Challenges in communicating risks of exposure to low levels of ionising radiation in contaminated environments

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Third International Symposium on
Remediation of Radioactive Contamination in the Environment,
Koriyama, 5th July 2014

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Outline

- Introductory thoughts on risk communication
  - Summary of FCO symposium
- Can knowledge and understanding help reduce perception of risk?
  - UK & Japanese experience in 1986 and 2011
    - The importance of transparency
    - How do UK & Japanese experiences compare?
  - Validated radiometrics
    - The importance of accuracy and traceability
    - to restore confidence data need to be correct and also accepted
    - Participation: engaging non-experts in measurements
  - Putting additional radionuclides in perspective
    - Can dose rate apportionment relative to natural source help?
  - Looking forward
    - Understanding radionuclide dynamics
    - Anticipating future effects from past experience
- Conclusions

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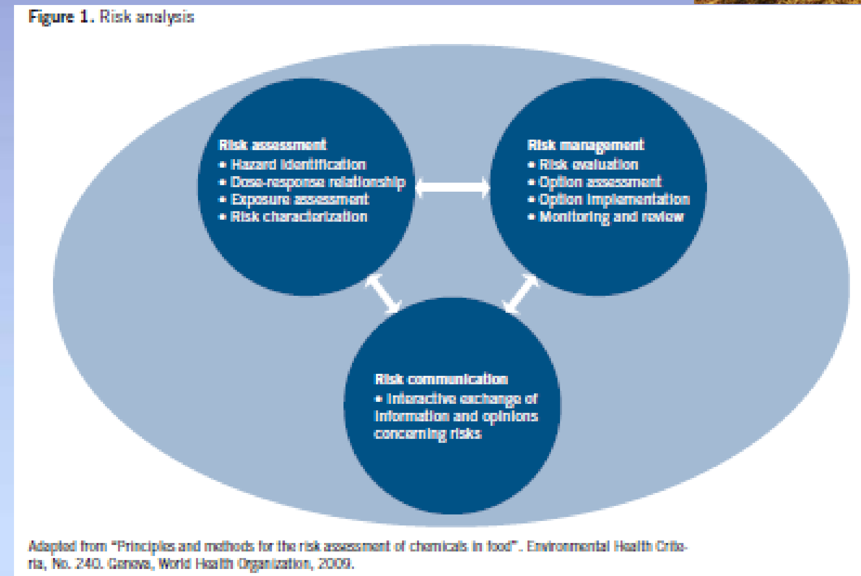
Effective Risk Communication: One Definition



Risk communication:
interactive exchange of information and opinions

Risk communication is a key component of the risk analysis process … proactive risk communication, coupled with public involvement in the remedial process, is critical to the success of any remedial activity. Addressing public health concerns is a major communication challenge. The building blocks of an effective risk communication strategy are trust, transparency, ethics, technical accuracy, values, credibility and expression of caring … Fears and perceptions need to be addressed – even if they are not commensurate with the actual risks.

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May 1986: Early indication of Chernobyl contamination in UK

Thyroid Monitoring

Name [redacted] No. K2

Sensitivity : 1.65 ± 0.02 cpm Bq⁻¹ ¹³¹I (at S/D = 14.0 cm)

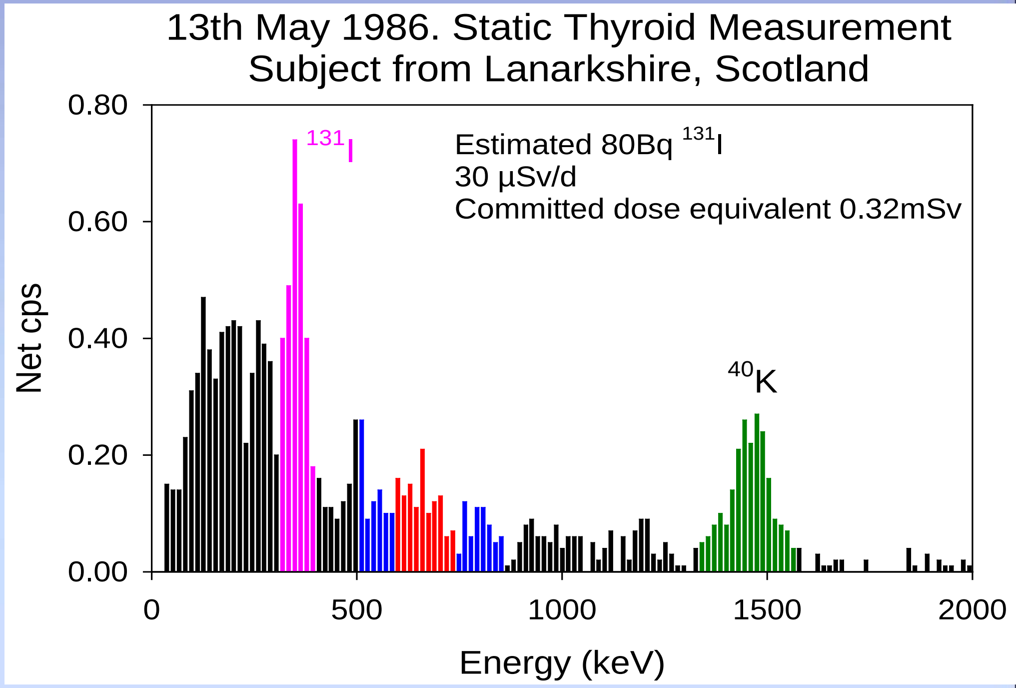
No	Date	Time	Channel Range	Gross Count	Bgd Count.	Net C.R. (c.p.m.)	S/D (cm)	S/D correct factor	Corrected c.r. (cpm)	Measured Act. (Bq)	
K2(1)	7/5	10:00	24-31	6612 ± 80	4740 ± 69	167.2 ± 10.6	15.5	0.910	183.7 ± 11.6	80.8 ± 5.1 / 111 ± 7	± 6.3
K2(2)	13/5	16:00	24-31	4879 ± 70	3884 ± 62	99.5 ± 9.4	"	"	109.3 ± 10.3	48 ± 4.4 / 66 ± 6	± 9.1
K2(3)	21/5	14:30	"	4426 ± 67	3740 ± 61	68.6 ± 9.0	"	"	75.4 ± 9.9	33.5 ± 4.4 / 46 ± 6	± 13.0
K2(4)	29/5	16:05	"	3776 ± 61	3528 ± 59	24.8 ± 8.5	"	"	27.3 ± 9.3	12.3 ± 2.4 / 17 ± 4	± 24
K2(5)	13/6	14:30	"	3507 ± 59	3320 ± 58	18.7 ± 8.3	"	"	20.5 ± 9.1	8.7 ± 4.4 / 12 ± 6	± 50

Decay Correction : Reference date T₀ 3.5.86 (12.00)

No.	Measured Act. (Bq)	Decay time DT₀ (d)	Decay factor DF₀	Decay Correct. Act. (Bq)	Mean Act A₀ (Bq)	Dose Rate (Ḋ)* µSv/d	Committed** DE (mSv)		
K2(1)	111 ± 7	3.92	1.436	159 ± 10	164 ± 9	29.8 ± 1.6	0.322		
K2(2)	66 ± 6	10.17	2.559	169 ± 15			± 0.017		
K2(3)	46 ± 6	18.10	5.329	245 ± 32					
K2(4)	17 ± 4	26.17	11.230	191 ± 45					

* For female gland; Dose rate for unit act. in gland = 0.182 µSv/d/Bq

** Committed dose equiv. assuming single intake of ¹³¹I.



- **SURRC Health Physics advice in 1986 was for young mothers to consider using powdered milk for 2 weeks**

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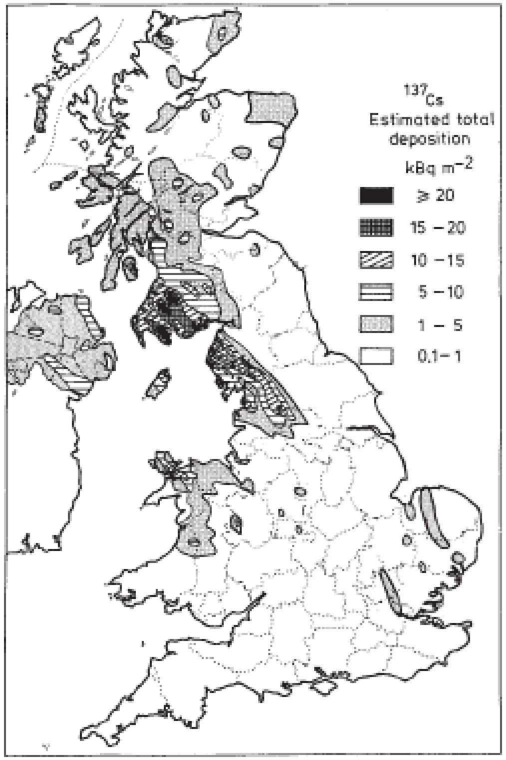
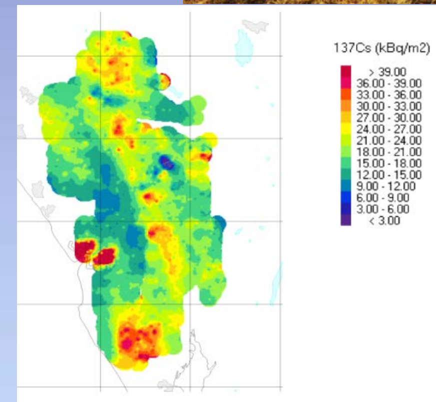


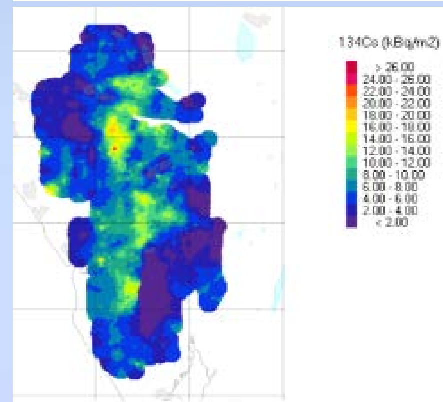
Fig. 2 Estimated total deposition of ^{137}Cs (kBq m^{-2}) over the United Kingdom due to Chernobyl releases, calculated from a washout factor of 6.5 10^5, the rainfall data and air concentrations.

