Environmental and Personal Monitoring After Fukushima Accident

Executive director
(Chair of Strategic Planning)
JHPS

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Contents

Present status on environmental radiation monitoring and personal exposure monitoring

A part of topic presented here was picked up from the IRPA 13 and the JHPS Fukushima accident special symposium I - IV which were held at Tokyo university in 2011 fiscal year

Environmental radiation monitoring

- E1: Implementation of general environmental monitoring
- E2: Preparation of the distribution map
- E3: Analysis on the atmospheric dispersion of radioactive materials

E1. Off-site environmental monitoring in emergency situation (March – July, 2011)

- **Monitoring area**
  - ✓Land, Marine, and Sky area
- **Monitoring frequency**
  - ✓Daily (basically)
- **Implementing agency**
  - ✓MEXT, Prefectures, NPA, MOD, USDOE
  - ✓JAEA, NUSTEC, JAMSTEC, JAXA, Universities
  - ✓Electric power companies and rerated companies

MEXT is conducting comprehensive environmental radiation monitoring and many institute took part in the environmental monitoring activities.

MEXT: Ministry of Education, Culture, Sports, Science and Technology
NPA: National Police Agency
MOD: Ministry of Defense
USDOE: U.S. Department of Energy
JAEA: Japan Atomic Energy Agency
NUSTEC: Nuclear Safety Technology Center
JAMSTEC: Japan Agency for Marine-Earth Science and Technology
JAXA: Japan Aerospace Exploration Agency
Prefectures: Tokyo, Hokkaido, and all the prefectures

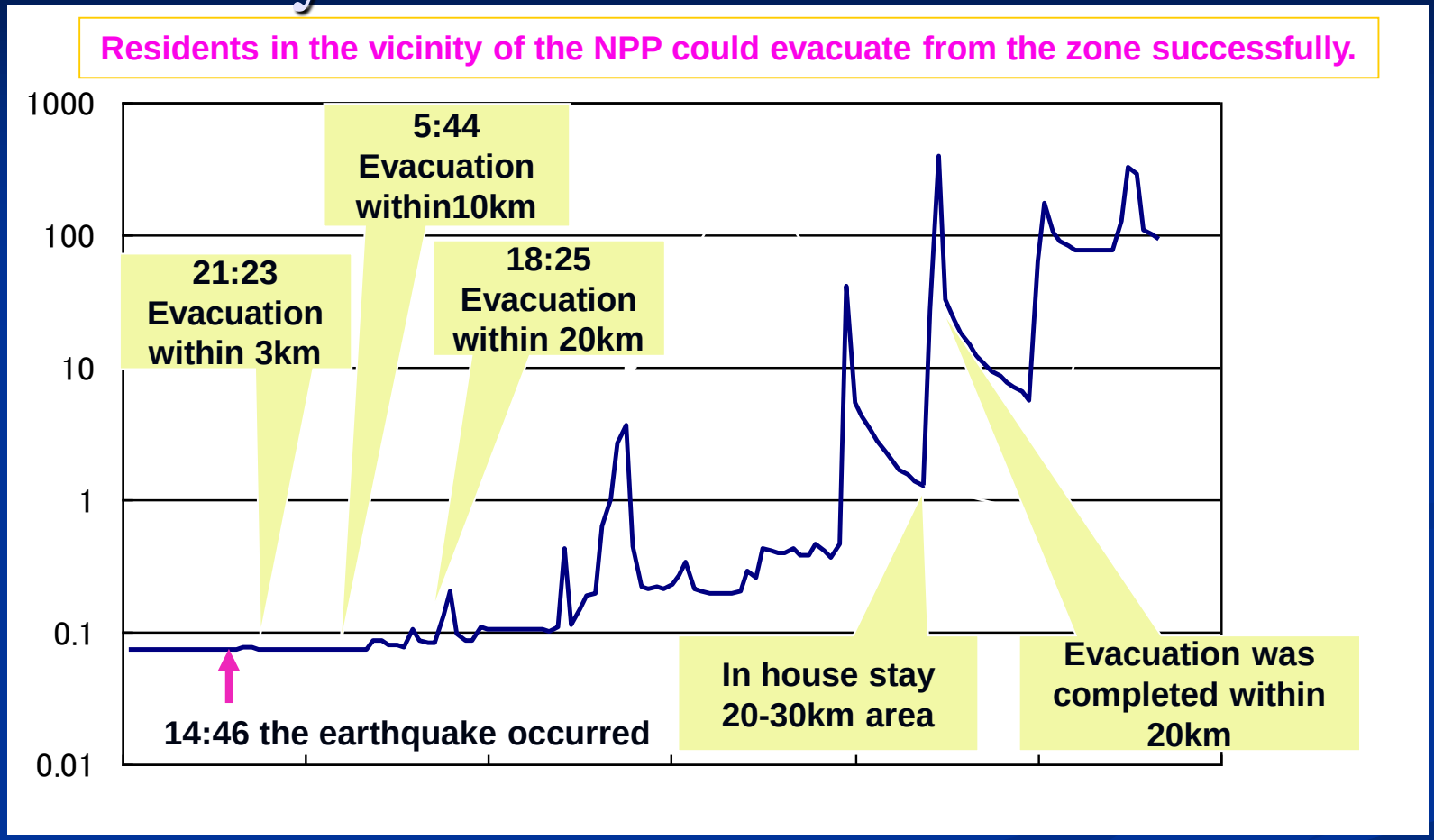
E1. Monitoring items in emergency situation

- Ambient dose rate
  - ✓ Measurement at fixed monitoring points (MEXT and 47 prefectures: All over Japan)
  - ✓ Measurement by monitoring vehicle
  - ✓ Measurement by aircraft
  - ✓ Measurement at the sea
- Integrated Dose
  - ✓ Measurement at fixed monitoring point
- Radionuclide quantitative analysis on environmental samples
  - ✓ Dust, Soil, Pond water, Weed
  - ✓ Drinking water, Fallout (47 prefecture: All over Japan)
  - ✓ Sea water, Sea-bottom soil

Continuous dust sampling include radioiodine sampling was not performed sufficiently because many radiation monitoring instrument at the monitoring post in Fukushima prefecture have been damaged by the impact of the earthquake and tsunami.

