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Fukushima – Lessons learned and issues
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Fukushima Health Risk Assessment: Lessons Learned

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Bundesamt für Strahlenschutz

Structure of the presentation

1) Summary of published work on Fukushima Health Risk Assessment (HRA)
2) Lessons learned:
    a) Levels of risk, from the results of the published work
    b) Practical issues arising during the HRA work (5 points) -
        includes suggestions relating to policy implications and research needs
3) Summary

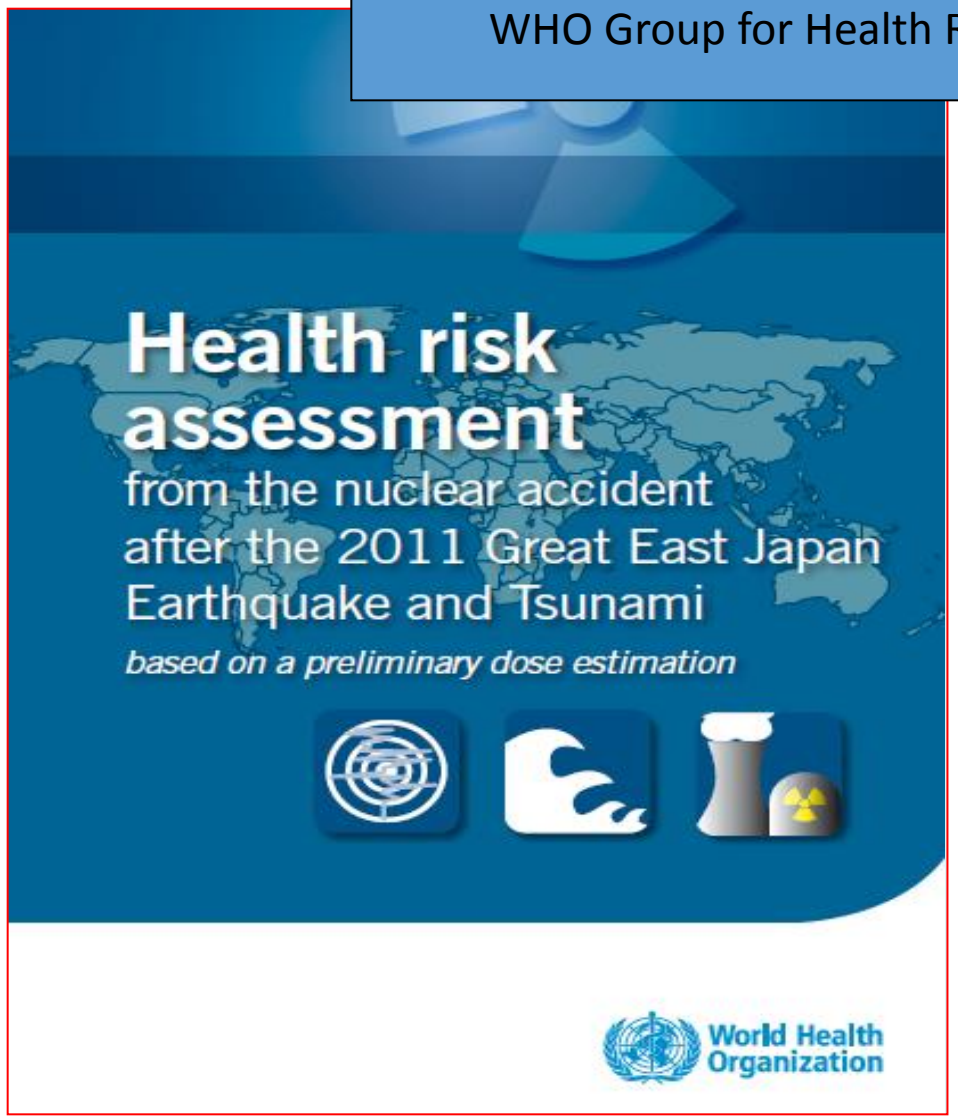
Summary of published work: First Fukushima Health Risk Assessment (HRA) by WHO