Chernobyl 28th April 1986

1988 MAFF Survey West Cumbria

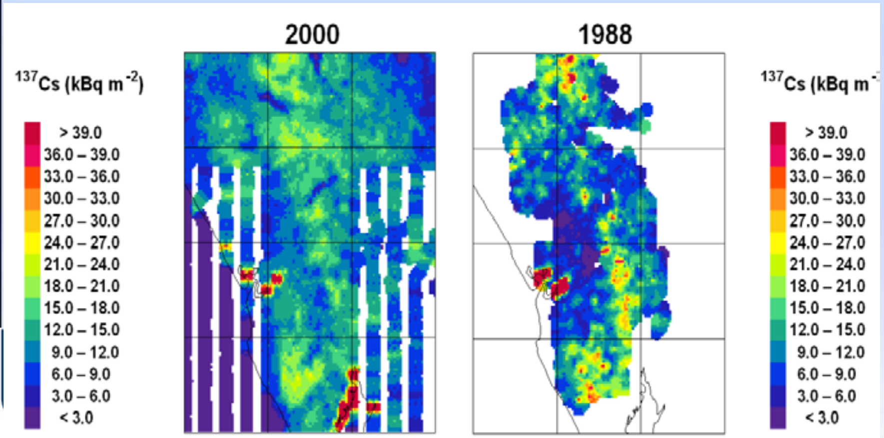
- **UK fallout arrives early May**
- **Initial deposition estimates based on limited ground sampling and meteorological modelling**
- **Early SURRC surveys – SW Scotland, Western Isles, West Cumbria, North Wales**
- **Later repeat surveys show long term migration of radionuclides**

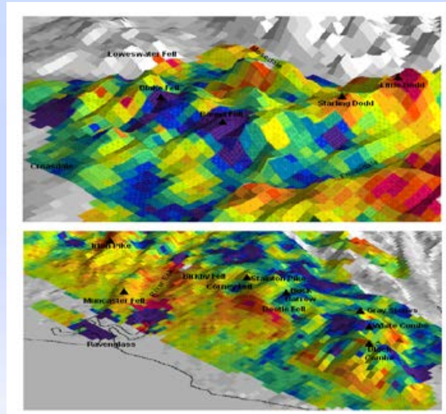




Clark M.J., Smith F.B. 1988, Wet and dry deposition of Chernobyl releases. *Nature* 332, 245-249.

Sanderson D.C.W., Cresswell A.J., White, D.C., Murphy, S., McLeod J. 2001, Investigation of Spatial and Temporal Aspects of Airborne Gamma Spectrometry. DETR Report DETR/RAS/01.001.





Sanderson D.C.W., Scott E.M.,1989, Aerial Radiometric Survey In West Cumbria In 1988, MAFF Report N611 120

2001 DETR study "Spatial and Temporal Aspects of Airborne Gamma Spectrometry"

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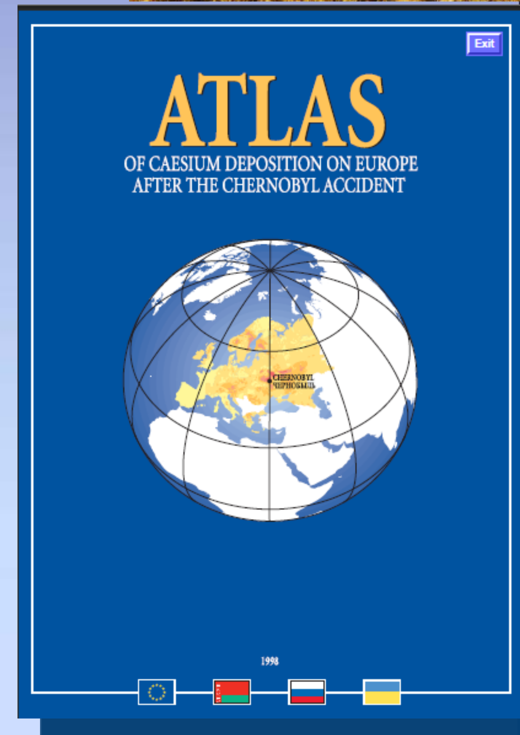
Regional scale mapping following the Chernobyl accident on 28th April 1986



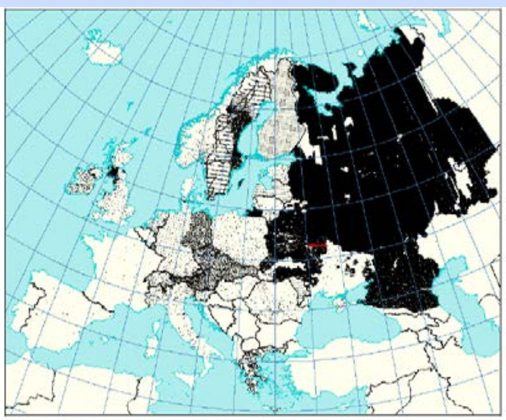
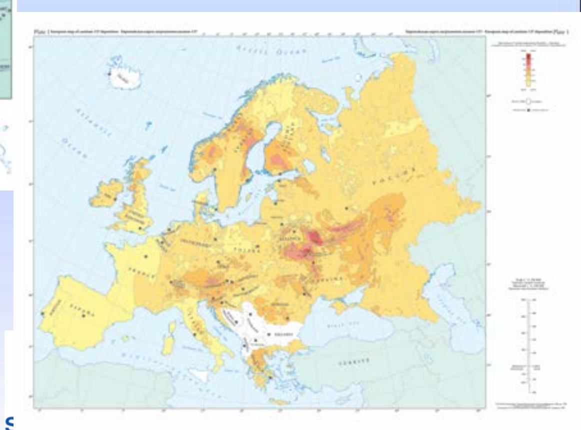
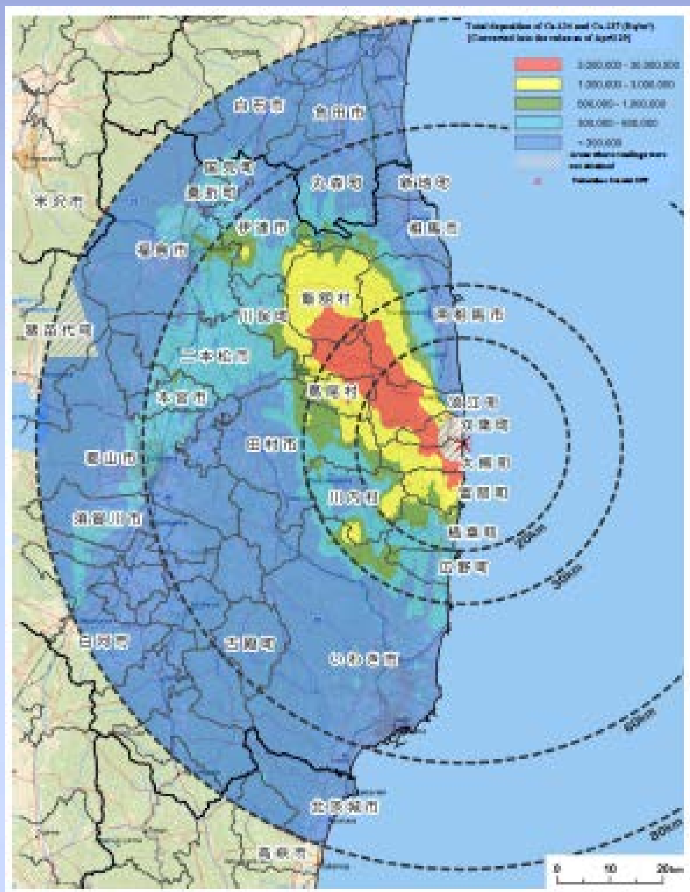


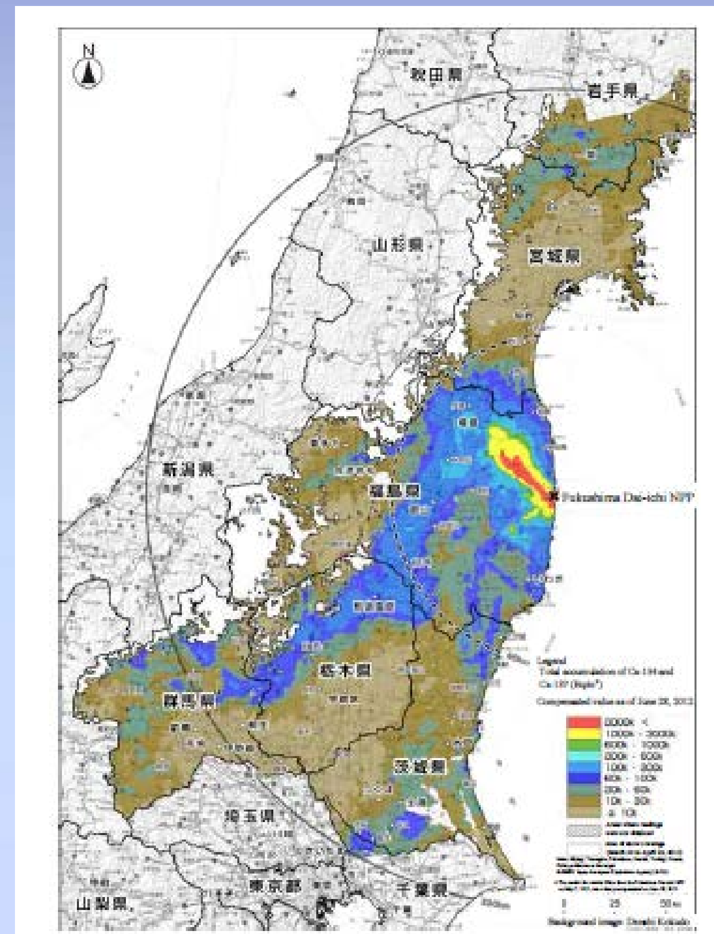
Fig. B.1: Spatial distribution of the caesium-137 deposition data used for the Atlas



