

Radiologische und radioökologische Aspekte des Reaktorunfalles von Fukushima

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IAEA

International Atomic Energy Agency

Inhalt

- Erste Gegenmaßnahmen
- Expositionspfade
- Freisetzung in die Atmosphäre
- Freisetzung ins Meer
- Dosisleistung in der Umgebung
- Radionuklide in Nahrungsmitteln
- Exposition im Nordwesten Gegenmaßnahmen
- Fukushima und Tschernobyl
- Andauernde Aktivitäten

Erste Gegenmaßnahmen

Early countermeasures

- **11 March**

- 14:46 Earthquake
- 19:03 Nuclear emergency declared
- 20:50 Instruction for evacuation within 0-2 km
- 21:23 Evacuation within 2-3 km, Stay indoors within 3-10 km

- **12 March**

- 05:44 Evacuation within 10 km
- 18:25 Evacuation within 20 km

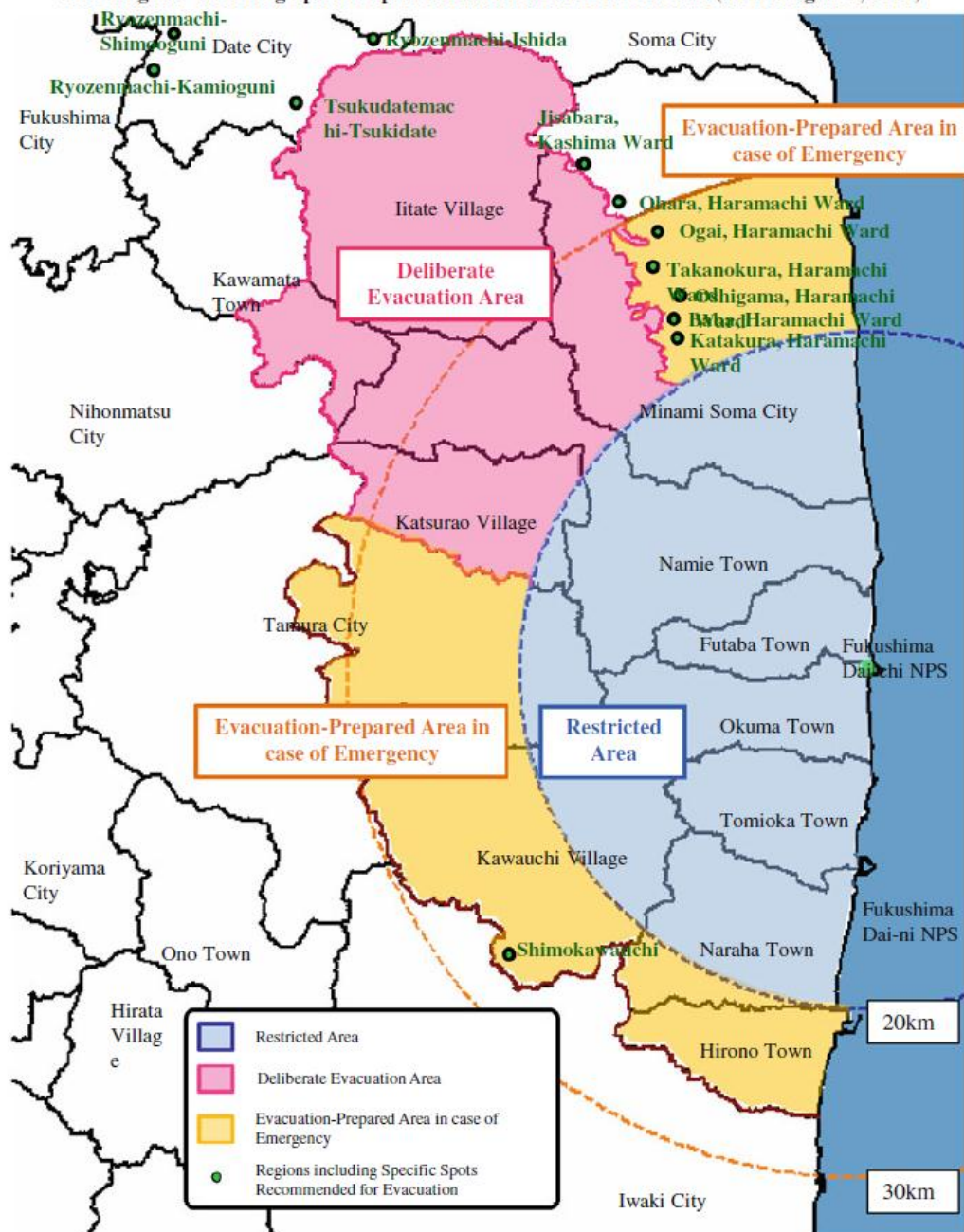
- **15 March**

- 11:00 Stay indoors within 20-30 km

- **22 April**

- Recommendation to leave the area NW outside 20 km

Restricted Area, Deliberate Evacuation Area, Evacuation-Prepared Area in case of Emergency
And Regions including Specific Spots Recommended for Evacuation (As of August 3, 2011)



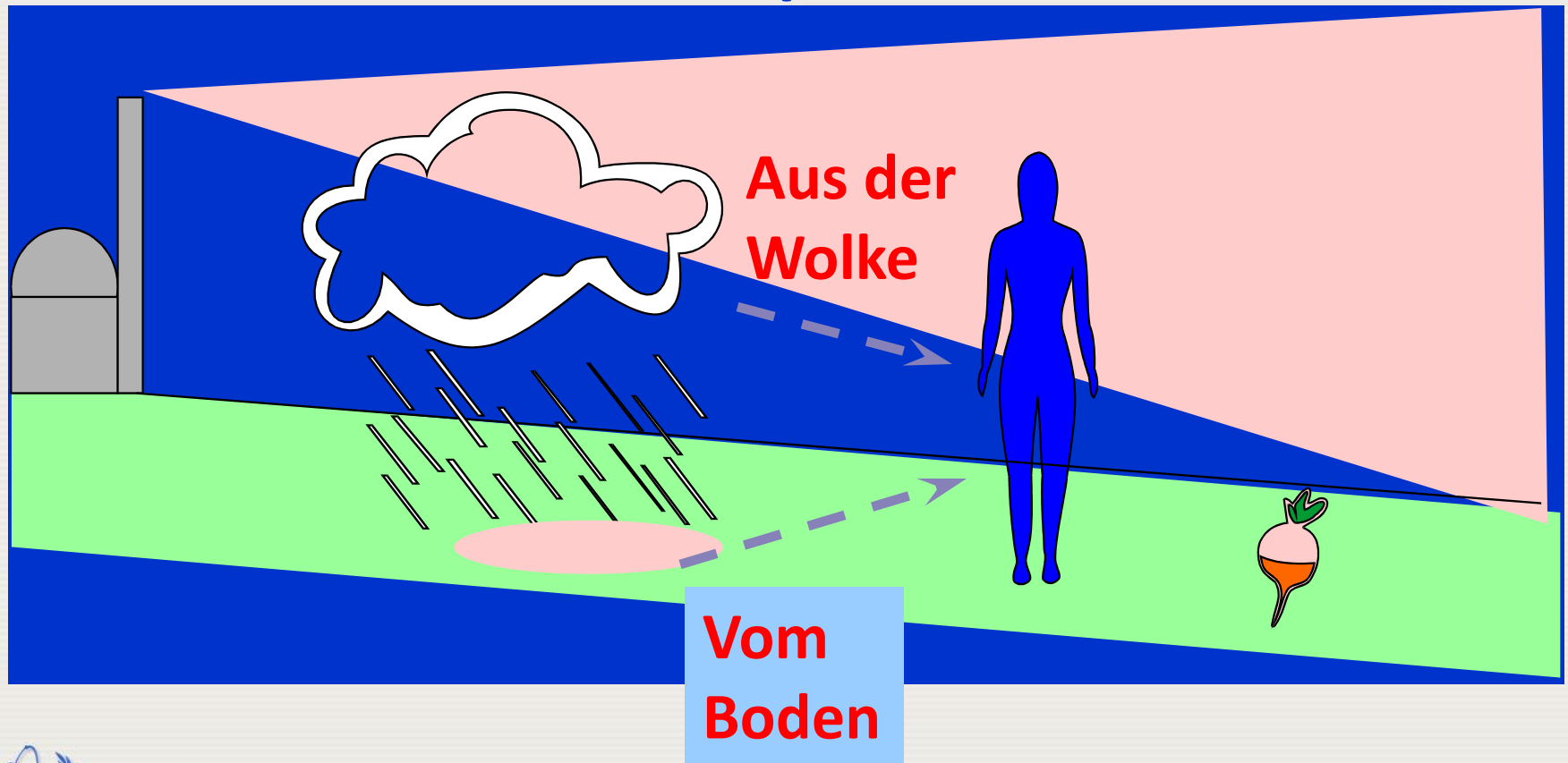
Areas with instructions
or recommendations
for evacuation or
staying indoors

K. Akahane et al. (2012): The Fukushima Nuclear Power Plant accident and exposures in the environment, *The Environmentalist*
DOI 10.1007/s10669-011-9381-2