• WHO was responsible for the coordination of advice and assistance on public health risk assessment after the accident in the Fukushima nuclear power reactors, after the earthquake and tsunami on 11 March 2011

• Two international expert groups were set up by WHO:
Group for Hazard Identification & Exposure Assessment
Group for Health Risk Assessment (HRA)

• The HRA group, assessed health effects and calculated lifetime risks of cancers for different age groups, and assigned levels of risk to the exposed populations (BASED ON DOSE ESTIMATES FROM DATA AVAILABLE UP TO MID-SEP 2011) – THE RESULT WAS

WHO Group for Health Risk Assessment



Makoto Akashi
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Nick Gent
Peter Jacob
Dominique Laurier
Charles Miller
Ohtsura Niwa
Maria Perez
Roy Shore
Angelika Tritscher
Richard Wakeford
Linda Walsh
Wei Zhang
and others listed on page 2 of report (published on 28.2.2013)

http://www.who.int/ionizing_radiation/pub_meet/fukushima_risk_assessment_2013/en/

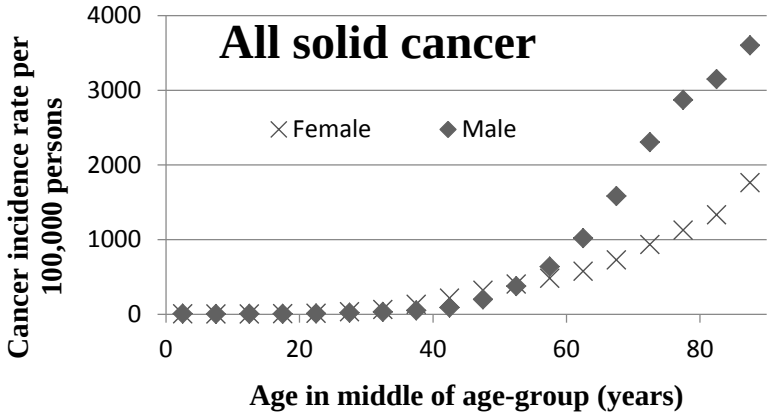
WHO – HRA: Aims

Comprehensive assessment of carcinogenic and non-carcinogenic detrimental health effects from the radiation releases.
Non-cancer effects were assessed but not modelled (e.g., thyroid nodules, thyroid dysfunction, developmental changes in embryo and fetus, hereditary effects and other non-cancer effects).

• To provide Lifetime Attributable Risk (LAR) estimates of radiation related cancer risk based on the organ doses to representative individuals and also Lifetime Baseline cancer Risk (LBR) for comparison.

- The cancer types considered for the risk analysis were :
  - all solid cancer incidence
  - leukaemia incidence (using mortality data)
  - thyroid cancer incidence
  - female breast cancer incidence

Matsuda et al. Jpn J Clin Oncol 2010



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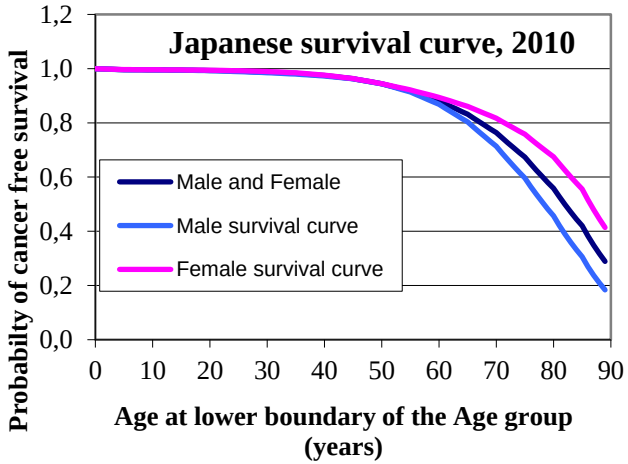