(monitoring results are available from http://radioactivity.mext.go.jp/)

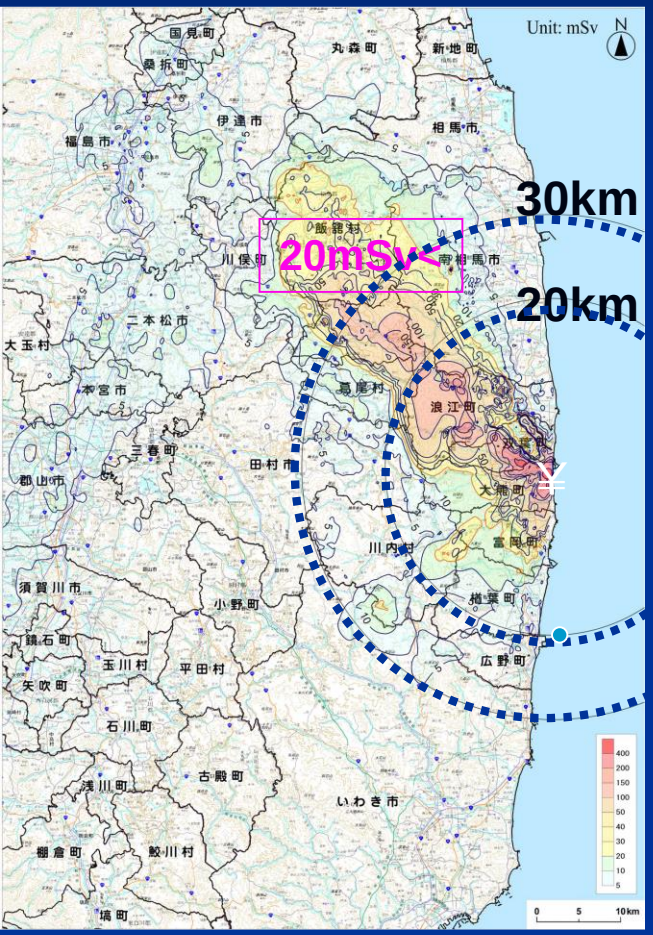
E1. Chronological change of ambient dose in the vicinity of F1 NPP and evacuation

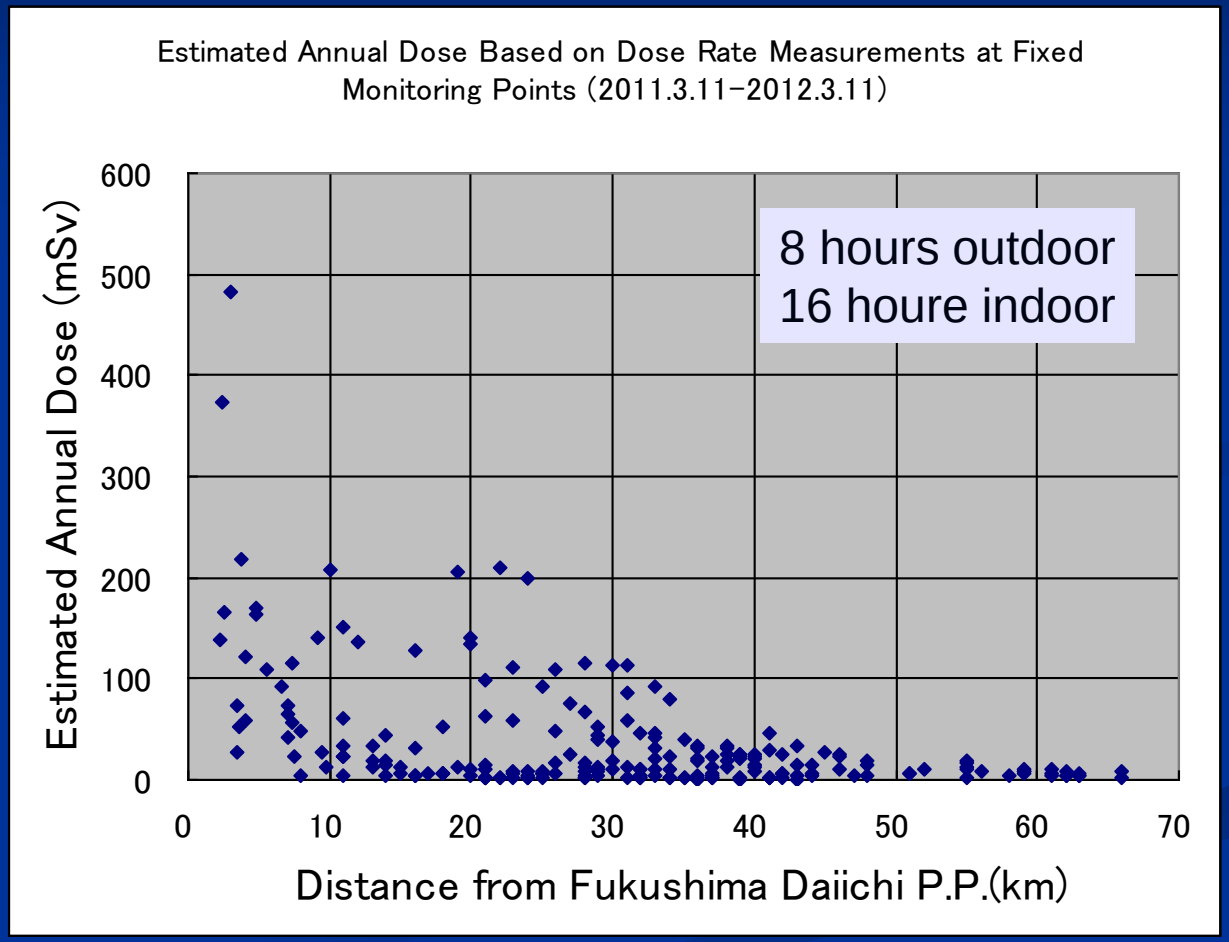


Monitoring post at Ohkuma town ohno（5km west from F1 NPP）

(Data Source : Fukushima pref. Website)

E1. Estimated Annual Dose at the Fixed Monitoring Points





(Source : Monitoring information of environmental radioactivity level, the Ministry of Education, Culture, Sports, Science & Technology(MEXT) Website)