Expositionspfade

Expositionspfade

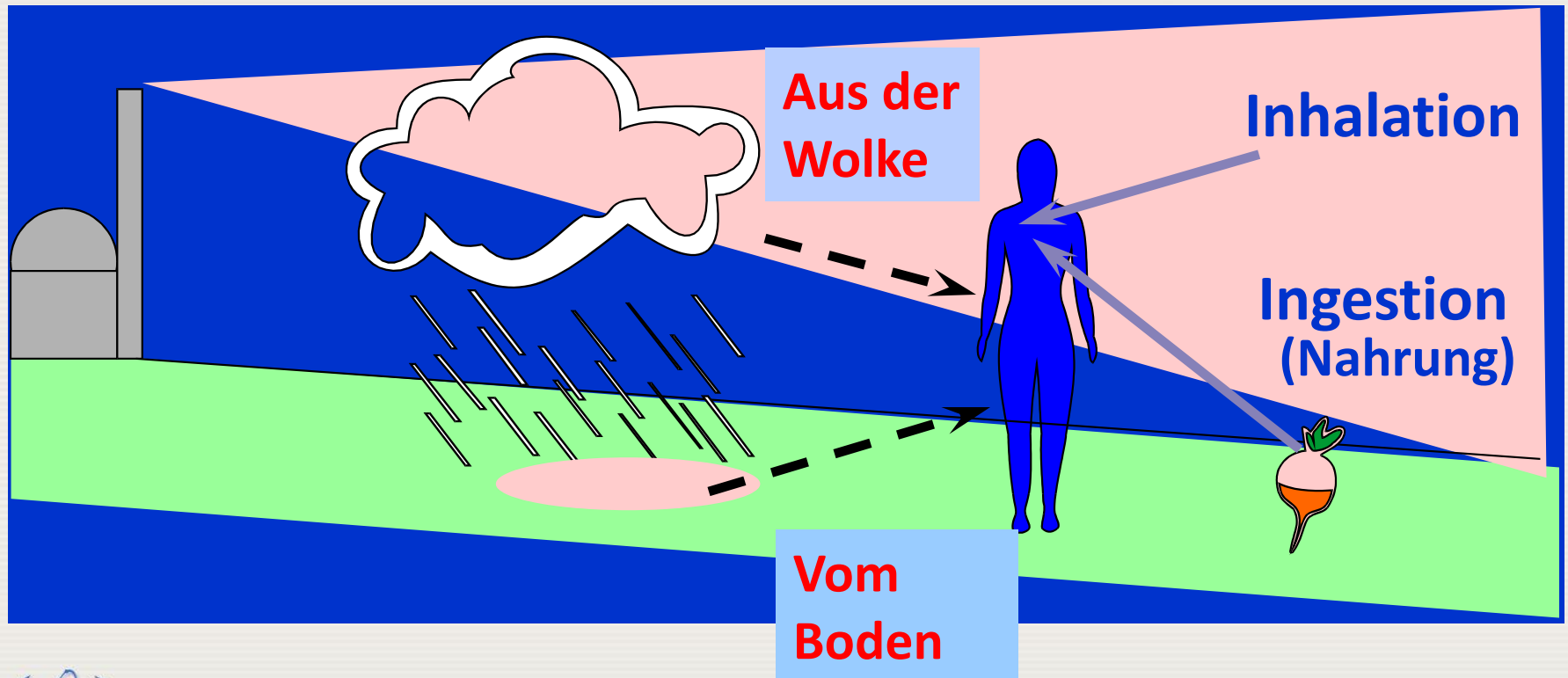
Externe Exposition



Expositionspfade

**Externe
Exposition**

**Interne
Exposition**



Strahlenexposition

Effektive Dosis (Sievert)

- Energiedosis:
 - Absorbierte Energie/Masse
- Qualitätsfaktor
 - “Biologische Wirksamkeit” verschiedener Strahlenarten (alpha-, beta- gamma-Strahlen)
- Gewebe-Wichtungsfaktor
 - Empfindlichkeit der Organe hinsichtlich Kanzerogenität

Aggregiert

- Externe und interne Exposition
- Alle Strahlenarten
- Expositionen aller Organe

Natürliche Strahlenexposition (UNSCEAR 2008)

Quelle	Jährliche effektive Dosis (mSv/a)	
	Durchschnitt	Bandbreite
Ingestion	0.3	0.2 - 1
⁴⁰ K U- und Th- Zerfallsreihe Kosmische Radionuklide	0,17 0,12 0,01	
Inhalation	1.256	0.2 - 10
U- Th- Zerfallreihe Radon (²²² Rn/ ²²⁰ Rn und Zerfallsp.)	0,006 1,25	
Externe Exposition	0.87	0.6 - 2
Kosmische Strahlung (0 m NN) Natürliche Nuklide im Boden	0,39 0,48	0,3 - 1 0,3 - 1
Gesamt	2.4	1 - 13

Medical exposure

- Global average (UNSCEAR 2008)
 - **0.6 mSv/a**
- German average (BfS, 2010)
 - **1.8 mSv/a**

Typische Werte für die effektive Dosis häufiger Röntgenmaßnahmen (Bundesamt für Strahlenschutz, 2009)

- Untersuchungen mit Röntgenaufnahmen
 - **< 0.01** – 1 mSv (Zahn/Wirbelsäule)
- Röntgenuntersuchungen mit Aufnahmen und Durchleuchtung
 - 0.3 – **30 mSv** (Organ/Untersuchungsdauer)
- CT-Untersuchungen
 - 2 – 16 mSv (Kopf/Bauchraum)

Dose limits and reference levels (ICRP, 2007; IAEA 2011)

- Dose limits (Grenzwert)
 - **Planned** exposures
 - Exposure from all **planned** activities must not exceed an effective dose of 1 mSv/a
- Reference levels (Richtwert)
 - Emergency situation: 20 - 100 mSv
 - Existing exposures: 1 - 20 mSv/a



Freisetzung in die Atmosphäre

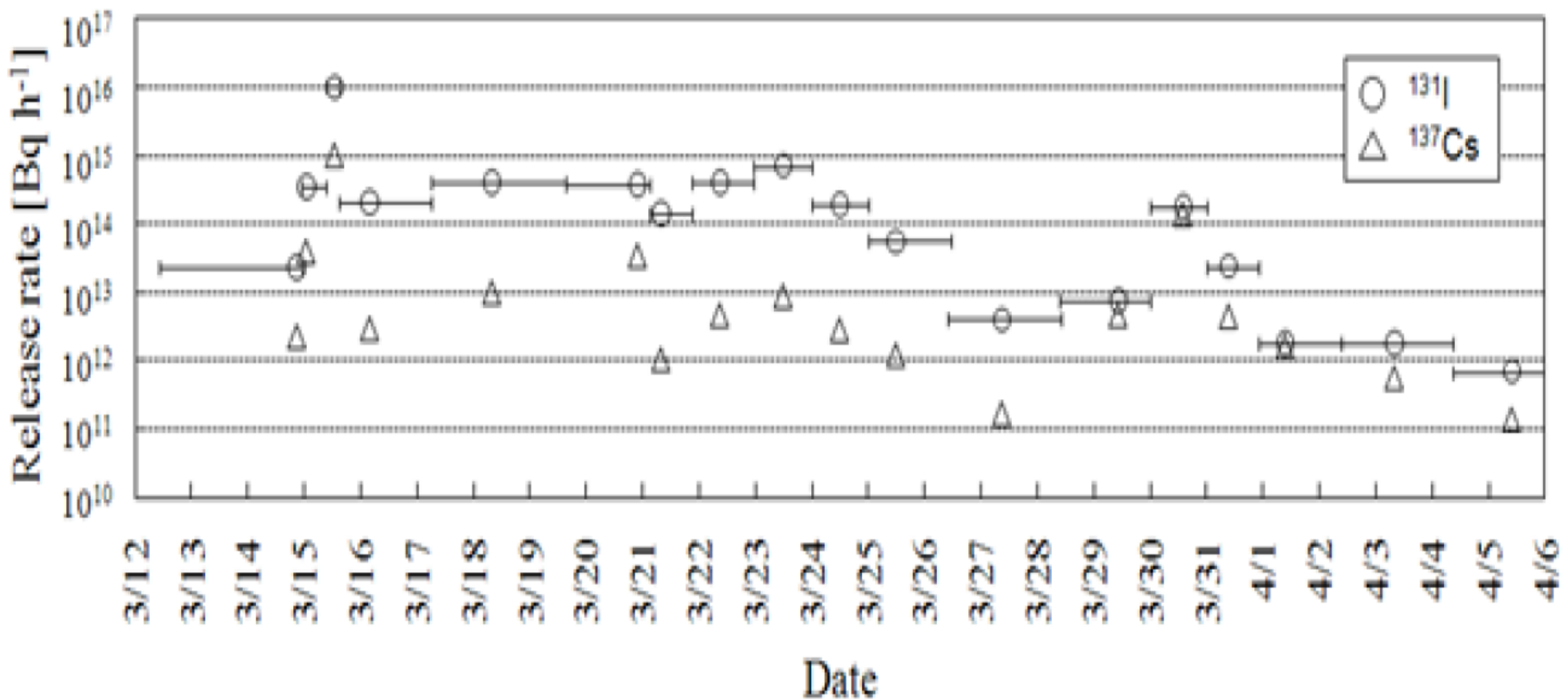
Freisetzung [Bq]

Radionuklid	Fukushima (NISA, 2011)	Tschernobyl (UNSCEAR, 2008)
I-131	$1,6 \times 10^{17}$	$1,8 \times 10^{18}$
Cs-137	$1,5 \times 10^{16}$	$8,5 \times 10^{16}$
Cs-134	$\sim 1,5 \times 10^{16}$	$\sim 4,8 \times 10^{16}$
Sr-90	$\sim 3 \times 10^{12}$	3×10^{15}
Pu-241	Spuren	$2,6 \times 10^{15}$
Pu-238/239/240	Spuren	$\sim 5 \times 10^{13}$