Lifetime baseline risk (*LBR*)

The cumulative baseline probability of having a specific cancer over lifetime

LBR	**All solid cancer**	**Thyroid**	**Leukaemia**	**Breast**
Males	0.41	0.002	0.006	
Females	0.29	0.008	0.004	0.056

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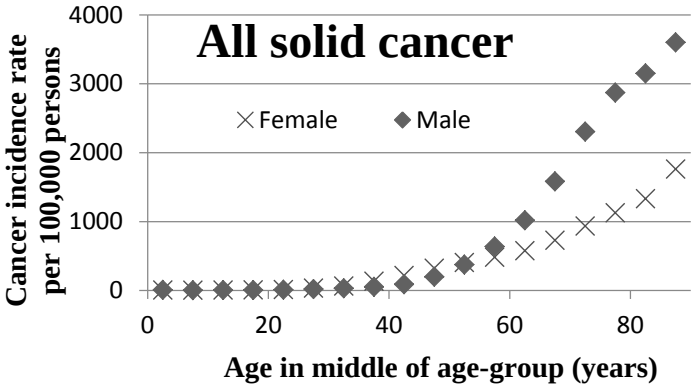

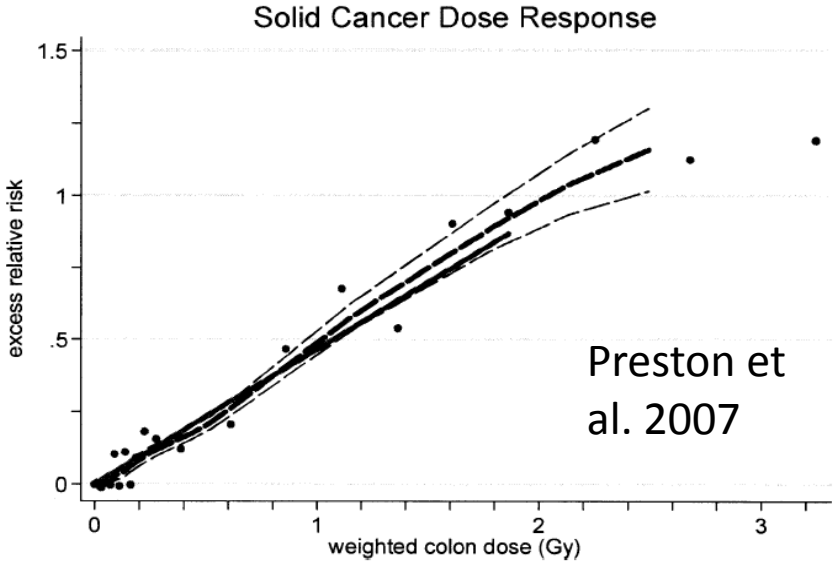

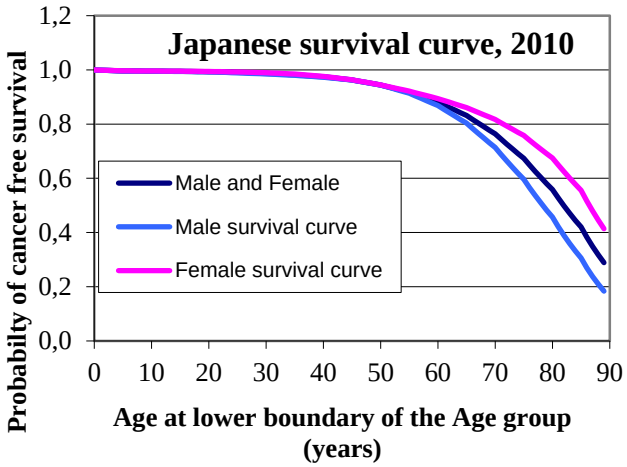

Lifetime Attributable Risk (*LAR*)

The lifetime attributable risk (LAR) specifies the probability of a premature incidence of cancer attributable to radiation exposure in a representative member of the population

