Fukushima Accident

a personal recollection of an "antimatter" physicist

Ryugo Hayano, U. Tokyo & CERN

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CERN

Jan 25, 2016, “54th International Winter Meeting on Nuclear Physics”, Bormio, Italy

Today: Jan 25, 2016, 1781 days = 4.87 years since the earthquake & Fukushima Dai-ichi accident

I teach in Tokyo and fly to Geneva; CERN **ASACUSA** spokesperson since 1997

No past experience in Radiation

Protection

nor Risk Communication

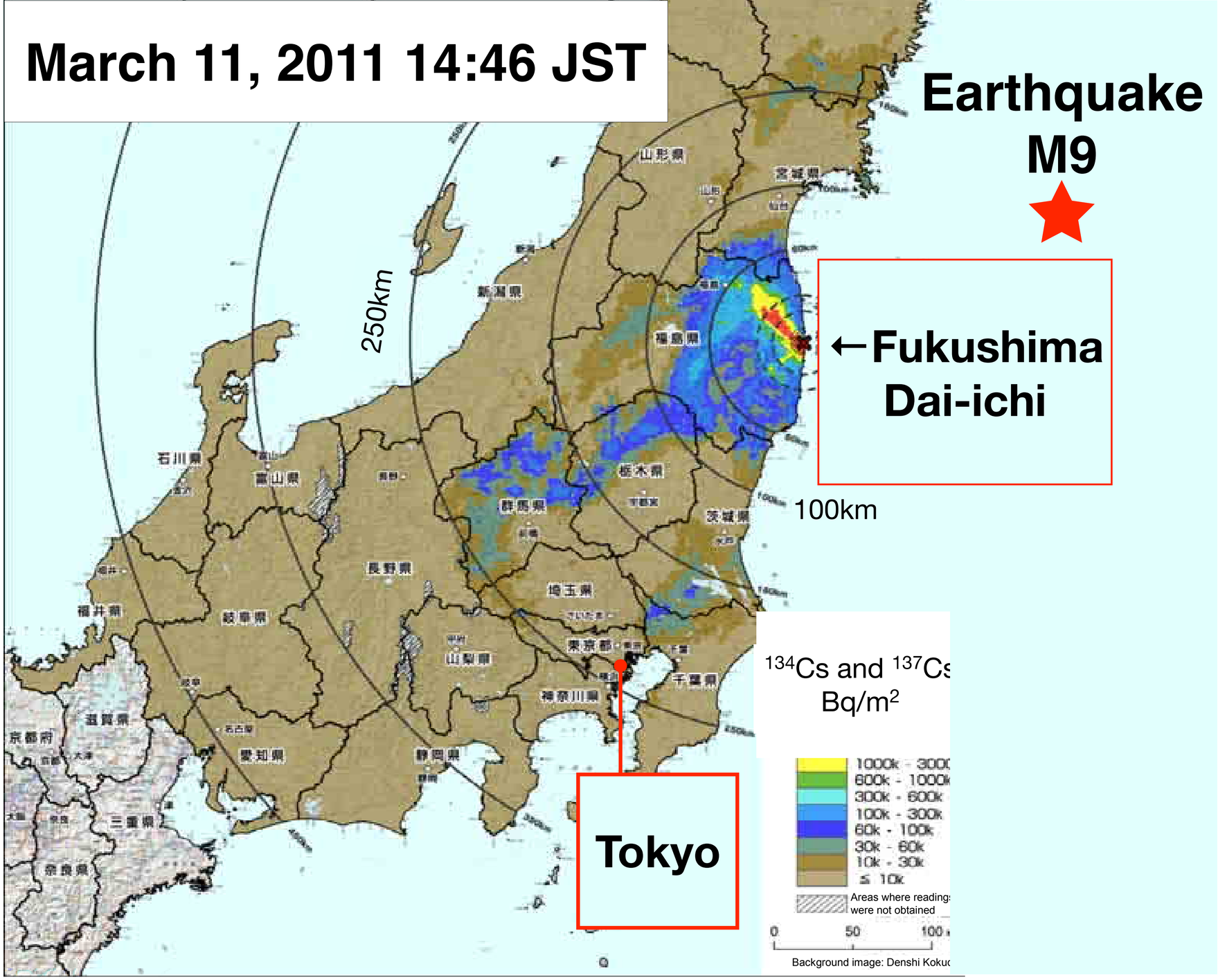
but

since 2011, worked on the radiation

protection of Fukushima people

Part 1

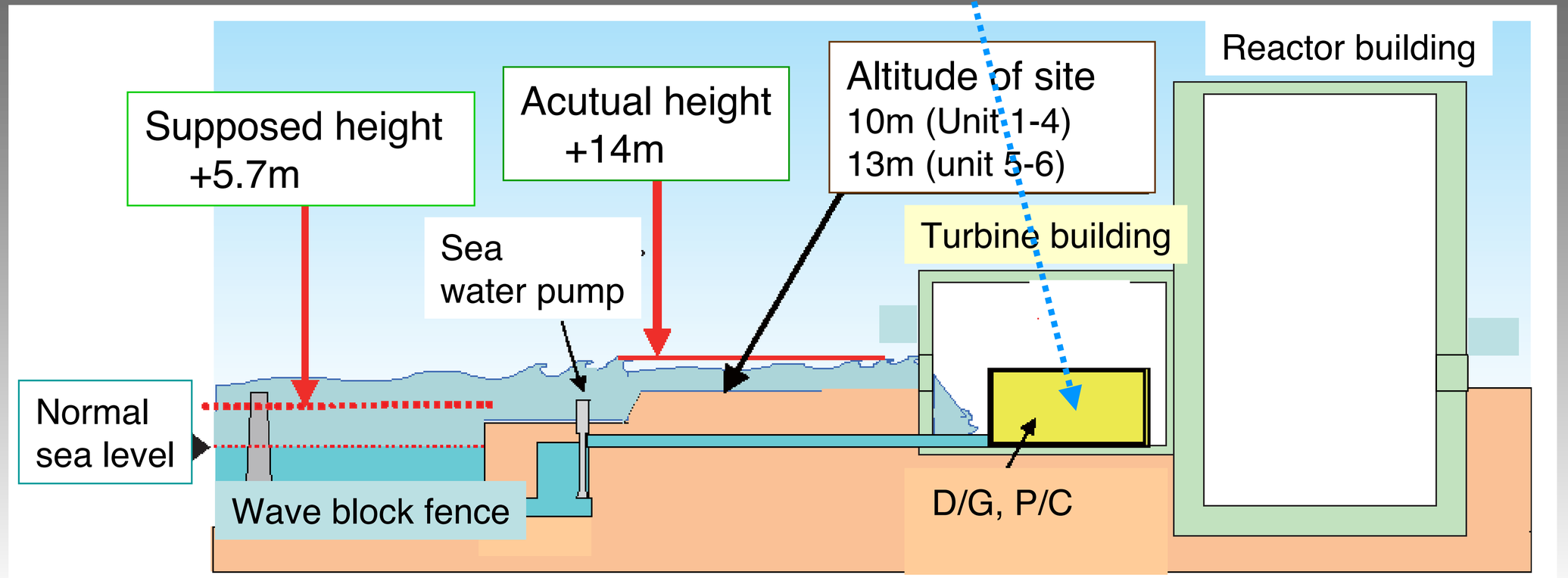
What happened at Fukushima Dai-ichi?


March 11, 2011 14:46 JST
Earthquake
M9
←Fukushima
Dai-ichi
250km
100km
Tokyo
134Cs and 137Cs
Bq/m2
1000k - 3000
600k - 1000k
300k - 600k
100k - 300k
60k - 100k
30k - 60k
10k - 30k
≤ 10k
Areas where readings were not obtained
0
50
100
Background image: Denshi Kokuc
山形県
宮城県
新潟県
福島県
栃木県
群馬県
茨城県
石川県
富山県
長野県
埼玉県
福井県
岐阜県
東京都
山梨県
千葉県
神奈川県
滋賀県
京都府
愛知県
静岡県
三重県
奈良県

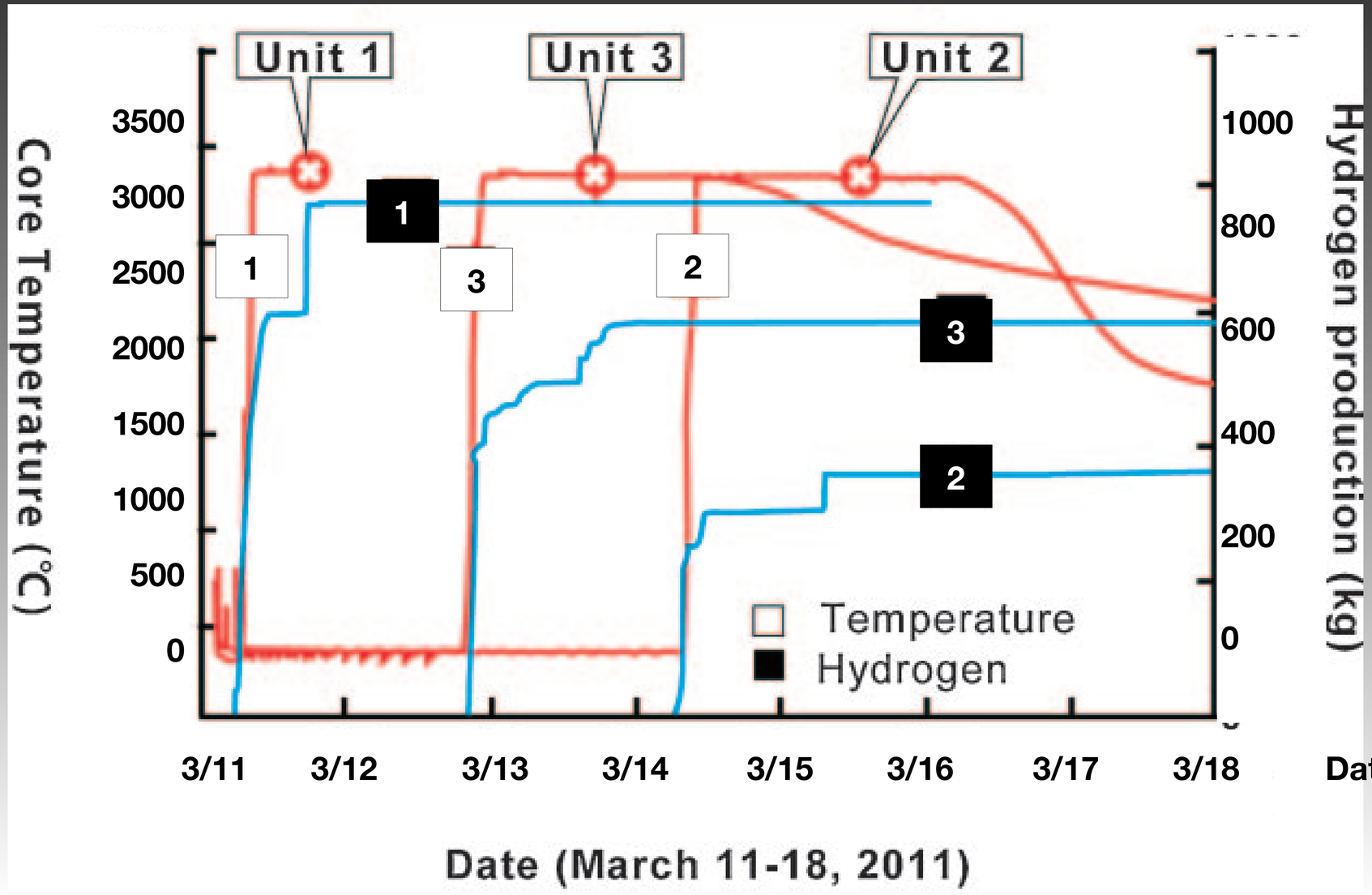
6 Nuclear Reactors @ Fukushima Dai-ichi
Units 1-3 were running on March 11, 2011

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Electric output (10,000 kW)	46.0	78.4	78.4	78.4	78.4	110.0
Commissioning	1971	1974	1976	1977	1978	1979
Fuel assemblies	400	548	548	548	548	764
Number of control rods	97	137	137	137	137	185

External power line destroyed by earthquake
but diesel generators turned on
40 minutes later …
Tsunami flooded diesel generators
→ total station blackout



No electricity, no cooling, core temperature >2500 °C
Fuel rods melted down→ release of radioactive substances



Evacuation order

3km - March 11 21:23

10km - March 12 5:44

20km - March 12 18:25

(~100,000 people)

after ~5 years, most of the people are still unable to return, even though the radiation levels in some areas have become low

←20 km

Food, water, milk …
Strict regulatory criteria

2011 Mar 17 ~

○ **Provisional regulation values for radioactive cesium[1]**

Category	Limit
Drinking water	200
Milk, dairy products	200
Vegetables	500
Grains	
Meat, eggs, fish, etc.	

Bq/kg

2012 Apr 1 ~

○ **New standard limits for radioactive cesium [2]**

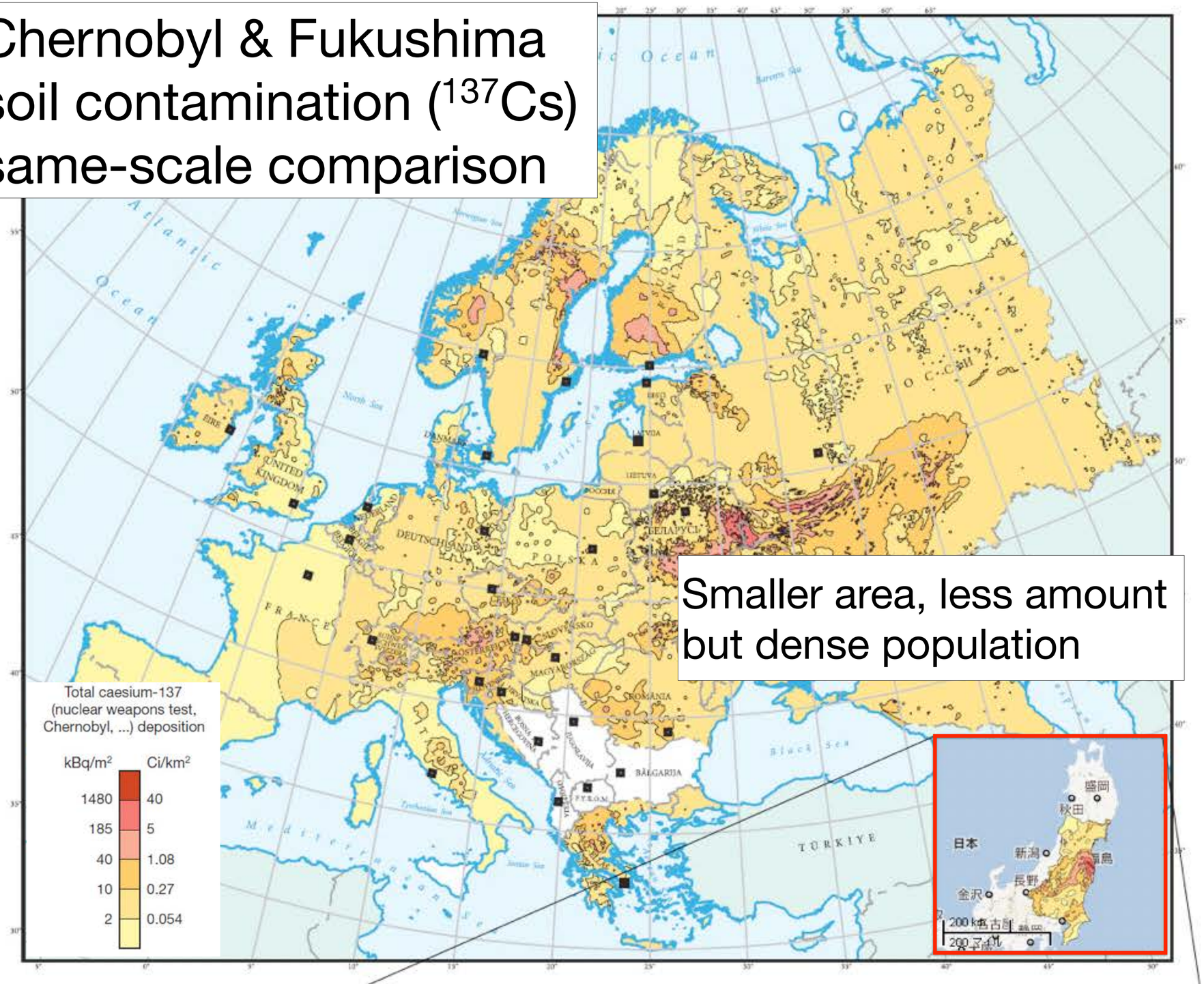
Category	Limit	EU
Drinking water	10	1,000
Milk	50	400
General Foods	100	1,250
Infant Foods	50	