Atmospheric release

- Release maximum:
=> 15 March, ~ 9:00 – 16:00



Radionuclide ratios (~ 17 March 2011)

- $^{134}\text{Cs} / ^{137}\text{Cs}$: ~ 1
- $^{131}\text{I} / ^{137}\text{Cs}$: ~ 10
- $^{132}\text{Te} / ^{137}\text{Cs}$: ~ 20
- $^{90}\text{Sr} / ^{137}\text{Cs}$: ~ 0.0002

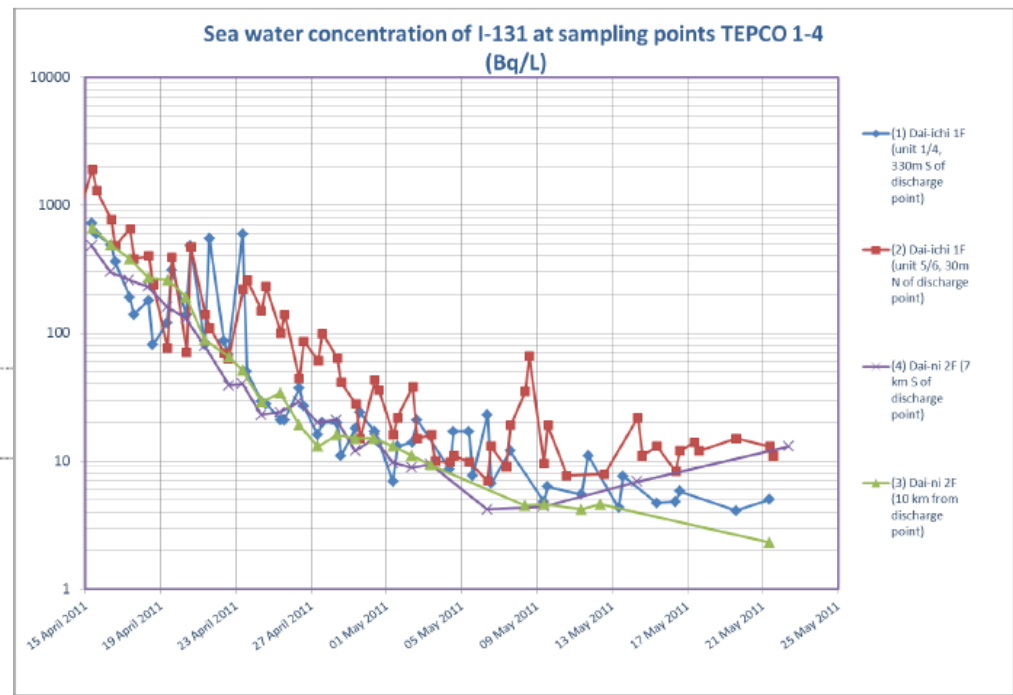
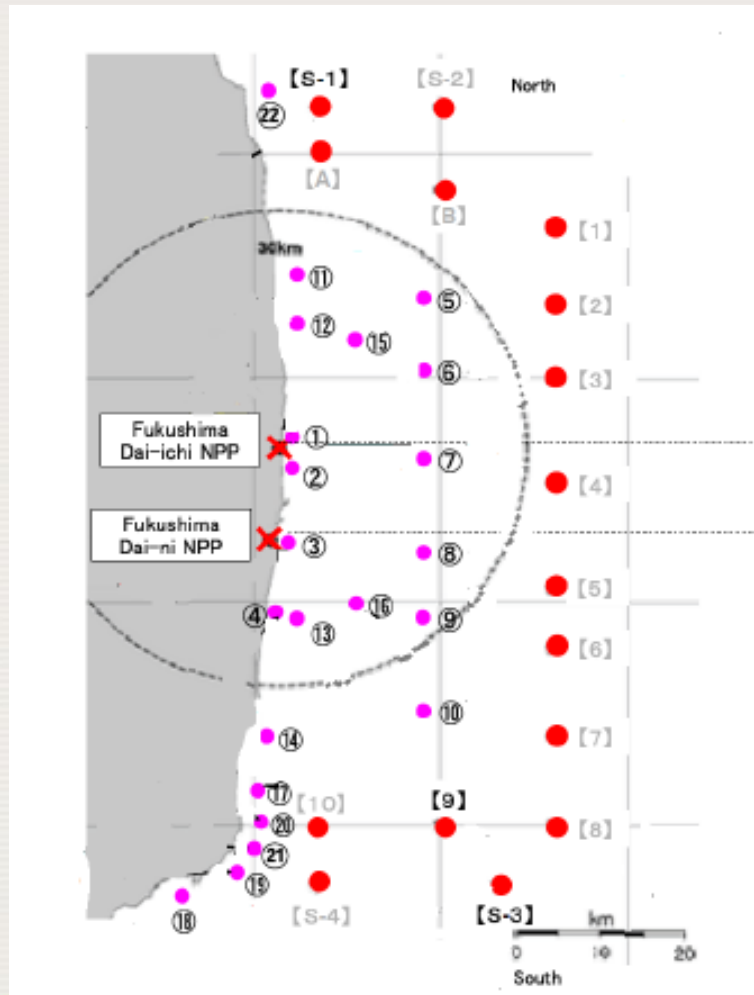
Freisetzung ins Meer

Releases to the sea (NISA, 2011)

- ^{131}I : 2.8×10^{15} Bq
- ^{134}Cs : 9.4×10^{14} Bq
- ^{137}Cs : 9.4×10^{14} Bq