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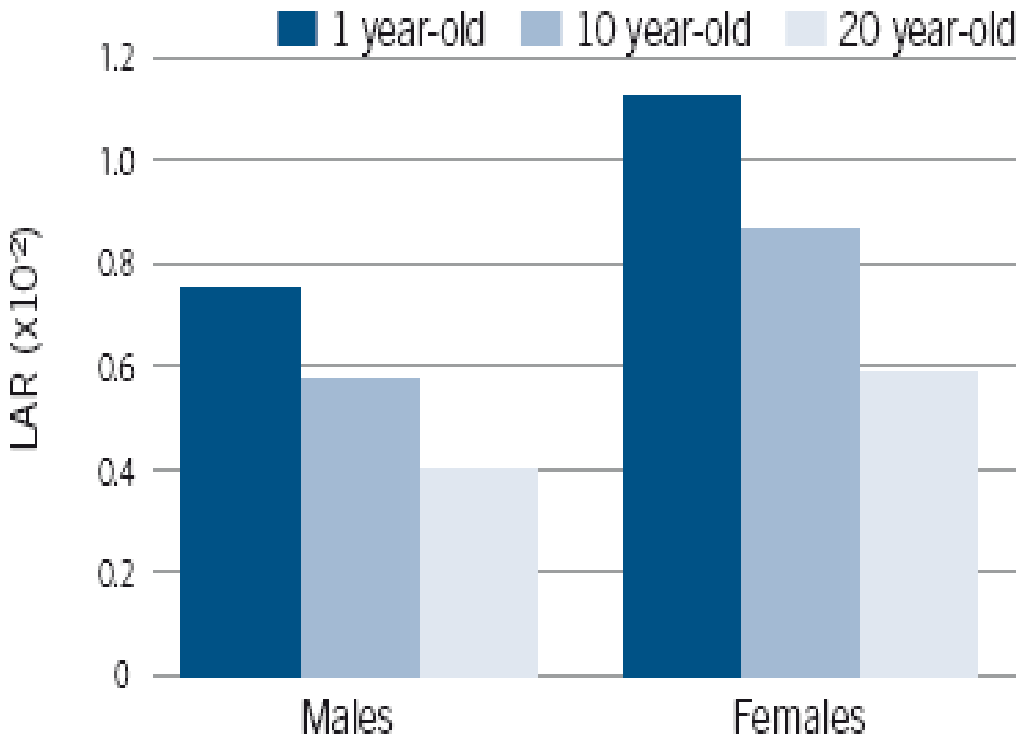
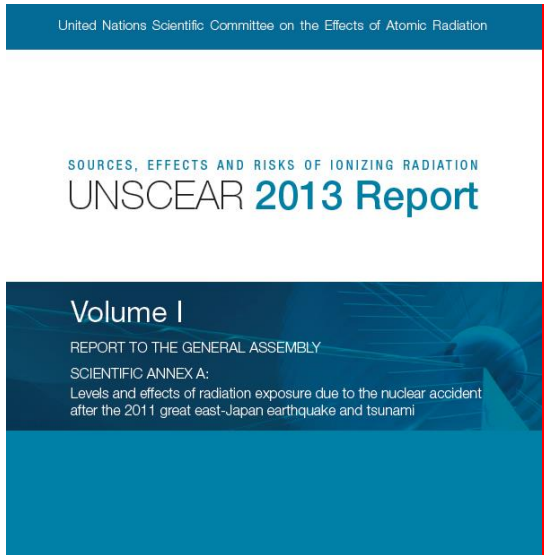
Figure 11. Lifetime attributable risk (LAR) and lifetime baseline risk (LBR) for all solid cancer in Group 1 Location ① for males and females exposed at 1, 10, 20 year-old.