Regional scale mapping following the Fukushima Accident



MEXT/US DoE Survey up to 29th April 2011
Released: May 6, 2011



MEXT Survey up to 28th June 2012
Released: September 28, 2012

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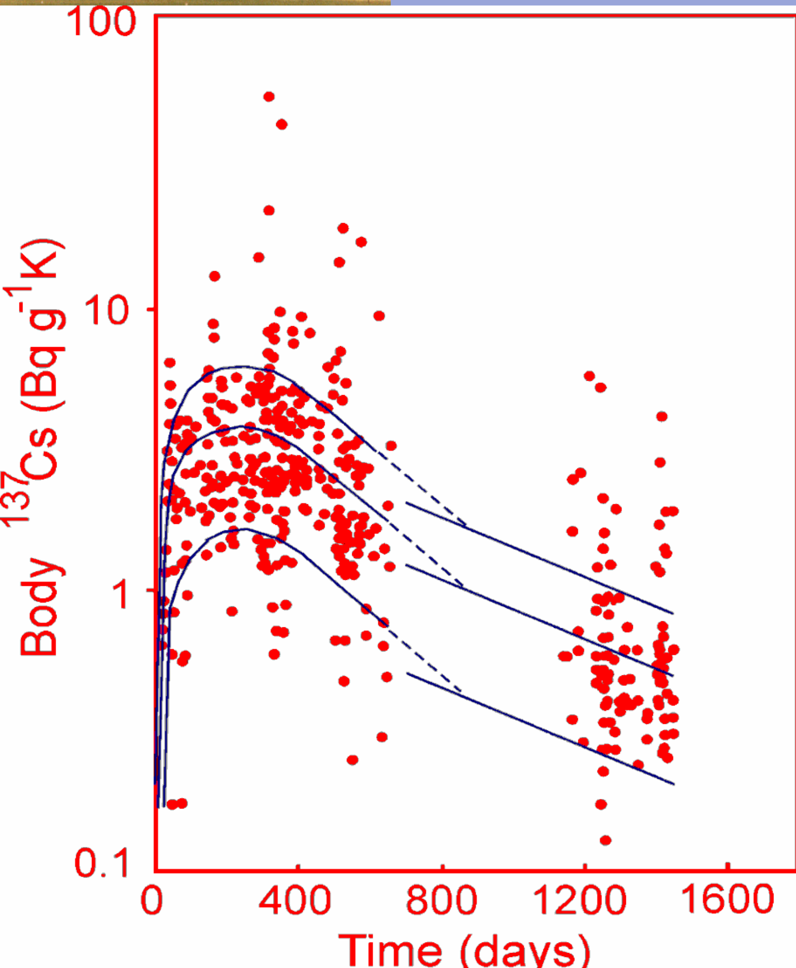
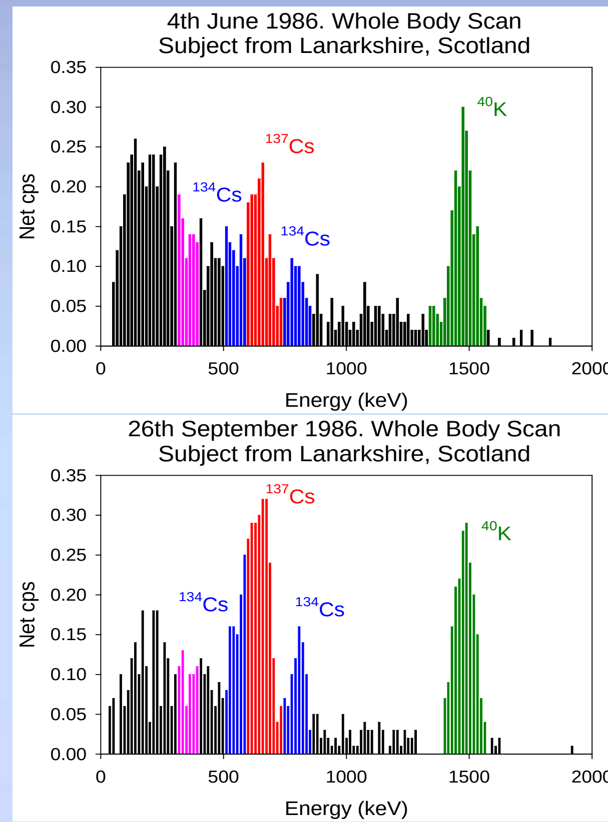
Whole body radiocaesium contamination from >250 volunteers from the Scottish Population





5 weeks after accident

5 months after accident

- Caesium activity in the body reaches maximum 8-12 months after the accident and then declines steadily
- Food chain and environmental mixing processes
- Average committed Cs dose 69 μSv (v. low)
- What about individuals?

BW East, I Robertson, 1988, 1991, Measurement of radioactivity from population groups in Scotland, DOE/HMIP/RW/88.103; RR/92.004

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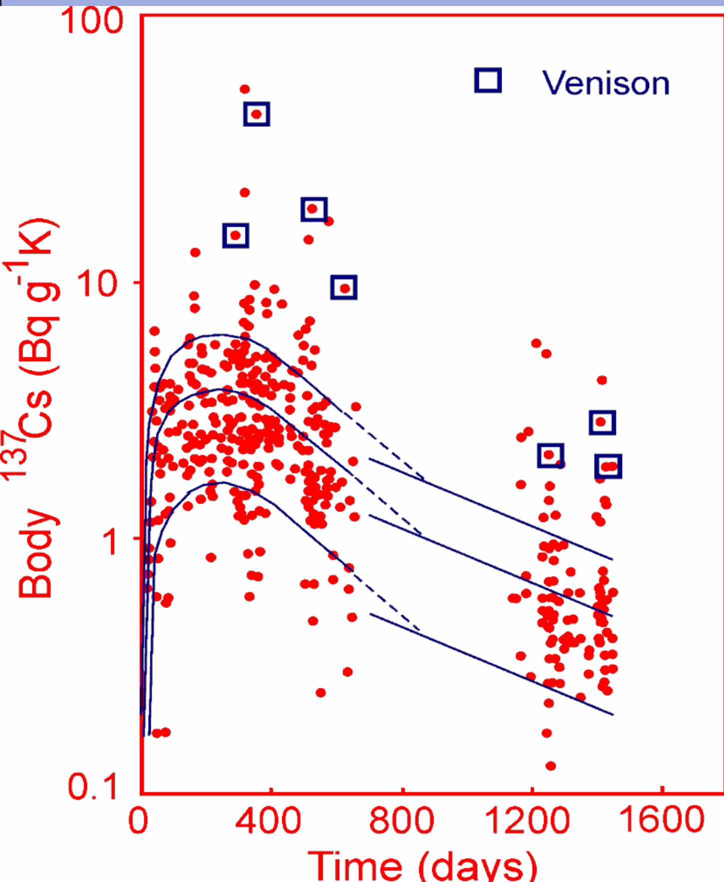
Individual groups with atypical dietary inputs

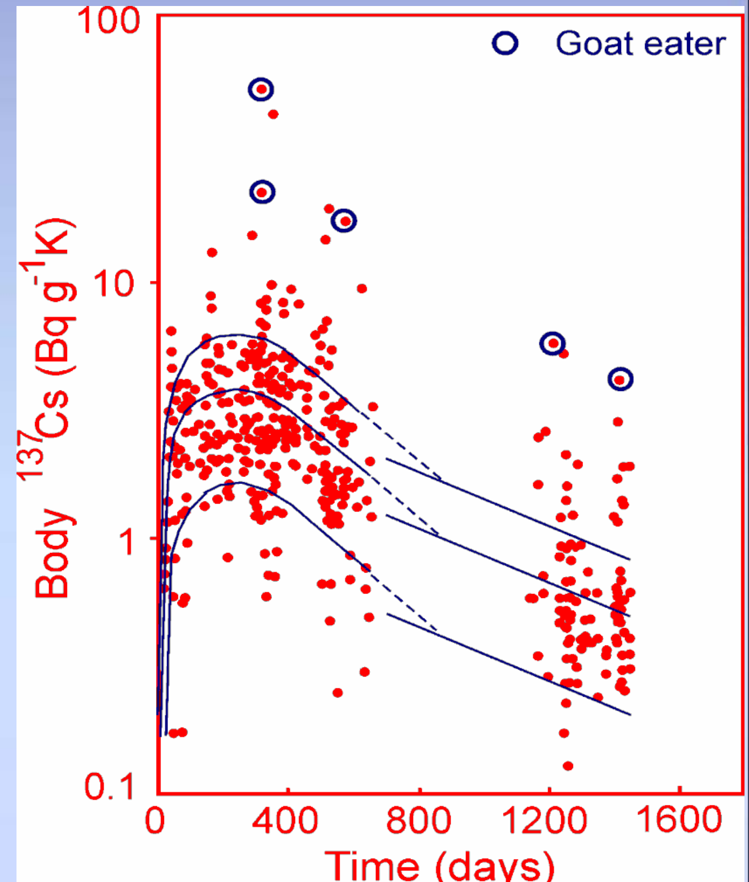


Venison was contaminated (up to 7000 Bq kg^{-1} ^{137}Cs) in the central highlands and individuals reporting high meat consumption had higher body caesium

Malcolm Rifkind, Secretary of State for Scotland, advised moderation

"if eating venison, don't gorge yourself"

A group from SW Scotland who consumed both goat meat and dairy products had the highest levels recorded (50-100 time higher than the lowest groups)



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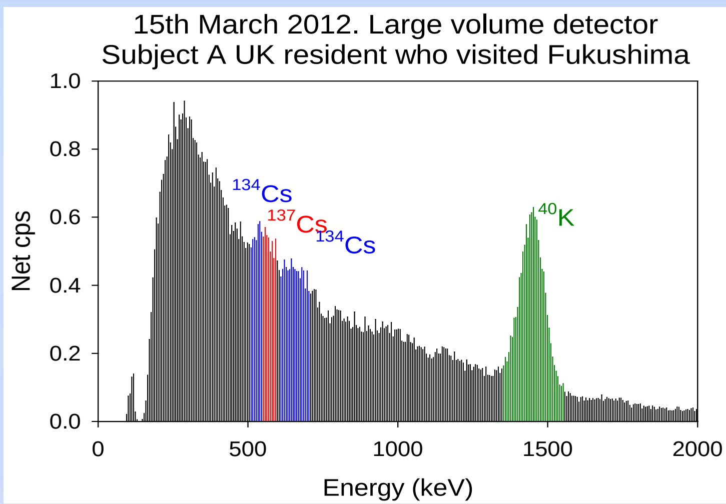
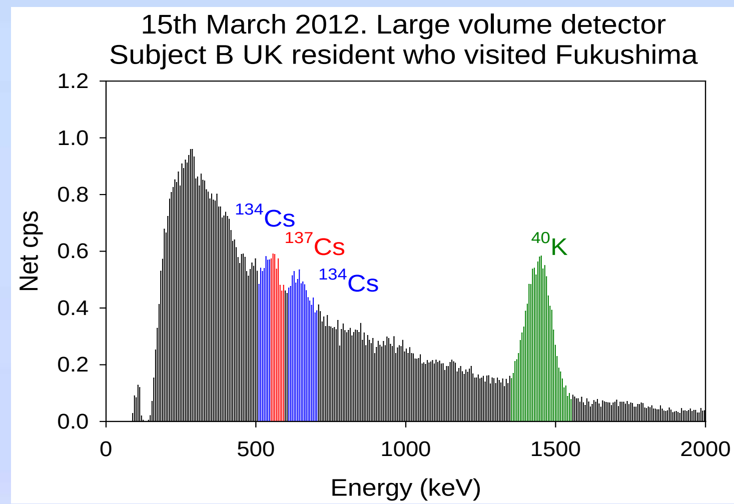
Checks made before and after visiting Fukushima on the first anniversary





Body activity equates with approx 2 Bq kg^{-1} in food dose 0.4 μSv

External radiation 80 μSv, of which 40 μSv was the cosmic ray dose from the air travel

