US EPA Lecture

Increased leukemias near nuclear power plants - the European evidence

Dr Ian Fairlie
Consultant on Radioactivity in the Environment
London, United Kingdom
www.ianfairlie.org

Childhood leukemias near NPPs: some history

- in UK, in 1980s and early 1990s, increases near several nuclear facilities (incl Sellafield)
- in Germany, near Krümmel NPP
- large public controversies
- UK NRPB said not due to radiation as doses were too low x ~300 - 1,000
- debate fizzled out after legal victory for BNFL

KiKK Report in Germany in 2008/9

Kinderkrebs in der Umgebung von KernKraftwerken

Kaatsch P, Spix C, Schulze-Rath R, Schmiedel S, Blettner M. 2008. Leukaemias in young children living in the vicinity of German nuclear power plants. Int J Cancer 122:721–726.

Spix C, Schmiedel S, Kaatsch P, Schulze-Rath R, Blettner M. 2008. Case–control study on childhood cancer in the vicinity of nuclear power plants in Germany 1980–2003. Eur J Cancer 44:275–284.

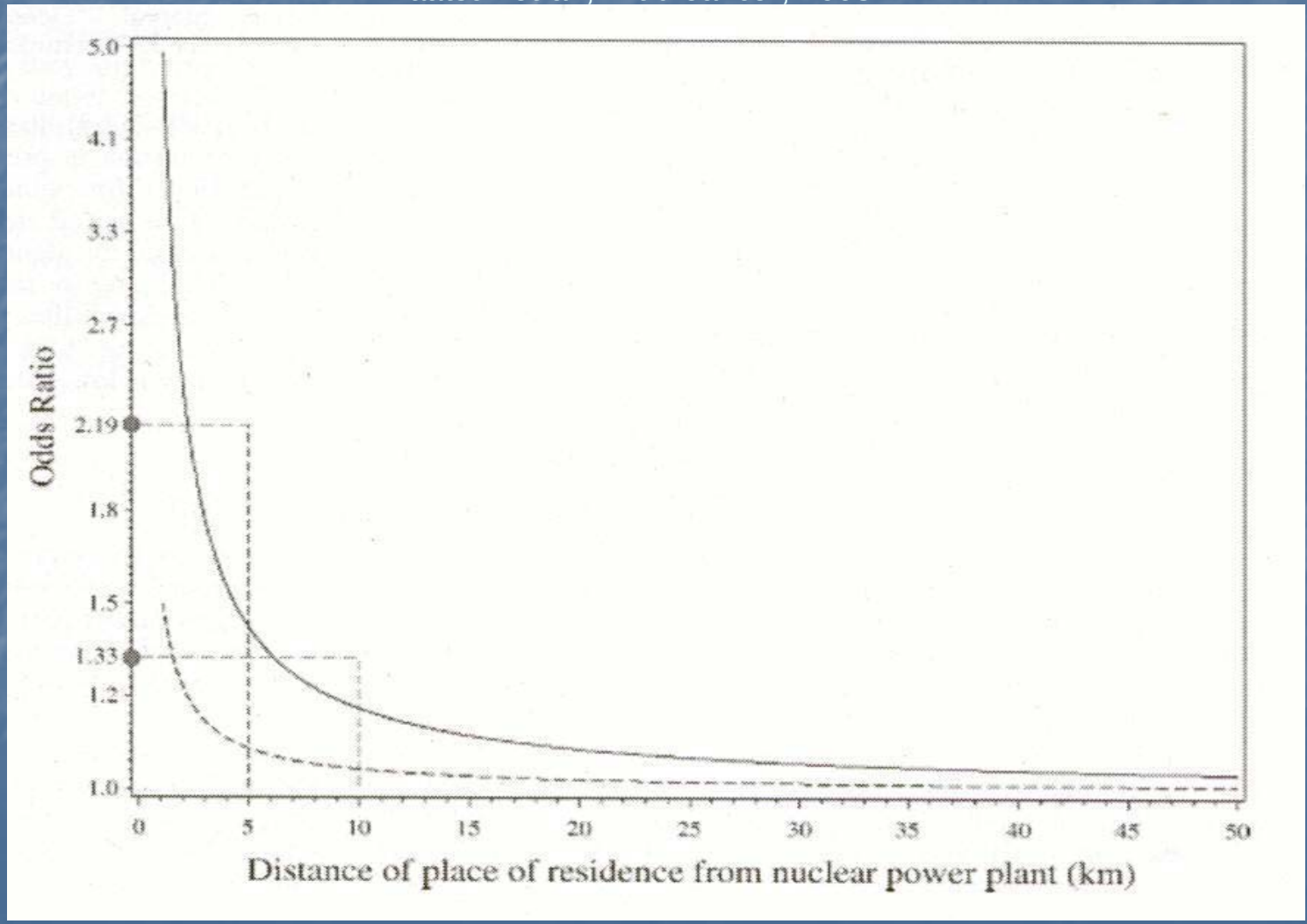
- KiKK reignited leukemia debate
- another large controversy in Europe
- relatively unknown in the US
- resulted in 4 EU states replicating it

KiKK Study: 2008

- very large study of cancer incidence near all 16 German nuclear power stations
- commissioned by German Government
- 120% increase in child leukemias
- 60% increase in embryonal cancers
- strongly linked to proximity to reactors
- validity accepted by German Government

the closer the reactor – the greater the leukemia risk

Kaatsch et al., Int J Cancer, 2008



Do Other Studies Back up KiKK?