Bq/kg

In Fukushima, ^{134,137}Cs need to be monitored (but not ^{90}Sr, nor Pu)

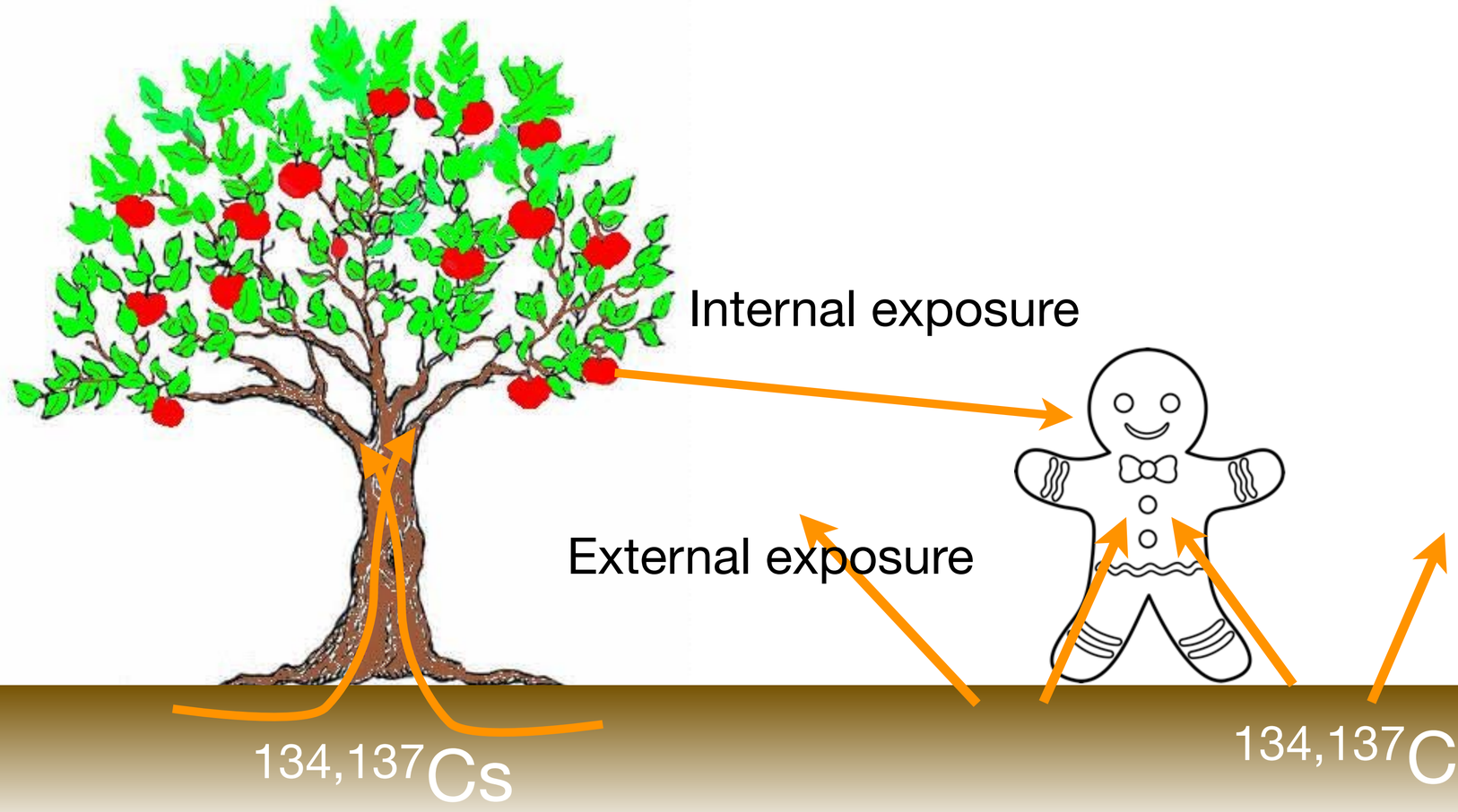
	Cs	Sr	Pu	
Maximum contamination (soil)	**10^7**	**10^4**	**10**	Bq/m^2

Chernobyl & Fukushima soil contamination (^{137}Cs) same-scale comparison



Smaller area, less amount but dense population

Concerns -
effect of low-dose exposures to the population



Important take-home messages

Fukushima Dai-ichi, serious accident

However,

No death due to **ACUTE** radiation effects

DISCERNIBLE long-term health effects
(e.g., cancer increase, incl. thyroid) **unlikely**
source - WHO, UNSCEAR, IAEA

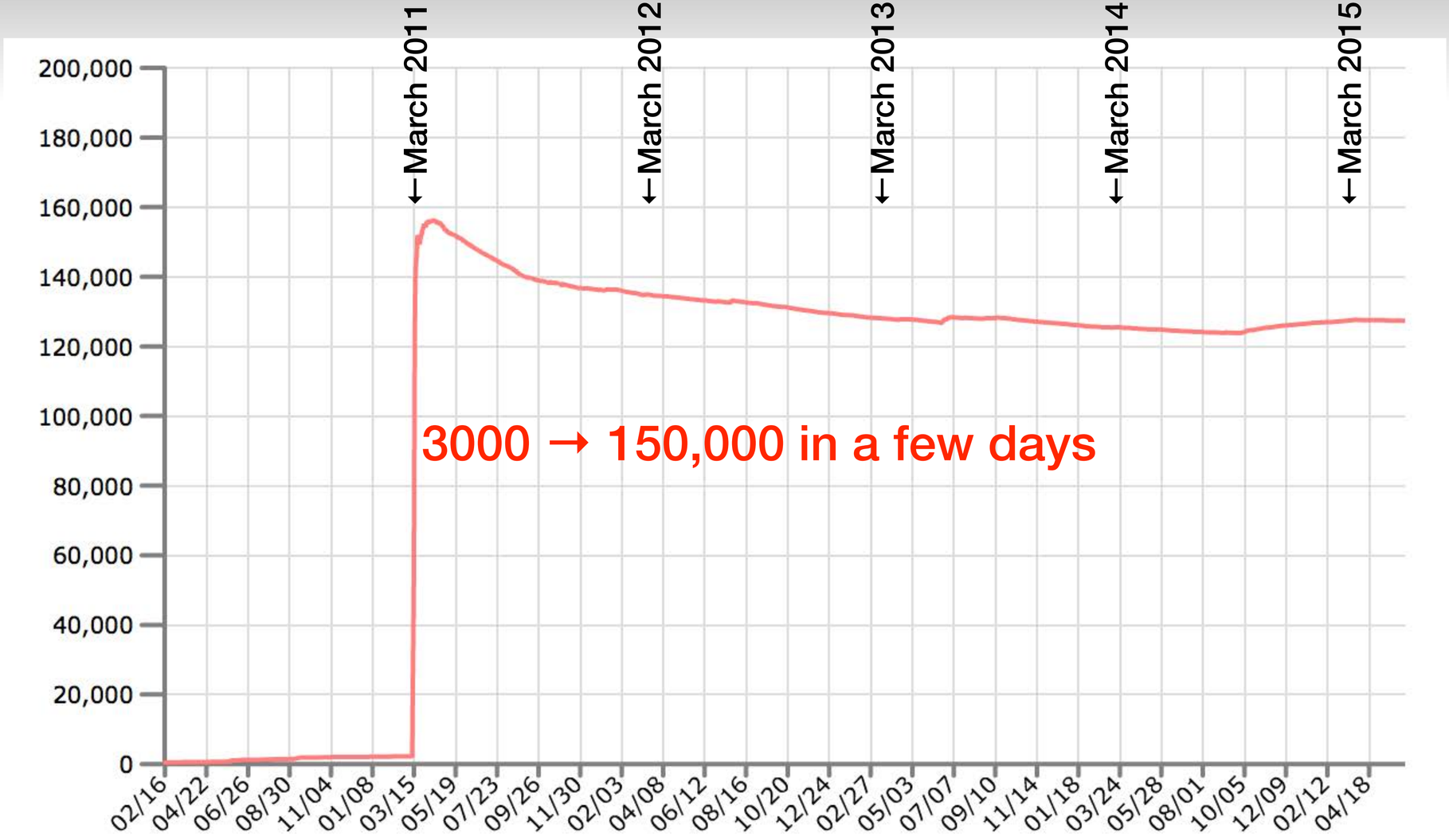
Fukushima food, tested & safety confirmed

Part 2

Why am I here today taking about Fukushima?

twitter @hayano

The number of my twitter followers



My first **Fukushima Tweet**: Mar 12, 2011, 14:22

89 characters

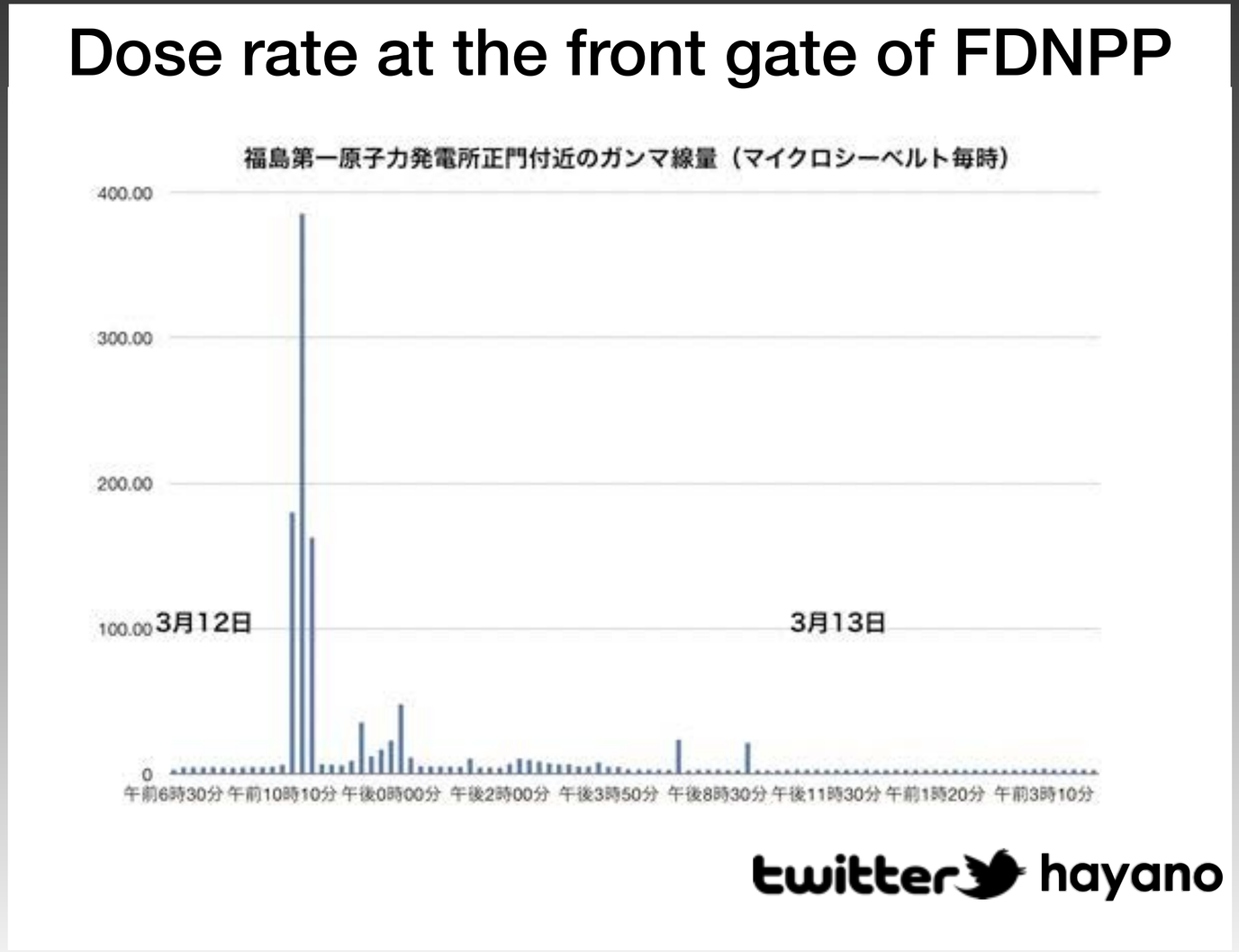
Cs137が出す662 keVのガンマ線を確認したという意味か．福島第一原子力発電所．Cs137は天然には存在せず，Sr90とともにウランの核分裂で生じる

Japanese tweets can contain more info

Cs137 decay was detected at Fukushima Dai-ichi? Cs137 does not exist in nature, and together with Sr90, typical fission product isotope.

181 characters

My first graph: Mar 13, 2011, 07:49



Ranked **7th**
among the most influential twitter accounts

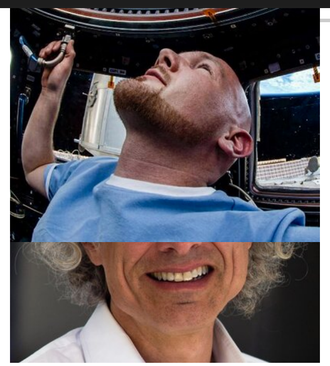
順位	ユーザ	被RT回数	
1	@NHK_PR	630459	TV station
2	@nhk_seikatsu	304824	TV station
3	@Asahi_Shakai	279259	Major newspaper
4	@nhk_news	209515	TV station
5	@nhk_HORIJUN	173995	TV caster
6	@tsuda	165434	
7	@hayano	145436	
8	@nhk_kabun	127916	
9	@earthquake_jp	114806	
10	@touhokujishin	112592	

source, Tohoku Univ. http://www.cl.ecei.tohoku.ac.jp/prj311/trend/rteduser/top100.html

Science Magazine Blog top 100 scientists on twitter

October 2014

MARTYN GREEN



20. Steven Pinker, *Cognitive scientist*

145,000 followers @sapinker (http://twitter.com/@sapinker)

Citations: 49,933 K-index: 105

Total number of tweets: 1,674

Harvard University, United States

21. Richard Wiseman, *Psychologist*

135,000 followers @RichardWiseman (http://twitter.com/@RichardWiseman)

Citations: 4,687 K-index: 209

Total number of tweets: 22,600

University of Hertfordshire, United Kingdom

22. Ryugo Hayano, *Nuclear physicist*

124,000 followers @hayano (http://twitter.com/@hayano)