Namie town in evacuation zone: colon dose in 1st 4 months: 22-26mGy depending on age at exposure

Summary of published work: Fukushima Health Risk Assessment (HRA)

1) WHO-HRA Report 2013
2) UNSCEAR Report 2014
3) Etherington et al. 2014
4) Walsh et al. 2014



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A Framework for Estimating Radiation-Related Cancer Risks in Japan from the 2011 Fukushima Nuclear Accident

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Worker doses and potential health effects resulting from the accident at the Fukushima nuclear power plant in 2011

George Etherington[1], Wei Zhang[1], John Harrison[1] & Linda Walsh[2]

[1]*Centre for Radiation, Chemical and Environmental Hazards, Public Health England (PHE), Chilton, Didcot, Oxon, UK, and* [2]*Department of Radiation Protection and Health, Federal Office for Radiation Protection (BfS), Neuherberg, Germany*

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Lessons learned: levels of risk

- In comparison to the WHO report, the UNSCEAR 2014 report could use more recent and more comprehensive data in their dose assessment. UNSCEAR & WHO dose estimates were generally consistent with each other (but WHO estimates were higher for some evacuated settlements).
- The UNSCEAR 2014 report stated (p. 250): “The WHO estimates of risks per unit dose were compatible with estimates of the committee in its earlier reports“ (i.e., UNSCEAR 2014 referred to e.g., the UNSCEAR 2008 report which provided lifetime cancer risks based on Japanese population data from 1994 and acute exposures)

Lessons learned: levels of risk - Public

In terms of specific cancers, for people in the most contaminated location, the estimated increased risks over what would normally be expected are:

1. All solid cancers – up to around 4 % in females exposed as infants;
2. Breast cancer – up to around 6% in females exposed as infants;
3. Leukaemia – up to around 7% in males exposed as infants;
4. Thyroid cancer - up to 70% in females exposed as infants (the normally expected risk of thyroid cancer in females over lifetime is 0.75% and the additional lifetime risk assessed for females exposed as infants in the most affected location is 0.50%).

For people in the second most contaminated location of Fukushima Prefecture, the estimated risks are approximately one-half of those in the location with the highest doses.

For all other locations in Japan and world-wide – radiation-related cancer risk were estimated to be much lower than usual fluctuations in the baseline cancer rates.

Lessons learned: levels of risk - Workers

WHO-HRA constructed 4 exposure scenarios
– reliability confirmed by UNSCEAR 2014 & Etherington et al. 2014

1. Lowest dose scenario (69% of workers) –any elevated cancer risk insignificant

2. Three higher dose scenarios – significantly elevated cancer risks were found:-

a) two intermediate dose scenarios – small number of cancer cases may occur but unlikely to be observed because variability in baseline cancer rates > predicted radiation-related rates

b) highest dose scenario (13 workers) – thyroid cancer LAR up to 3.5%, but increase unlikely to be observed due to the small number of workers

Lessons learned: levels of risk

Radiation doses from the damaged nuclear power plant **are NOT expected** to cause an increase in the incidence of miscarriages, stillbirths and other physical and mental conditions that can affect babies born after the accident.

WHO 2013 report notes that the psychosocial impact may have a consequence on health and well-being. UNSCEAR 2014 noted (p. 248) that "the most important and manifest health effects of the nuclear accident in the short term would appear to be on mental and social well-being" (Bromet, J Radiol Prot 2012).

Increases in incidences of human diseases, attributable to the radiation exposure from the accident, are likely to remain below detectable levels (but influence of cancer screening programmes requires careful evaluation).

Practical issues - Lesson 1:
relates to first year and lifetime dosimetric quantities (required for input into risk models)

From WHO Group for Hazard Identification & Exposure Assessment ?