E1. Airborne monitoring survey

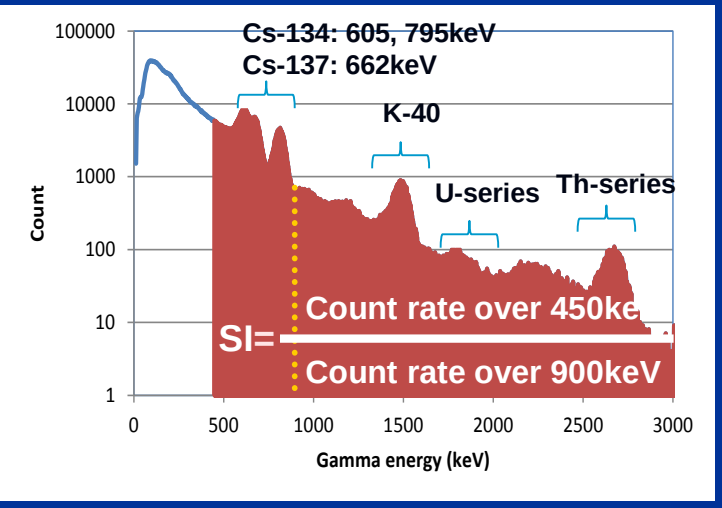
- Mar. 25, 2011 MEXT Press release of plan for aerial radiation monitoring
- Apr. 5, 2011 **<1st monitoring>** 60km zone from the NPP (DOE) + 60-80km (NUSTEC)
- May 17, 2011 **<2nd monitoring>** 80-100km zone from the NPP (NUSTEC)
- May 30, 2011 **<3rd monitoring>**
  40km zone from the NPP(NUSTEC + JAEA) + 40-80km (NUSTEC)
- Jun. 21, 2011 Miyagi-pref., Tochigi-pref., and Ibaraki-pref. (NUSTEC + JAEA)
- Aug. 2, 2011 **<East Japan monitoring>** (JAEA, NUSTEC, …)
- Oct. 22, 2011 **<4th monitoring>**
  40km zone from the NPP(NUSTEC + JAEA) + 40-80km zone (NUSTEC)
- Jan. 30, 2012 **<West Japan monitoring (Ongoing) >** (JAEA, NUSTEC, …)
- Feb. 6, 2012 **<monitoring above the warning area around the NPP>** (NUSTEC)

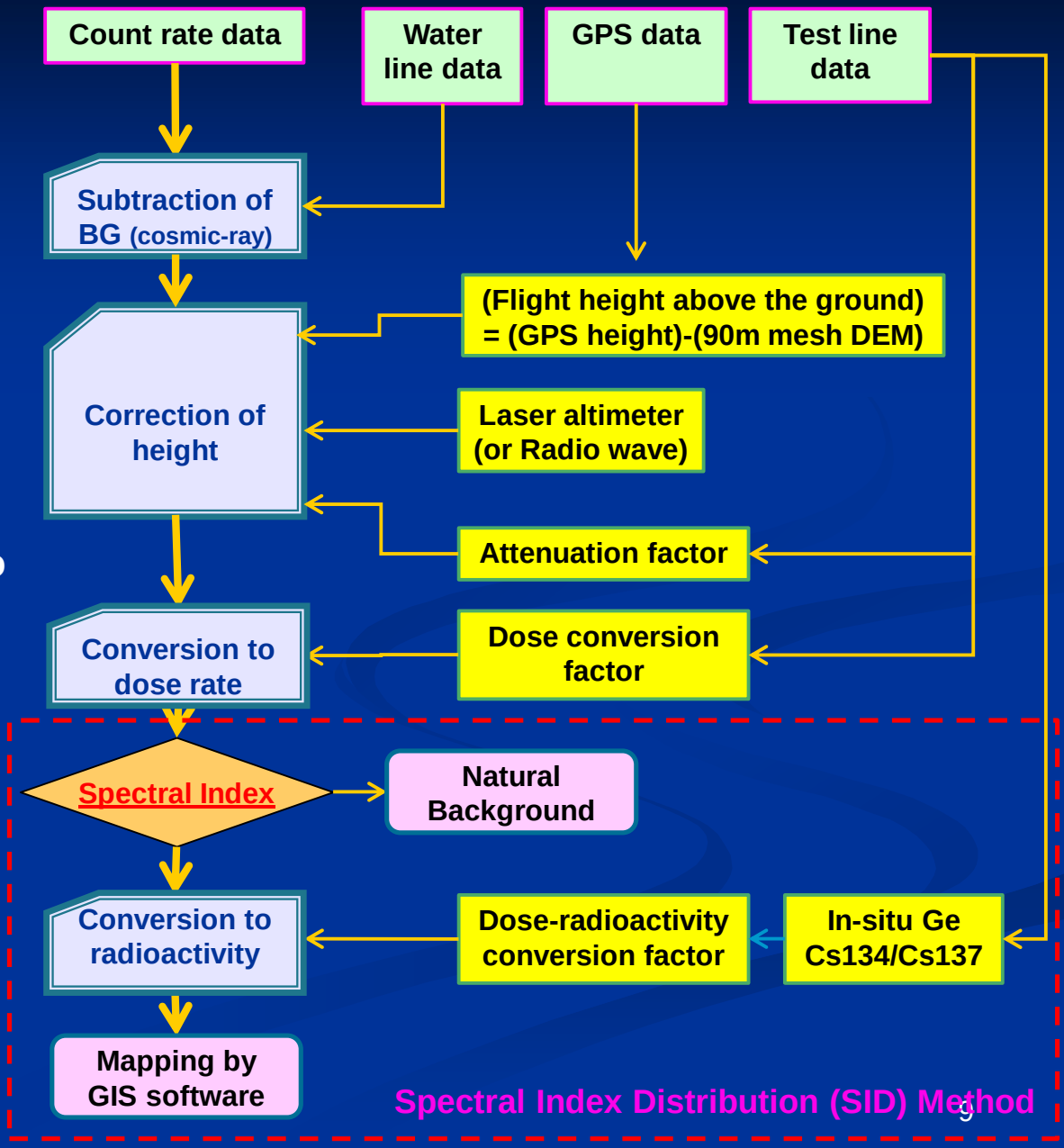
JAEA : Japan Atomic Energy Agency,
NUSTEC : Nuclear Safety Technology Center

Y. Sanada et al., IRPA13 P12.61

E1. Procedure of data analysis

- Helicopter flight above the ground 150-300m.
- Count rate was obtained from large size NaI(Tl) detector.
- Acquisition rate is 1 second interval.
- SI method can discriminate radio cesium and natural radio nuclides.