Total: 4.7×10^{15} Bq

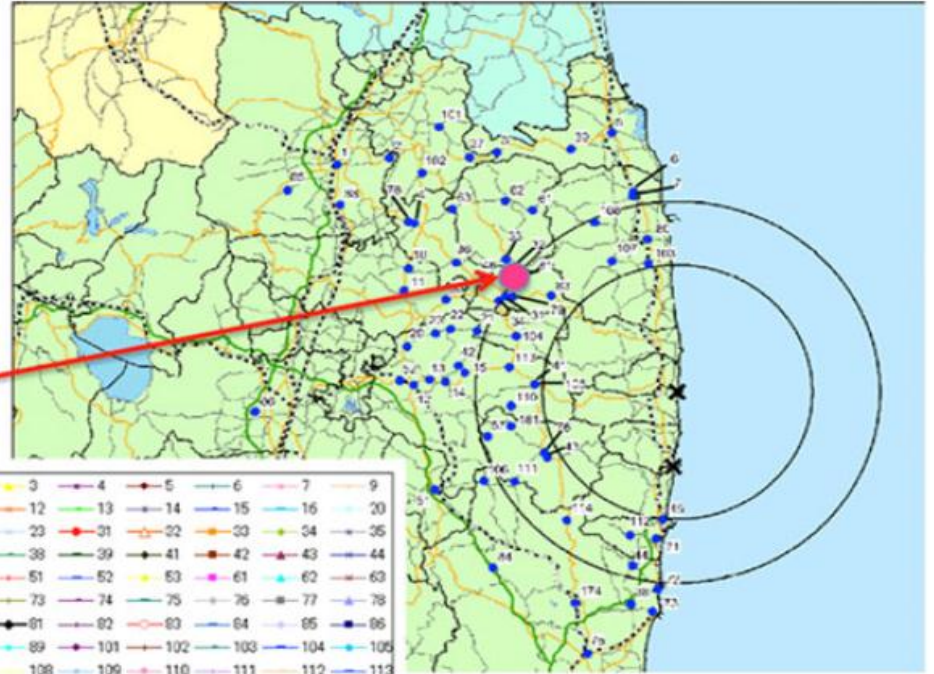
Sea Monitoring Data



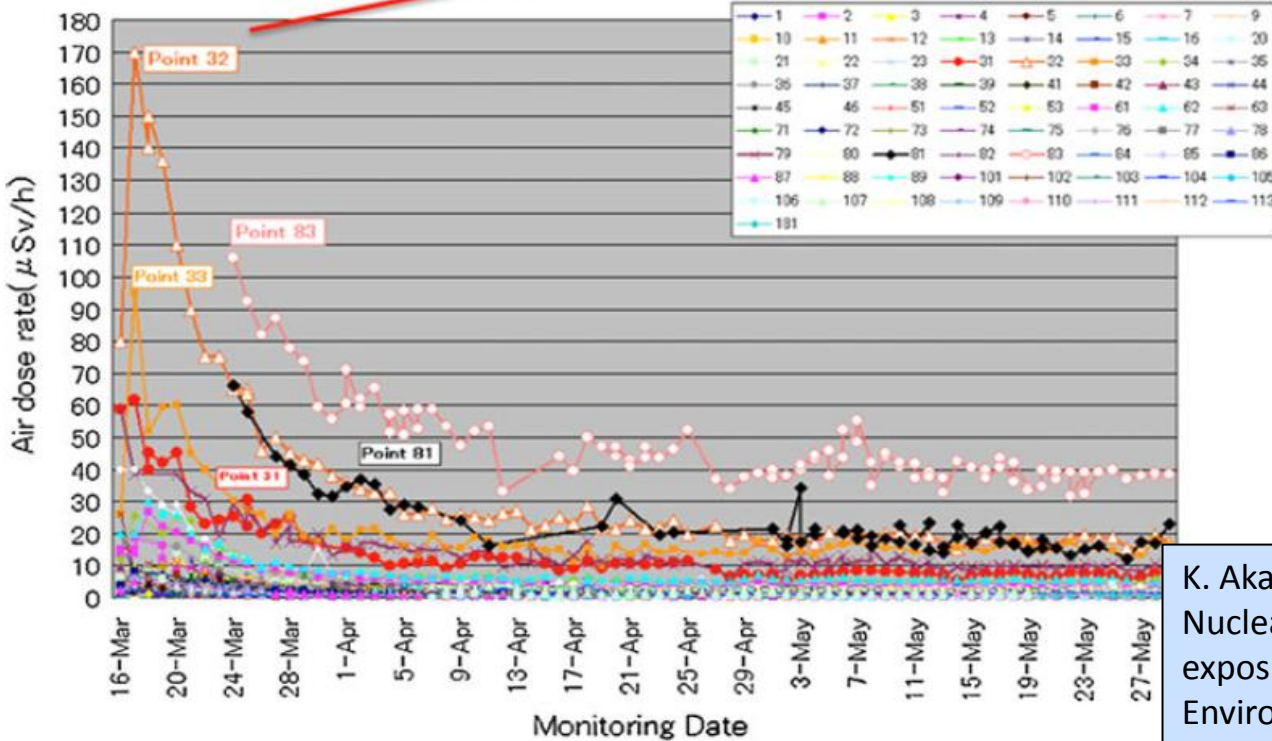
Gamma-Dosisleistung

Gamma dose rates outside 20 km

Highest dose rate
outside 20 km,
~ 170 $\mu\text{Sv/h}$ @ 17 March



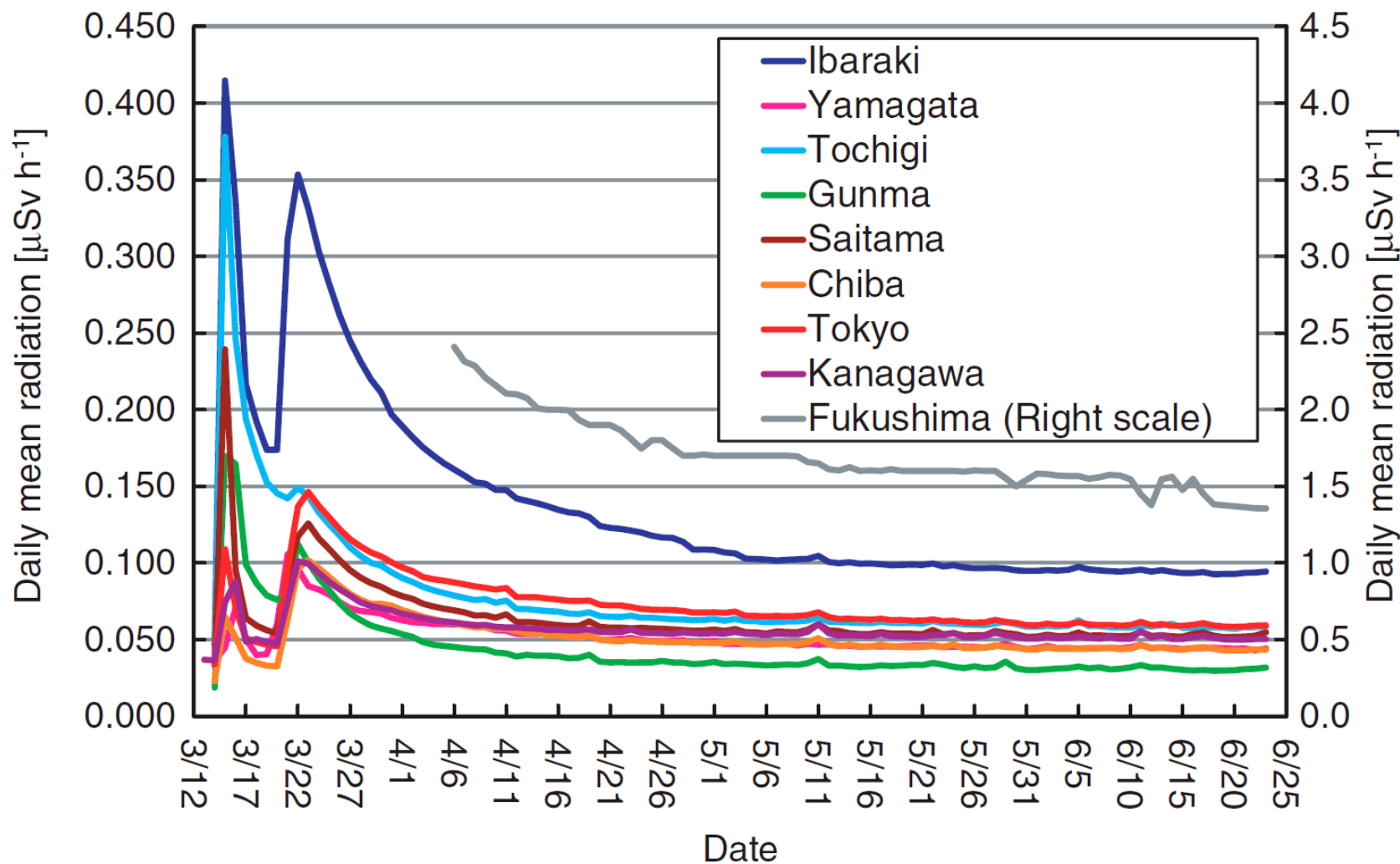
Rate out of Fukushima Dai-ichi NPP



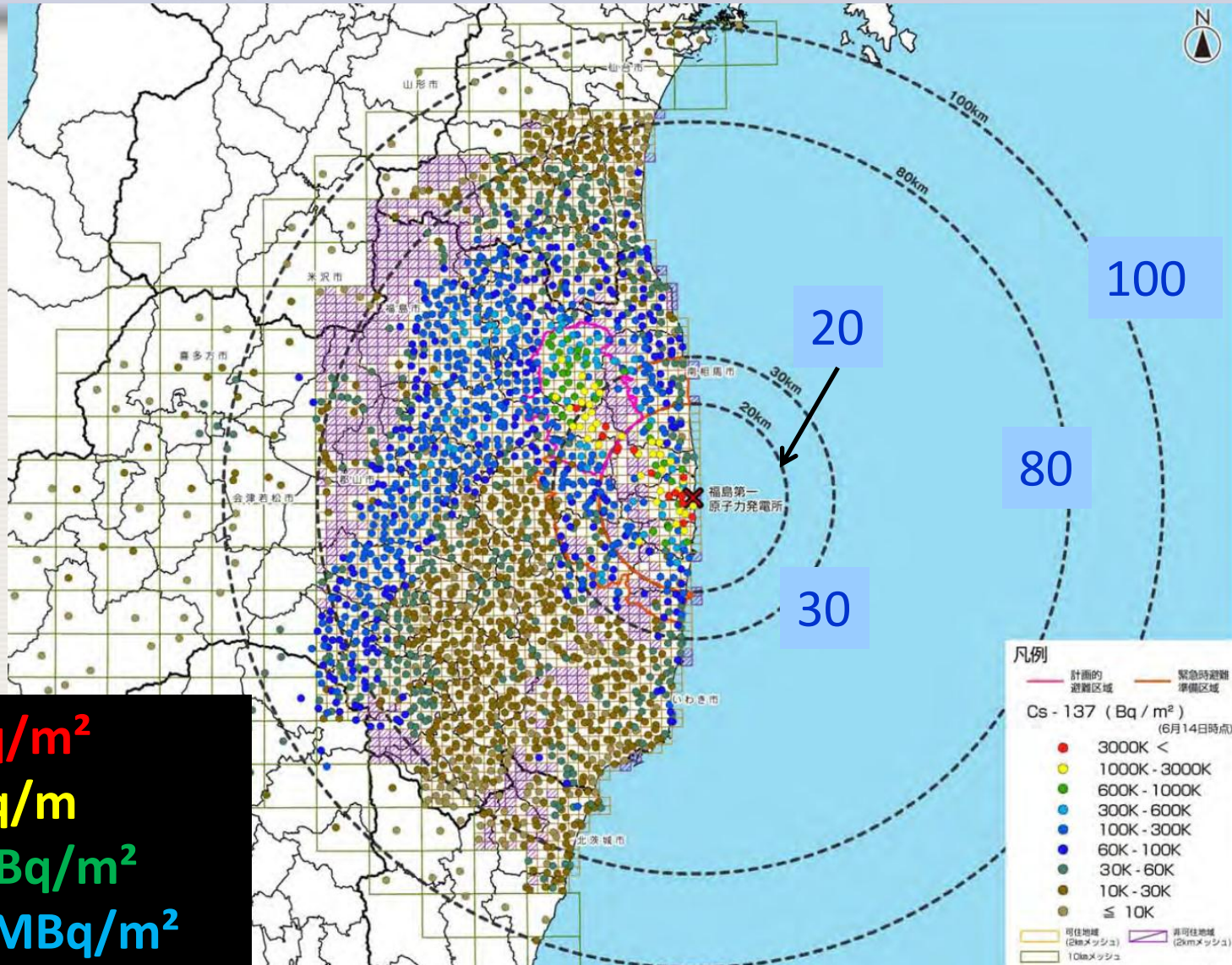
Time Dependence of Air Dose rate at Reading point out of 20 Km Zone of Fukushima Dai-ichi NPP