(1) Laurier D et al (2008) Epidemiological studies of leukaemia in children and young adults around nuclear facilities: a critical review. Radiat Prot Dosimetry 132(2):182-90. REVIEWED 26 MULTI-SITE STUDIES

(2) Laurier D, Bard D (1999) Epidemiologic studies of leukemia among persons under 25 years of age living near nuclear sites. Epidemiol Rev 21(2):188-206. LISTED 50 STUDIES (36 SINGLE AND 14 MULTI-SITE)

ie over 60 STUDIES worldwide

4 European studies - post KiKK

Körblein A and Fairlie I. French Geocap study confirms increased leukemia risks in young children near nuclear power plants. Int J Cancer. Article published online: 1 Sept 2012. DOI: 10.1002/ijc.27585

Acute leukaemias in under 5s within 5 km of NPPs

Country	Observed	Expected	SIR=O/E	90%CI	p-value
Germany	34	24.1	1.41	1.04-1.88	0.0328
GB	20	15.4	1.30	0.86-1.89	0.1464
Suisse	11	7.9	1.40	0.78-2.31	0.1711
France	14	10.2	1.37	0.83-2.15	0.1506
pooled data	**79**	**57.5**	**1.37**	**1.13-1.66**	**0.0042**

Possible explanations

- confounders ? X
- coincidence ? X
- population mixing ? X
- exposure to chemicals ? X
- exposure to viruses/fungi ? X
- exposure to radiation

KiKK: cancer increases strongly associated with proximity to nuclear reactors

- direct radiation from reactors? X
- EM radiation from power lines? X
- cooling tower emissions? X
- reactor emissions and discharges ?

KiKK: radiation exposures too low....

but large uncertainties in the estimated doses from NPP emissions

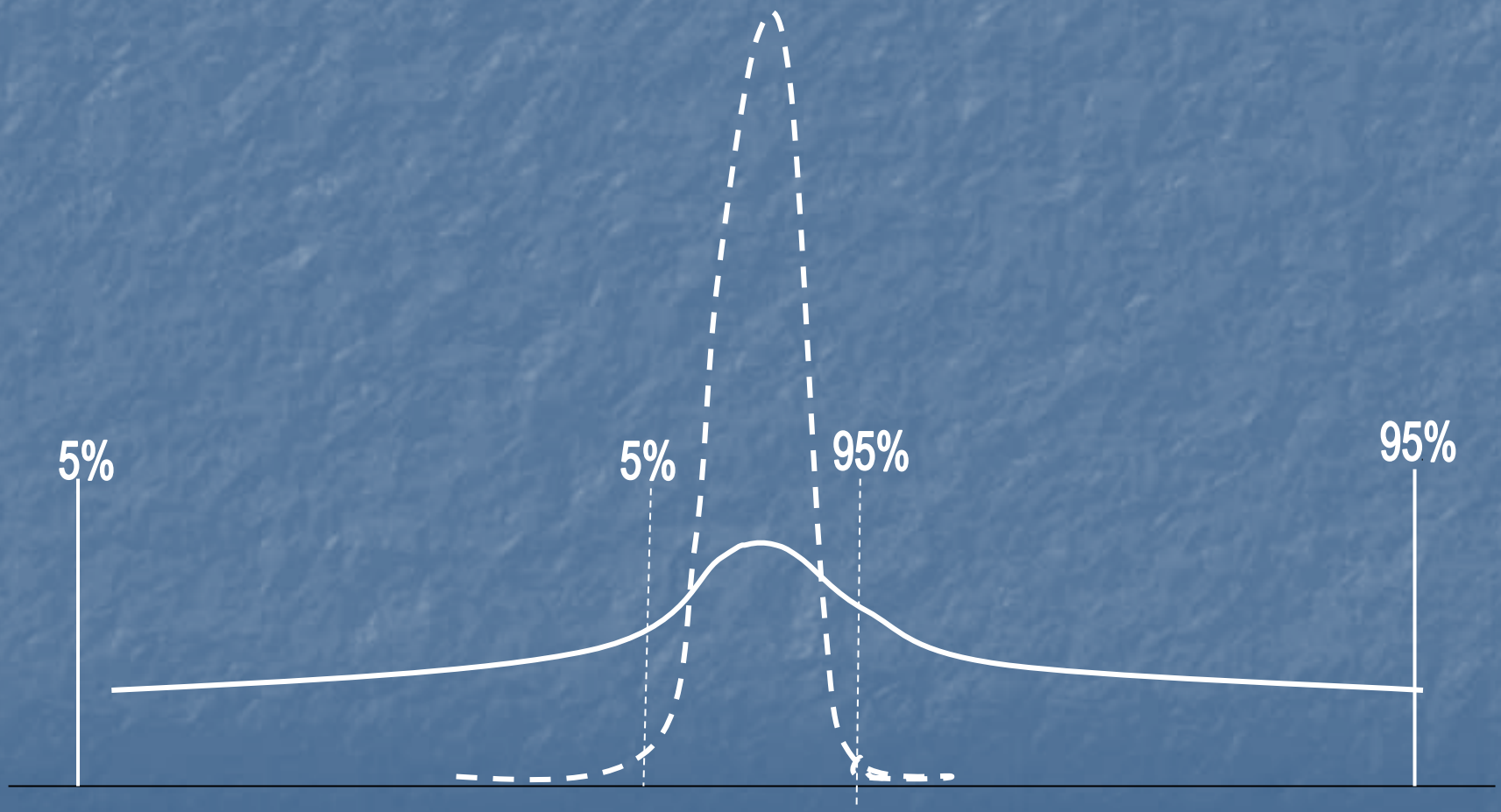
CURRENT ESTIMATES OF INTERNAL DOSES MAY CONTAIN LARGE UNCERTAINTIES

2004 Report by UK Government's Committee Examining the Radiation Risks of Internal Emitters (CERRIE) www.cerrie.org

Why large dose uncertainties? Partly because many models and many assumptions

- Source-term models (amounts released)
- Environmental models (behaviour of nuclides in environment)
- Biokinetic models (uptake and retention of nuclides in humans)
- Dosimetric models (convert Bq to mGy: mSv)
- Dose weighting factors (tissue W_T and radiation W_R)

Uncertainty distributions in model estimates



Uncertainties in Dose Coefficients

Goossens LHJ, Harper FT, Harrison JD, Hora SC, Kraan BCP, Cooke RM (1998) Probabilistic Accident Consequence Uncertainty Analysis: Uncertainty Assessment for Internal Dosimetry: Main Report. Prepared for U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, USA. And for Commission of the European Communities, DG XII and XI, B-I049 Brussels Belgium. NUREG/CR-6571 EUR 16773.

