childhood Cancer, in particular Leukaemia?

Target tissues not lung and doses smaller!
Very large studies needed

Childhood leukaemia is relatively rare; relatively easily induced by radiation.

Some positive ecological studies

Case/Control studies of Radon and Childhood Cancer

Author	*Year*	*Reference*	*Endpoint*	*Cases*	*Findings*
Lubin	1998	JNCI 90(4) 294-300	ALL	505	Nothing significant
Steinbuch	1999	BJC 81(5) 900-906	AML	173	Nothing significant overall
Kaletsch	1999	REB 38(3) 211-215	All cancers	82+82	XS solid cancers (chance?)
UKCCS	2002	BJC 86(11) 1721-26	All cancers	3838	Dominated by response bias
Raaschou - Nielsen	2008	Epidem. 19(4) 536-43	Most	2400	**Significant ALL elevation**
Kendall	2013	Leukaemia 27(1) 3-9	All cancers	27447	Nothing significant

Do Terrestrial Gamma Rays induce cancer?

Studies in areas with high natural background (HNBR)

Studies of childhood cancer

Studies in HNBR Areas

Kerala, India (Nair 2009)
1379 cancers in 70,000 adults followed for 10.5y
Mean Cumulative dose to end of follow-up ~161 mGy
ERR (excl. leukemia) -0.13 Gy-1 (95% CI: -0.58, 0.46).

Yangjiang, China (Tao 2012)
956 cancer deaths in 31,604 adults followed for 19 years.
Mean cumulative doses to end of follow-up 84.8 mGy
ERR (excl. leukemia) 0.19 Gy-1 (95% CI: -1.9, 3.0).

NCRP Commentary 27, 2018
NCI Review (2019??)

Studies in HNBR Areas - problems

High background rates of adult cancers

Several potent other causes (potential confounders eg smoking)

Comparability of control groups

Comparability of cancer registration between groups

Accuracy of dose estimation

Register Based Studies of Childhood Cancer and Background Radiation

Childhood cancers are relatively rare (low background)

Relative risks higher

National Registers of Childhood Cancers provide large numbers of cases free of participation bias

Lack of known confounders for childhood leukaemia

But

Radiation Exposures must be estimated

No interview-based data on confounders

Are Register Based Studies all the same?

Study Design – case-control; case-cohort; ecological

Endpoints – Leukaemia, all cancers, CNS, …

Type of radiation – Gamma? CR? Radon?

Dose – Dose rate?
- Cumulative based on diagnosis?
- Cumulative based on birthplace?

Method for estimating dose rates

Register Based Studies of NBR and childhood leukaemia

	Study	Leukemias	RR - Radon	RR - Gamma
Denmark	Raaschou-Nielsen 2008	1,153	1.34 (0.97 - 1.85)	
Great Britain	Kendall 2013	9,058	1.03 (0.96 - 1.11)	1.12 (1.03 - 1.22)
Switzerland	Haurii 2013 Spycher 2015	530		1.04 (1.00 - 1.08)
Finland	Nikkilä 2016	1,093		0.97 (0.89 - 1.06)
France	Demoury 2017	2,763	1.00 (0.97 - 1.02)	1.00 (0.99 - 1.01)
Germany	Spix 2017	13,374		1.04 (0.91 - 1.20)

NCRP on Childhood Leukaemia Studies

(not just register based)

“Some compatibility with LNT model” but

- Applicability of ambient radiation measurements?
- Potential for uncontrolled confounding,
- Participation rates,
- Migration,
- Limited statistical power

NCRP Commentary 27, 2018

Cancer and Natural Radiation
Summary

Natural radiation is ubiquitous and dominant

Only medical exposures can compete

Epidemiology demonstrates that radon causes lung cancer

Natural radiation might be expected to cause small numbers of other cancers. So far the evidence is only suggestive, but perhaps increasingly suggestive.

Quiz 1

For most people the most important component of exposure to radiation is usually

- Cosmic Rays
- Nuclear Power
- Radon

Quiz 1

For most people the most important component of exposure to radiation is usually

- Cosmic Rays
- Nuclear Power
- Radon

Quiz 2

Epidemiology of adult cancers in areas of High Natural Background shows

- A clear link with leukaemia
- A clear link with all other cancers
- Both of the above
- Neither of the above

Quiz 2

Epidemiology of adult cancers in areas of High Natural Background shows

- A clear link with leukaemia
- A clear link with all other cancers
- Both of the above
- Neither of the above

Quiz 3

Epidemiology has demonstrated a link between exposure to radon and lung cancer in

- Occupational exposures in mines
- Domestic exposures in homes
- Both of the above
- Neither of the above

Quiz 3

Epidemiology has demonstrated a link between exposure to radon and lung cancer in

- Occupational exposures in mines
- Domestic exposures in homes
- Both of the above
- Neither of the above

U.S. Department of Health & Human Services

National Institutes of Health | National Cancer Institute

cancer.gov/dceg

1-800-4-CANCER

Produced September 2019