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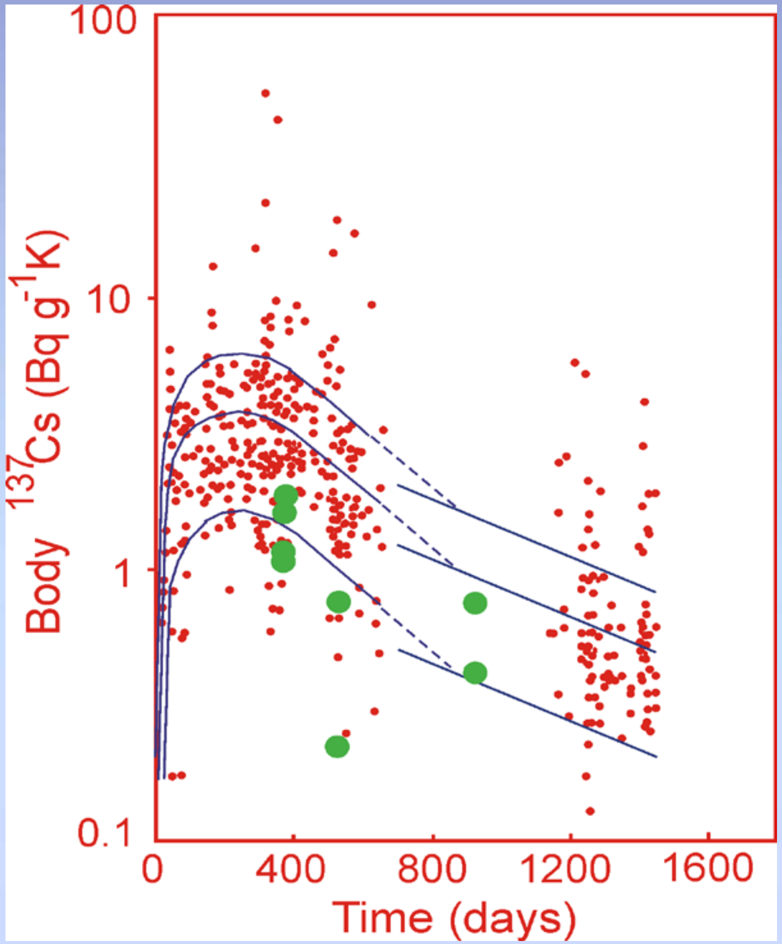
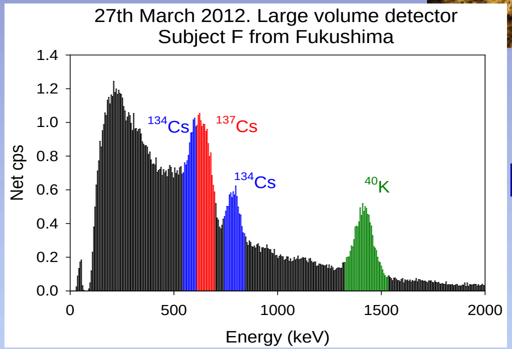
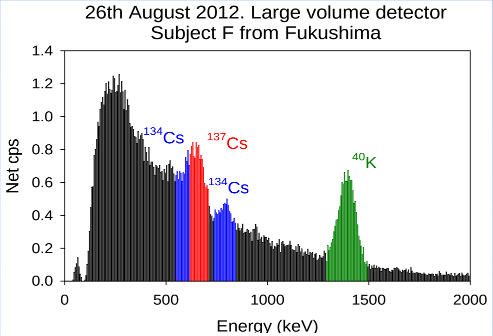
Visitors from Fukushima from 300-900 days after the earthquake

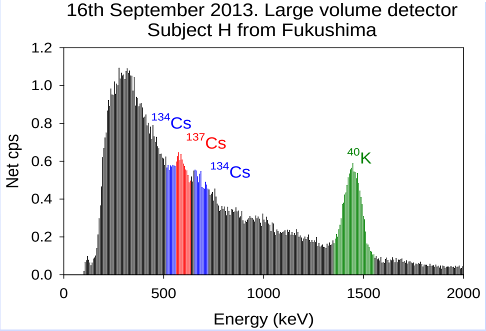




March 2012



Sept. 2012



Sept. 2013

Peak activity 286 Bq, committed dose scaled to East et al 1991 25.4 μSv
Lower than UK post Chernobyl levels, despite the higher levels of deposited activity in Japan compared with UK experience

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Japanese Experience

Example: Tsubokura et.al. PLOS ONE 9 (2014). 30622 subjects Mar 2012-Mar 2013, measurements at Minamisoma & Hirata hospitals

Lower sensitivity than SURRC/SUERC systems, much larger number of participants

Individuals with >50 Bq/kg ^{137}Cs effective annual dose 0.06-0.40 mSv.

Consistent with other studies, 99.9% <1mSv

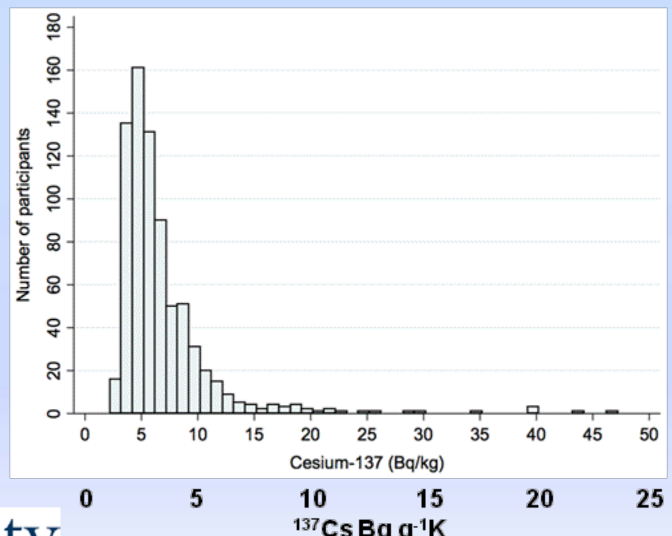
Post-Chernobyl experience would predict larger doses (~5mSv using UNSCEAR 1988 transfer factors)

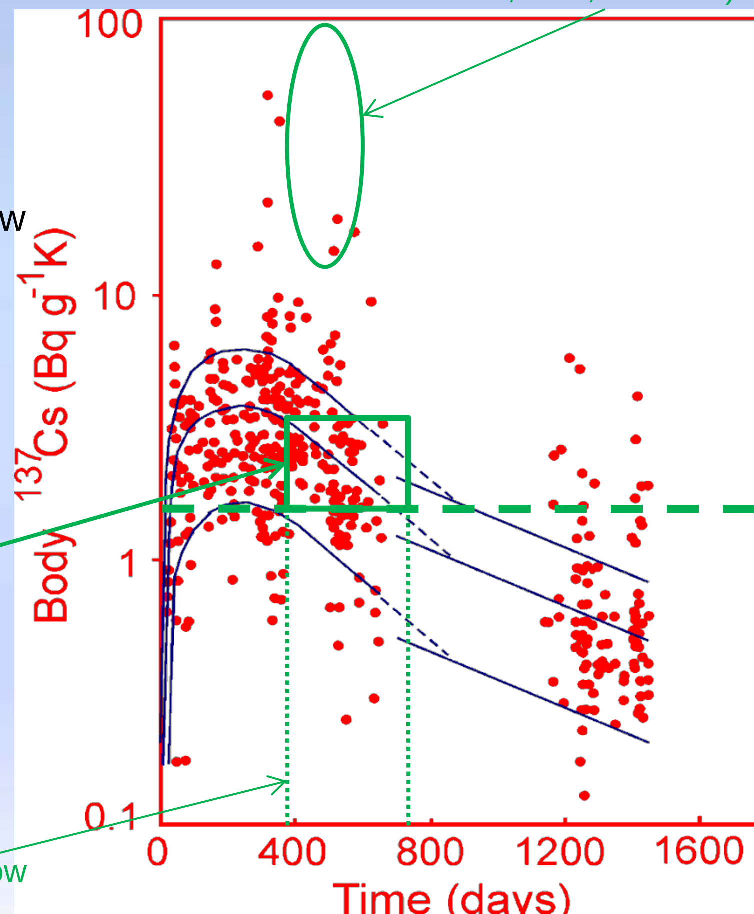
Demonstrates effectiveness of food controls

External exposure most significant in Fukushima

UK experience can predict future reduction in ^{137}Cs in people to below detection limit of systems used in these large studies

Nine >50 Bq/kg ^{137}Cs (consumers of local wild mushrooms, boar, river fish).





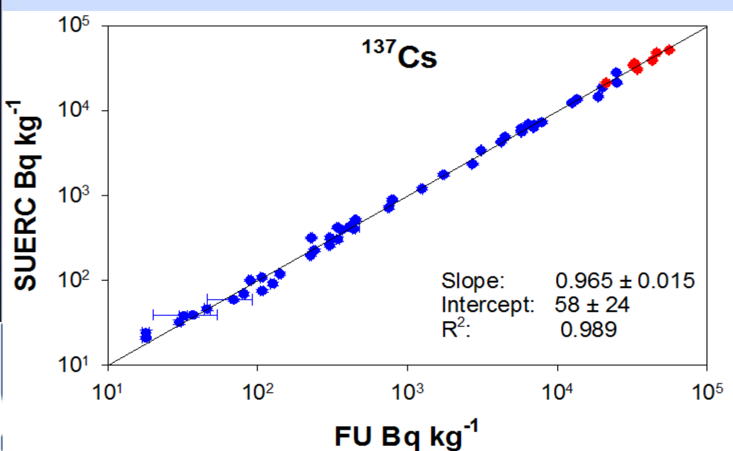
Approx. detection limit

~29000 subjects below detection limit

Validated mapping

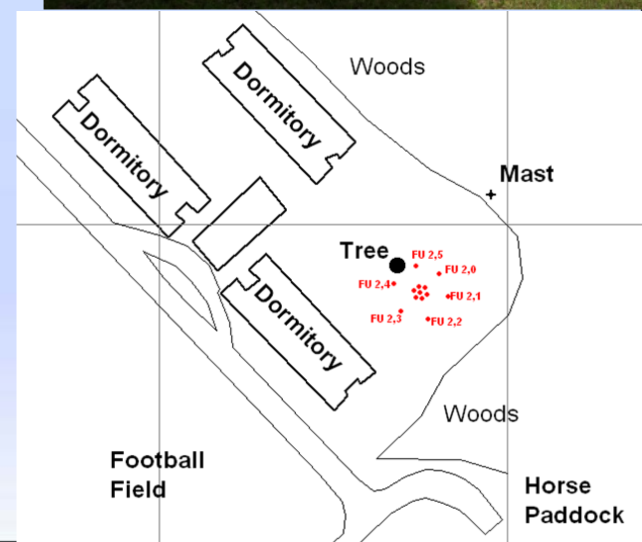
Technical accuracy is an aspect of a definition of effective risk communication.
Laboratory analyses can be validated using reference materials.
Field measurements require reference sites.
Reference sites were established in SW Scotland for validation of radiometric systems as part of the ECCOMAGS project (2001/2).
SUERC/Fukushima University developed two reference sites in 2012
FU Campus and Fruit Tree Research Institute
Lab gamma at FU and SUERC in concordance

Reference values for dose rate and activity per unit area
May be used by any ground based instrument



July 2012 reference values (FU site)

Mean mass depth : 0.9 ± 0.1 g cm^{-2}
^{137}Cs 265 ± 20 kBq m^{-2}
^{134}Cs 165 ± 20 kBq m^{-2}
Dose rate 1.24 ± 0.13 μGy h^{-1}