Nuclide	Intake	Organ	U Range = (ratio of 95th/5th percentiles)
Cs-137	ingestion	red bone marrow	4
I-131	inhalation	thyroid	9
Sr-90	ingestion	red bone marrow	240
Pu-239	ingestion	red bone marrow	1,300
Sr-90	inhalation	lungs	5,300
Ce-144	inhalation	red bone marrow	8,500
Pu-239	ingestion	bone surface	20,000

Also large risk uncertainties, because of inappropriate model

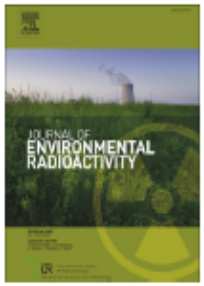
- BEIR VII risk model based on data from 1945 Japanese bomb survivors: LSS study
- Is this appropriate for environmental exposures from NPPs?
- Higher risks in infants?
- Even higher risks from *in utero* exposures?

Journal of Environmental Radioactivity xxx (2013) 1–8

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad



A hypothesis to explain childhood cancers near nuclear power plants

Q4 Ian Fairlie*

Q1 115 Riversdale Road, London N5 2SU, United Kingdom

ARTICLE INFO

Article history:
Received 4 November 2012
Received in revised form
5 June 2013
Accepted 29 July 2013
Available online xxx

Keywords:
Cancer
Leukemia
Radioactivity
Radiation
Nuclear power stations
Relative risk

ABSTRACT

Over 60 epidemiological studies world-wide have examined cancer incidences in children near nuclear power plants (NPPs): most of them indicate leukemia increases. These include the 2008 KiKK study commissioned by the German Government which found relative risks (RR) of 1.6 in total cancers and 2.2 in leukemias among infants living within 5 km of all German NPPs. The KiKK study has retriggered the debate as to the cause(s) of these increased cancers. A suggested hypothesis is that the increased cancers arise from radiation exposures to pregnant women near NPPs. However any theory has to account for the >10,000 fold discrepancy between official dose estimates from NPP emissions and observed increased risks. An explanation may be that doses from spikes in NPP radionuclide emissions are significantly larger than those estimated by official models which are diluted through the use of annual averages. In addition, risks to embryos/fetuses are greater than those to adults and haematopoietic tissues appear more radiosensitive in embryos/fetuses than in newborn babies. The product of possible increased doses and possible increased risks per dose may provide an explanation.

Hypothesis to explain KiKK findings

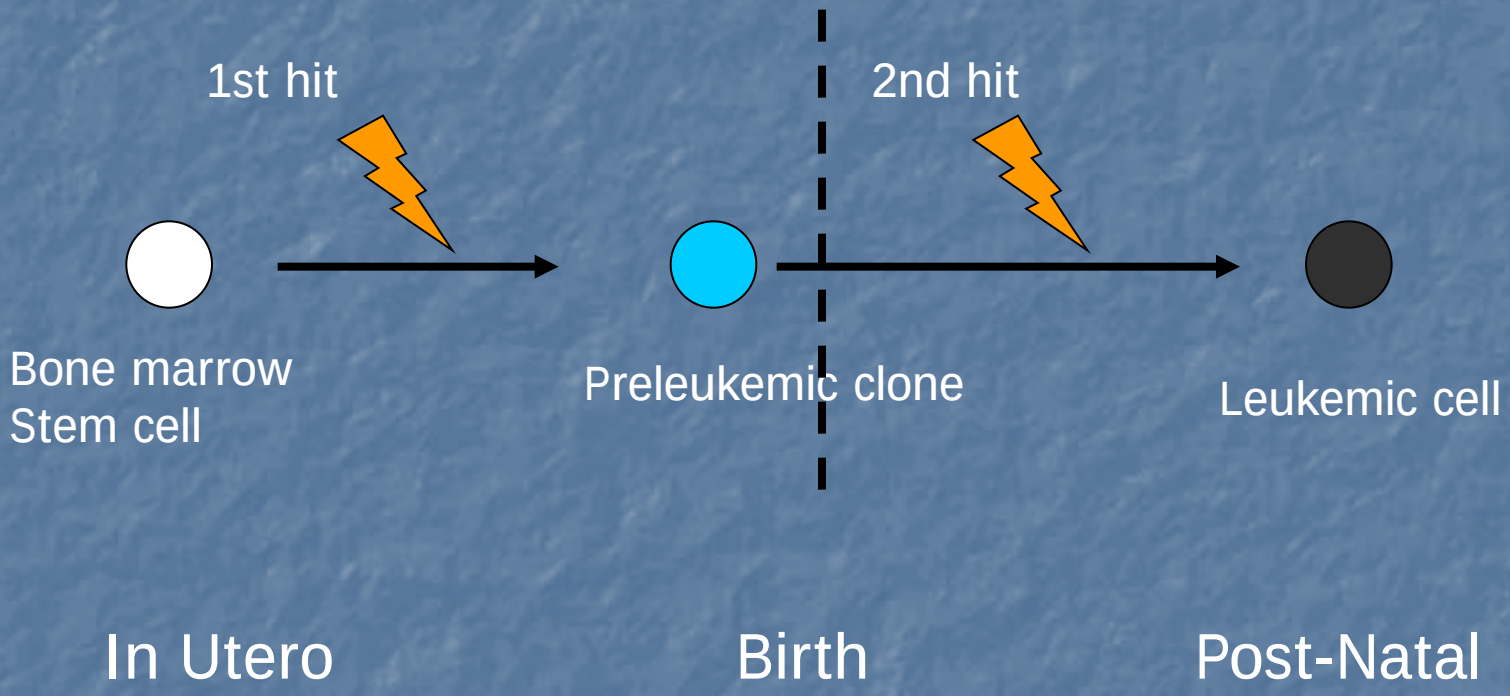
Fairlie I Journal of Environmental Radioactivity 133 (2014) 10-17