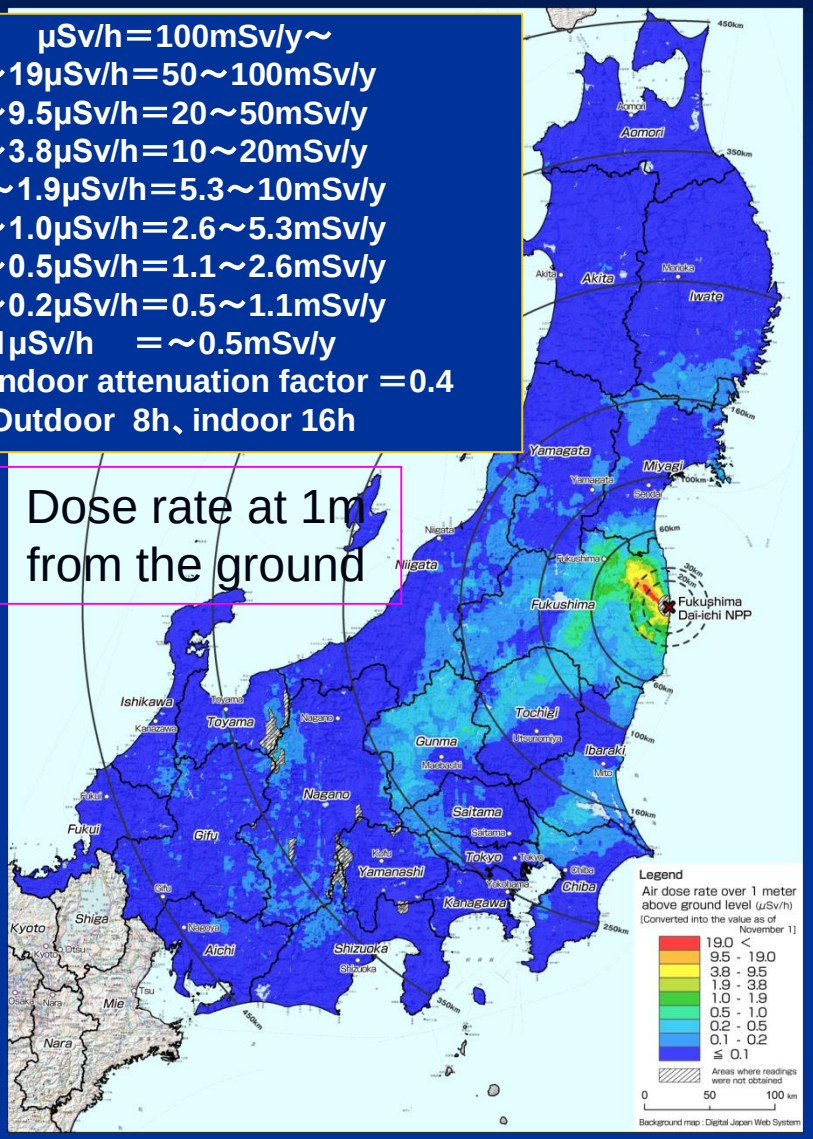




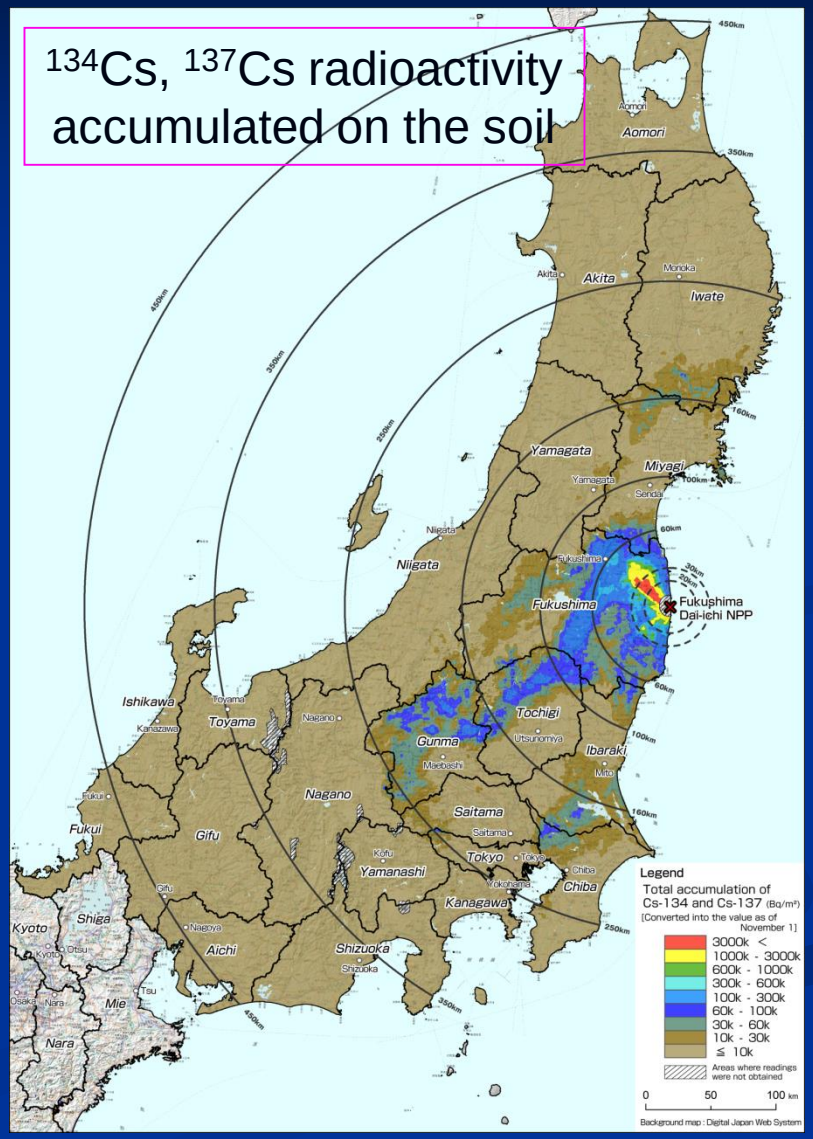
E1. Airborne monitoring survey in the eastern part of Japan (Converted into the value as of November 1)

19～　μSv/h＝100mSv/y～
9.5～19μSv/h＝50～100mSv/y
3.8～9.5μSv/h＝20～50mSv/y
1.9～3.8μSv/h＝10～20mSv/y
1.0～1.9μSv/h＝5.3～10mSv/y
0.5～1.0μSv/h＝2.6～5.3mSv/y
0.2～0.5μSv/h＝1.1～2.6mSv/y
0.1～0.2μSv/h＝0.5～1.1mSv/y
～0.1μSv/h　＝～0.5mSv/y
indoor attenuation factor ＝0.4
Outdoor 8h、indoor 16h