Citations: 956 K-index: 319

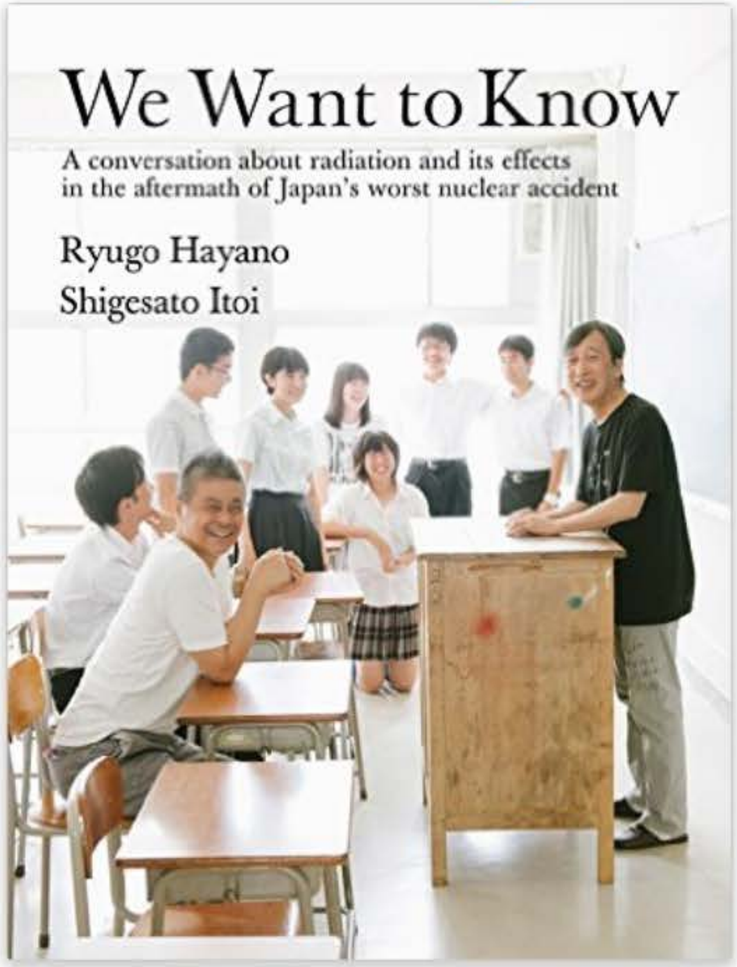
Total number of tweets: 56,500

University of Tokyo, Japan

>100,000 copies sold so far

Kindle version (English) available

Leggi l'estratto



We Want To Know: A conversation about radiation and its effects in the aftermath of Japan's worst nuclear accident (English Edition) Formato Kindle

di Ryugo Hayano (Autore), Shigesato Itoi (Autore)

Recensisci per primo questo articolo

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A conversation about radiation and its effects in the aftermath of Japan's worst nuclear accident

Lunghezza: 120 pagine

Word Wise: Abilitato

Miglioramenti tipografici: Abilitato

Power of the social media

is bi-directional

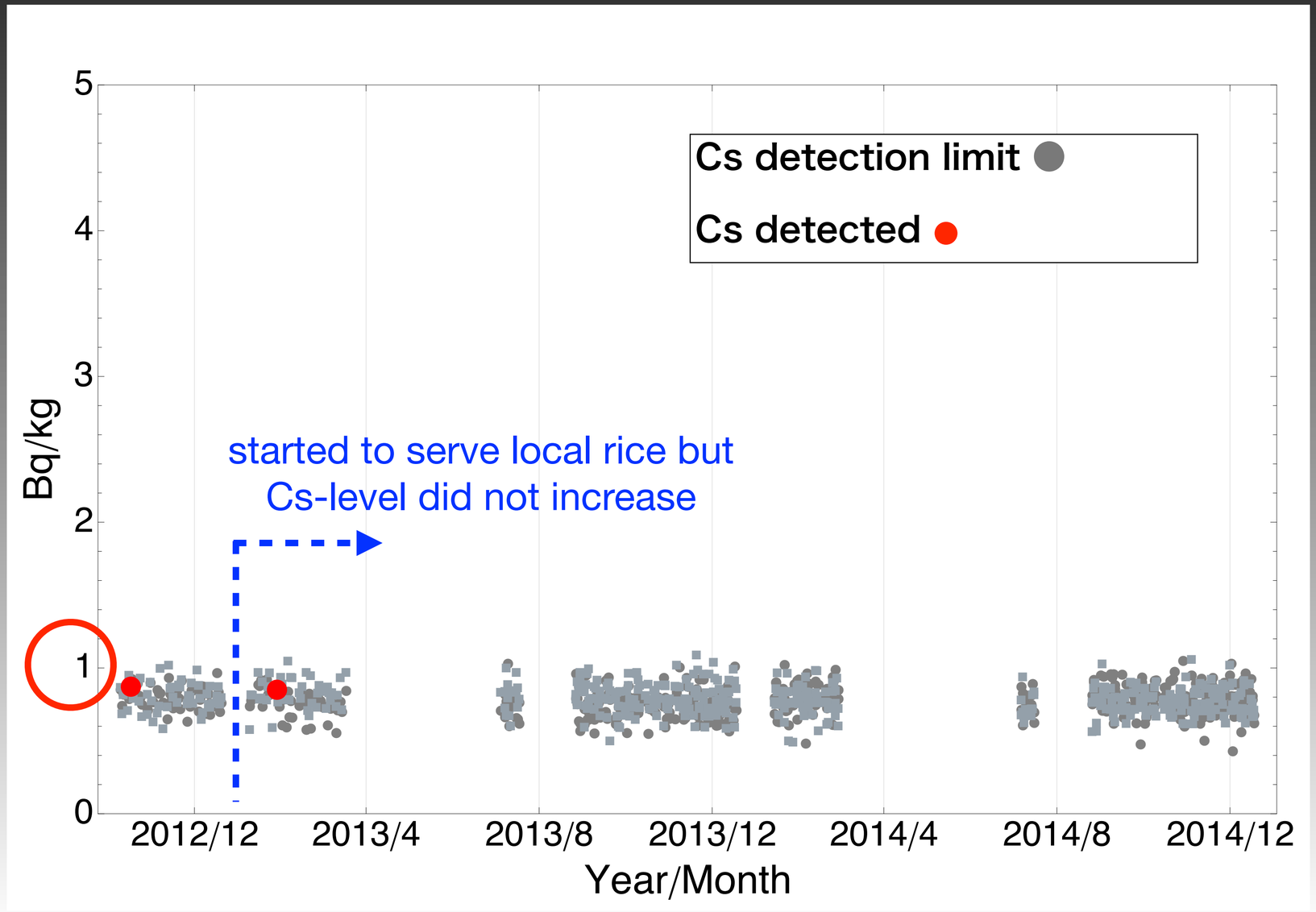
summer, 2011

increasing number of mothers started to tweet:
what about food safety?

I proposed to measure school lunch;

the government funded the project from 2012

Fukushima-city school lunch: free of radiocaesium (results of other municipalities are similar)



social media connect people

I got connected to

- medical doctors in Fukushima
- ICRP & other experts
- TV and newspaper reporters
- school teachers/students
- government officials/offices

(in most cases, they found me)

With medical doctors in Minamisoma City Hospital 23km north of FDNPP fall 2011

Part 3

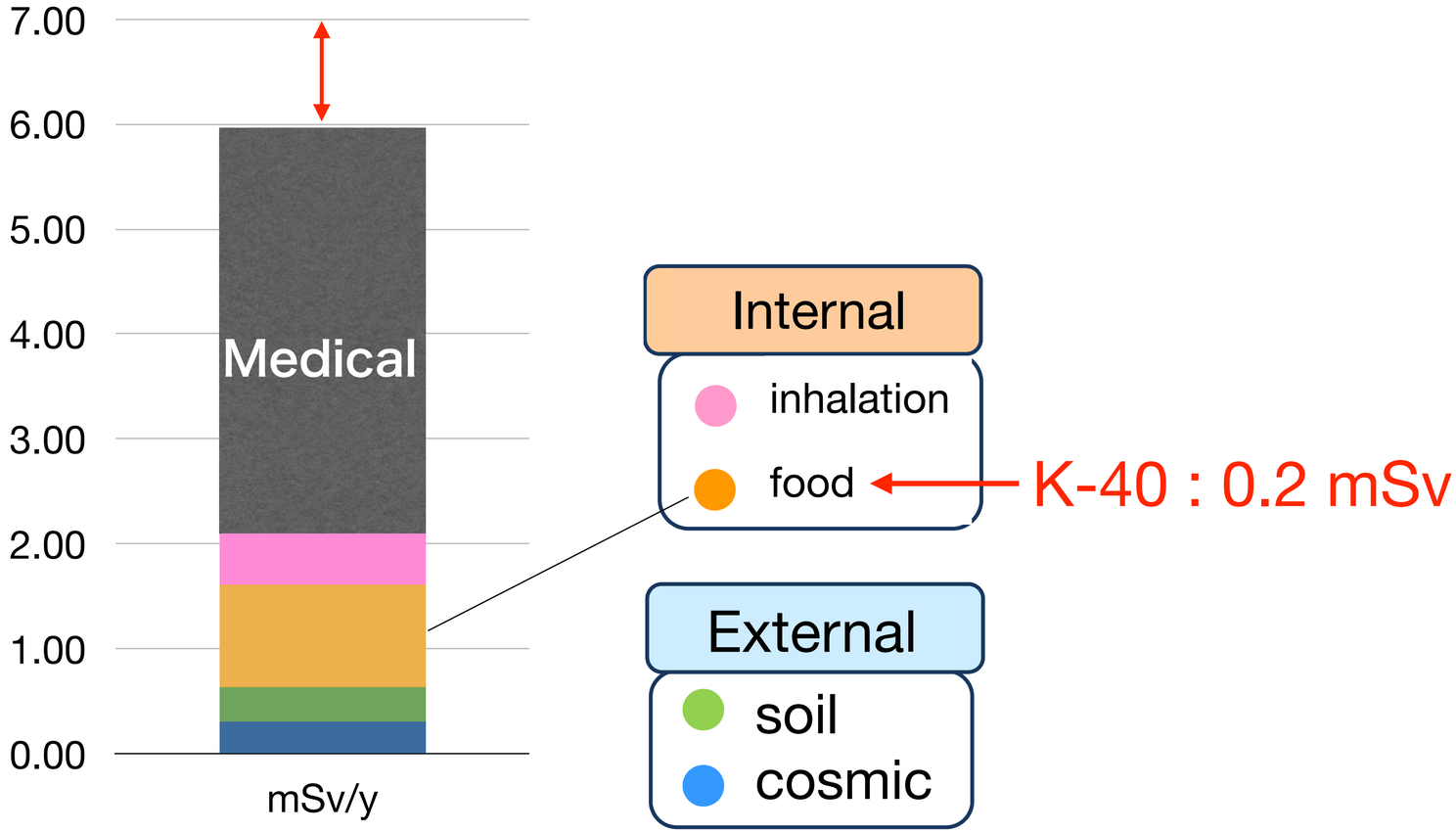
Internal Exposure

Q: how much radiocaesium are Fukushima people eating?

A: much less than naturally-occurring K-40

Average dose of Japanese (before the accident)
6 mSv/y (2.1 without medical)

The goal is to limit the EXCESS public dose to 1 mSv/y



K-40 - about 4,000 Bq in adults' body
→ ~0.2 mSv/year

Half life, 1.3 billion years!

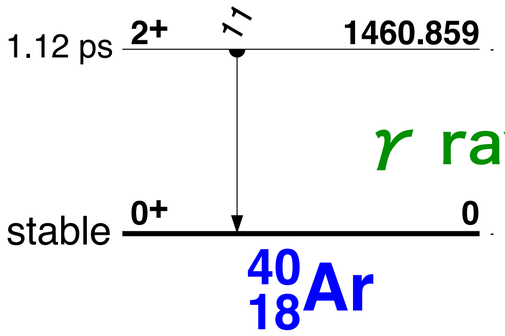
$^{40}_{19}K$

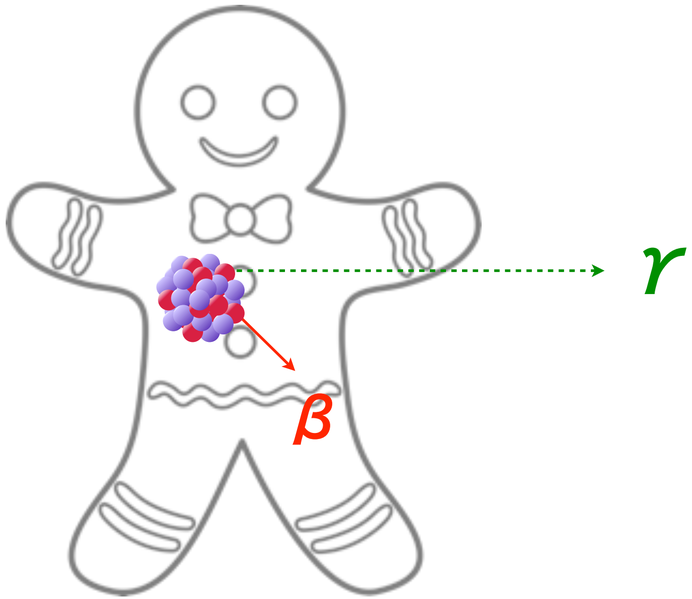
10.72%

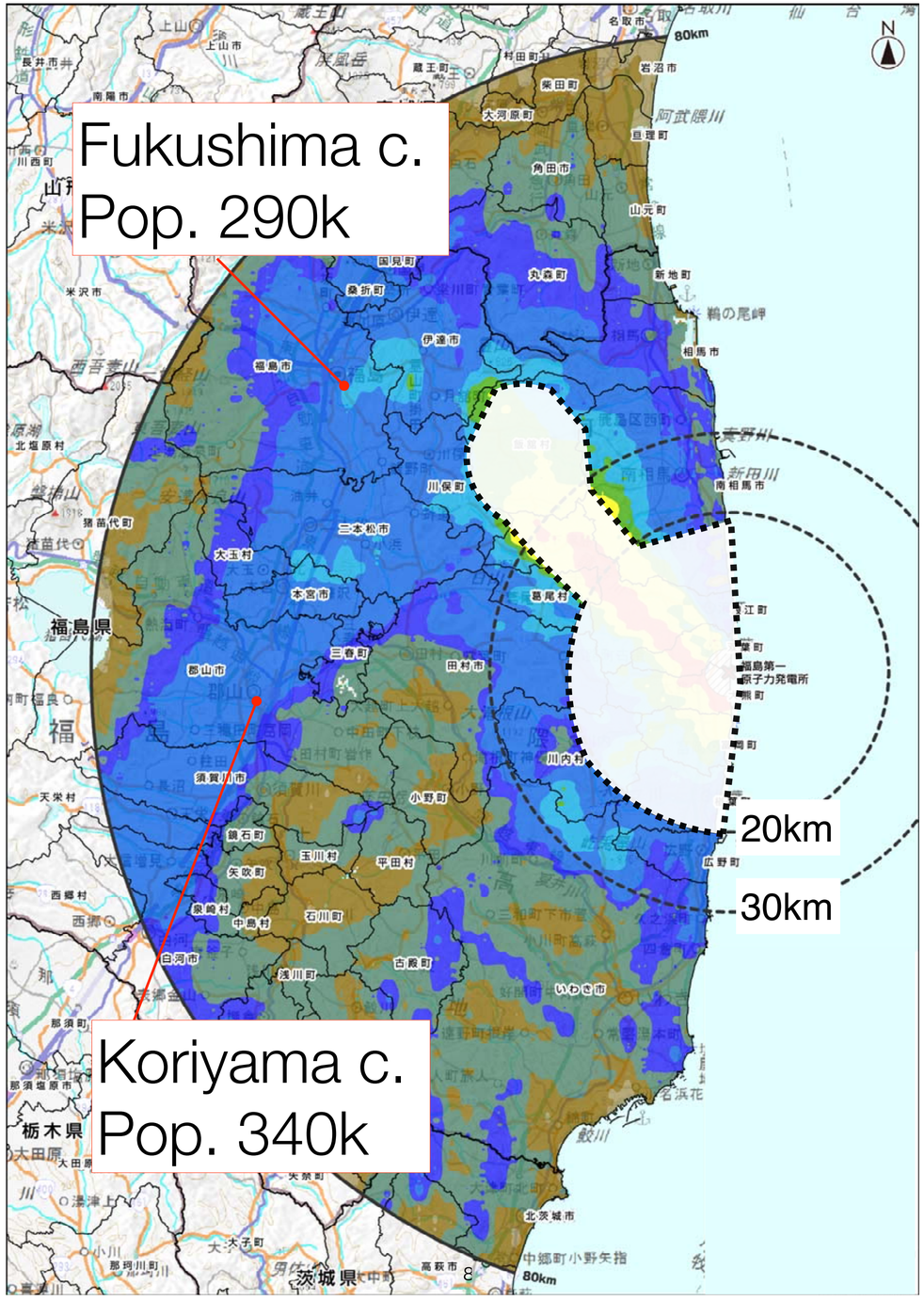
β ray

0+

$^{40}_{20}Ca$



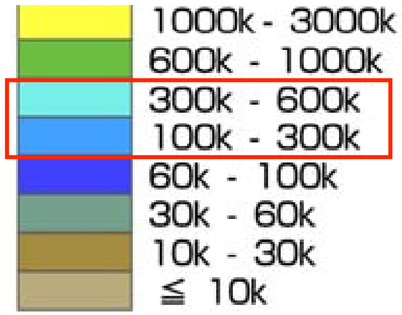


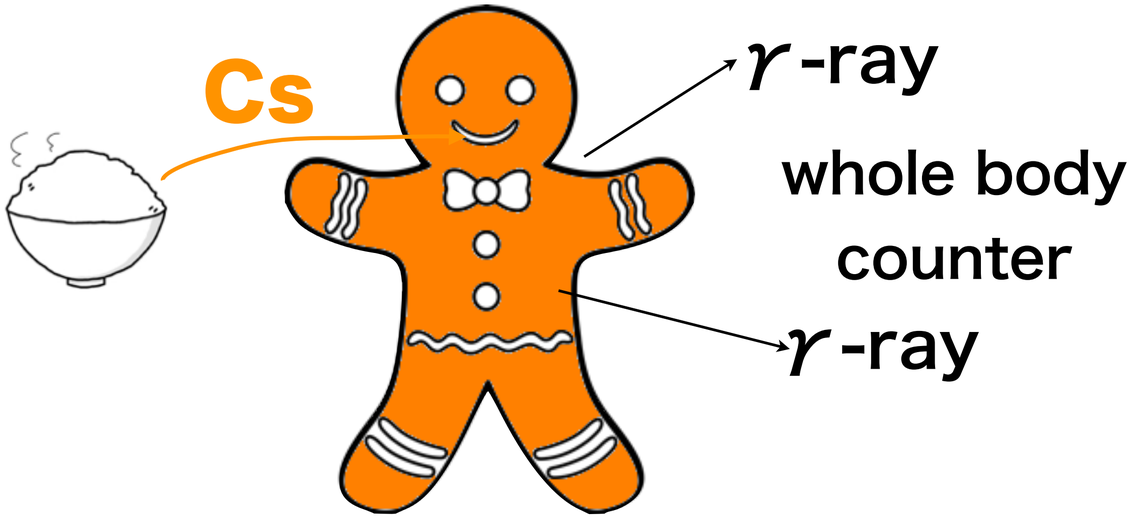


Chernobyl studies,
i.e., soil→food→people
infer:

average internal dose of
e.g., Fukushima city
residents ~ 5 mSv/y
(initial estimate)