K. Akahane et al. (2012): The Fukushima Nuclear Power Plant accident and exposures in the environment, The Environmentalist
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Gamma dose rates in adjacent prefectures



Activity of Cs-137 on the ground



> 3 MBq/m²
1-3 MBq/m²
0.6-1 MBq/m²
0.3-0.6 MBq/m²

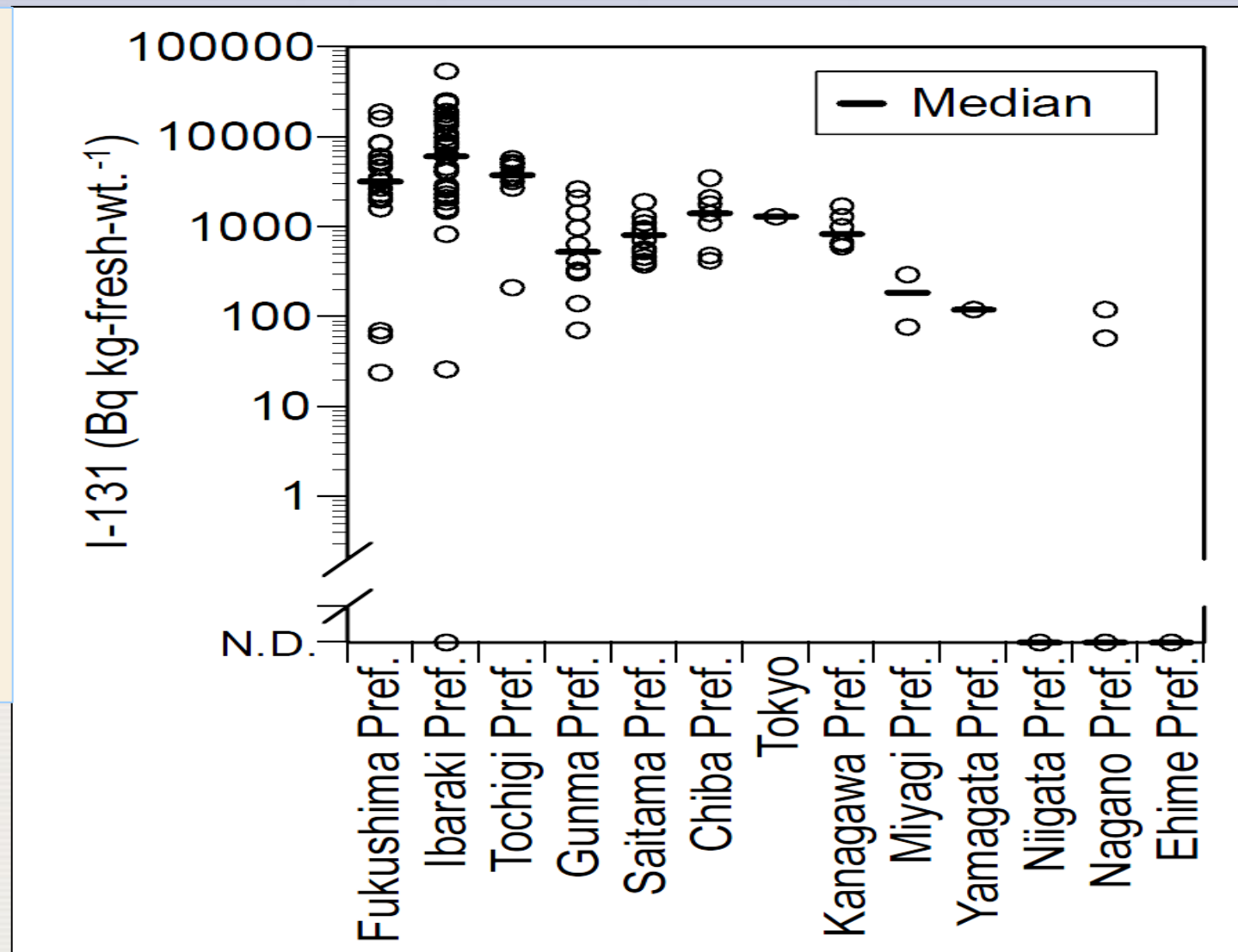
Affected areas (August 2011)

- Annual exposures above 20 mSv/a
 - ~ 500 km²
- Annual exposures from 5 - 20 mSv/a
 - ~ 1300 km²
- 75 % of this area is forest

Activities in foodstuffs

I-131 in spinach in different prefectures, March 2011.

(Ministry of Health, Labour and Welfare, 2011)

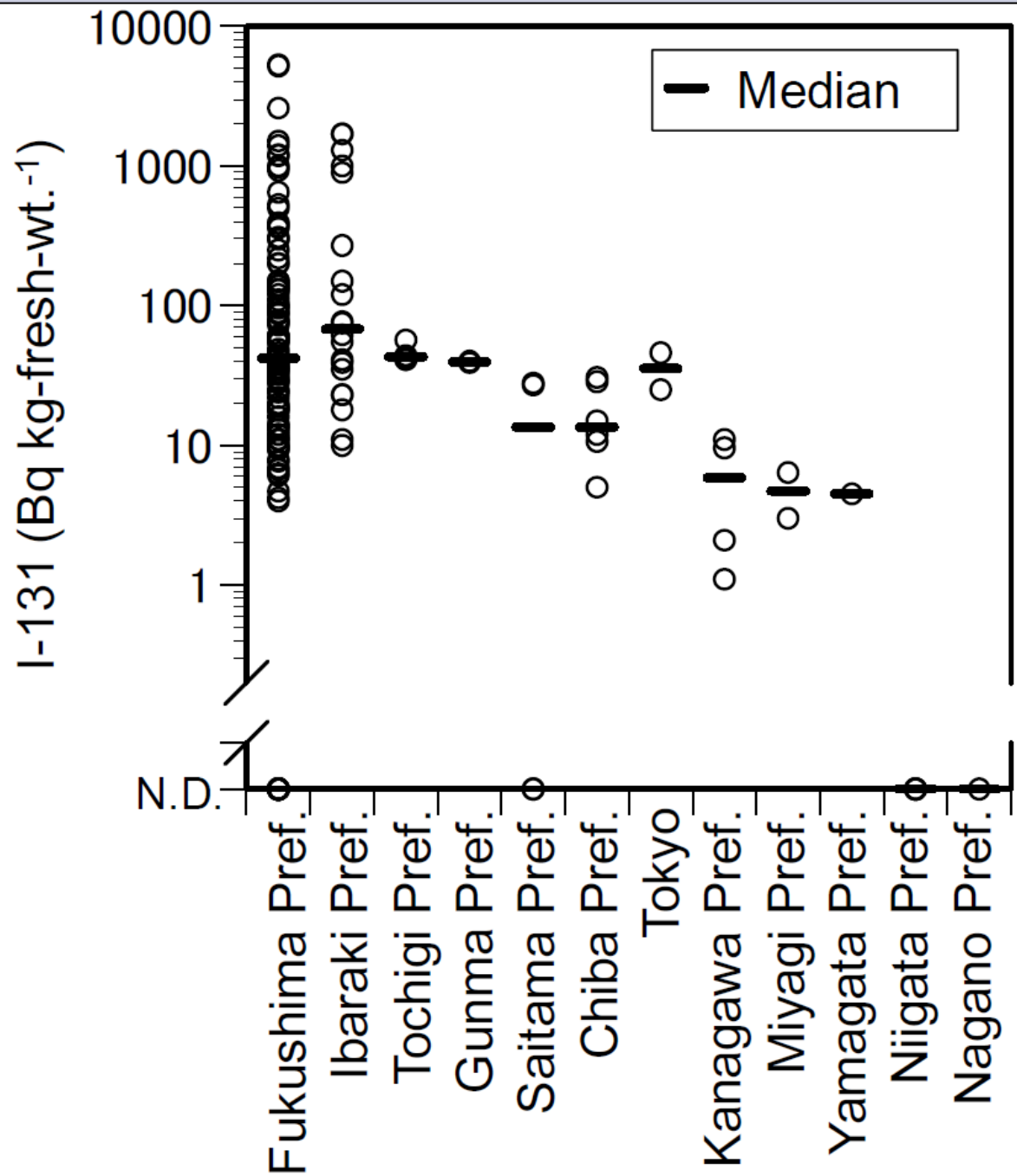


In: M. Murakami, T. Oki:

Estimation of thyroid doses and health risks resulting from the intake of radioactive iodine in foods and drinking water by the citizens of Tokyo after the Fukushima nuclear accident. Chemosphere 2012. In press.