Urban Mapping in the UK

Over recent years, SUERC have engaged small numbers of non-specialists (students) for radiometric mapping, concentrating on urban areas

Students have learnt about radioactivity, and shared with their peers

Collecting data using instruments with real-time results, and mapping radionuclide distribution, allows non-specialists to understand more about their environment

Recent work has concentrated on two areas:

- The Royal Mile, Edinburgh, connecting the Castle with Holyrood Palace
- Aberdeen, the “Granite City”, in particular the Old Town near the university

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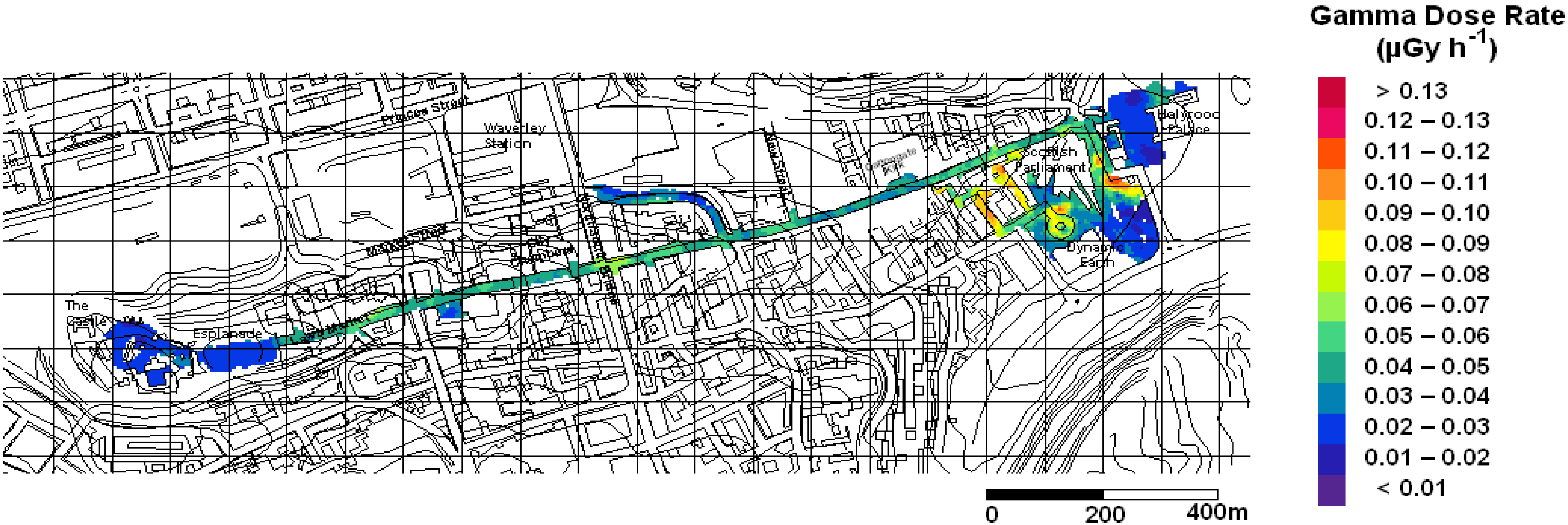
Mapping the Royal Mile, Edinburgh



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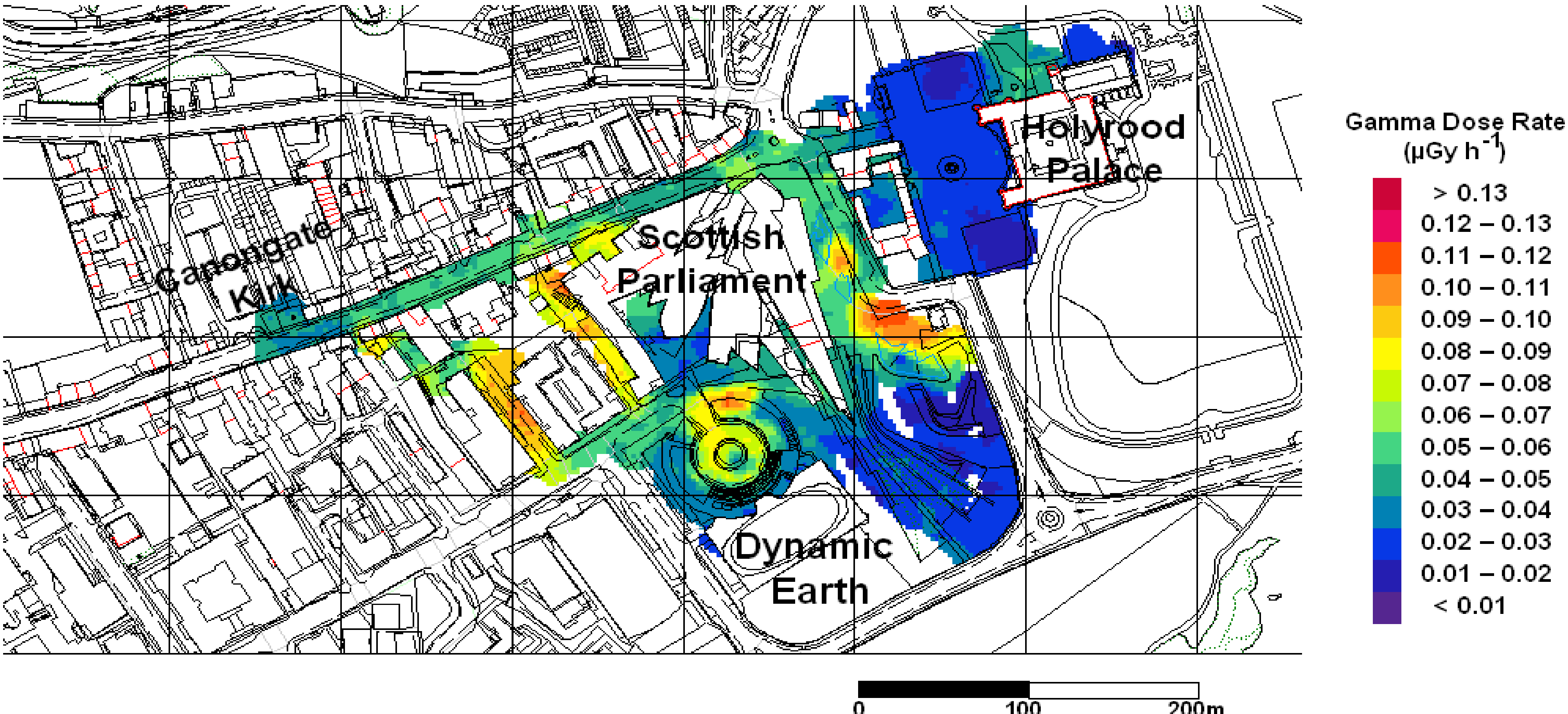
Holyrood Palace
Scottish Parliament
Canongate Kirk
Dynamic Earth
Gamma Dose Rate (μGy h^{-1})
> 0.13
0.12 – 0.13
0.11 – 0.12
0.10 – 0.11
0.09 – 0.10
0.08 – 0.09
0.07 – 0.08
0.06 – 0.07
0.05 – 0.06
0.04 – 0.05
0.03 – 0.04
0.02 – 0.03
0.01 – 0.02
< 0.01
0
100
200m

Old Aberdeen

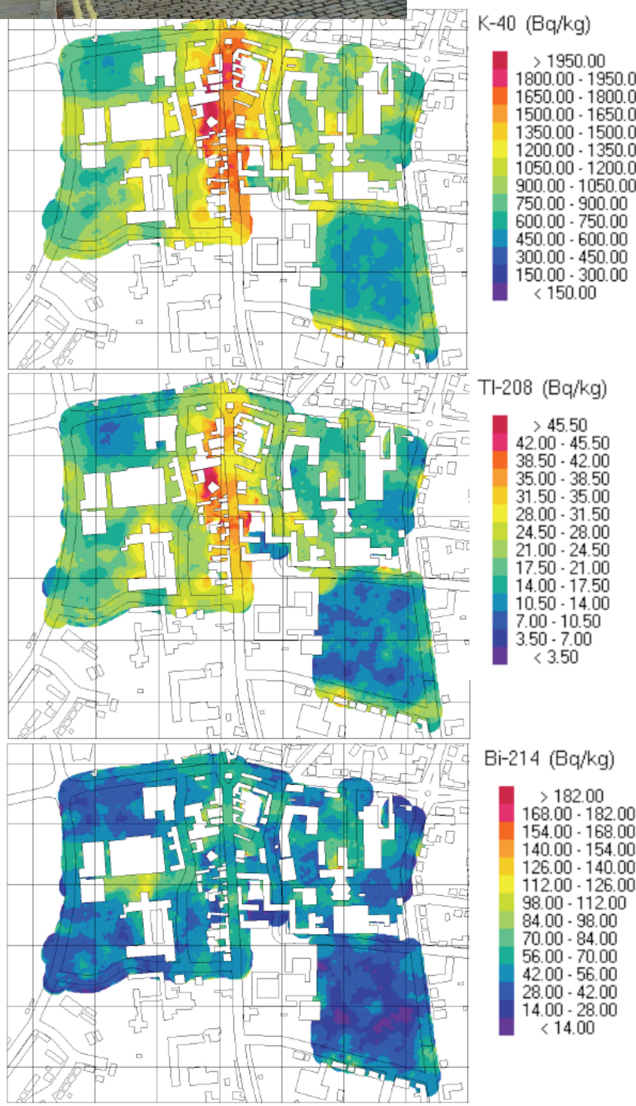

Figure 3. Activity distributions of ^{40}K, ^{208}Tl and ^{214}Bi for Old Aberdeen.

Aberdeen beach – Past discharges to sea of Oil industry NORM scales have led to ^{226}Ra contamination of the beach near Aberdeen Harbour. Red areas show the distribution in 2007 (Hazeldine, 2007).

2007

2013

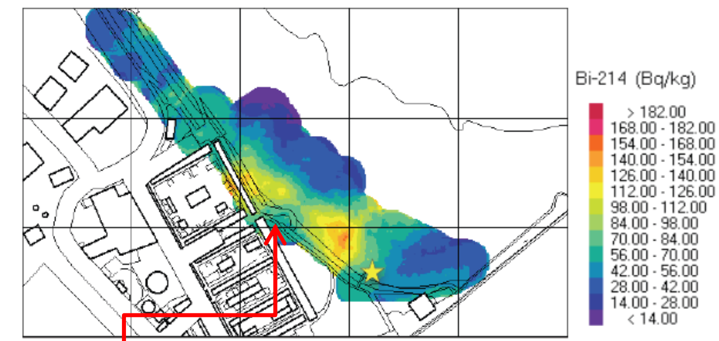

Figure 6. Distribution of activity concentration of ^{214}Bi for Footdee Beach.

The central areas have been decontaminated by SEPA, based on external dose rate criteria. Nuclide specific remapping in 2013 shows the limits of decontamination, and verifies that residues continue to move. Samples are being analysed to reassess active phases.