- episodic spikes in reactor releases
- high concentrations in pregnant women
- high exposures to embryos/fetuses
- resulting babies are born pre-leukemic
- in 1-2 years, develop full leukemia

ie teratogenic effect of radiation exposure

Leukemogenesis in Children

(after Professor Rössig,2008, Radiat Prot Dos, 132, 114-118)



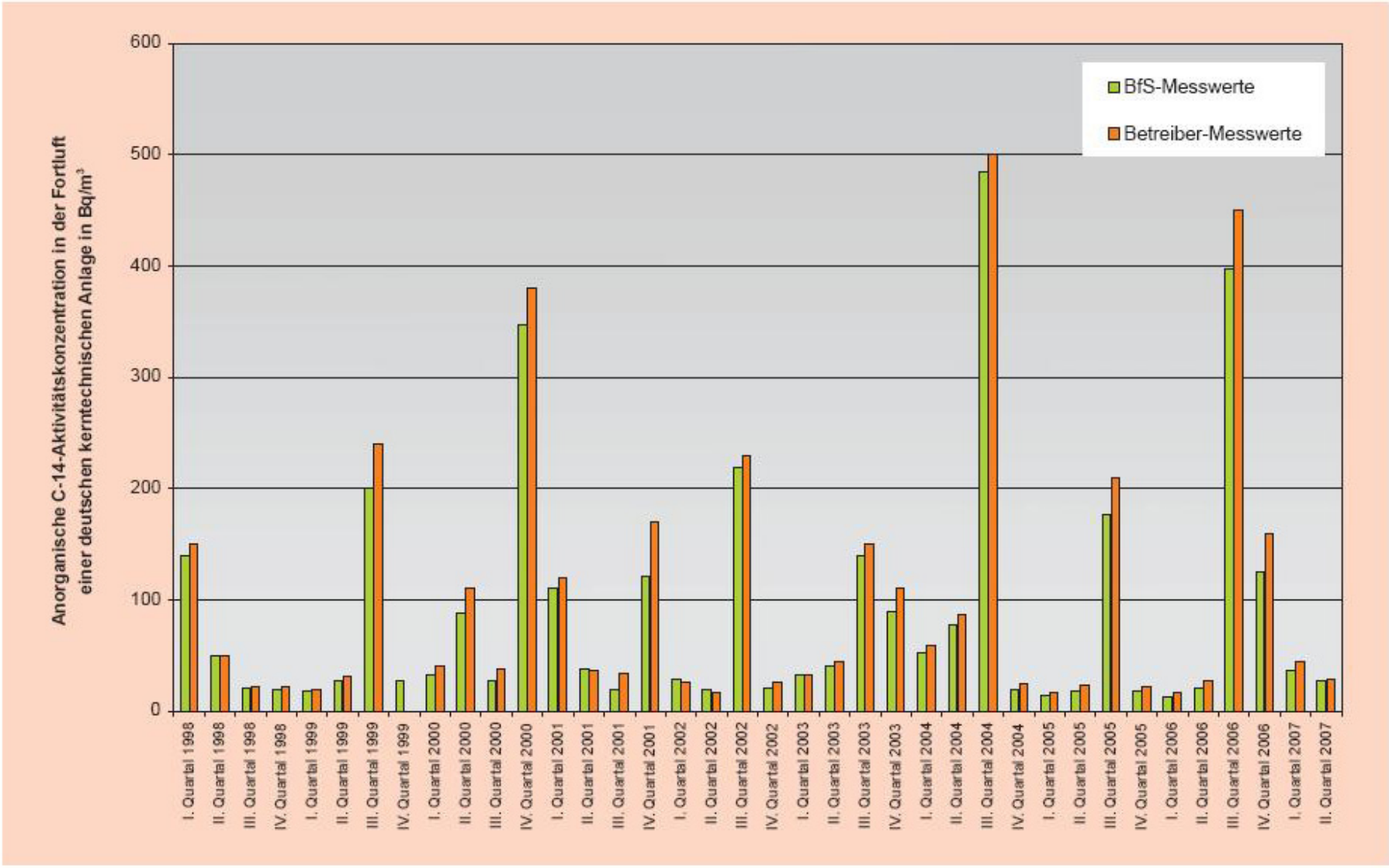
All childhood leukemias arise from in-utero radiation exposures

- Ie including spontaneous leukemias – resulting from background radiation

- O'Neill KA, Bunch KJ, Murphy MF Intrauterine growth and childhood leukemia and lymphoma risk. Expert Rev Hematol. 2012 Oct;5 (5):559-76