I-131 in milk & milk products in different prefectures, March 2011

(Ministry of Health, Labour and Welfare, 2011a)



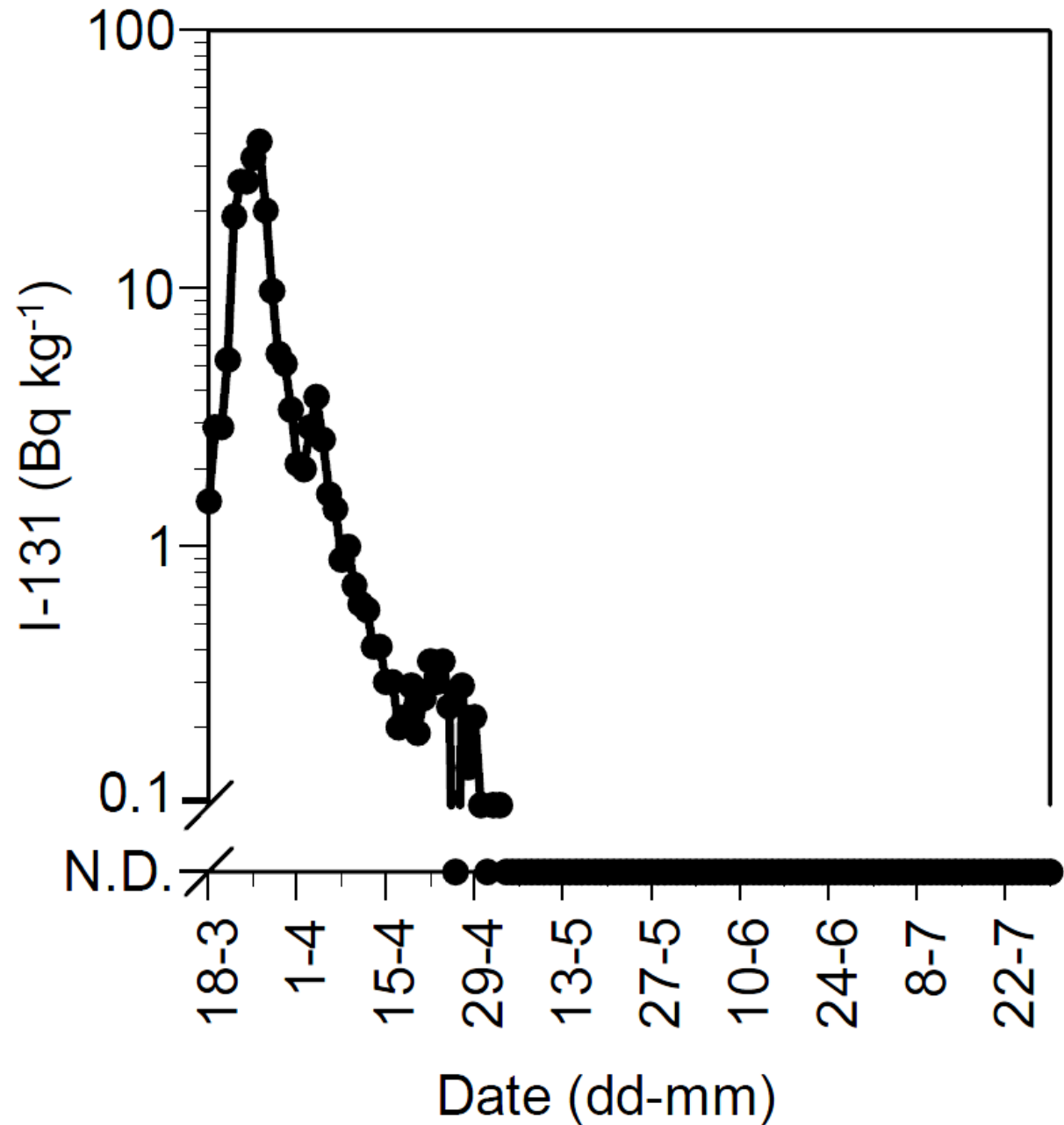
In: M. Murakami, T. Oki:

Estimation of thyroid doses and health risks resulting from the intake of radioactive iodine in foods and drinking water by the citizens of Tokyo after the Fukushima nuclear accident.

Chemosphere 2012. In press.

I-131 in tap water of Tokyo

(Tokyo Metropolitan
Institute of Public Health,
2011)



In: M. Murakami, T. Oki:
Estimation of thyroid doses and health
risks resulting from the intake of
radioactive iodine in foods and drinking
water by the citizens of Tokyo after the
Fukushima nuclear accident.
Chemosphere 2012. In press.

Grenzwerte für Aktivitäten in Nahrungsmitteln

Nahrungsmittel	Radio-Iod (Bq/kg)	Radio-Cäsium (Bq/kg)
Trinkwasser	300	
Milch und Milchprodukte	300	
Blattgemüse	2000	
Sonst. Gemüse		500
Getreide		500
Fleisch, Eier, Fisch		500

Food monitoring

- Intensive food monitoring
 - Focus on Fukushima prefecture
 - Includes also other area
- Data collected in the FAO data base
- Most samples below Japanese limits!

Why?

- Monitoring concentrates on areas close to the limits
- Restrictions on areas with levels above the limits are restricted
 - => **No further monitoring**

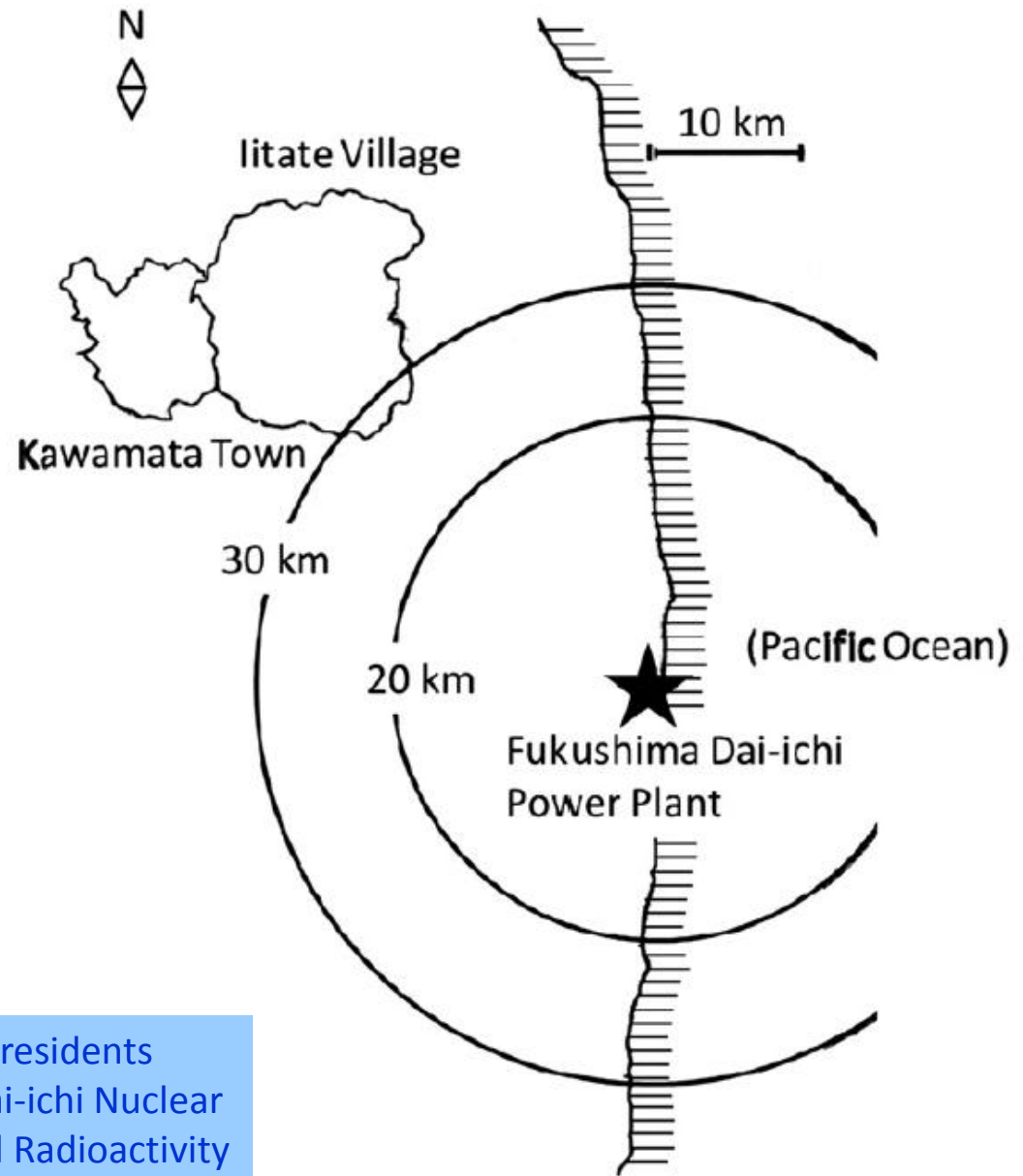


Rice

- In 2011, Cultivation of rice prohibited, if soil activity $> 5000 \text{ Bq/kg}$ ($^{134}\text{Cs} + ^{137}\text{Cs}$)
- On experimental fields activity in rice usually below 500 Bq/kg ($^{134}\text{Cs} + ^{137}\text{Cs}$)
- Trend to reduce permissible levels in food