^{137}Cs deposition
Bq/m^2
(2011/11/5)

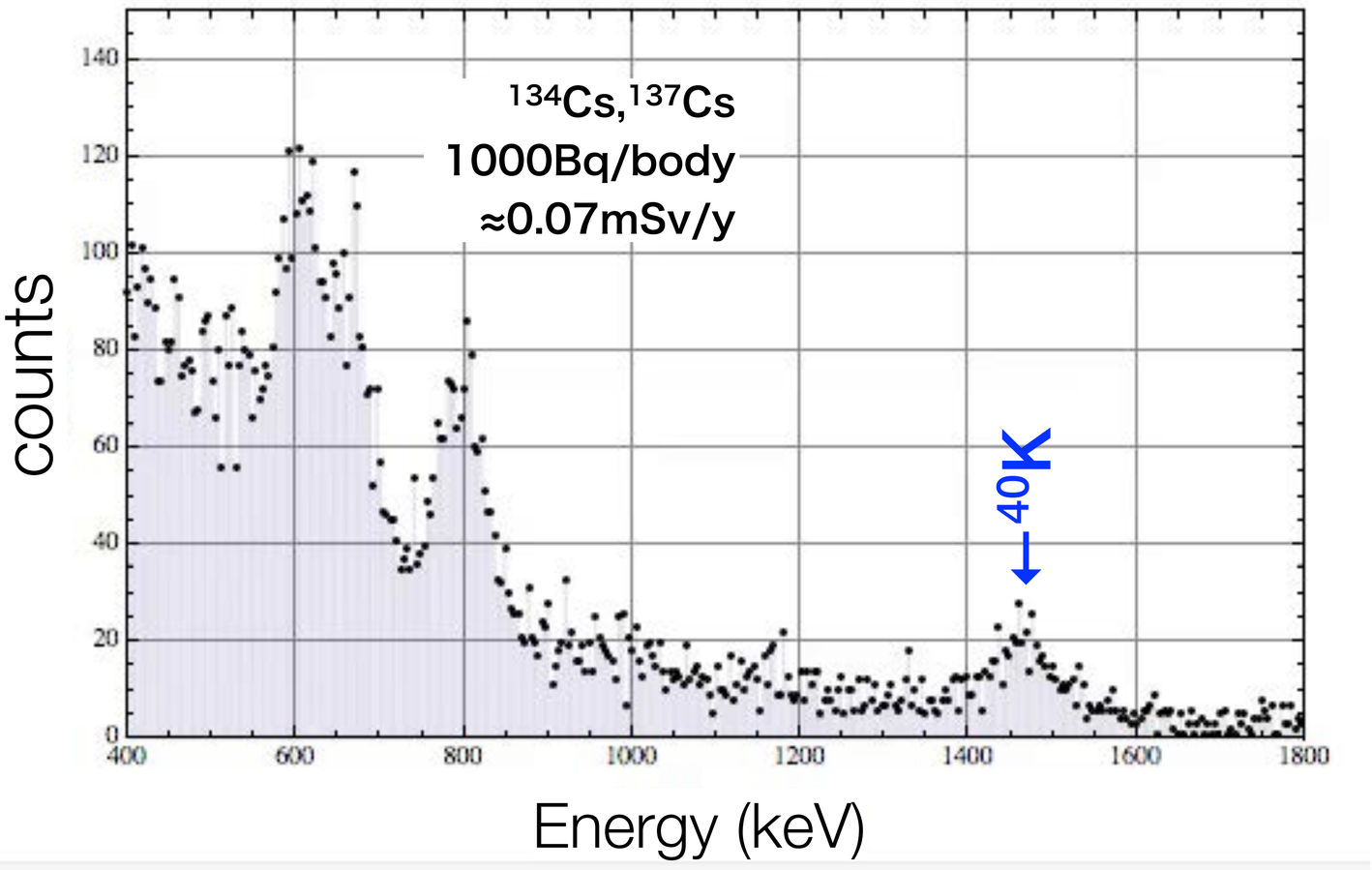



Cs
γ-ray
whole body
counter
γ-ray


FASTSCAN

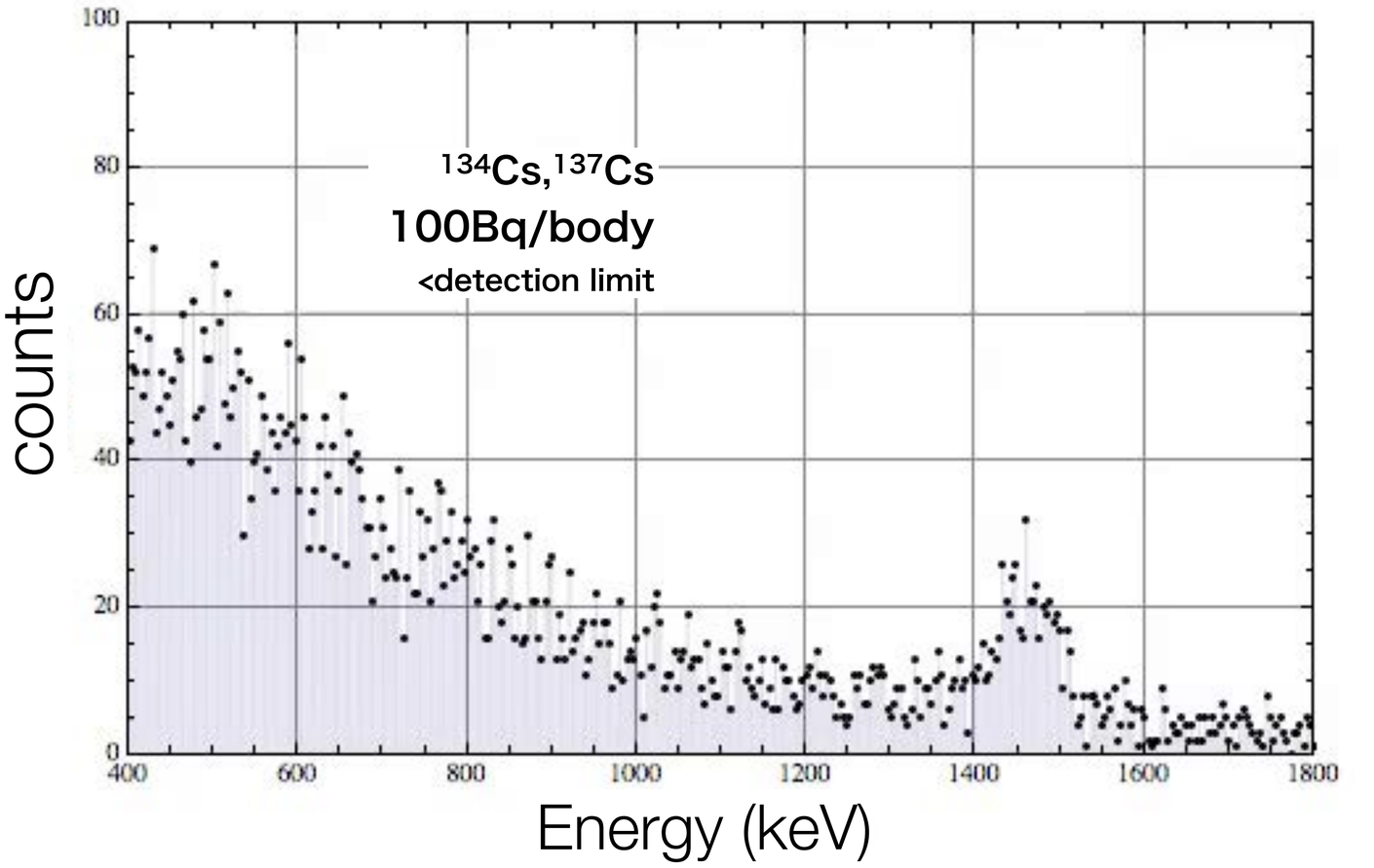
WBC spectra (simulations based on actual data)

This is already < 0.2 mSv/y



WBC spectra (simulations based on actual data)

Below detection limit



My first “medical” paper

No. 4] Proc. Jpn. Acad., Ser. B **89** (2013) 157

Internal radiocesium contamination of adults and children in Fukushima 7 to 20 months after the Fukushima NPP accident as measured by extensive whole-body-counter surveys

By Ryugo S. Hayano,[*1,†] Masaharu Tsubokura,[*2] Makoto Miyazaki,[*3] Hideo Satou,[*4] Katsumi Sato,[*4] Shin Masaki[*4] and Yu Sakuma[*4]

- Internal exposure of Fukushima people surprisingly low

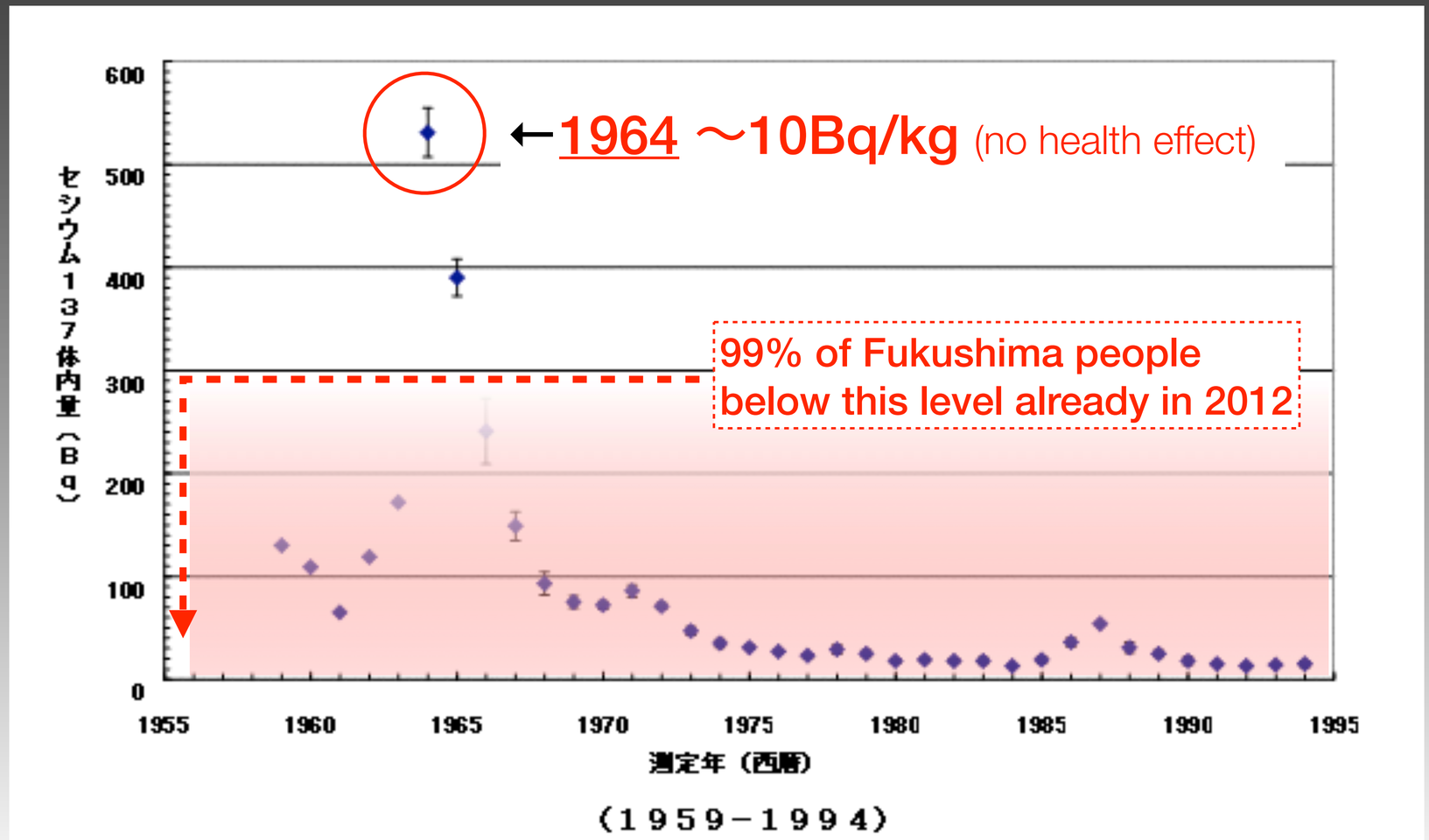
- i.e., food contamination is negligible

- children 100% (adult 99%) below detection limit already in 2012

- much lower than in 1960s (global fallout)