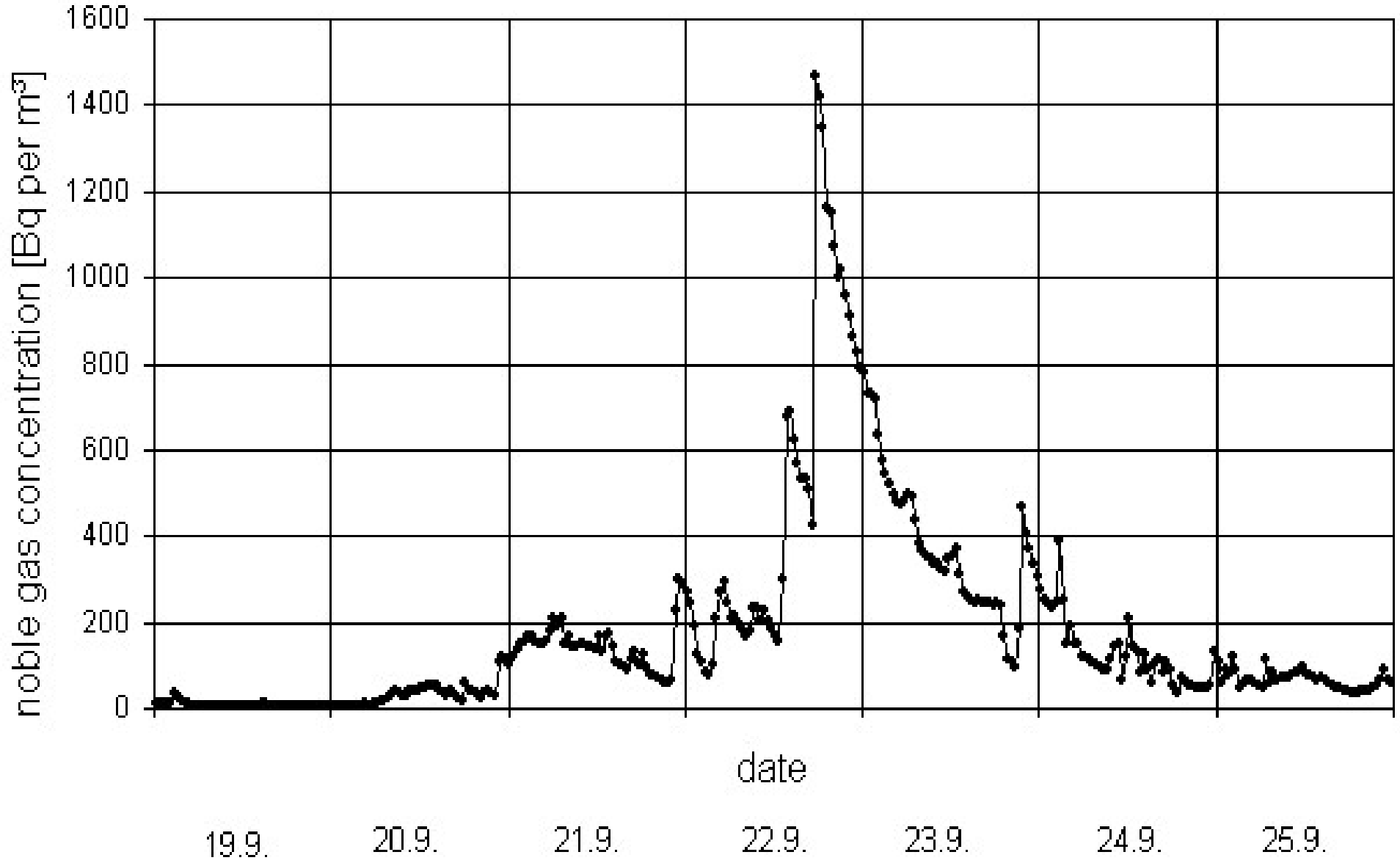
1st Stage – Environmental Emissions

- NPP refuelling ~once a year
- reactors opened - large spike of radioactive gases



Vergleich der vom Betreiber und dem BfS ermittelten Kohlenstoff-14-Aktivitätskonzentrationen in der Fortluft am Beispiel eines süddeutschen Druckwasserreaktors (KKW Neckarwestheim 2)