Exposures in the Northwest of Fukushima

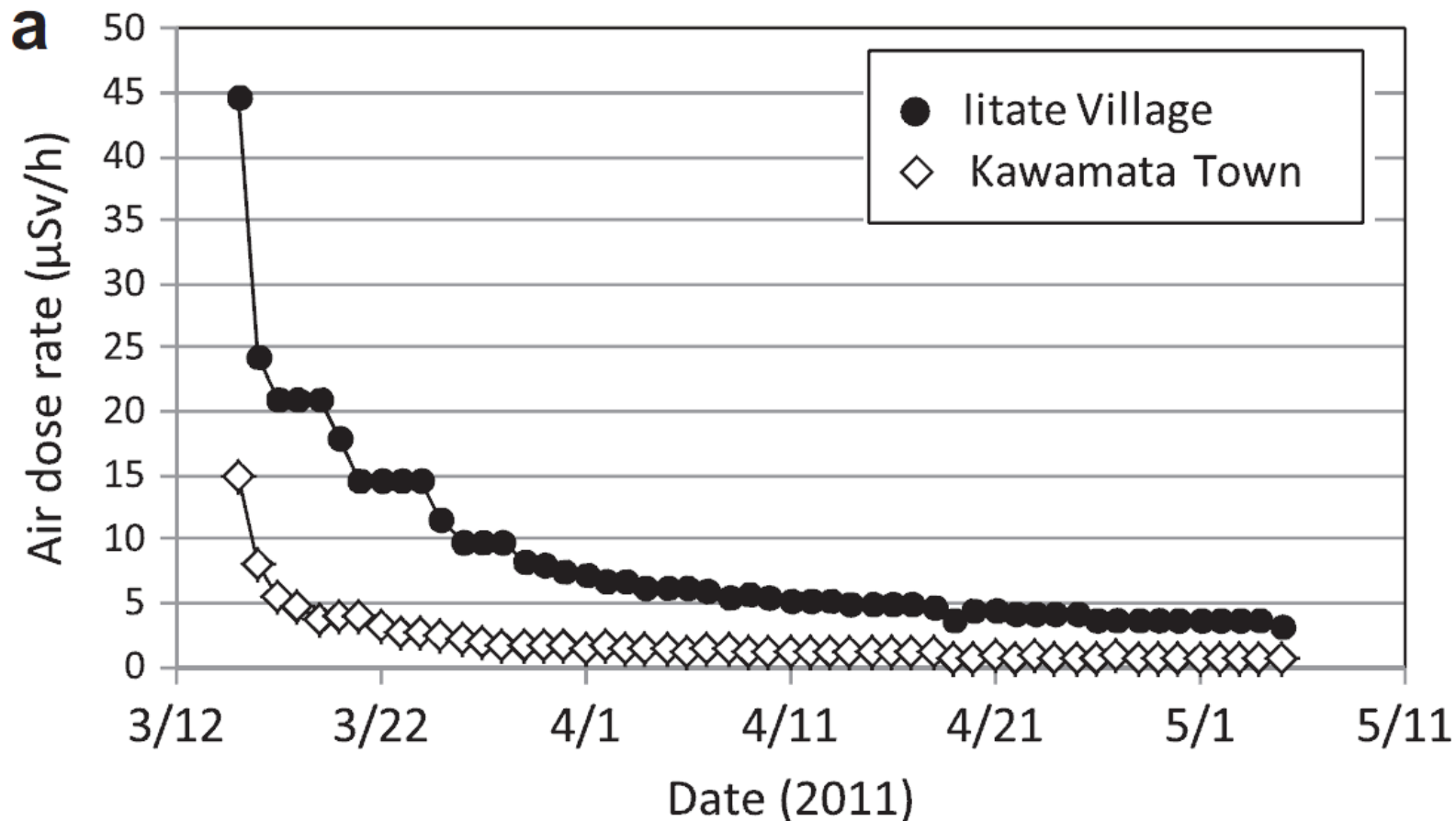
Iitate Village and Kawamata Town in Fukushima Prefecture.



Kamada et al: Radiation doses among residents living 37 km NW of the Fukushima Dai-ichi Nuclear Power Plant, *Journal of Environmental Radioactivity* 110, 84-89 (2012)

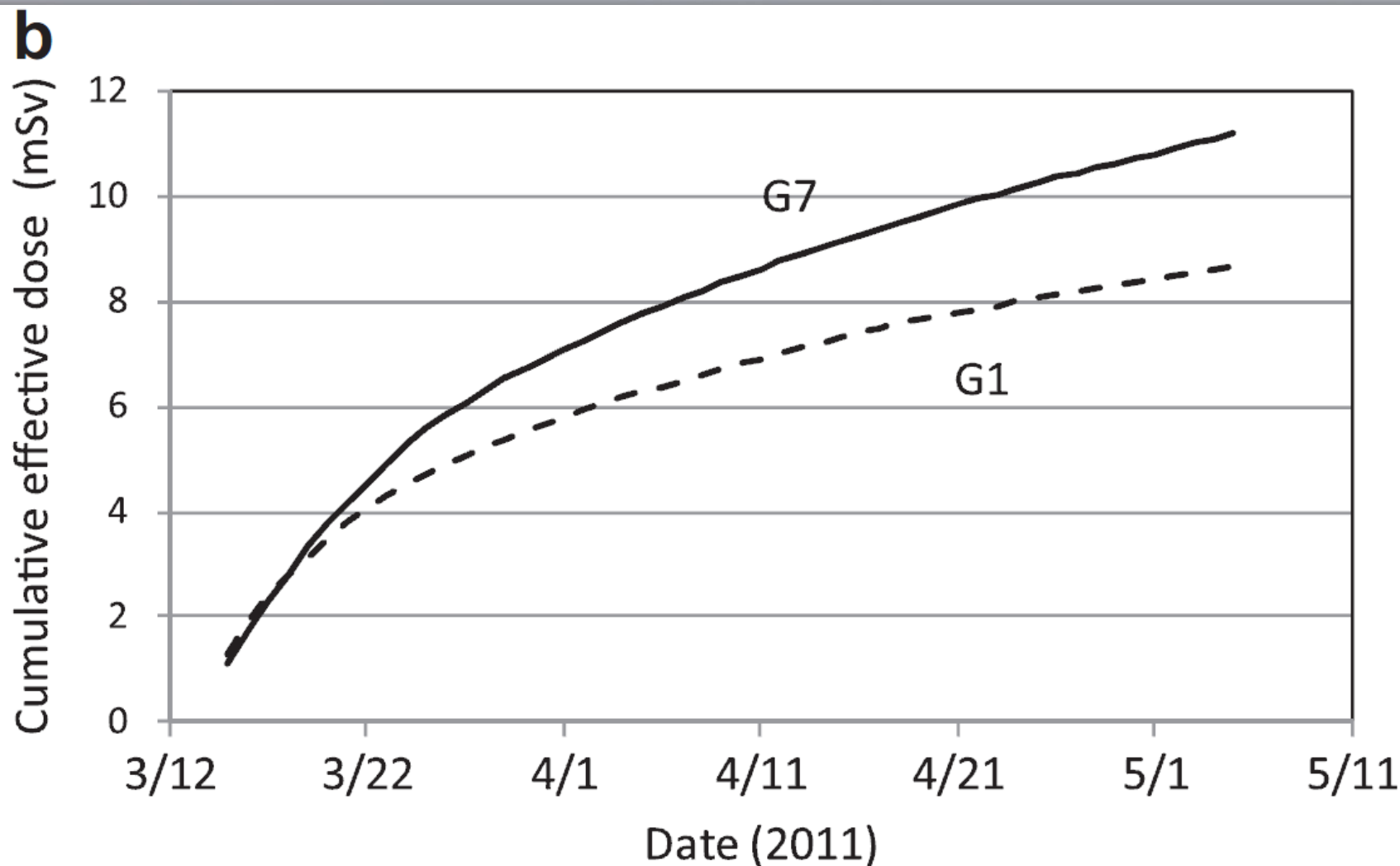


Gamma dose rate in Kawamata Town (G1) and in Iitate Village (G2), in [$\mu\text{Sv}/\text{h}$]



Kamada et al: Radiation doses among residents living 37 km northwest of the Fukushima Dai-ichi Nuclear Power Plant, Journal of Environmental Radioactivity 110, 84-89 (2012)

Cumulative external exposure (mSv) in Kawamata Town (G1) and in Iitate Village (G7) due to until 11 May