- supported by other recent studies

^{137}Cs in Japanese adult male in 1964 was much higher than in Fukushima NOW



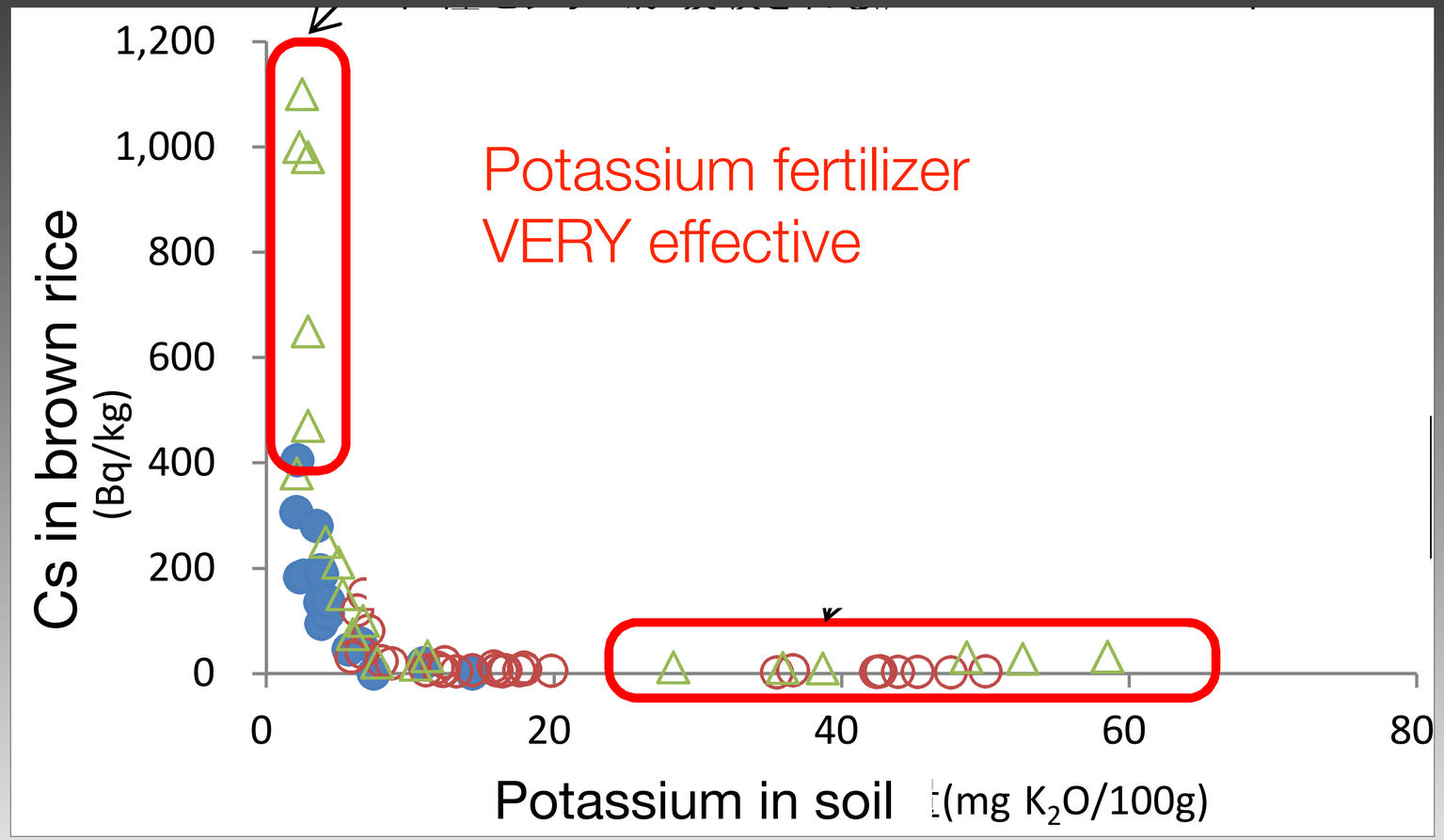
Why so low?

1. measurement & restriction
2. countermeasures

this is how the rice bags are measured

>10,000,000 rice bags (30 kg each) measured every year	
71 exceeded the 100 Bq/kg limit in 2012	
28	in 2013
2	in 2014
0	in 2015

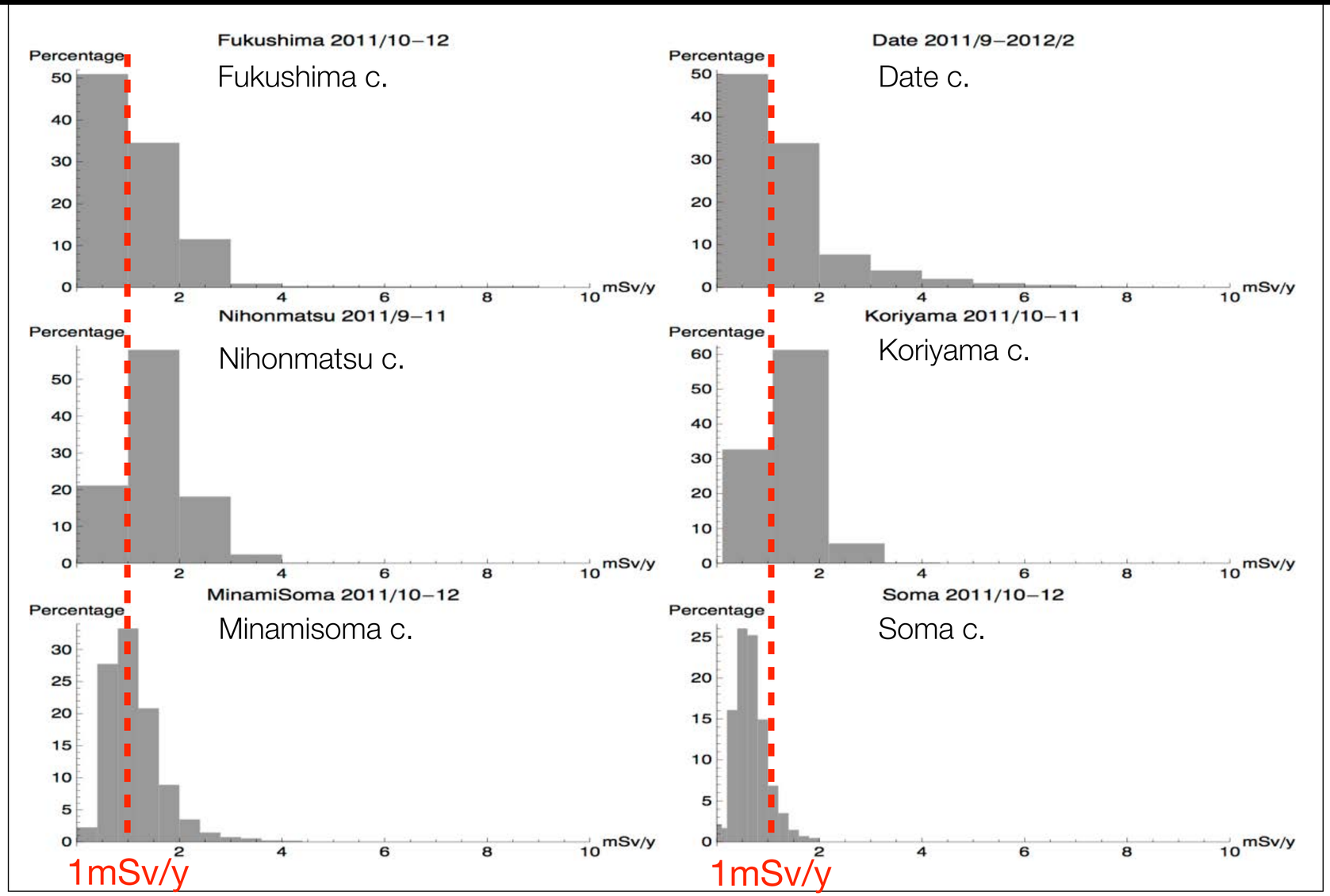
Countermeasures:
Soil → rice transfer can be suppressed



Part 4

External Exposure

Personal dosimetry results
~50% below 1mSv/y in winter 2011



2~3 mo. results extrapolated to 1 year

Radiological protection problems, much less than initially feared.

However, still lots of psycho-social problems…

Parents are really worried about their children

Problems solved?

Not at all

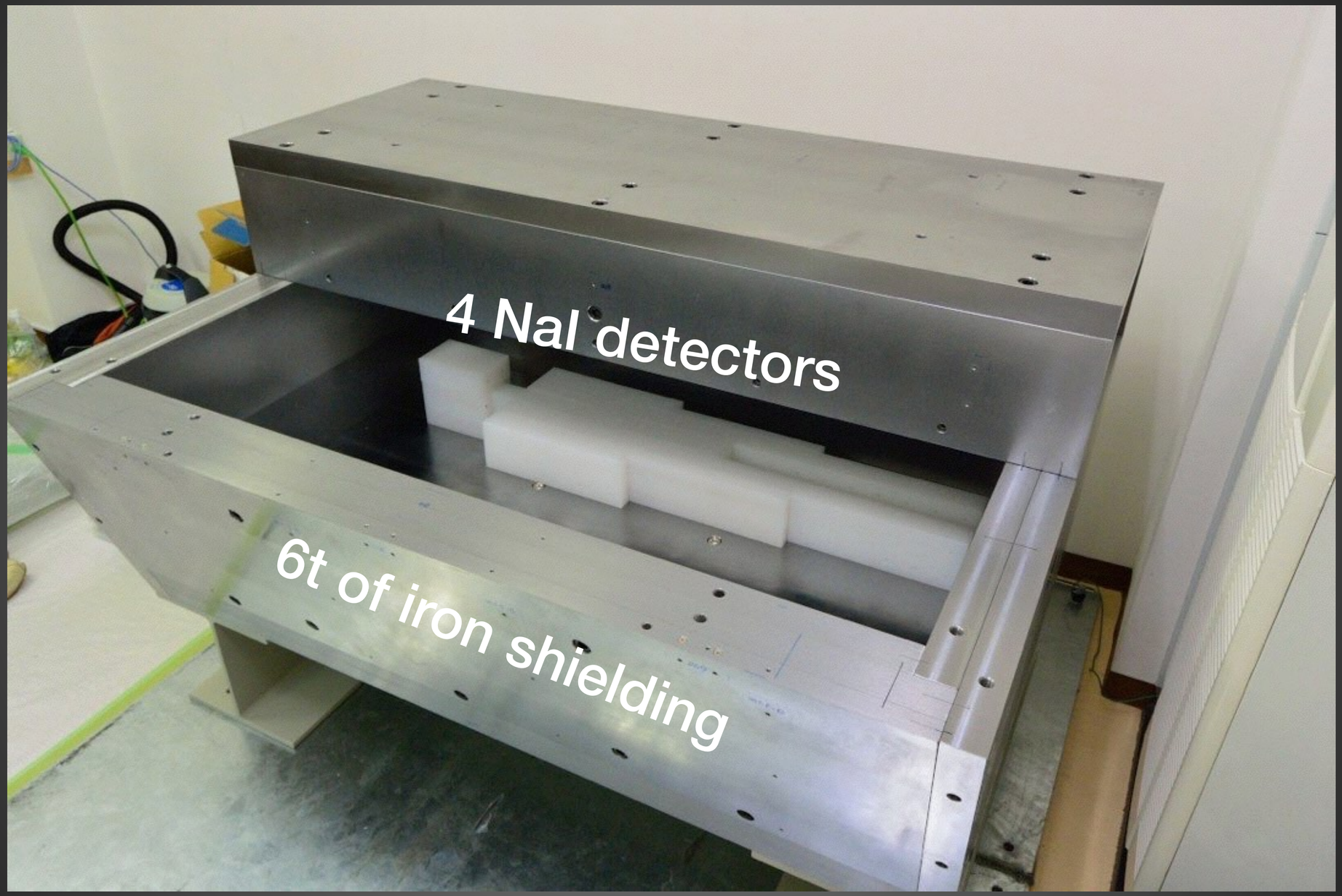
Radiological protection problems, much less than initially feared.

However, still lots of psycho-social problems…

Parents are really worried about their children

Part 5

BABYSCAN story



BABYSCAN

I made a whole-body counter for babies

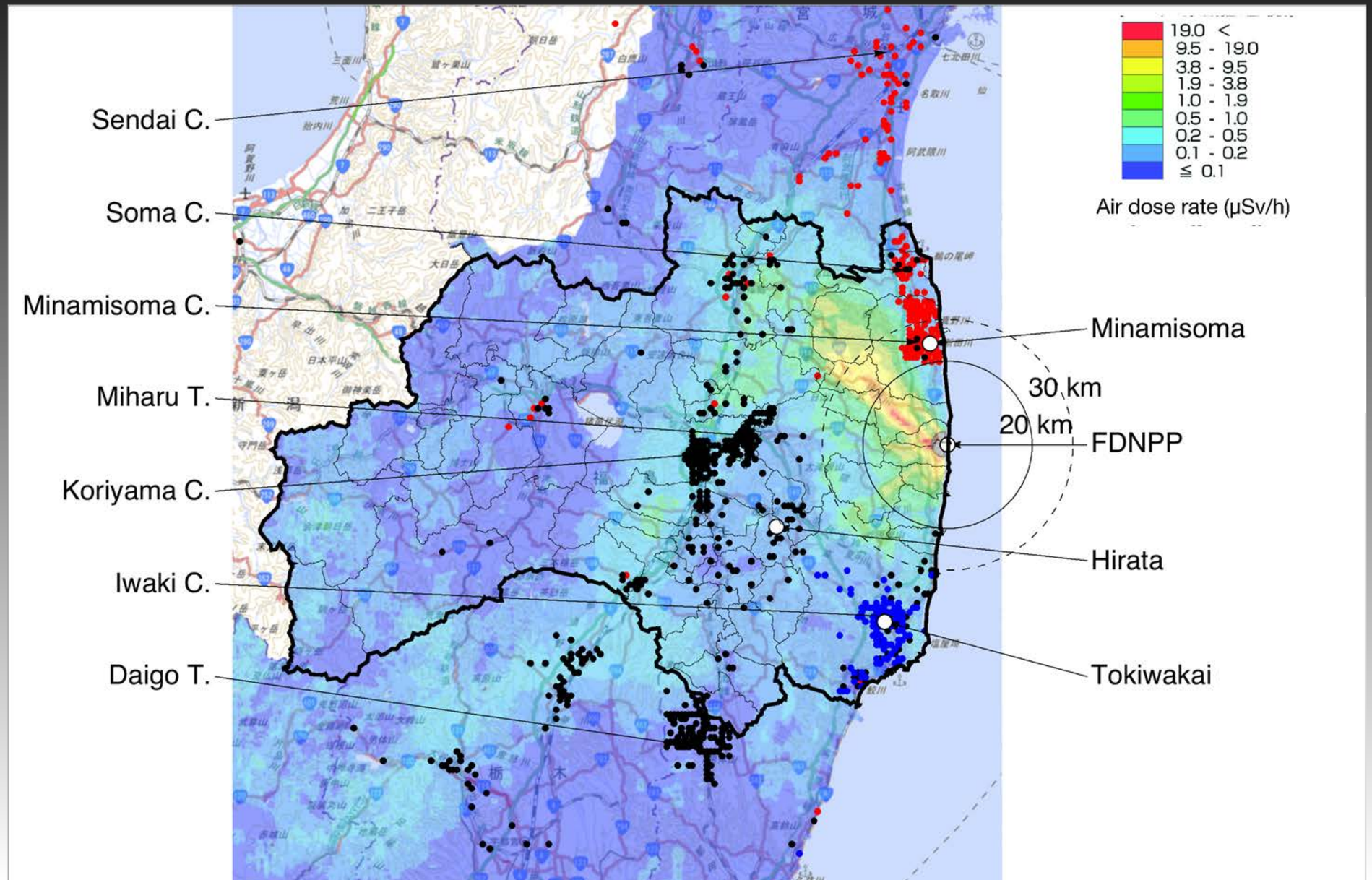
Courtesy, NHK World

> 2700 babies scanned in 2014

Whole-body counter surveys of over 2700 babies and small children in and around Fukushima Prefecture 33 to 49 months after the Fukushima Daiichi NPP accident

By Ryugo S. Hayano,[*1,†] Masaharu Tsubokura,[*2] Makoto Miyazaki,[*3] Akihiko Ozaki,[*4] Yuki Shimada,[*4] Toshiyuki Kambe,[*4] Tsuyoshi Nemoto,[*4] Tomoyoshi Oikawa,[*4] Yukio Kanazawa,[*4] Masahiko Nihei,[*5] Yu Sakuma,[*5] Hiroaki Shimmura,[*6] Junichi Akiyama[*6] and Michio Tokiwa[*6]