Dose rate at 1m from the ground

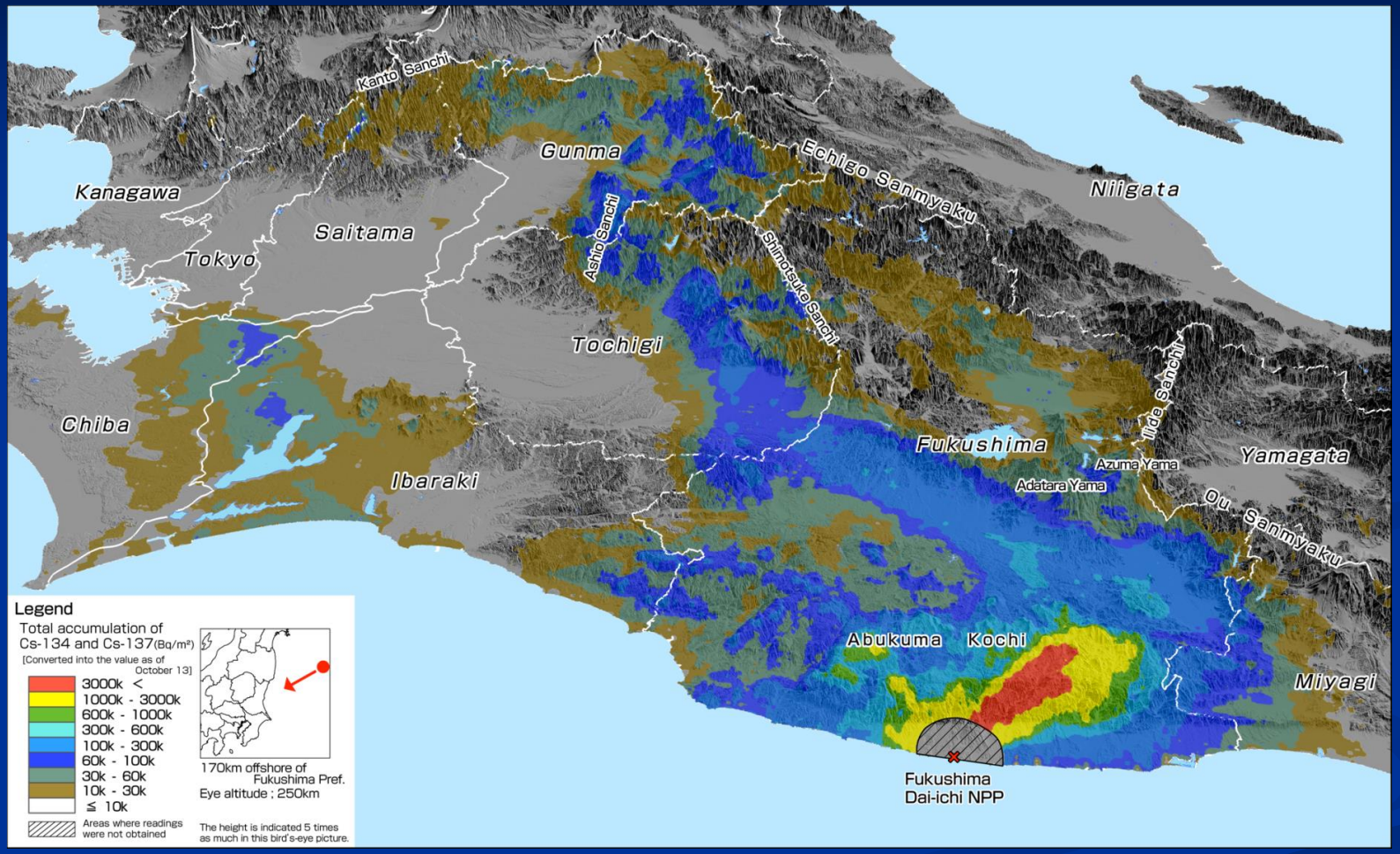


^{134}Cs, ^{137}Cs radioactivity accumulated on the soil



(Source : Monitoring information of environmental radioactivity level, the Ministry of Education, Culture, Sports, Science & Technology(MEXT) Website)

E1. 3D map of radiocesium distribution



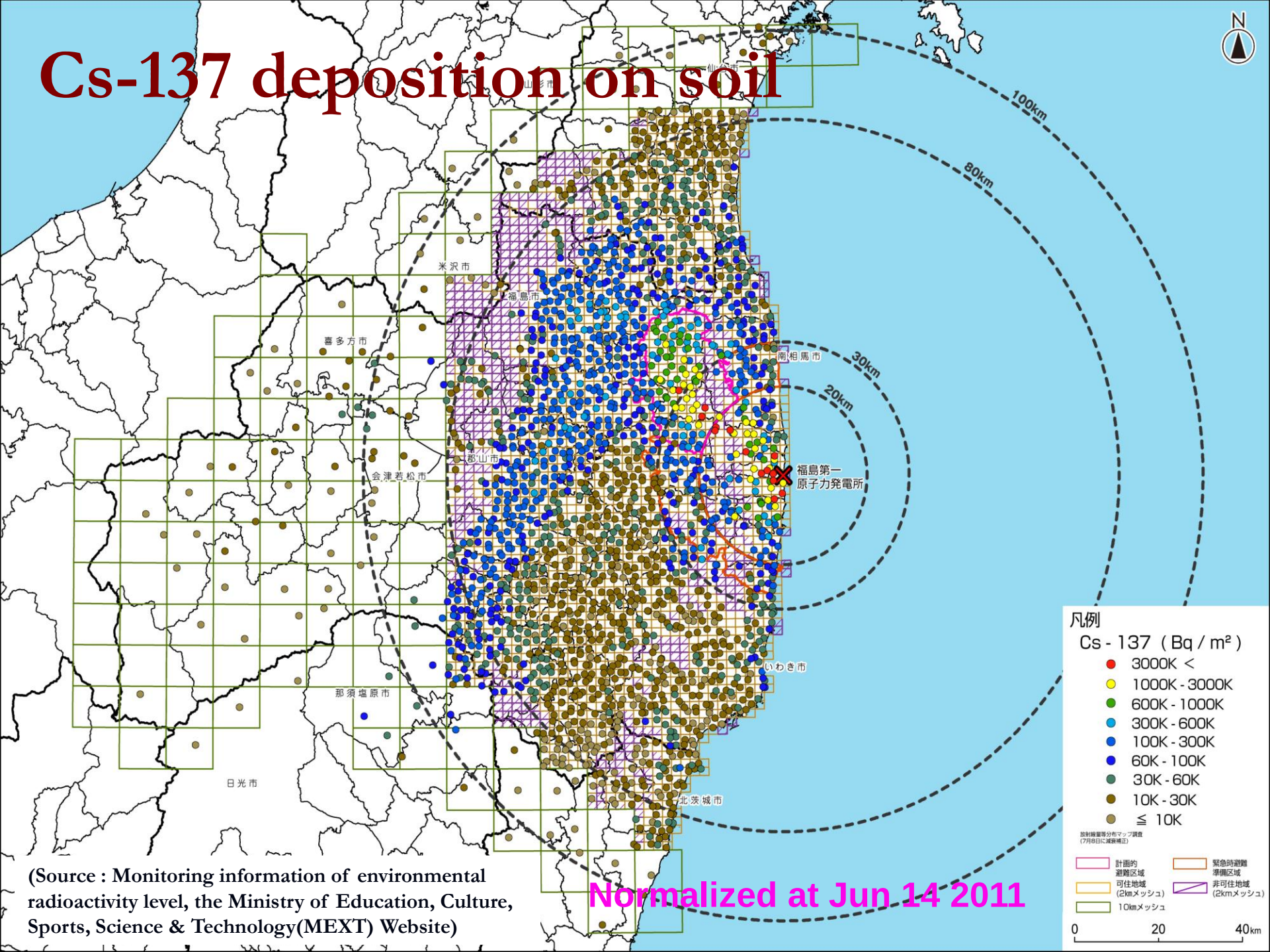
Radio cesium was mainly deposited within surrounding mountains.