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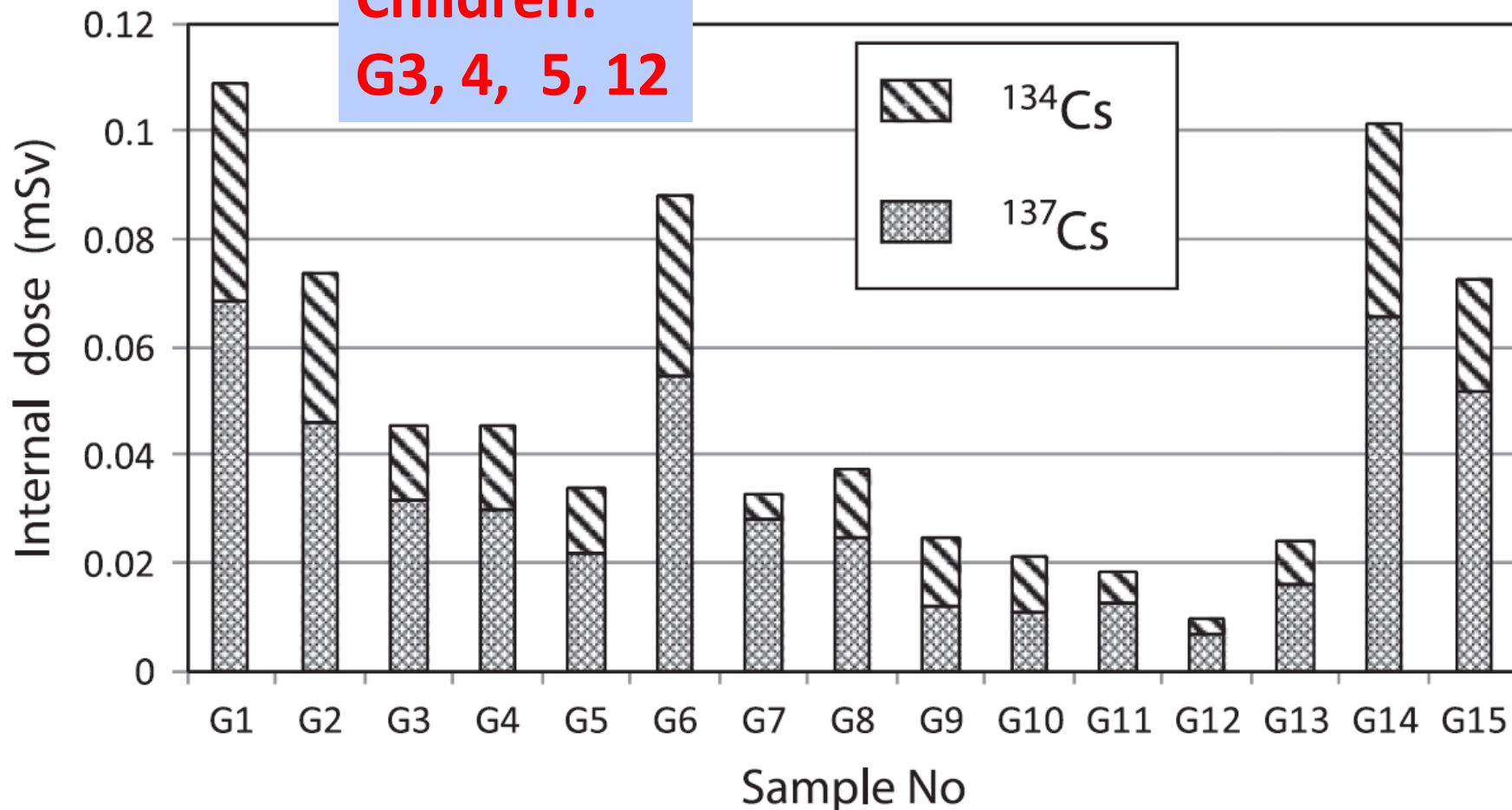
Kamada et al: Radiation doses among residents living 37 km northwest of the Fukushima Dai-ichi Nuclear Power Plant, *Journal of Environmental Radioactivity* 110, 84-89 (2012)

Estimations of **internal exposure** in Kawamata and Iitate

- Urine sampling in 15 residents
 - 5 May
 - 30 May – 5 June
- Analysis for
 - ^{134}Cs and ^{137}Cs
 - ^{131}I
- Reconstruction of effective and thyroid dose
 - Biokinetic models as published by ICRP

Internal dose to residents of Kawamata in litate [mSv] up to 54 d after deposition

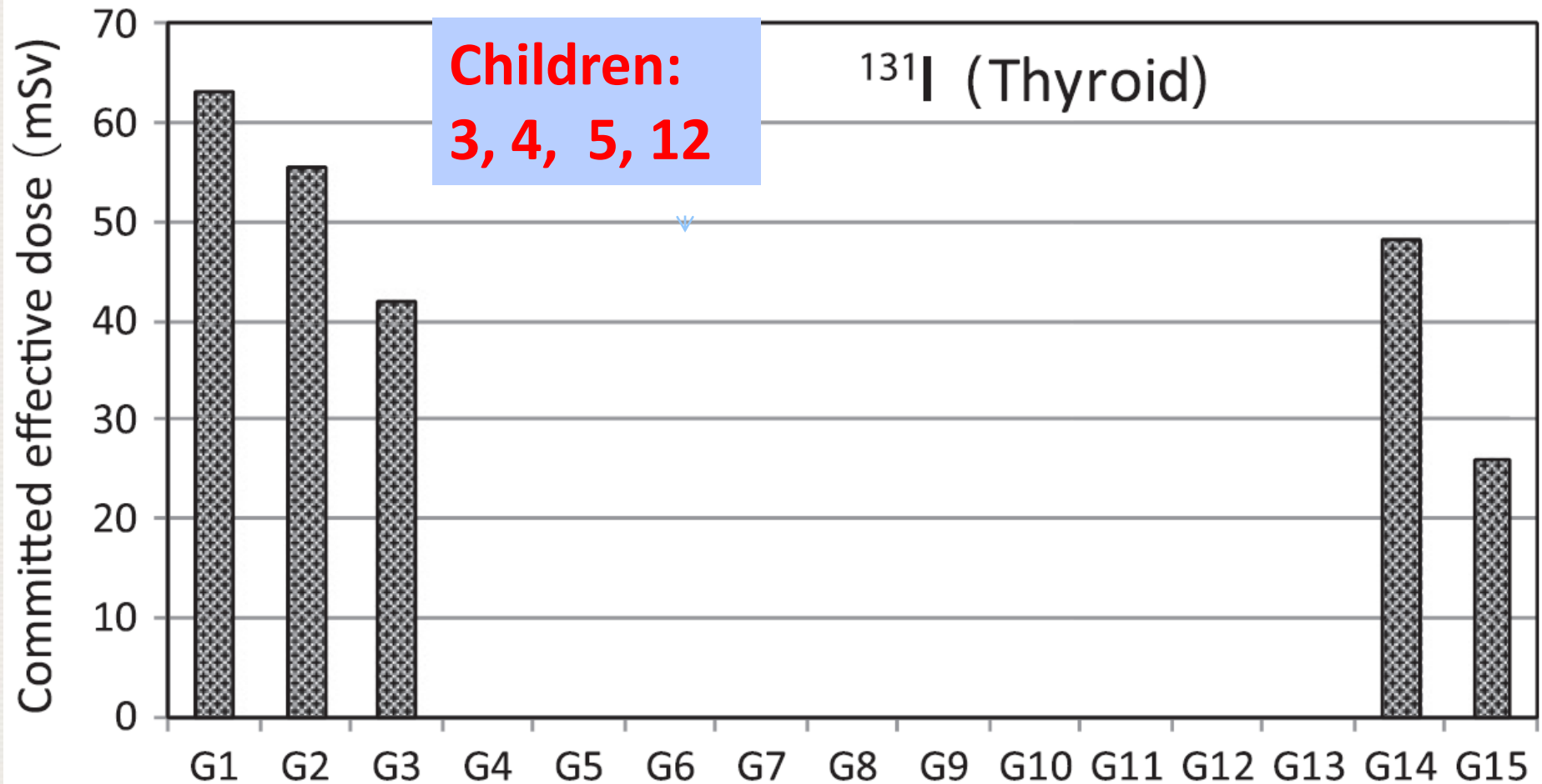
Children:
G3, 4, 5, 12



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Kamada et al: Radiation doses among residents living 37 km northwest of the Fukushima Dai-ichi Nuclear Power Plant, Journal of Environmental Radioactivity 110, 84-89 (2012)

Thyroid dose in residents of Kawamata and Iitate [mSv]



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Kamada et al: Radiation doses among residents living 37 km northwest of the Fukushima Dai-ichi Nuclear Power Plant, Journal of Environmental Radioactivity 110, 84-89 (2012)

Fukushima und Tschernobyl

Wechselwirkung von Exposition mit Lebensgewohnheiten, Monitoring und Information

	Fukushima	Tschernobyl
Unfallzeitpunkt	Vor der Vegetationsperiode	Nach Beginn der Vegetationsperiode
Milchkonsum	niedrig	hoch
Lebensmittelüberwachung	intensiv	Weniger intensiv
Selbstversorgungsgrad	Gering	Hoch bis sehr hoch
Information der Bevölkerung	rasch	schleppend
=> Schilddrüsenexposition durch Ingestion	Relativ gering	Hoch

Naturräumliche Verhältnisse

	Fukushima	Tschernobyl
Intensität der landwirtschaftlichen Nutzung	Hoch	Gering
Einsatz von Kalidünger	Moderat bis hoch	Gering
Anteil an versauerten, organischen, nährstoffarmen Böden	Gering	Hoch
= > Verfügbarkeit von Cäsium im Boden	Gering bis moderat	Hoch bis sehr hoch
Selbstversorgungsgrad	Gering	Hoch bis sehr hoch
=> Beitrag der Ingestionsdosis an der Gesamtexposition	Gering	Hoch

Ongoing activities

Remediation of contaminated areas

- Areas with effective doses above 20 mSv/a:
=> Reduce doses to levels below 20 mSv/a
- Areas with effective doses below 20 mSv/a:
=> Continue remediation efforts
=> Long-term goal is 1 mSv/a
- Specific attention to children (school, kindergarten)

Most important measures

- Removal of surface soil
- Decontamination of surfaces
- Ploughing / deep ploughing

- Final strategy not decided yet

Current international activities

- WHO

- Initial evaluation of radiation exposure from the nuclear accident after the 2011 Great East-Japan earthquake and tsunami, (April 2012)
 - Fukushima prefecture outside the 20 km zone
 - Rest of Japan & Global impact

- UNSCEAR

- Exposures from the events at the TEPCO nuclear power plant following the Tohoku earthquakes and tsunami (May 2012 & 2013)
 - All population groups
 - Doses to workers
 - Radiological impact to the environment

Summary

- Cs-134 and Cs-137 are the dominating radionuclides
- External exposure is the dominating pathway
- Internal exposure is less important due to strict food monitoring
- Deposition of radionuclides in whole Japan, but focus is clearly in Fukushima prefecture
- Most affected area Northwest of the reactor
- International activities for a comprehensive assessment of doses started (WHO, UNSCEAR)
- Remediation work started