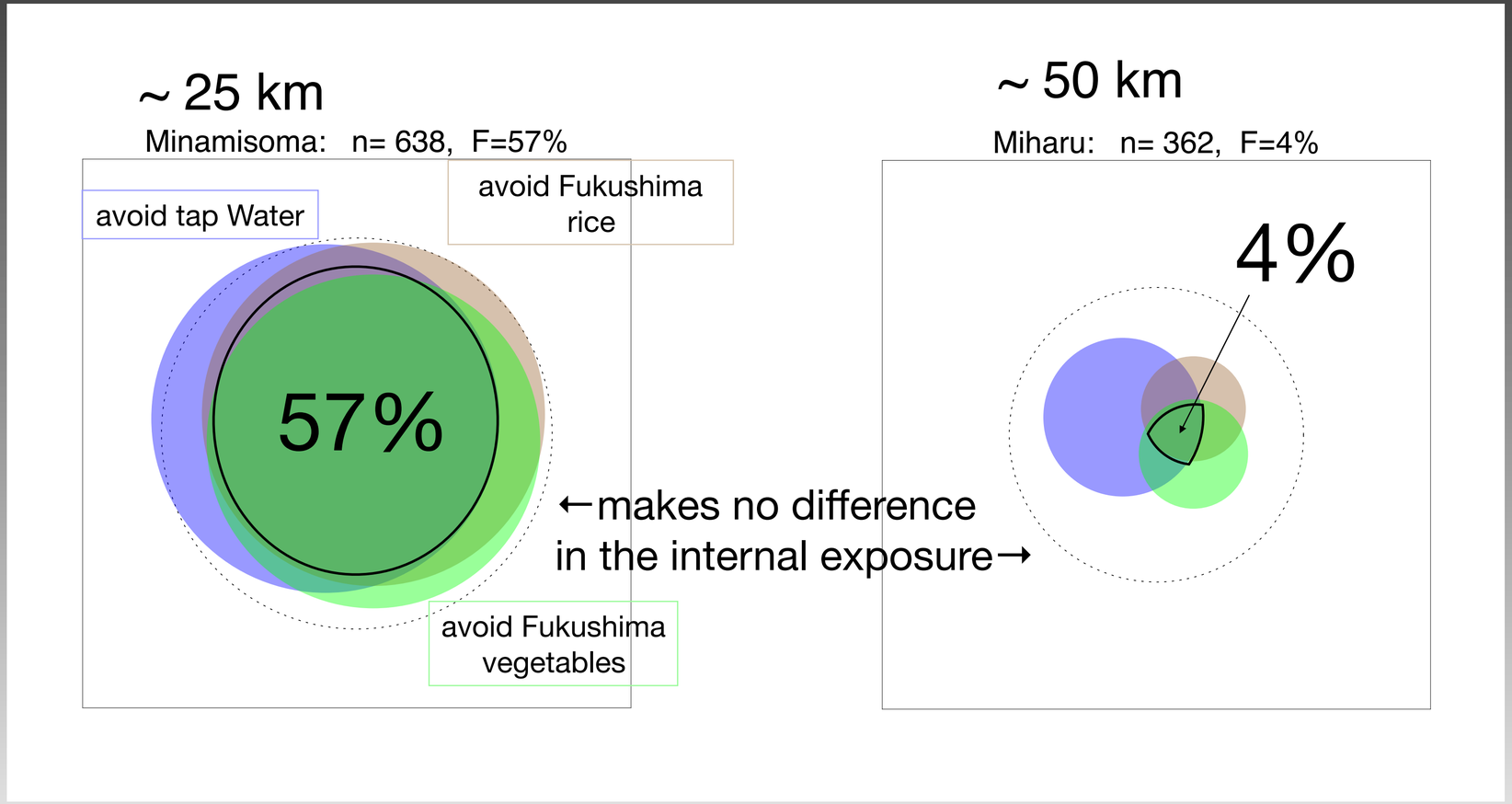
3 BABYSCANs were used to measure the 2700 babies



Nobody had detectable level of radiocaesium

Differences in risk perception in Minamisoma vs Miharu

illustrating the psycho-social aspect of the situation

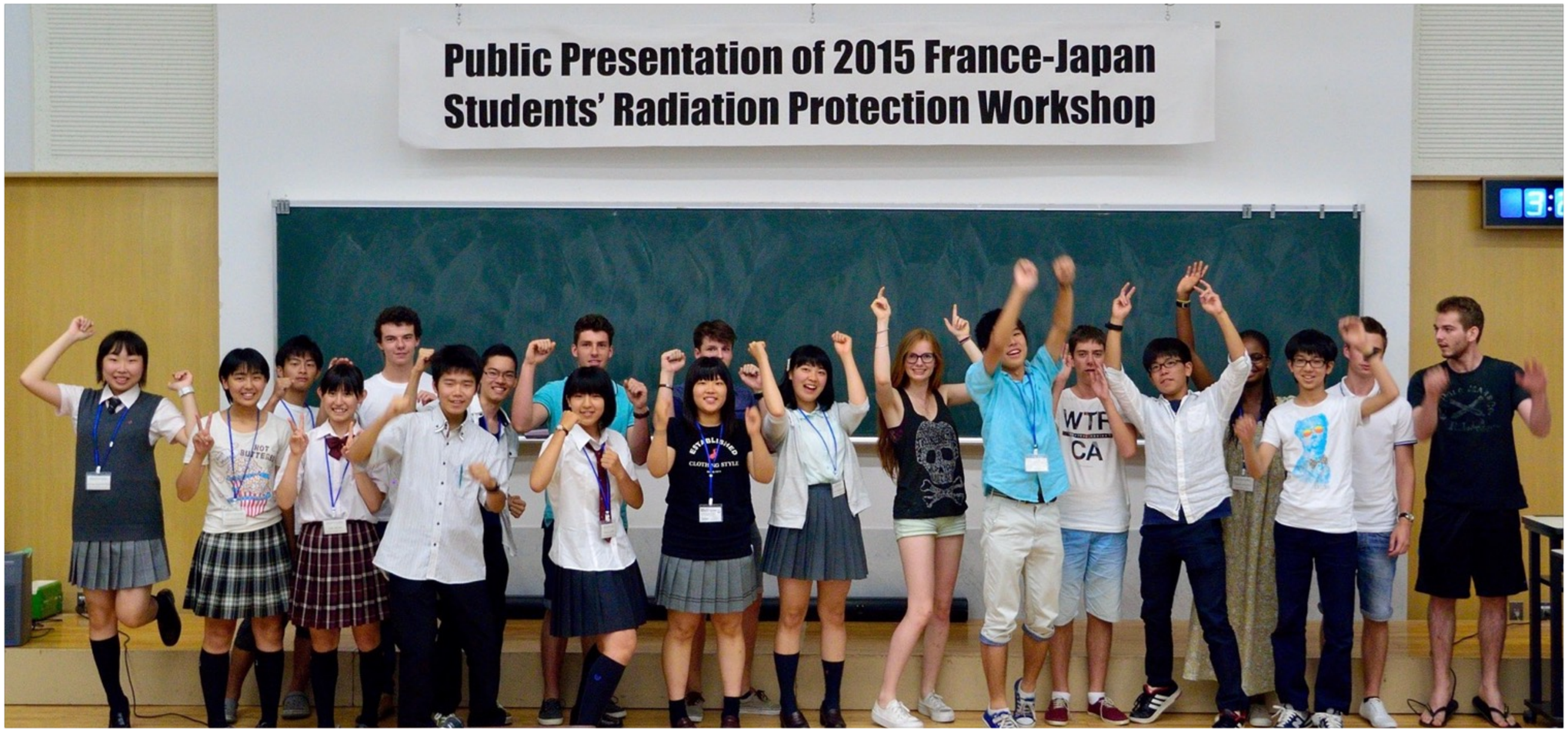


Importance of face-to-face communication

Dr. Masaharu Tsubokura, Minamisoma, explaining to the parents that there is K-40 in the baby's body, but not Cs-134/137

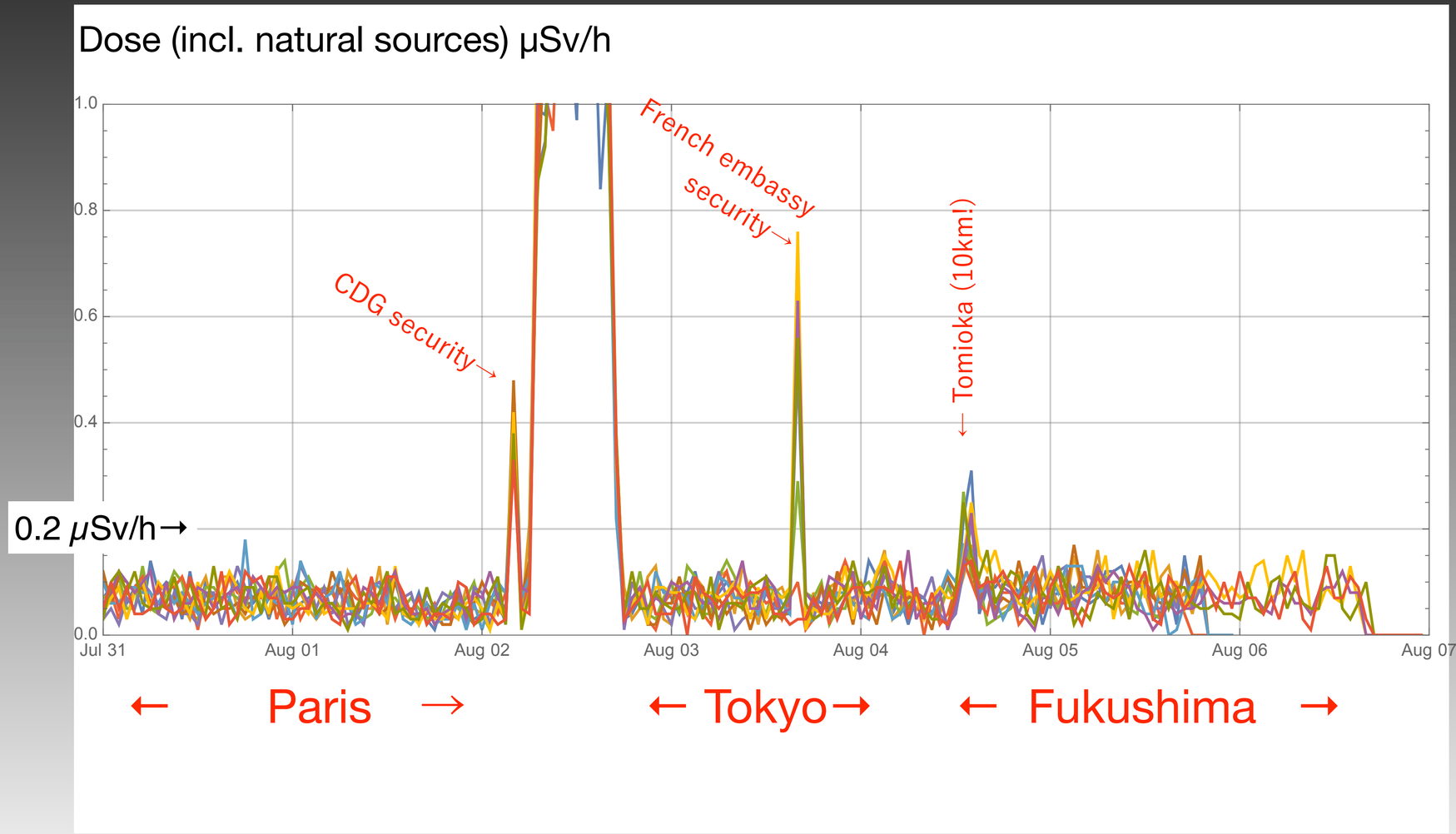
Part 6

Having young generation actively involved

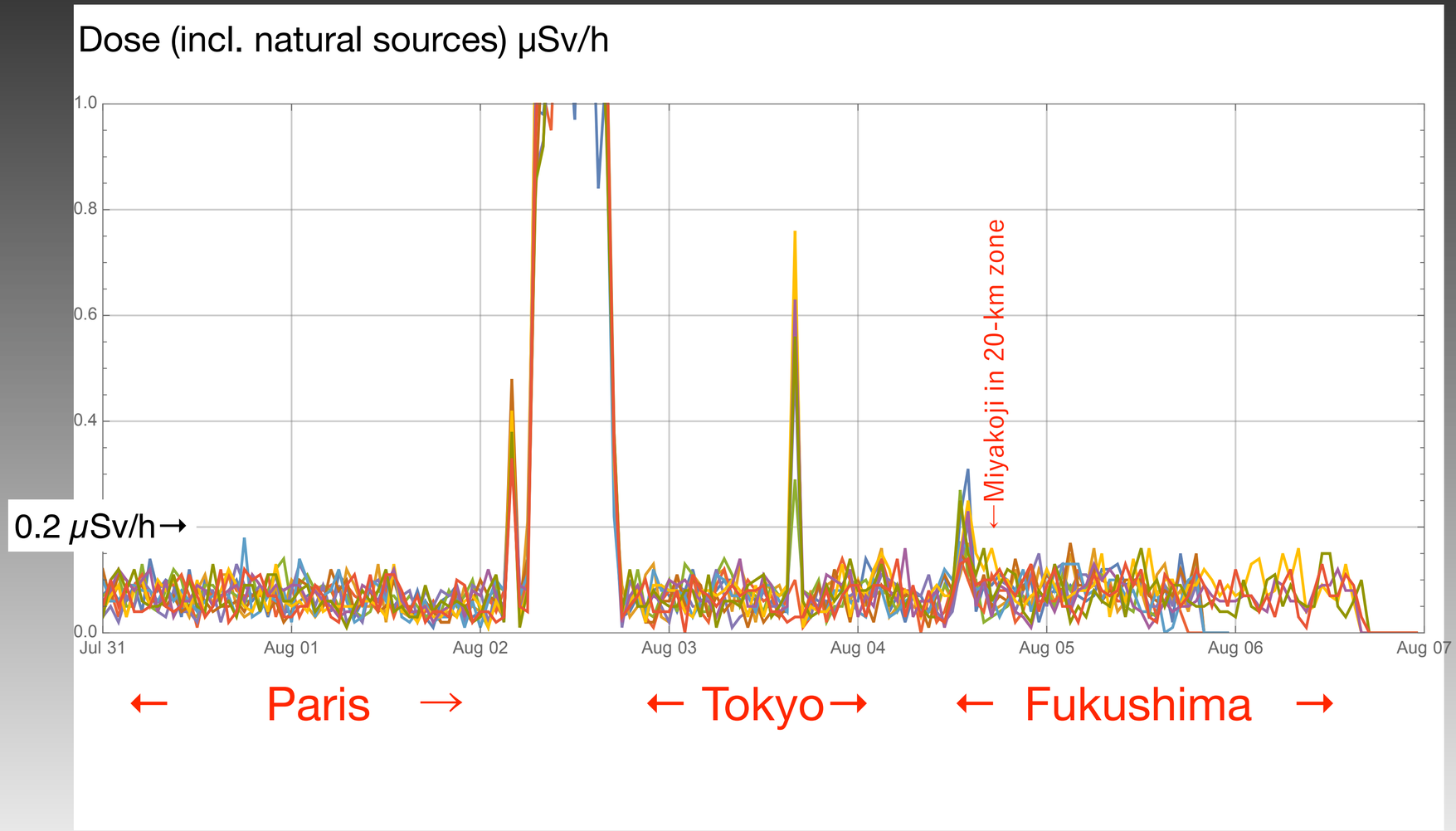


French students came to Fukushima last month with “D-shuttle” (personal dosimeter)