Y. Sanada et al., IRPA13 P12.61

E2. Preparation of the Distribution Map of Radiation Doses and Activity Concentration in Soil

- MEXT and other cooperative institutes measured ambient dose rates and radioactivity concentration in soil at around 2,200 locations within approximately 100 km from the F1 NPP.
  - ✓ Object
    Continuously check of the impact on the health of residents and the environment
  - ✓ Soil collecting periods
    First period: 2011 June 6 to June 14
    Second period: 2011 June 27 to July 8
  - ✓ Other cooperative institute
    Total participants: 409 people from 94 organizations.

Cs-137 deposition on soil

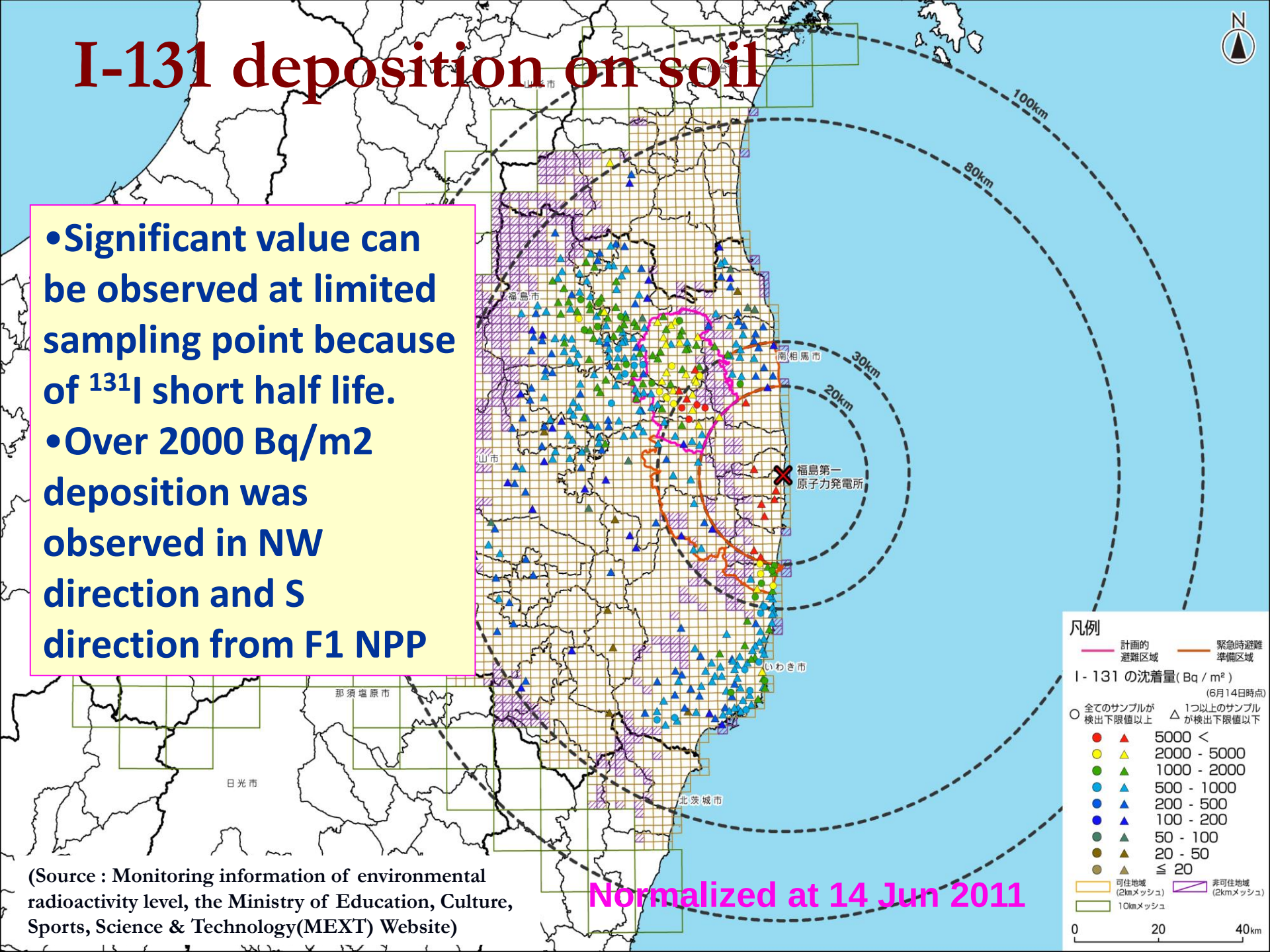


(Source : Monitoring information of environmental radioactivity level, the Ministry of Education, Culture, Sports, Science & Technology(MEXT) Website)

Normalized at Jun 14 2011

I-131 deposition on soil

- Significant value can be observed at limited sampling point because of ^{131}I short half life.
- Over 2000 Bq/m2 deposition was observed in NW direction and S direction from F1 NPP

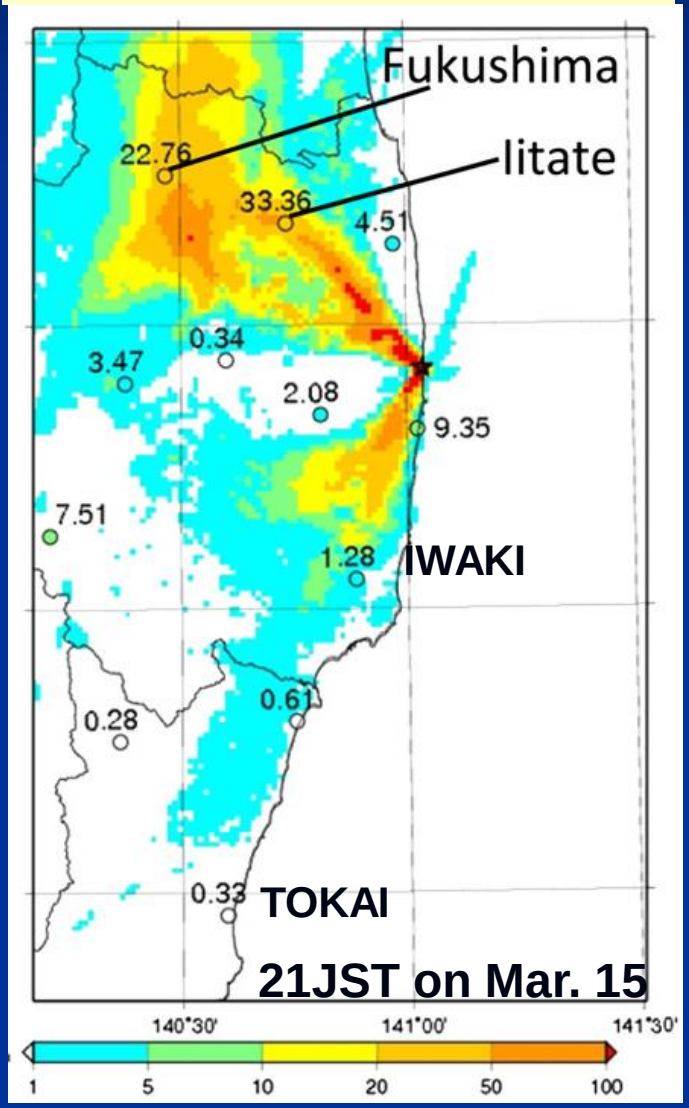


(Source : Monitoring information of environmental radioactivity level, the Ministry of Education, Culture, Sports, Science & Technology(MEXT) Website)