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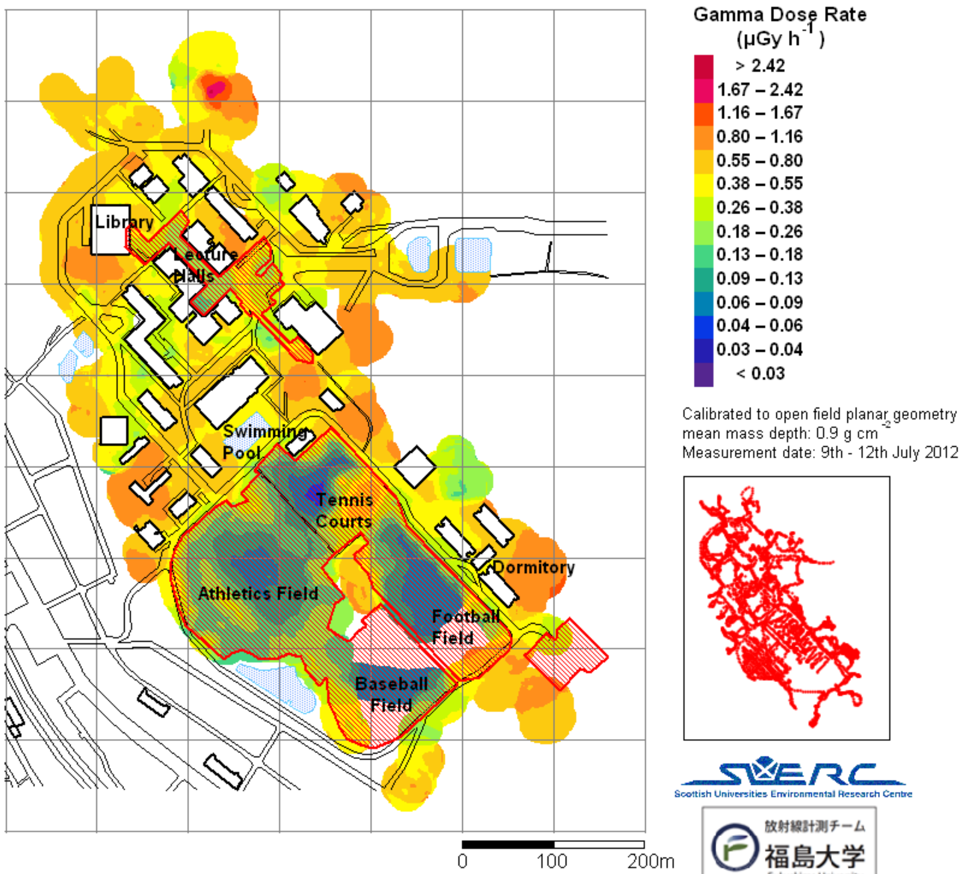
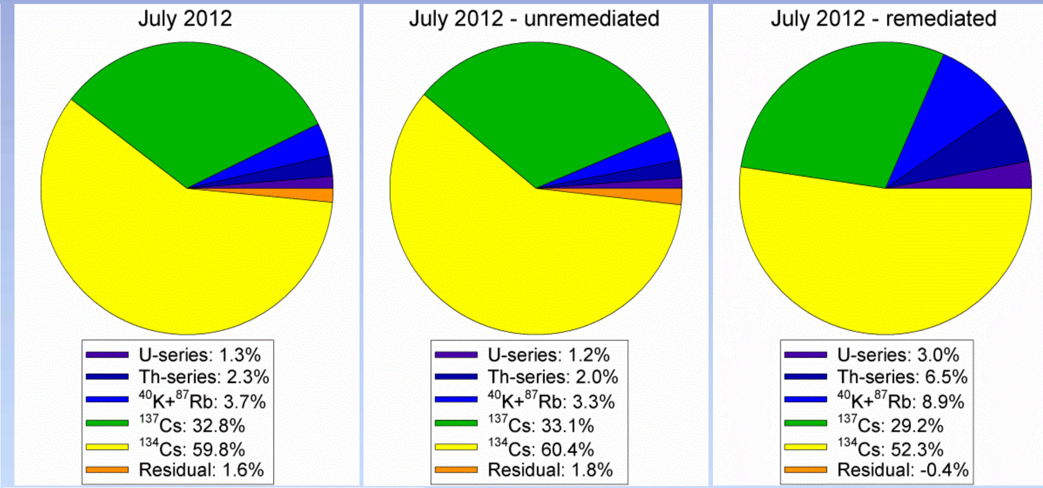
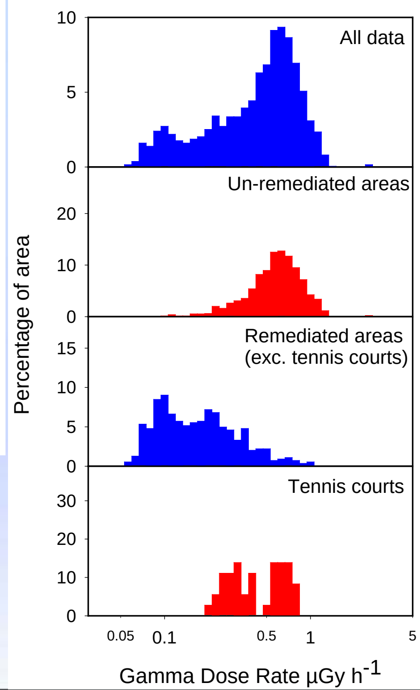
Apportionment of dose rate: Remediation







Fukushima University Campus July 2012

Areas remediated prior to survey show factor 4 reduction in dose rate

Corresponding decrease in Cs contribution to dose rate

Sanderson, et.al. (2013) Validated Radiometric Mapping in 2012 of Areas in Japan Affected by the Fukushima-Daiichi Nuclear Accident.
http://eprints.gla.ac.uk/86365

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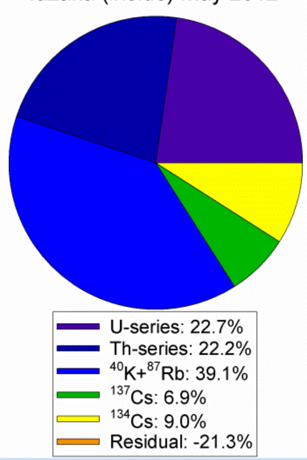
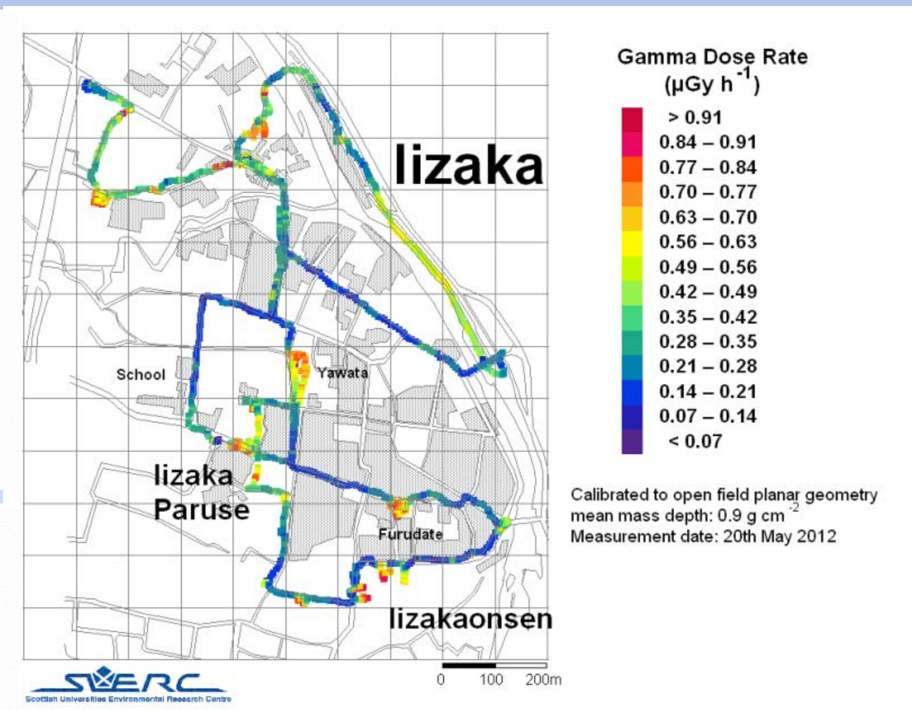
Apportionment of dose rate: Lifestyle

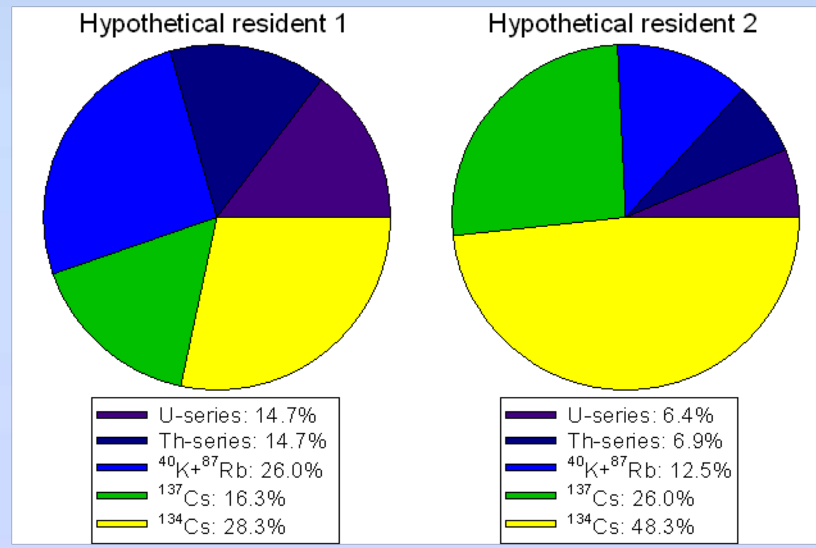
Based on May 2012 backpack survey data of public spaces and building interiors
Two hypothetical individuals who live and work in the same area.
What dose do they receive? What proportion due to Cs?