NOT REALLY DIRECTLY FEASIBLE SINCE THIS REPORT PUBLISHED ONLY WIDE DOSE BANDS (e.g.,
1 to 10 mSv
10 to 50 mSv
10 to 100mSv) FOR FIRST YEAR DOSES (EFFECTIVE DOSES AND EQUIVALENT DOSES TO THE THYROID) IN SEVERAL AREAS

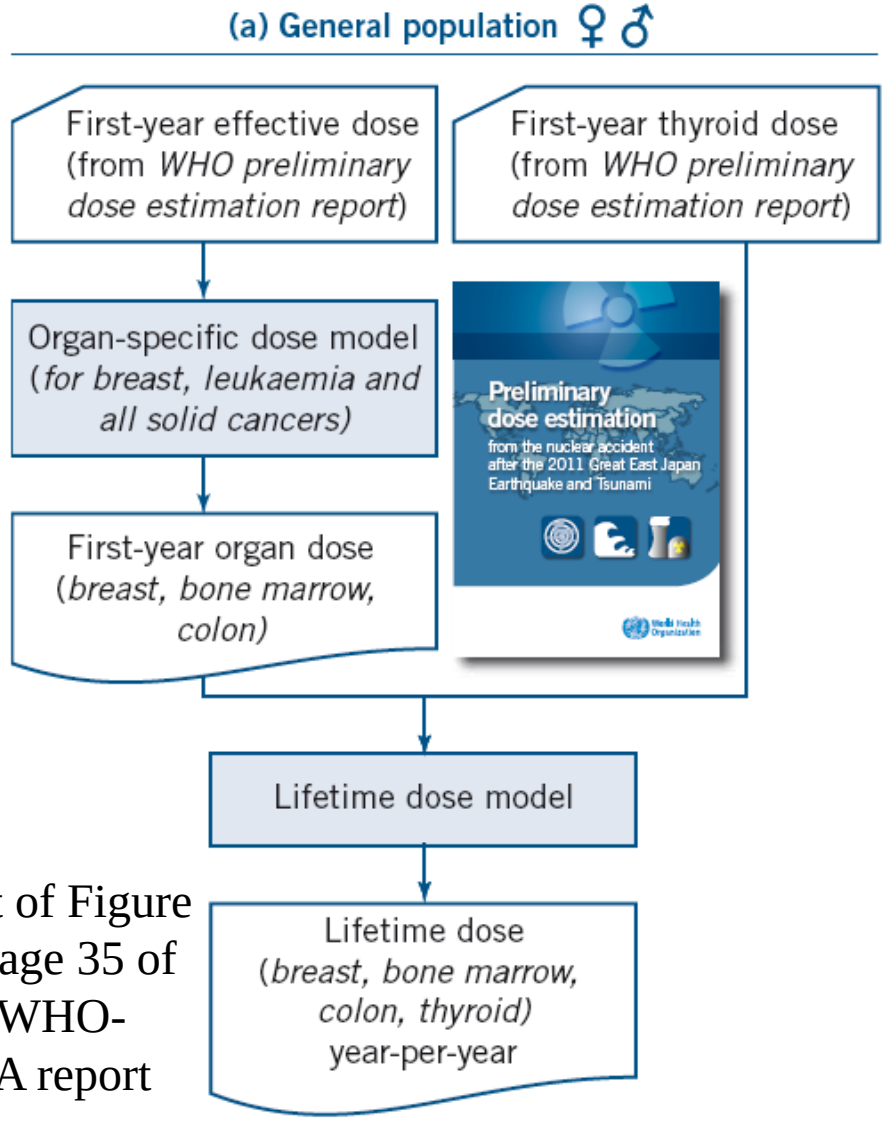
Published in May 2012

http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en/

Practical issues - Lesson 1:

The initial WHO dosimetry assessment could be seen as being ‘‘too compartmentalized‘‘ from the WHO HRA.

Suggestions for policy implications – in future, it is suggested that HRA specialists need to be involved in dosimetry assessments right from the start.



Part of Figure 3, page 35 of the WHO-HRA report

Practical issues - Lesson 2:

No flexible software was generally available for calculating the Lifetime Attributable Risks and Lifetime Baseline Risks for cancer incidence at the time of the WHO assessment.

Suggestions for policy implications & research needs – adoption of a standard program for calculating risks in future HRAs after nuclear accidents.