Normalized at 14 Jun 2011

E3. Source term estimation by WSPEEDI reverse estimation method

Air dose rate (μGy/h)

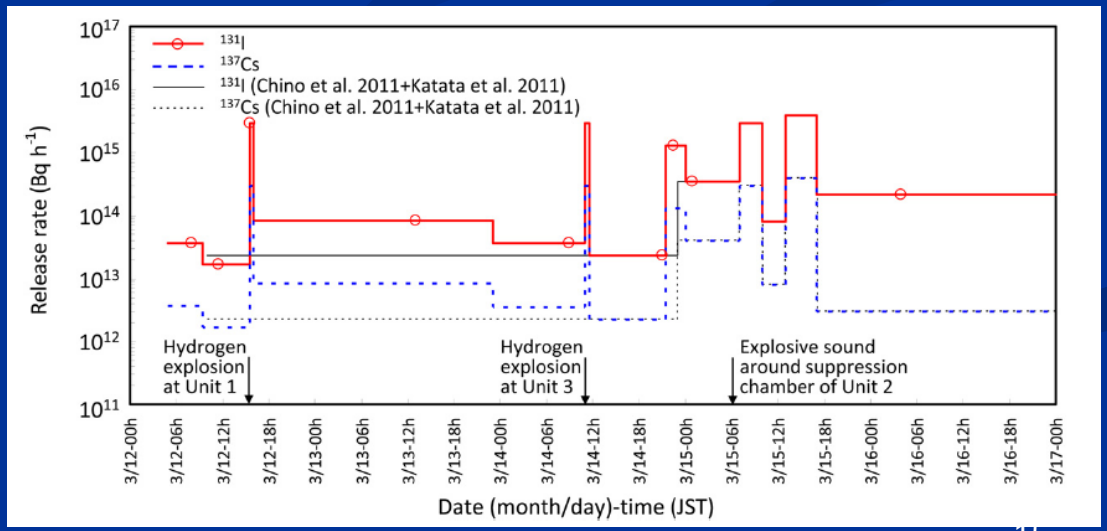


- The atmospheric release rate of ^{131}I and ^{137}Cs from F1 site was estimated by combining environmental monitoring data with atmospheric dispersion simulations with WSPEEDI-II.

$$Q_i = M_i / C_i$$

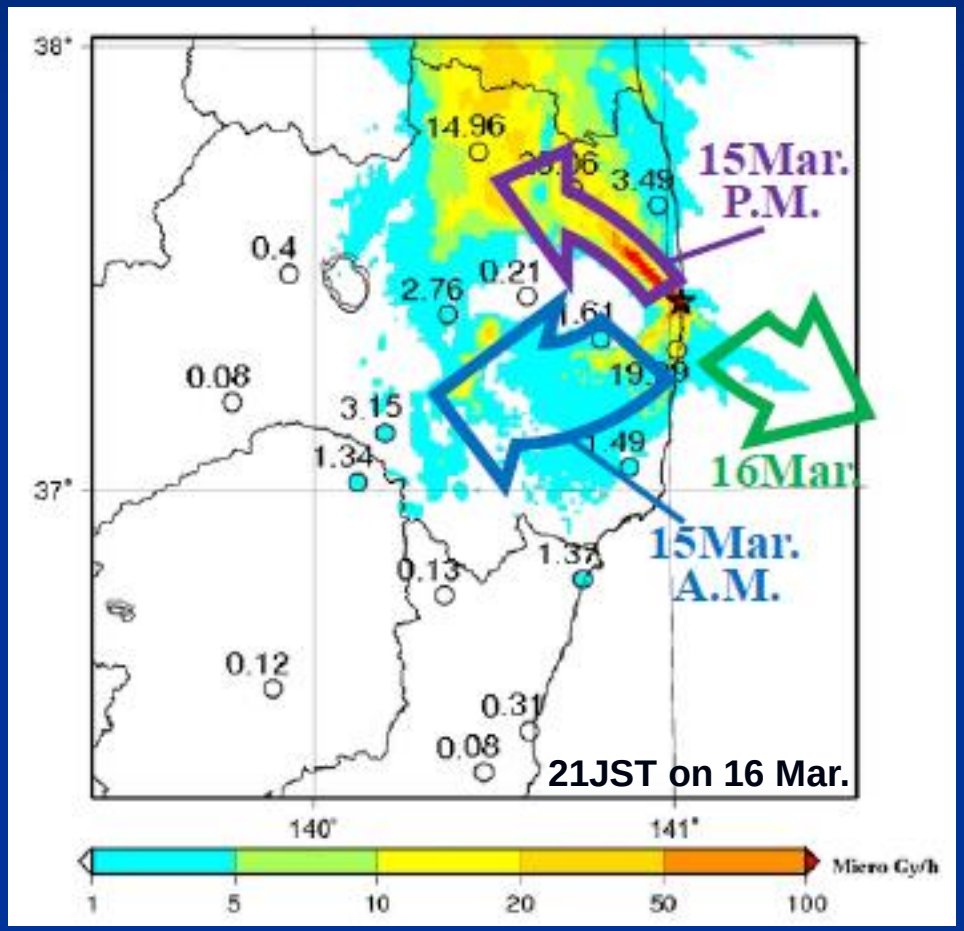
Q_i : Release rate (Bq h^{-1}) of nuclide i,
M_i : Measured air concentration (Bq m^{-3}) of nuclide i,
C_i : Dilution factor (h m^{-3}) of nuclide i.

Dilusion factor was derived by WSPEEDI under the assumption of a unit release rate (1 Bq/h).