Spikes in NPP releases



Unit Conversions

1500 Bq/m^3 = ~40 nCi/m^3

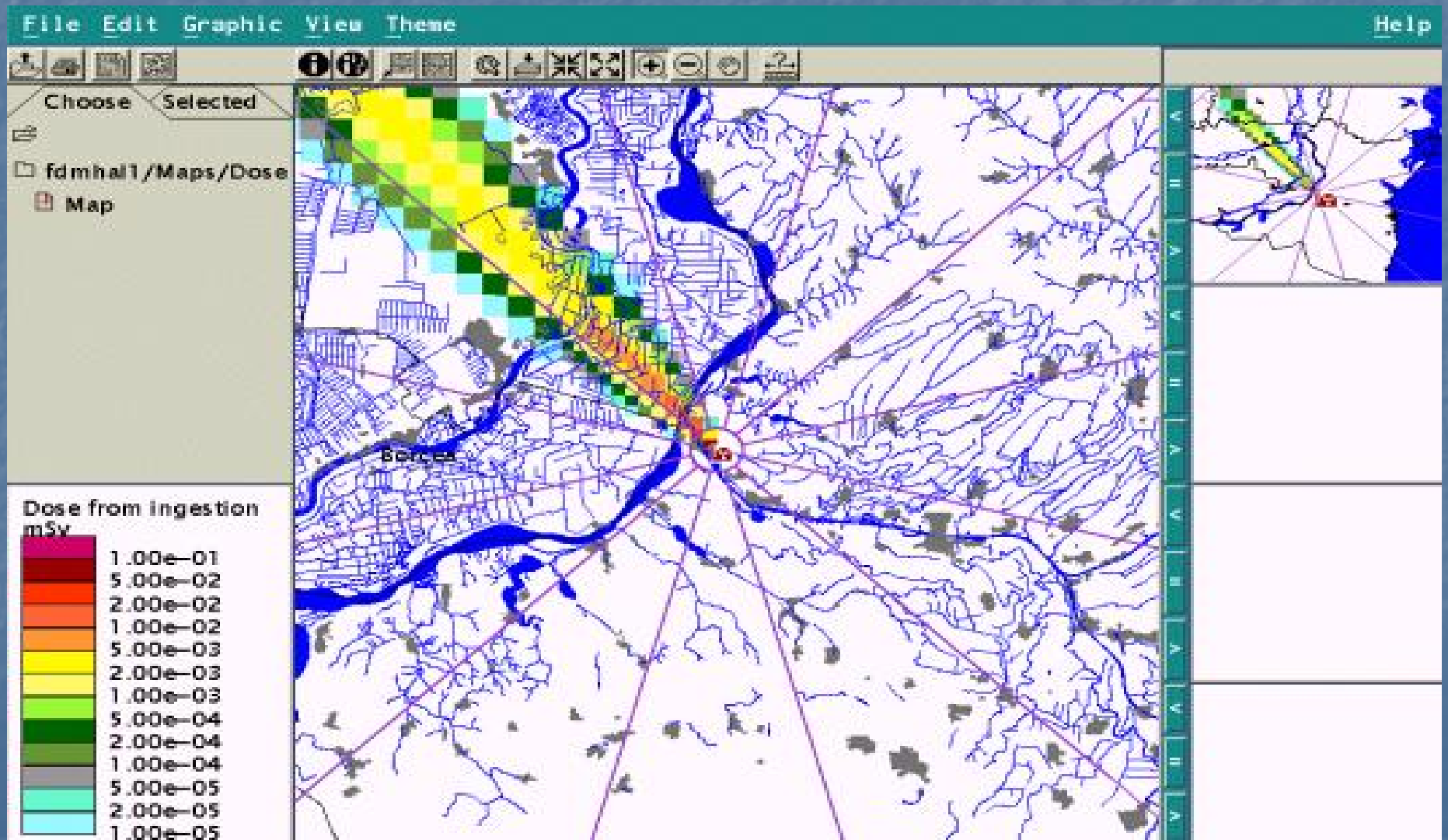
1 Bq = 1 disintegration/sec

(1 MBq = ~27 µCi)

(1 Ci = ~37 GBq)

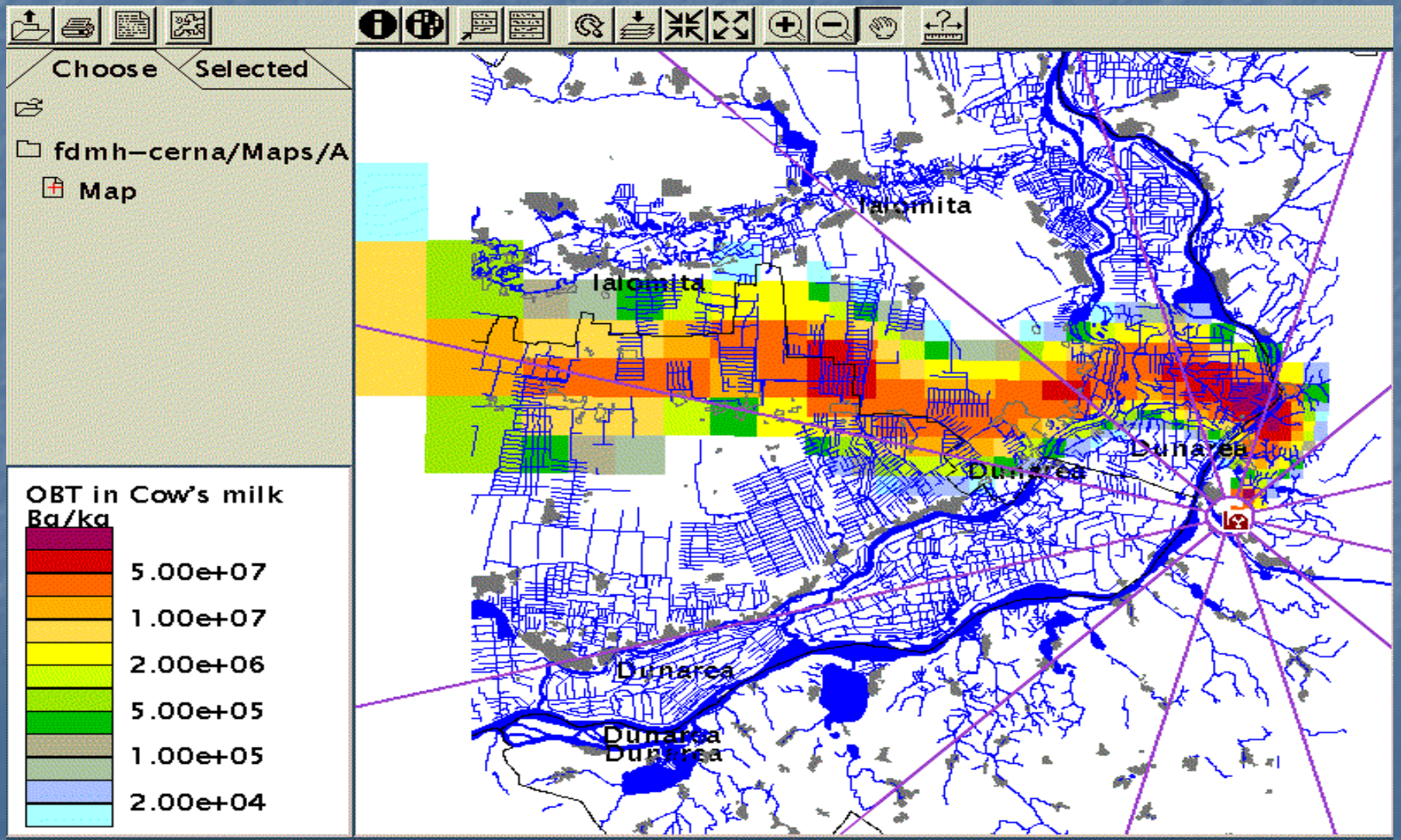
Tritium doses from ingestion (EU RODOS Model) in mSv

8th Meeting of the IAEA (EMRAS) Tritium & C-14 Working Group
May 30 - June 1, 2007 - Bucharest, Romania (http://www.nipne.ro/emras/)