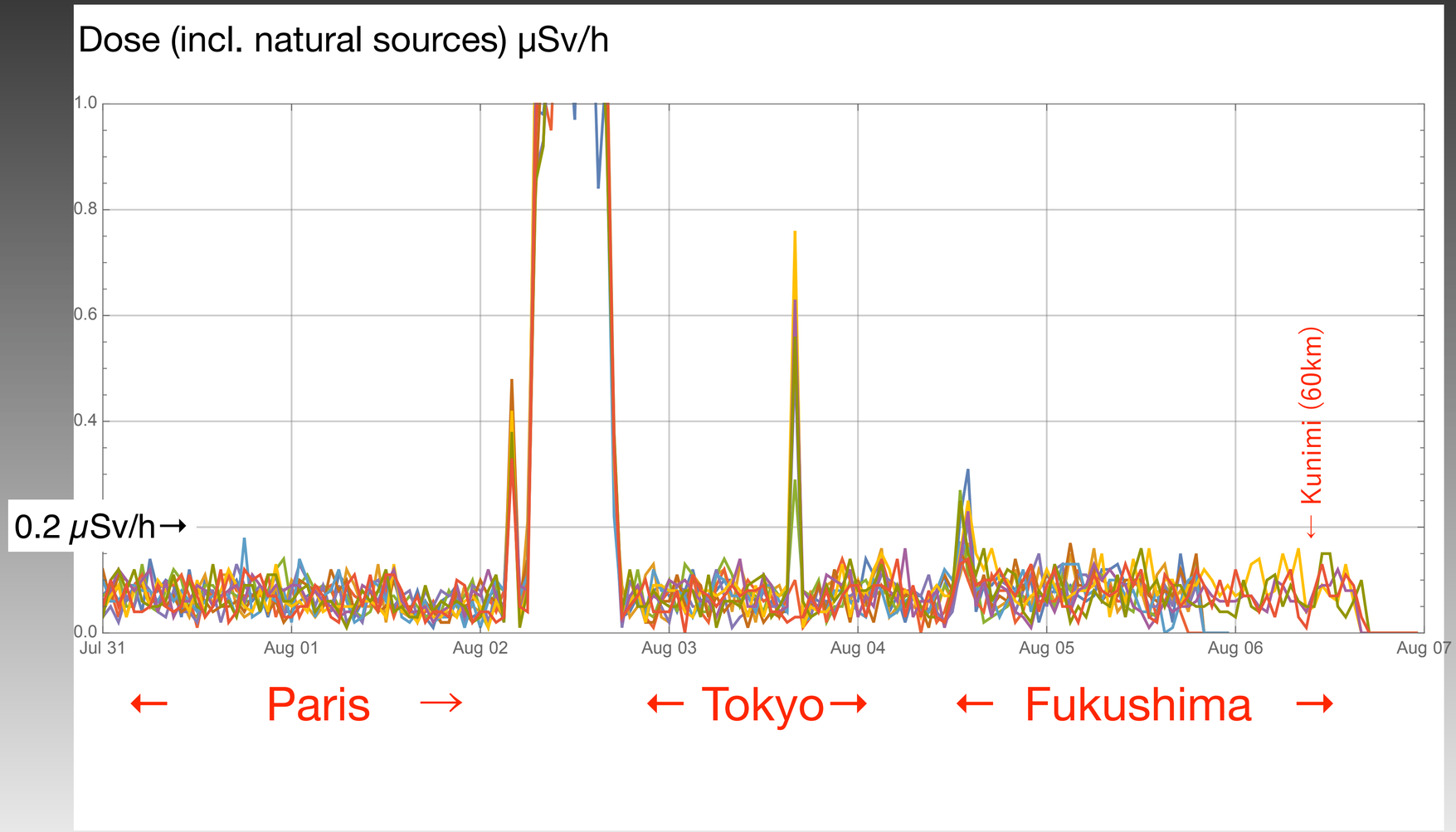
D-shuttle data, 8 students, 4 teachers&experts



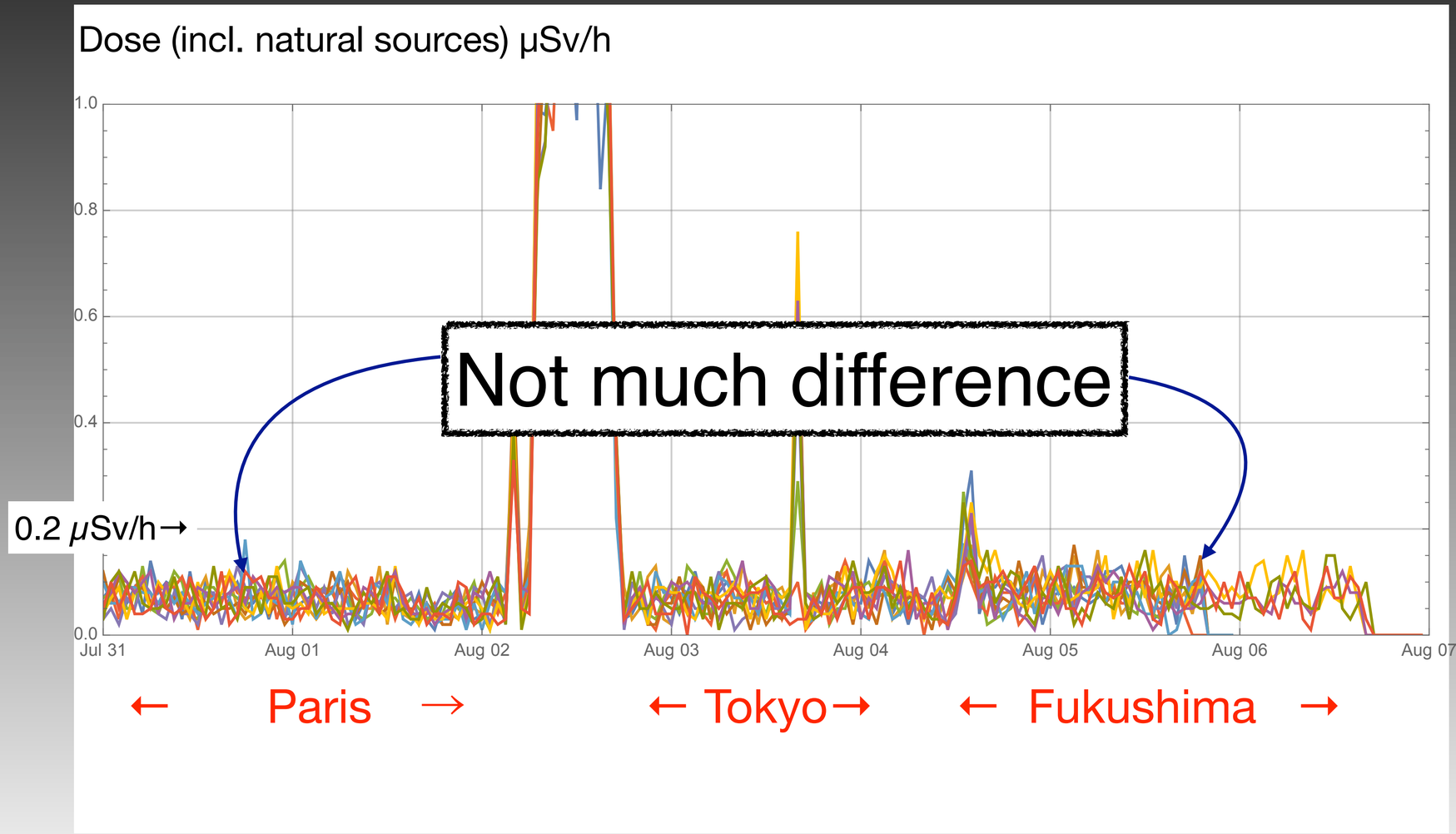
D-shuttle data, 8 students, 4 teachers&experts



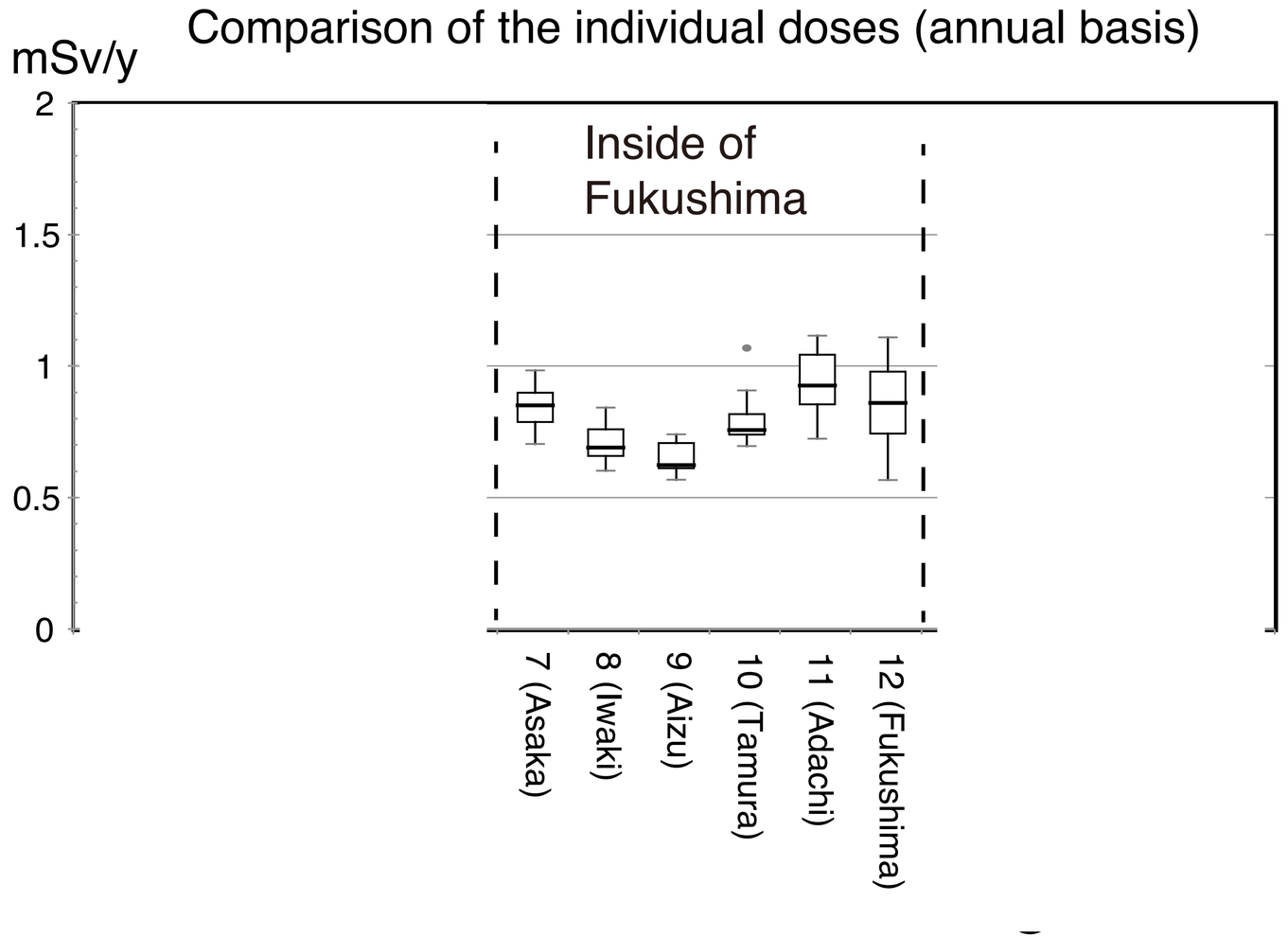
D-shuttle data, 8 students, 4 teachers&experts



D-shuttle data, 8 students, 4 teachers&experts



Comparing personal dose of high-school students, same dosimeter, incl. natural background



Japan-France-Poland-Belarus, >200 high school students co-authored a paper comparing personal dose (published in the Journal of Radiological Protection)

OPEN ACCESS
IOP Publishing | Society for Radiological Protection
Journal of Radiological Protection
J. Radiol. Prot. **36** (2016) 49–66
doi:10.1088/0952-4746/36/1/49

Measurement and comparison of individual external doses of high-school students living in Japan, France, Poland and Belarus—the 'D-shuttle' project—

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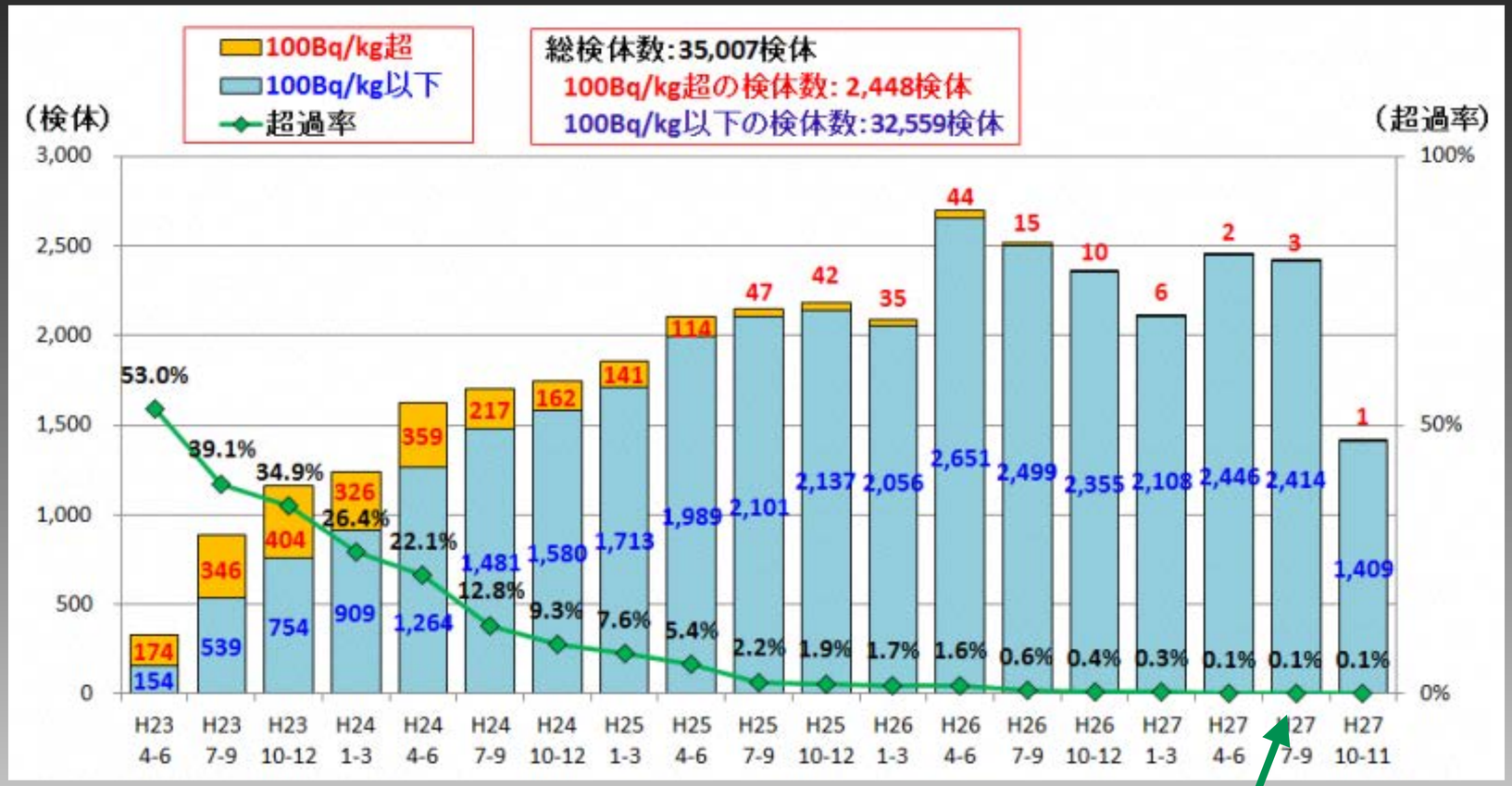
BTW

data dissemination by the government
- gradually getting better -

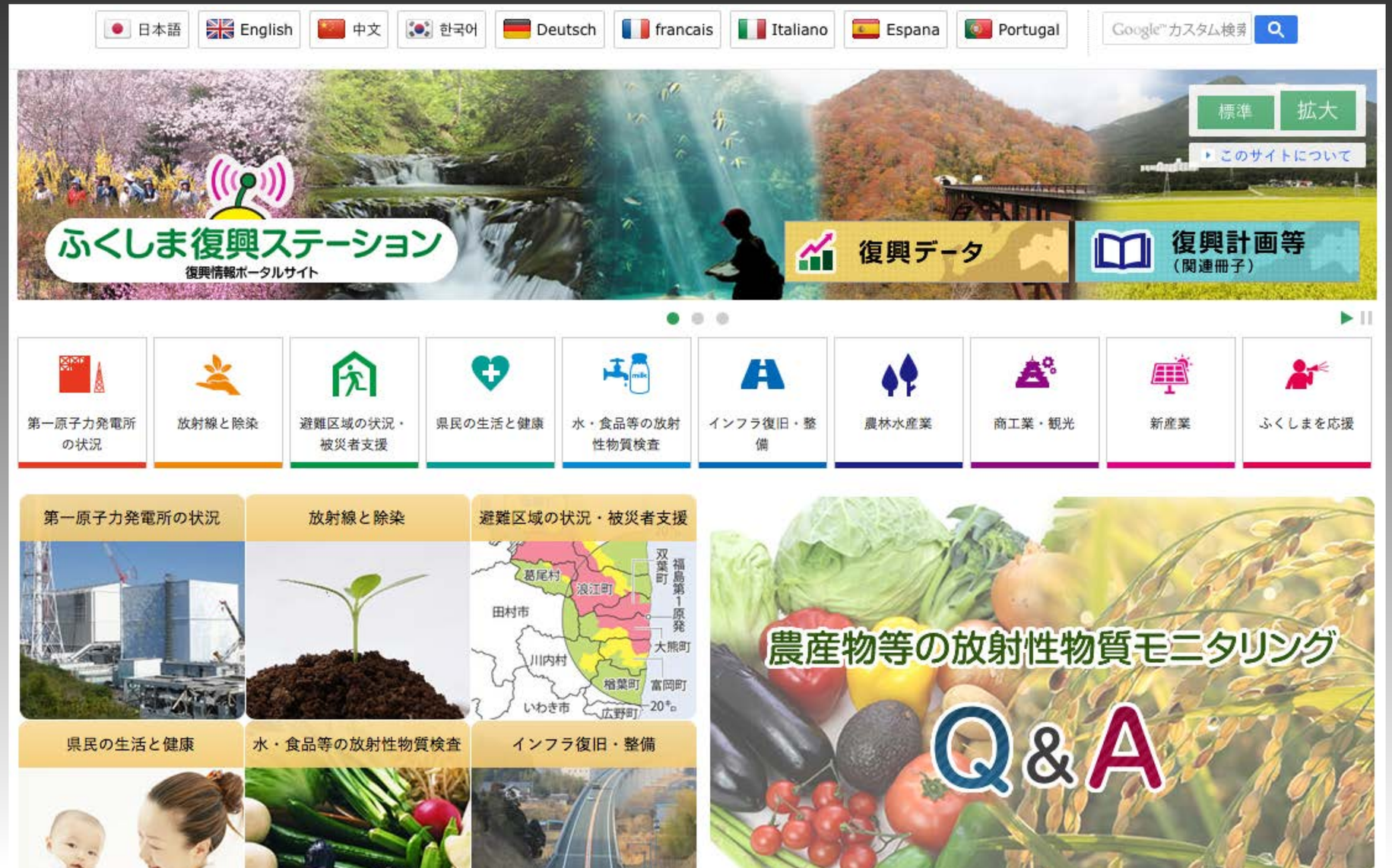
Fisheries agency (now showing graphs)