SUGGEST: NCI-RadRAT because –

a) follows the methodology of the WHO-HRA framework very closely
b) due to include population data from other countries within the next year (up to now only with USA population data)

IOP PUBLISHING JOURNAL OF RADIOLOGICAL PROTECTION

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RadRAT: a radiation risk assessment tool for lifetime cancer risk projection

Amy Berrington de Gonzalez[1], A Iulian Apostoaei[2], Lene H S Veiga[3], Preetha Rajaraman[2], Brian A Thomas[2], F Owen Hoffman[2], Ethel Gilbert[1] and Charles Land[1]

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Practical issues - Lesson 3:

WHO-HRA group did not have enough time to undertake a full quantitative assessment of uncertainties in the risk calculations.

Suggested research requirement: Adoption of a standard program for calculating UNCERTAINTIES in risks in future HRAs after nuclear accidents.

NOTE: NCI-RadRAT has a quite comprehensive evaluation of uncertainties (but ignores uncertainties in the time and age radiation risk effect modifiers).

Practical issues - Lesson 4:

Population data could only be quickly acquired from either web sites or published material. This was not optimal for three reasons:

1) The data was not as “up-to-date” as potentially possible – we used cancer rates for 2004 NOT 2011.
2) The data was not as precise as potentially possible e.g., thyroid and breast cancer incidence rates per 100,000 person-years in Japan only found to be given to one decimal place in journal publications (i.e. any rates under 5 cases per 10 million person-years set to zero cases which leads to zero radiation risk with a multiplicative radiation risk model).
3) The ICD codes for the cancer sites of interest did not match exactly (between LSS models & Cancer registries).

Suggestions for policy implications & research needs – build data base with contact information of cancer registry staff who are able to quickly supply precise and up-to-date cancer rates for country of interest for any ICD grouping.

Practical issue lesson 4: relates to demographic data from Japan

FEMALE		Age group (years) lower/upper																	
Site ICD - 10	lower age	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	upper age	4	9	14	19	24	29	34	39	44	49	54	59	64	69	74	79	84	
	age in middle of age																		
Table 3 of Matsuda et al, 2010	group	2.5	7.5	13	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5
All sites	C00-C96	9.6	5.1	6.3	10.6	13.1	35.3	66.4	136.5	219.5	326.6	408.7	486.8	585.1	739.6	945.1	1144.3	1350.2	1784.8
All leukaemia	C91-95	3.3	1.2	1.2	2.2	0.9	1.9	1.2	2.6	2.6	4.1	3.5	5.1	8.2	11.8	10.4	17.6	18.3	22.1
Thyroid	C73	0	0	0.3	1.3	3.4	4.4	6.1	7.6	10.2	14.3	16.3	23.7	17.1	21.1	17.1	15.7	13.2	13.8
Breast	C50,D05	0	0	0	0	0.5	5.9	21.4	55.7	106.9	157.8	142.2	142.8	147	131.5	115.5	113.9	100	87.8
for comparison with A-bomb breast cancer models:C50																			
All sites-leukaemia	C00-C90	6.3	3.9	5.1	8.4	12.2	33.4	65.2	133.9	216.9	322.5	405.2	481.7	576.9	727.8	934.7	1126.7	1331.9	1762.7
for comparison with A-bomb all-solid cancer models:C00-C89																			

MALE																			
	lower age	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	upper age	4	9	14	19	24	29	34	39	44	49	54	59	64	69	74	79	84	
	age in middle of age group	2.5	7.5	13	18	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5
All sites	C00-C96	13.2	5.6	6.8	7.8	13.3	23.7	33.8	55.9	94.4	202.7	383.6	648.8	1032.7	1601.6	2326.8	2907.5	3190.5	3643.6
All leukaemia	C91-95	4.3	2.3	1.3	1.5	1.7	2.9	2.4	3.8	4.7	3.6	7.2	10.6	13.4	17.5	20.7	35.7	40.9	41.7
Thyroid	C73	0	0	0.1	0.3	0.6	0.8	1.9	1.4	2.6	2.8	4.3	4.9	4.1	9.2	6.4	10.7	8.6	7
All sites-leukaemia	C00-C90	8.9	3.3	5.5	6.3	11.6	20.8	31.4	52.1	89.7	199.1	376.4	638.2	1019.3	1584.1	2306.1	2871.8	3149.6	3601.9
for comparison with A-bomb all-solid cancer models:C00-C89																			