Iazaka (inside) May 2012

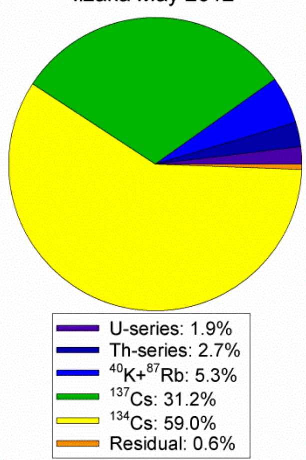




Hypothetical lifestyle:
1 – office worker (40h/week), outside for short periods (8h/week)
2 – outside worker (40h/week)



Iizaka May 2012



	Resident 1	Resident 2
Total annual dose (mGy) in 2012	0.46	1.07
$^{134}Cs+^{137}Cs$ (mGy) in 2012	0.21	0.79

Sanderson, et.al. (2013) Validated Radiometric Mapping in 2012 of Areas in Japan Affected by the Fukushima-Daiichi Nuclear Accident. http://eprints.gla.ac.uk/86365

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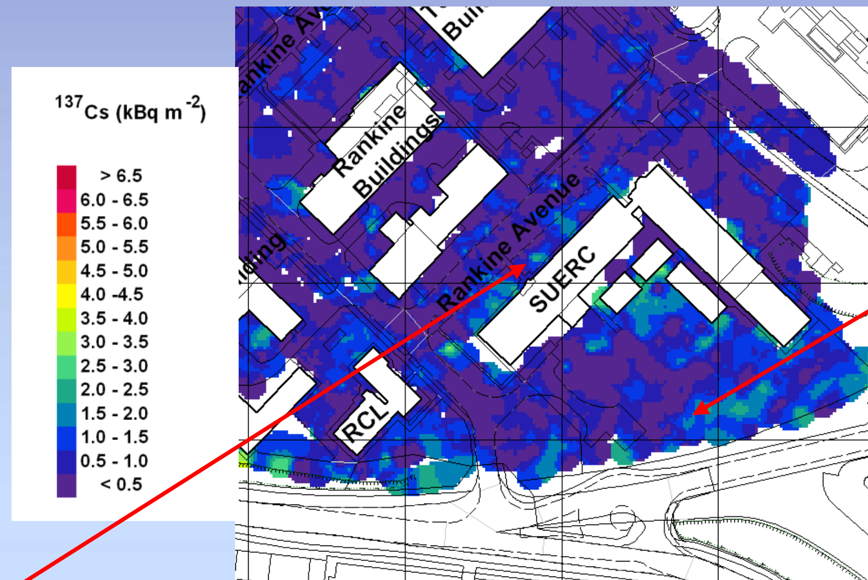
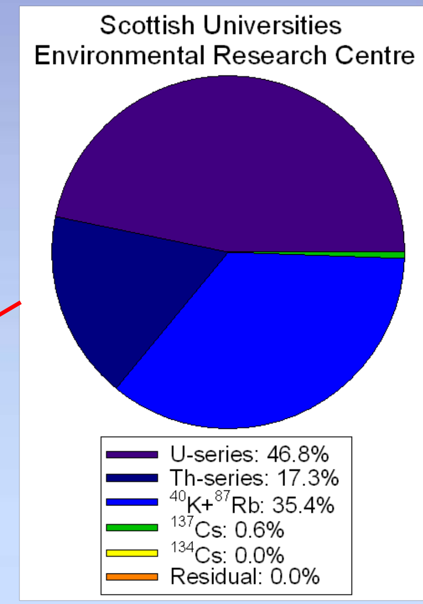
Apportionment of dose rate: Longer Time Scale

1988: In-situ measurements and soil cores from front of SURRC building. 52% of dose rate due to ^{134}Cs & ^{137}Cs

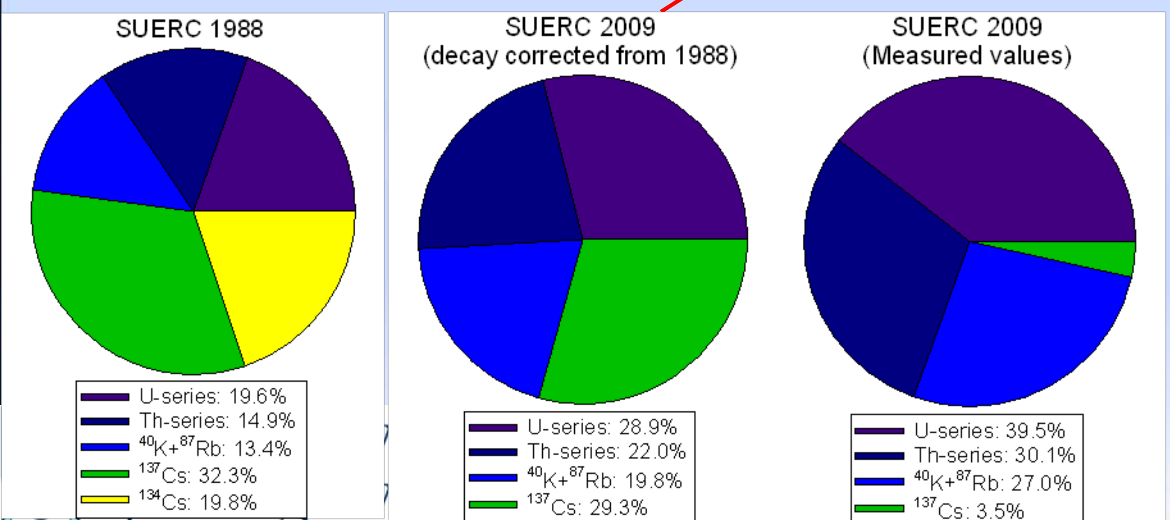
2009: Backpack measurements from front of SUERC building. 3.5% of dose rate due to ^{137}Cs

Physical decay alone should give 29%, self-remediation evident





Cresswell et.al. J.Env.Rad 124 (2013), 22-28.



2009: Backpack measurements from back of SUERC building. 0.6% of dose rate due to ^{137}Cs.

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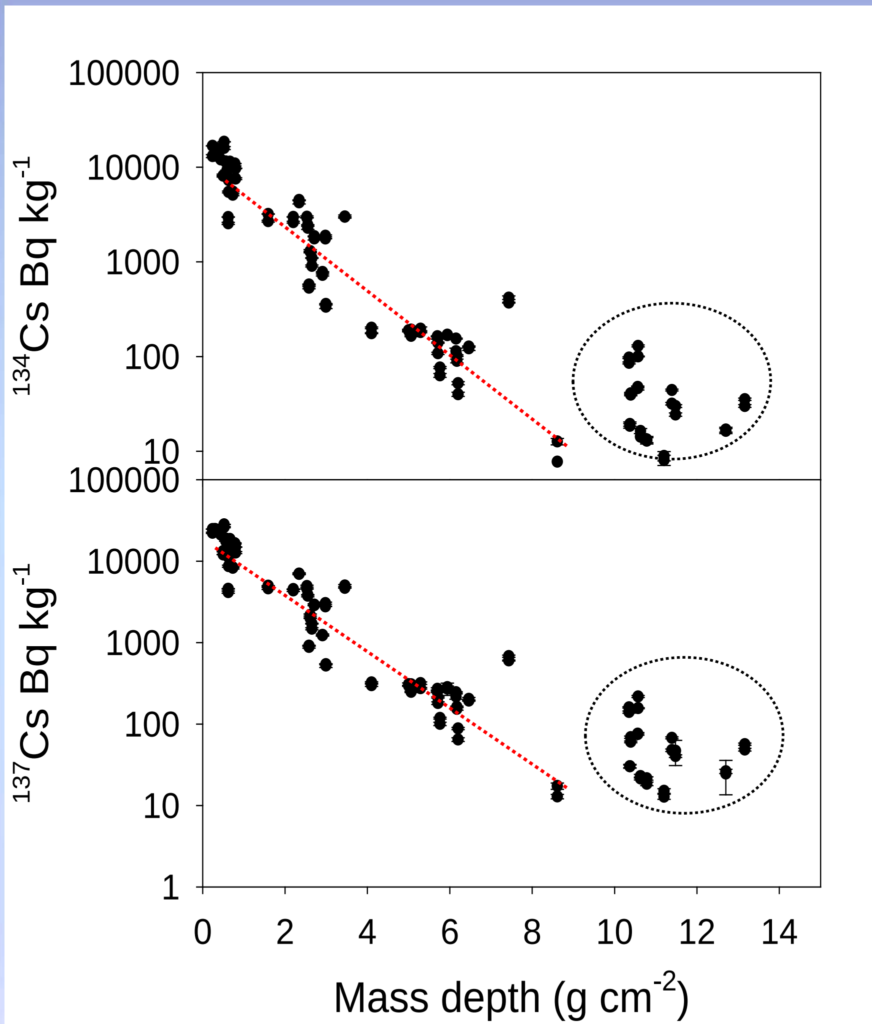
A behavioural study of radionuclide contamination of Japanese Soils from Fukushima



- Are there speciation or isotopic differences between ^{134}Cs, ^{137}Cs and ^{129}I in Japanese soils at different depths?
- Feasibility study under investigation by Dr. G MacKinnon, Prof. D. Sanderson, Dr. Sheng Xu, Dr. A. Cresswell, (SUERC), Dr. B. Seitz (Glasgow)
- Soil cores from calibration sites at Fukushima University & Fruit Tree Research Institute show non-exponential component
- Investigation by sequential extraction methods for radionuclide speciation from samples at different depths
- Measurement by high resolution gamma spectrometry & AMS

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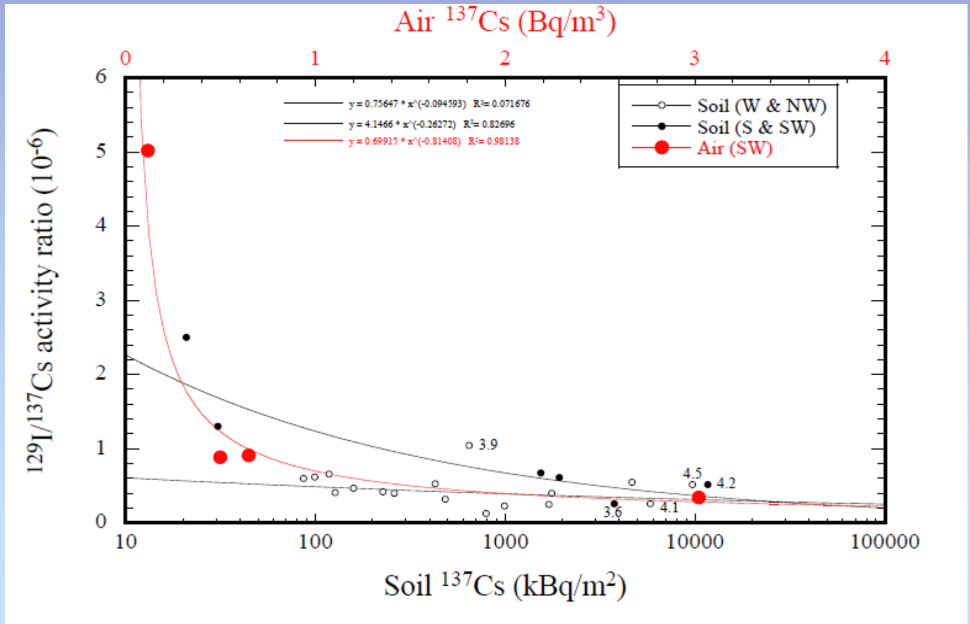
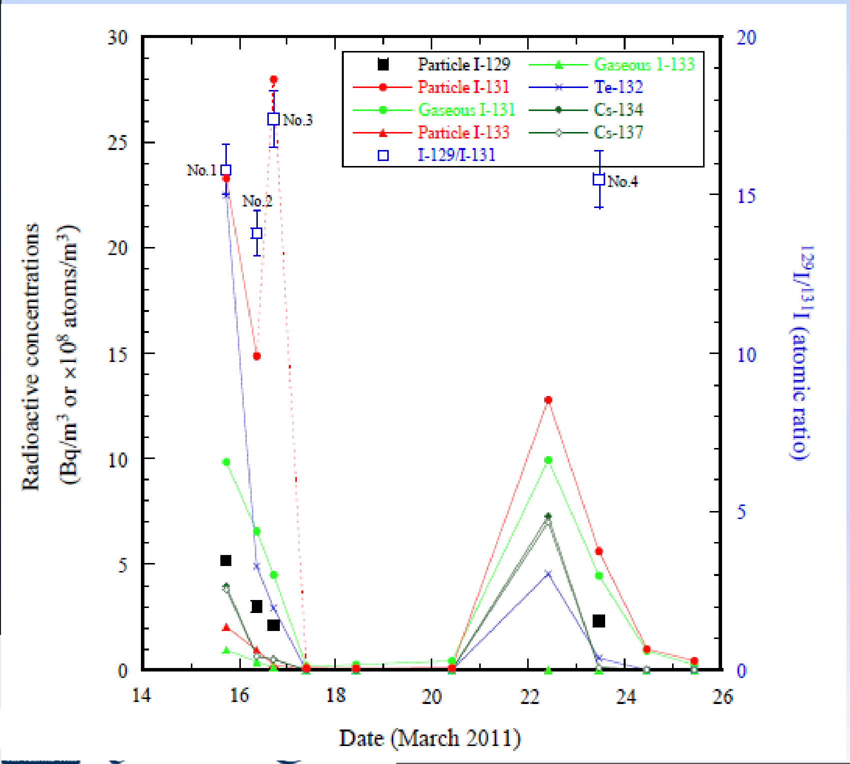
^{129}I AMS Studies