Percentage of fish off the coast of Fukushima Dai-ichi (fishing and marketing restricted) which exceeded the 100 Bq/kg criteria. Now ~0%

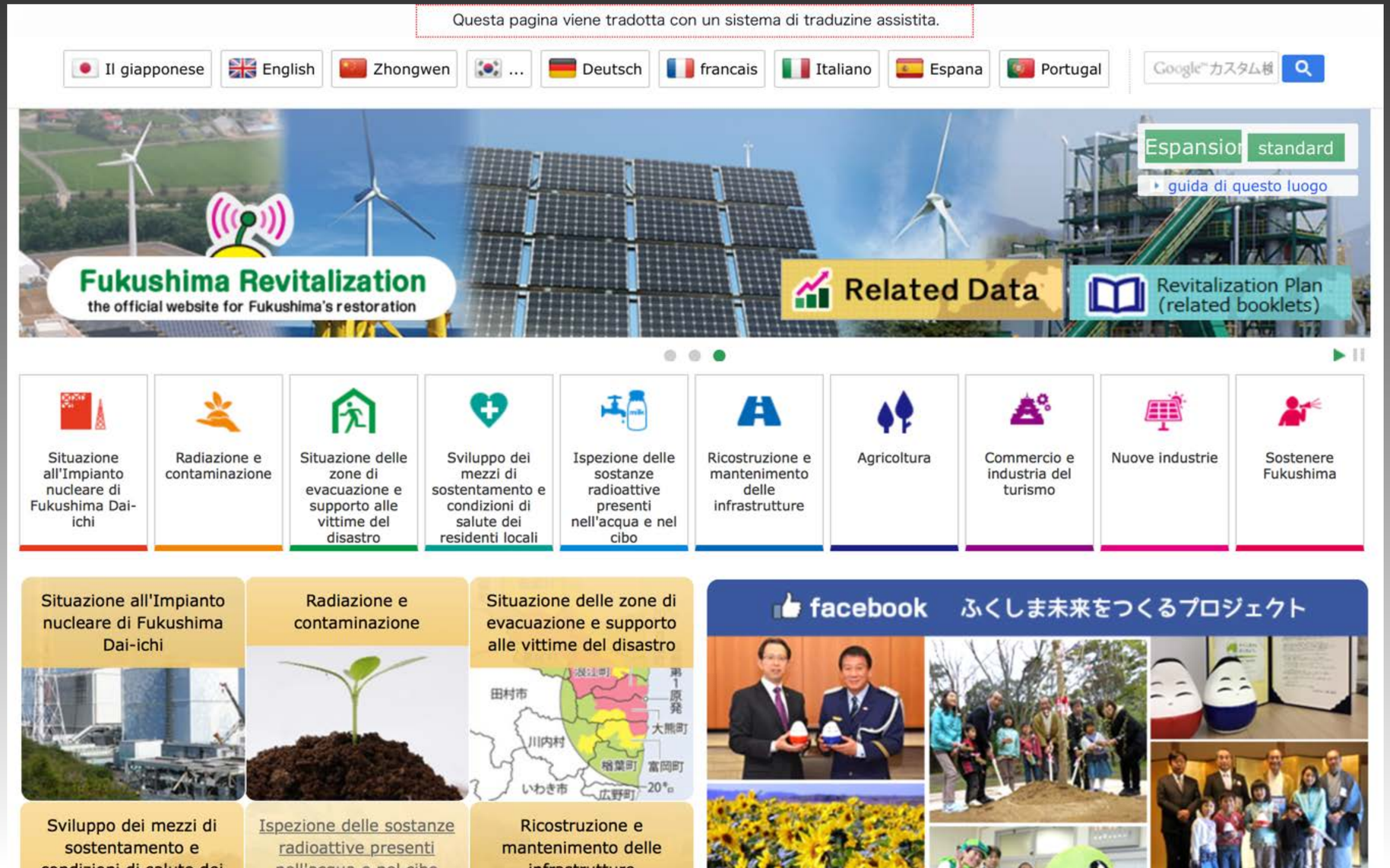
Fukushima prefecture portal is now multilingual

http://www.pref.fukushima.lg.jp/site/portal/

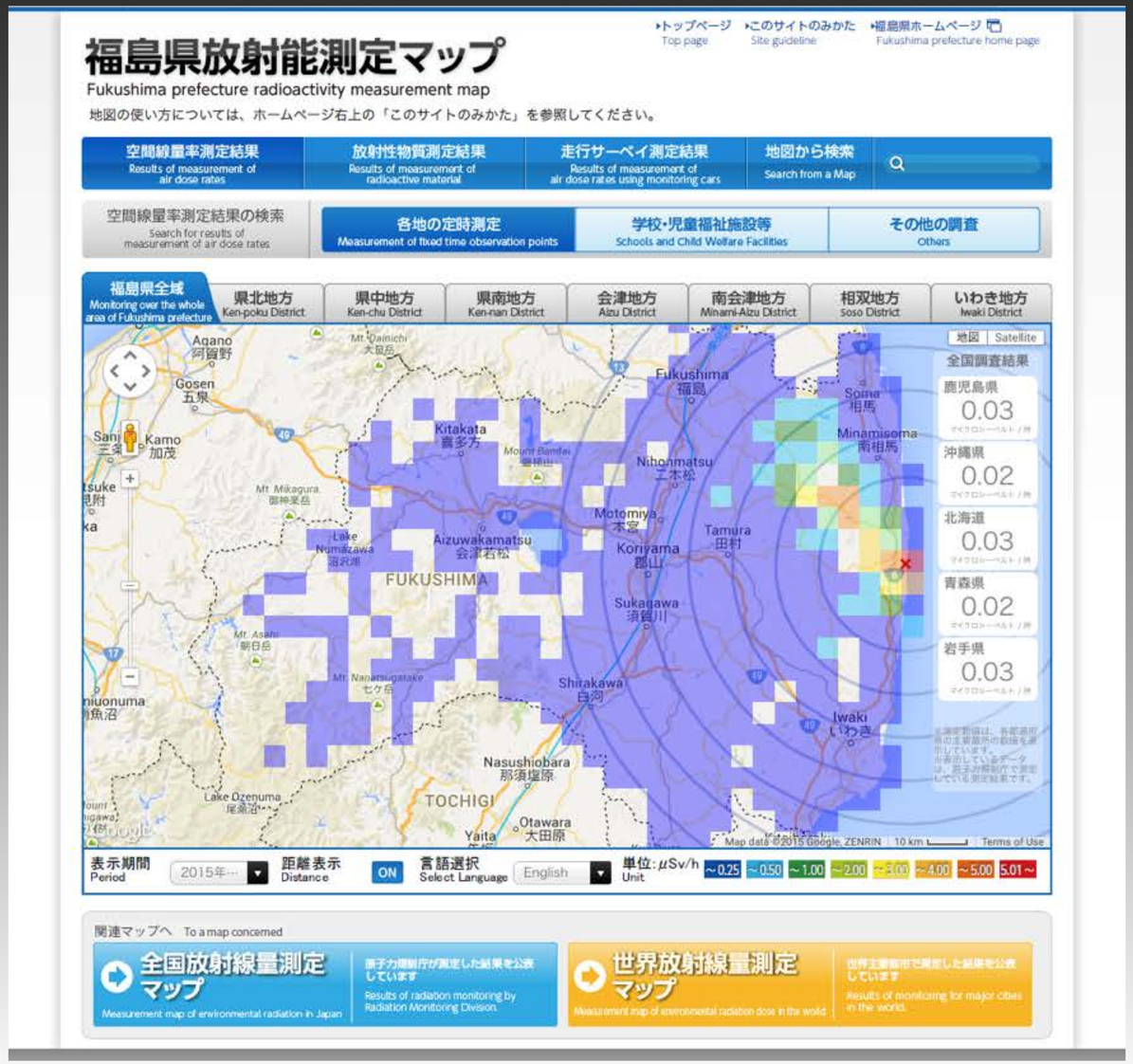


Fukushima prefecture portal is now multilingual (machine tra

http://www.pref.fukushima.lg.jp/site/portal/

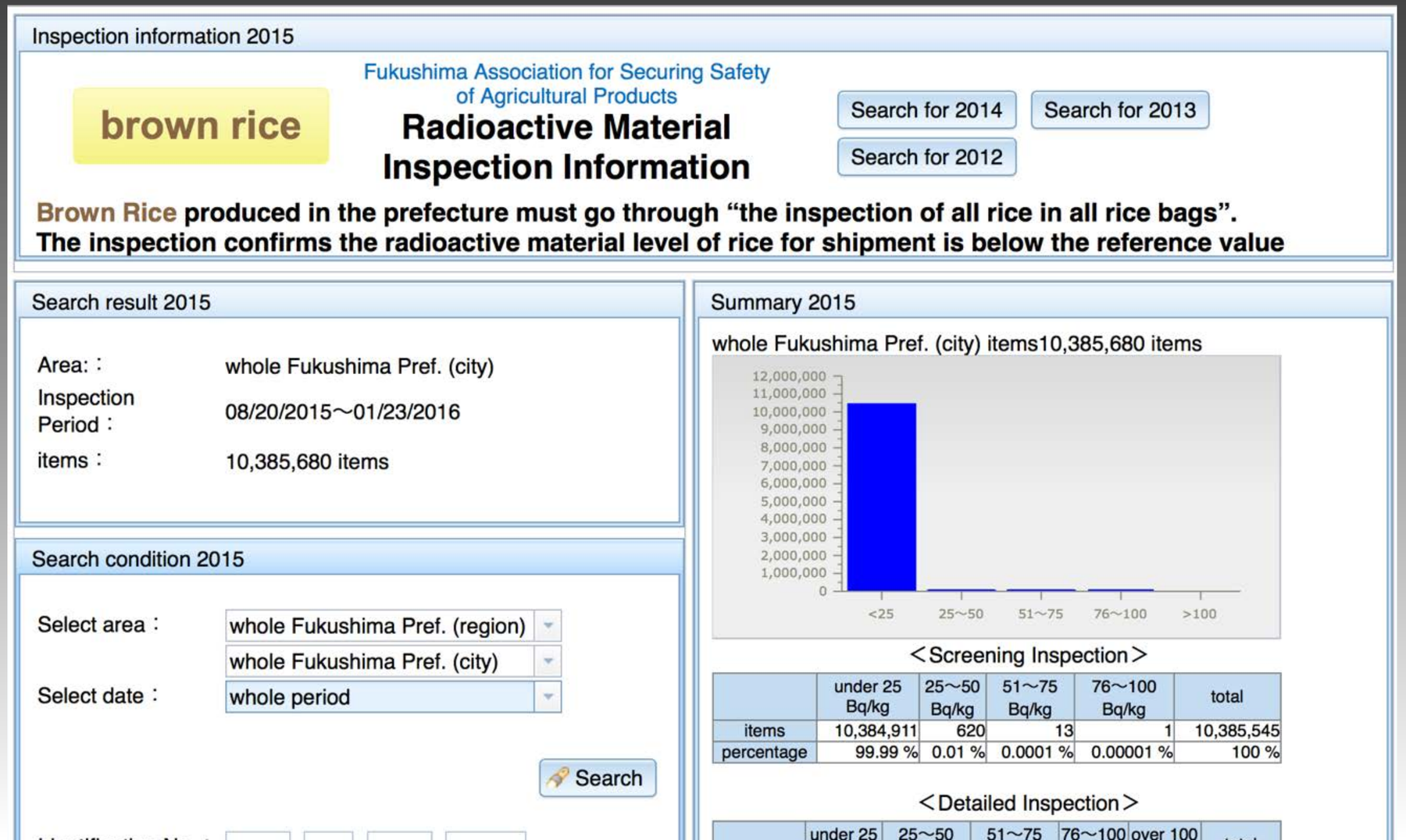


Real time and clickable radiation monitor map



searchable rice-test database with a graph (since 2012)

https://fukumegu.org/ok/kome/



Inspection information 2015

brown rice

Fukushima Association for Securing Safety of Agricultural Products

Radioactive Material Inspection Information

Search for 2014 | Search for 2013 | Search for 2012

Brown Rice produced in the prefecture must go through "the inspection of all rice in all rice bags". The inspection confirms the radioactive material level of rice for shipment is below the reference value

Search result 2015

Area: : whole Fukushima Pref. (city)

Inspection Period : 08/20/2015～01/23/2016

items : 10,385,680 items

Search condition 2015

Select area : whole Fukushima Pref. (region) / whole Fukushima Pref. (city)

Select date : whole period

Search

Summary 2015

whole Fukushima Pref. (city) items10,385,680 items

＜Screening Inspection＞

	under 25 Bq/kg	25～50 Bq/kg	51～75 Bq/kg	76～100 Bq/kg	total
items	10,384,911	620	13	1	10,385,545
percentage	99.99 %	0.01 %	0.0001 %	0.00001 %	100 %

＜Detailed Inspection＞

	under 25	25～50	51～75	76～100	over 100	

Conclusions

Despite soil contamination,
the internal exposure of Fukushima people is negligibly low
↔ Fukushima food safety

BUT

Parents with small children are much concerned about internal exposure
 - necessity of the BABYSCAN

Radiation is NOT the only problem - psycho-social aspects are VERY important

Take-home messages

Fukushima Dai-ichi, serious accident

However,

No death due to **ACUTE** radiation effects

DISCERNIBLE long-term health effects
(e.g., cancer increase, incl. thyroid) **unlikely**
source - WHO, UNSCEAR, IAEA

Fukushima food, tested & safety confirmed


ネバーギブアップ 鶴見
日立GE ニュークリア・エナジー(株)
(株)日立プラントテクノロジー
C7-2


0.30 mSv
この列は
APD
警報設定値
0.30 mSv
この列は
APD
警報設定値
0.30 mSv
0.30 mSv
＜APD等の正しい着用方法について＞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6