Monitoring of Cancer Incidence in Japan project (MCIJ):
age-specific incidence rates per 100,000 population in Japan on the basis of data collected from 14 of 31 population-based cancer registries according to gender and primary site for 2004 (adapted from table 3 of Matsuda et al. Jpn J Clin Oncol 2010)

Practical issues - Lesson 5:

Applying the Japanese A-bomb survivors Life Span Study (LSS) models for all solid cancer along with the models for the specific sites (thyroid and female breast), means that some cancers have an overlap in the risk evaluations. WHO-HRA report noted that - no models for all other types of solid cancer have yet been published.

Suggested research requirement ‘‘**Radiation risk models for all solid cancers other than those types of cancer requiring individual assessments after a nuclear accident” – an article containing details of such models (Walsh et al.) is almost ready to be submitted for publication.**

Table E1. WHO's estimates of lifetime baseline risk, LBR, and lifetime attributable risk, LAR for areas within Fukushima Prefecture with effective doses of 12–25 mSv in the first year [W12]

The calculations were based on absorbed doses to the colon, bone marrow and breast of 20 mGy for the whole population, and absorbed doses to the thyroid of about 100, 75 and 50 mGy for an age at exposure of 1, 10 and 20, respectively. The values calculated by WHO were quoted to two significant figures and have been reproduced here. The use of such precision should not imply that the numbers are accurately known. For example, consideration of the uncertainty associated with the LAR estimates would suggest that the actual values likely lie within bounds that are perhaps 2–3 times higher or lower. The LBR are also associated with uncertainty and variability between different years

Age at exposure (y)	*Sex*	*Risk quantity*	*All solid cancer[a]*	*Leukaemia*	*Breast cancer*	*Thyroid cancer*
1	Male	LAR LBR	0.6% 41%	0.03% 0.60%	–	0.10% 0.21%
	Female	LAR LBR	1.2% 29%	0.02% 0.43%	0.26% 5.5%	0.43% 0.77%
10	Male	LAR LBR	0.5% 41%	0.02% 0.58%	–	0.04% 0.21%
	Female	LAR LBR	0.8% 29%	0.01% 0.41%	0.17% 5.5%	0.19% 0.77%
20	Male	LAR LBR	0.3% 41%	0.01% 0.57%	–	0.01% 0.21%
	Female	LAR LBR	0.5% 29%	0.01% 0.40%	0.11% 5.6%	0.07% 0.76%

[a] Includes the risk of thyroid cancer taking into account the relatively high absorbed dose to the thyroid, while the WHO report calculated the risk of all solid cancer assuming that the absorbed dose to all organs was equal to the dose to the colon.

Summary of HRA lessons learned

Since a very important aspect on health effects of the nuclear accident in the short term would appear to be connected with mental and social well-being of persons in the affected area.

I suggest being well prepared in advance of future events by:

1) Initially including HRA experts in the dosimetry assessments
2) Deciding in advance on dose levels below which no quantitative HRA is required (10 mGy organ/tissue dose?)
3) Keeping an up-to-date list of cancer registry staff able to quickly provide precise population data for any ICD grouping and for any "representative" country
4) Adoption of a standard software for risk calculation (in advance) that :
   a) is based on the framework applied in the WHO-HRA
   b) includes a full uncertainty treatment
   c) either includes, or is flexible enough to input, up-to-date cancer radiation risk models
   d) either includes, or is flexible enough to input, up-to-date population data for any country
5) Presentation of the results of such an HRA, by risk communication specialists, within a few months of the event, to members of the public in the affected area.