^{129}I:^{137}Cs ratios much more variable, especially at greater distance from the reactor (lower ^{137}Cs activity per unit area). Estimation of ^{131}I deposition from ^{137}Cs measurements unreliable





Data from air filters, Tsukuba, March 2011 show constant ^{129}I:^{131}I ratio, consistent with water (Fukushima University) and soil samples. ^{129}I measurements can be used to reconstruct ^{131}I deposition. (Xu et.al. Env.Sci.Tech 47(2013), 10851-10859).

Cedar needles and bark shown to retain ^{129}I offering possible means of verifying reconstructed ^{131}I deposition pattern from reanalysis of AGS data (Torii et.al. Health Phys 105 (2013), 192-200)

Scottish Universities Environmental Research Centre

Forest Remediation

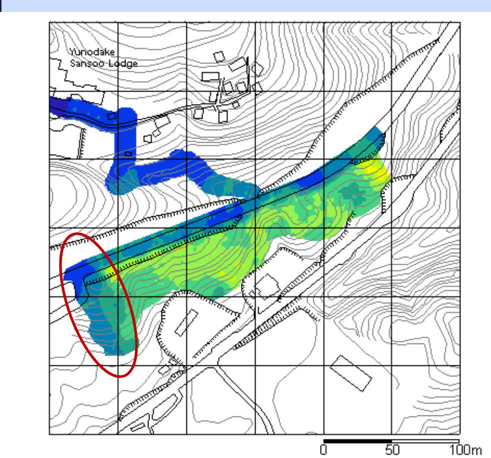
January 2013: Fieldwork with the Iwaki “Friends of the forest NGO” to map contamination prior to community resourced forest litter removal

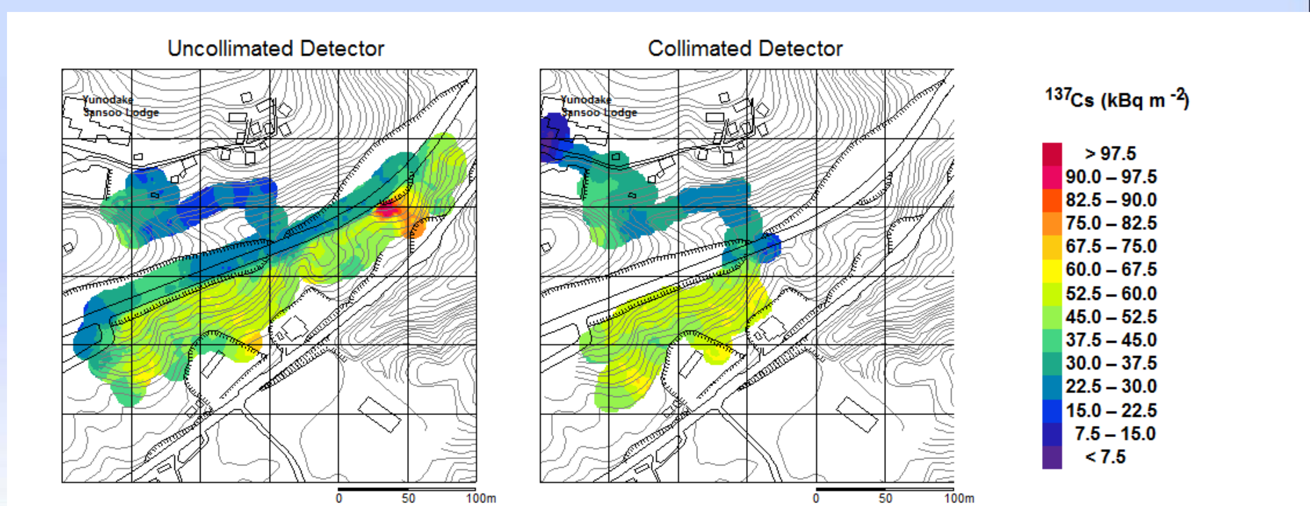
15x45m area, 2.1 tonnes of forest litter removed. 5 people, 160 person hours. Dose incurred approx. 50µSv
Dose rate reduction 0.31 µSv/h to 0.22 µSv/h. Dose rate from waste store: 0.62 µSv/h

February 2014: Repeat survey after litter removal shows 35-40% radiocaesium removed.

Kazuyoshi MATSUZAKI (Chairman Yunodakesansonai)
Tstomu TAKANO (Forest Research Centre)
Yasunori BAHARA (Hokkaido University)
Hirohisa YOSHIDA (Tokyo Metropolitan University)
Jenri TANAKA (Nagoya University)

Collimated detector system attenuates radiation from canopy by ~50%

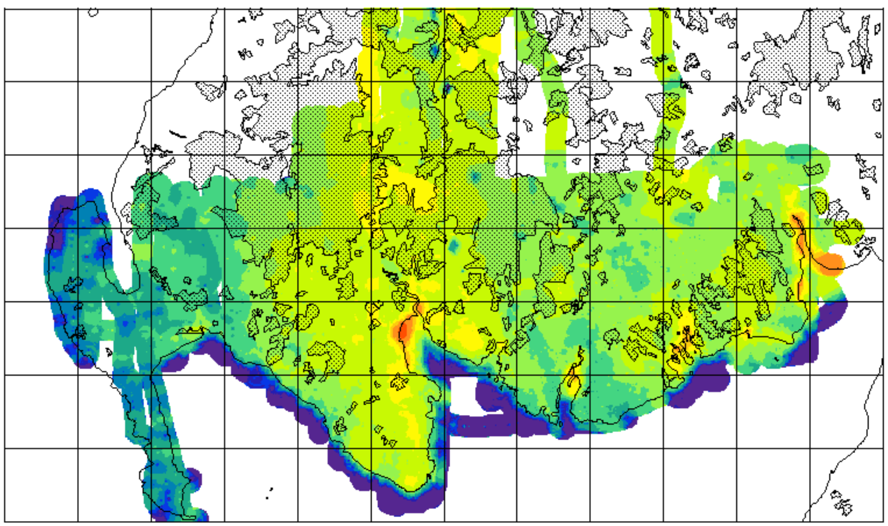




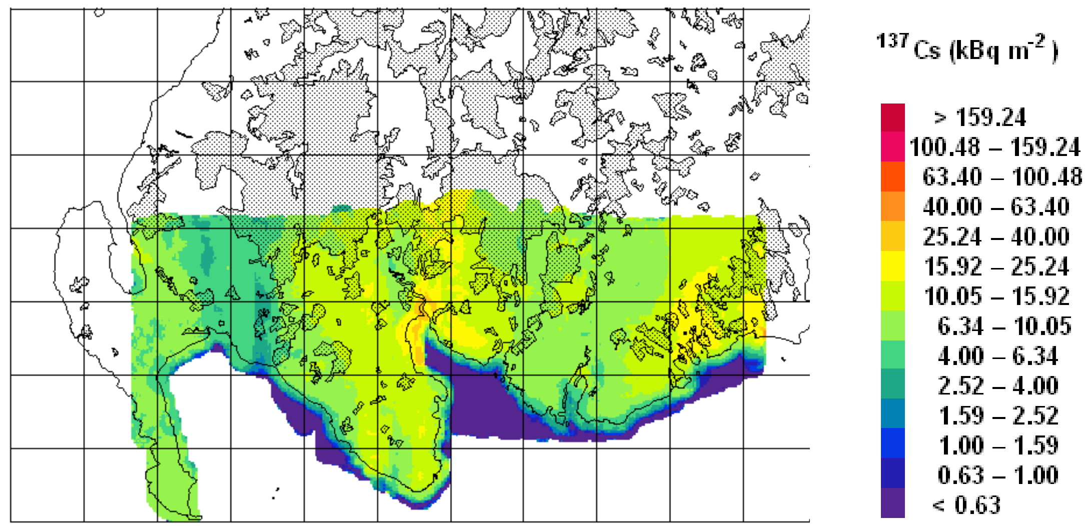
UK Forest Experience

In UK, and rest of Europe, large areas of forest were contaminated in 1986.
Active remediation not pursued on a large scale.
What has happened with just self-remediation?
Several areas covered in two SUERC airborne surveys with forested areas
What would 2014 look like? What would this tell us about the next 20 years in Japan?

1993 Scottish Office Survey



2002 ECCOMAGS Exercise



Conclusions

It is suggested that anxiety and fears about environmental radiation exposure are not alleviated by simple risk based discussions.

There is a requirement to rebuild trust and credibility for communication to occur.
An exchange of knowledge and understanding is a promising approach.
This includes engagement with affected communities and individuals, to identify and address their fears and perceptions, and increase public knowledge and understanding of radioactivity through transparent and cooperative activities.

External validation is an important part of this, as is discussion, self awareness and direct observation. Important role for independent organisations.

Conclusions

In the examples shown here, both in the UK and in Japan, food chain contamination does not present the major pathway for public exposure. Moreover on the basis of the cases discussed it appears that Japanese food controls are highly effective. Nonetheless it is understandable that food chain contamination should be a cause of concern.

For dose minimisation external exposure pathways are more important. Remediation is an important part of this, despite the cost.

"proactive risk communication, coupled with public involvement in the remedial process, is critical to the success of any remedial activity" (WHO, 2013)