Estimated tritium levels in cow's milk (EU RODOS Model) OBT Bq/kg

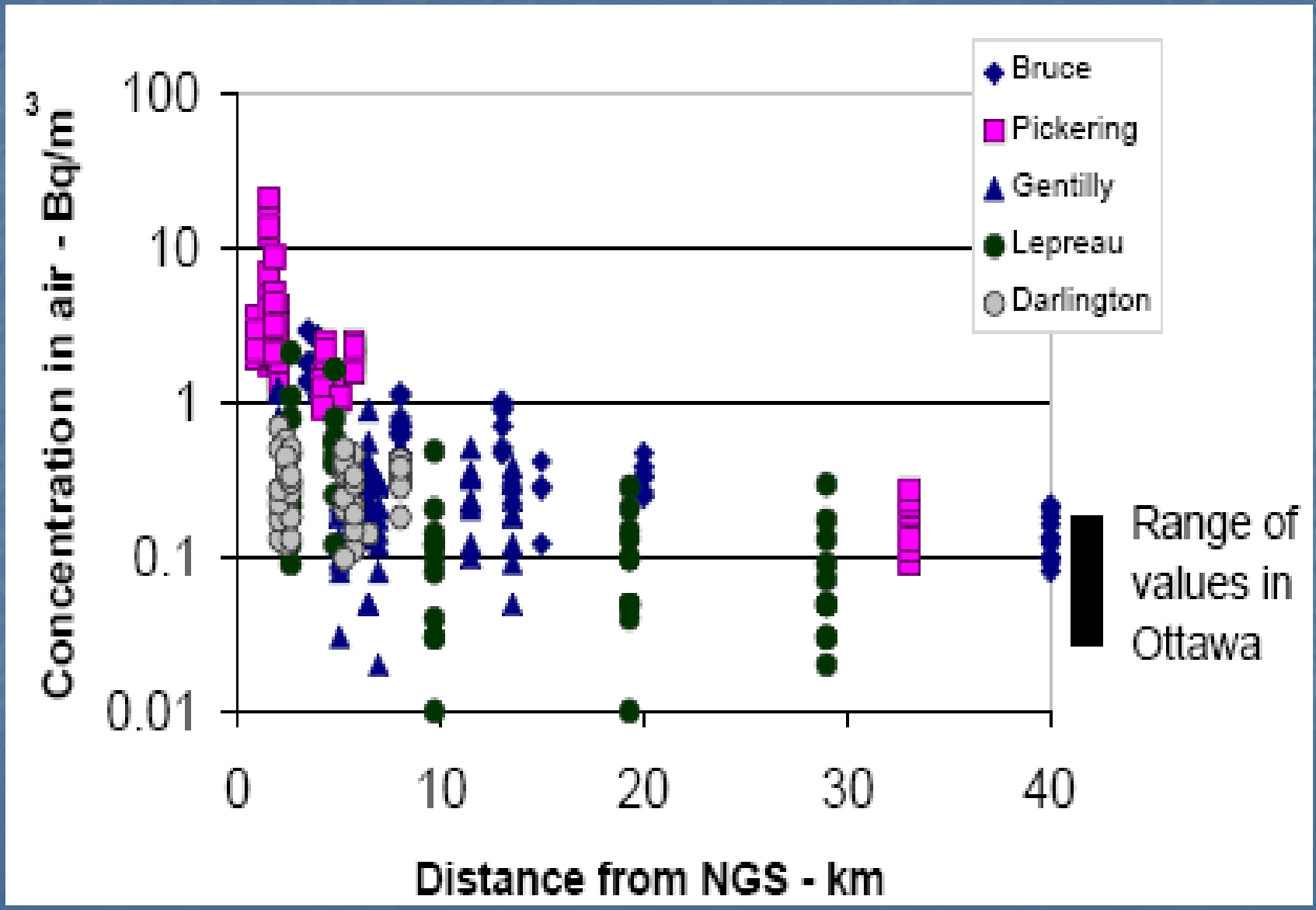
8th Meeting of the IAEA (EMRAS) Tritium & C-14 Working Group
May 30 - June 1, 2007 - Bucharest, Romania (http://www.nipne.ro/emras/)



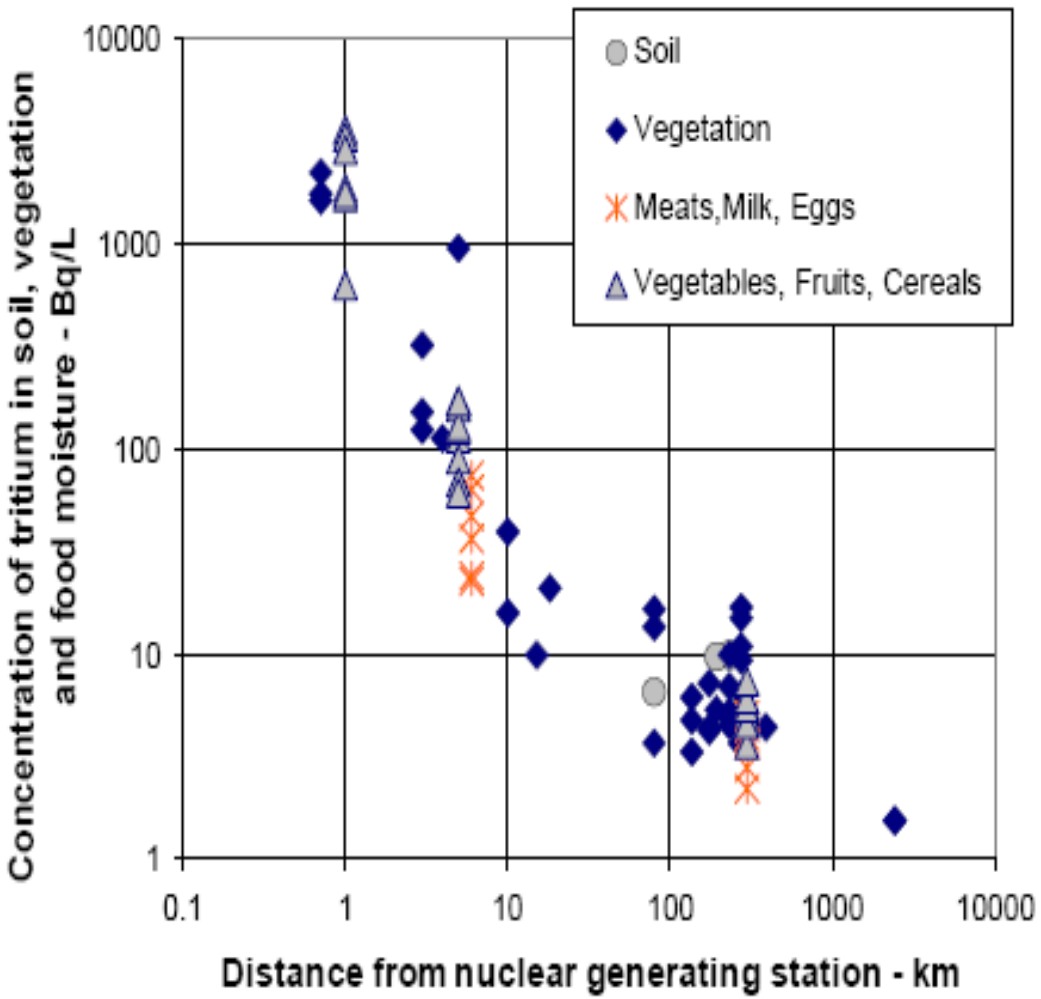
Main emissions from US nuclear facilities

- noble gases (Kr, Xe, Ar etc)
- tritium (HTO and HT forms)
- plus smaller amounts of C-14, I-131, I-129 ...
- and very small amounts of other nuclides

Tritium conc's in air



Tritium conc's in food



What is tritium?

- the radioactive isotope of hydrogen
- half-life = 12.3 years
- beta emitter, av energy 5.7 kev
- mostly in the form ^{3}H-O-H, ie radioactive water
- but, many misconceptions

Unusual Tritium Properties

- extreme mobility and cycling
- high rates molecular exchange
- builds up as OBT, sticks inside us
- very short range, so damage depends on location in cell, eg DNA?
- often described as “weak”, but higher RBE than “strong” emitters

RESULT: Official models significantly underestimate its doses and risks

Hazardous Properties

(after G Kirchner, 1990 J Environ Rad 11, pp 71-95)

tritium = √

1. large releases to environment √
2. rapid nuclide transport, cycling in biosphere √
3. high solubility√
4. many environmental pathways to humans √
5. rapid molecular exchange rates √
6. high uptake to blood after intake √
7. organic binding in biota √
8. long biological half-life in humans √
9. long radiological half-life √
10. global distribution √
11. long decay chains + toxic daughters
12. high radiotoxicity (ie high dose coefficient)

Reports discussing tritium

1. AGIR HPA Report (2007) Review of Risks from Tritium
2. Melintescu A, Galeriu D and Takeda H (2007) Reassessment Of Tritium Dose Coefficients For The General Public. Radiat Protect Dosim June 2007, pp. 1–5
3. Fairlie I (2007) RBE and w_R values of Auger emitters and low-range beta emitters with particular reference to tritium. Journal of Radiol Prot. Vol 27 pp 157-168
4. US EPA draft White Paper. Modifying EPA Radiation Risk Models Based on BEIR VII. August 1 2006
5. Makhijani A, Smith B, and Thorne MC (2006) Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk. See chapter 7 on tritium. http://www.ieer.org/campaign/report.pdf

More recent reports discussing tritium

AGIR. Review of risks from tritium. Documents of the Health Protection Agency: Radiation, Chemical and Environmental Hazards, REC-4. November 2007.

ASN (2010) White Paper on Tritium. Autorite de Securite Nucleaire (French Nuclear Safety Authority). Paris France.

CNSC (2010) Health Effects, Dosimetry and Radiological Protection of Tritium. Canadian Nuclear Safety Commission. INFO-0799. Ottawa, Canada.

Fairlie I (2008) The hazards of tritium revisited. Medicine, Conflict and Survival. Vol 24:4. October 2008. pp 306-319.

IRSN (2010a). Sources of production and management of tritium produced by nuclear plants. Institute de Radioprotection et Surete Nucleaire. Fonteney-aux-Roses, Paris France

IRSN (2010b). Tritium in the Environment - Review of the IRSN. Institute de Radioprotection et Surete Nucleaire. Fonteney-aux-Roses, Paris France.

IRSN (2010c). Tritium in the Environment - A View from the IRSN on the key issues and avenues of research and development. Institute de Radioprotection et Surete Nucleaire. Fonteney-aux-Roses, Paris France

Precautionary Principle

- (a) uncertainty not excuse for inaction
- (b) if reasonable evidence, take precautionary steps
- advise NPPs to refuel at night-time, or during windy weather, or when wind is blowing away from high populations

John F. Kennedy: April 2, 1960

“Radiation, in its simplest terms - figuratively, literally and chemically - is poison …. there is no amount of radiation so small that it has no ill effects at all on anybody. There is actually no such thing as a minimum permissible dose. Perhaps we are talking about only a very small number of individual tragedies - the number of atomic age children with cancer, the new victims of leukemia, the damage to skin tissues here and reproductive systems there - perhaps these are too small to measure with statistics. But they nevertheless loom very large indeed in human and moral terms.”

http://www.jfklibrary.org/Research/Research-Aids/JFK-Speeches/Milwaukee-WI_19600402-Wisconsin-Assoc-of-Student-Councils.aspx

Credits

Dr Alfred Körblein, Germany
Dr Richard Osborne, Canada
Dr Mike Thorne, UK
IPPNW, Germany
Professor Claudia Rössig, Germany

Thanks

Dr Keith Baverstock, Finland
Dr Steve Sheppard, Canada

(Any errors remain my responsibility)