G. Katata et.al ;Journal of Environmental Radioactivity 109 (2012) 103-113

E3. Analysis on the Atmospheric dispersion of radioactive materials

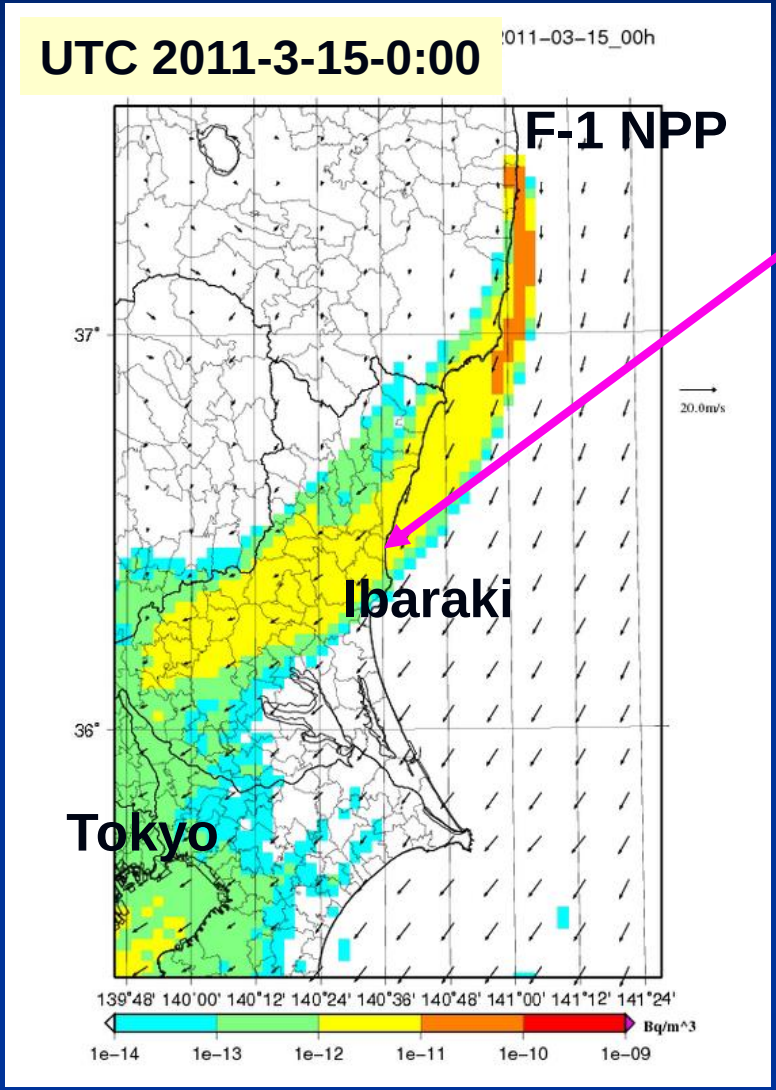


- The mechanism for the formation of high dose rate zone around north-west direction from the F1 NPP has been investigated in this analysis.
- It became clear that the significant atmospheric release on 15 March and the following wet deposition caused the formation of high dose rate zone around north-west direction from the F1 NPP.

Source: H. Nagai; Jpn. Health Phys.,47(1),13-16(2012)

E3. Continuous dust and iodine sampling

Surface concentration of ^{131}I estimated by using WSPEEDI-II



Source: Nuclear Safety Commission in Japan web site

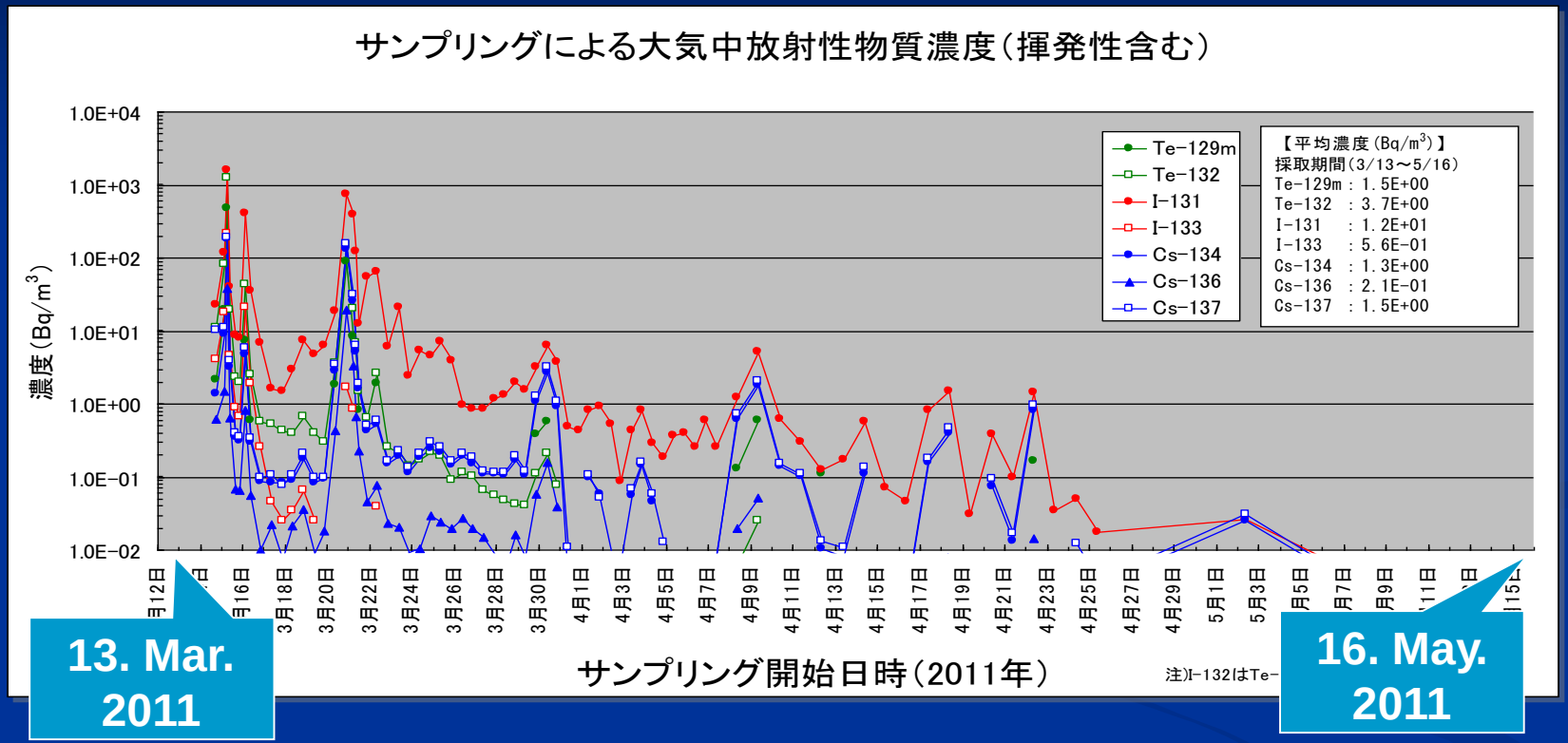
JAEA Tokai in Ibaraki pref.

The significant radioactive plume was estimated to come to Ibaraki pref. at around 0:00 15 Mar., around 0:00 16 Mar., and around 22 20 Mar. by using WSPEEDI.

Result suggest that this monitoring point was representative position for internal dose evaluation in Ibaragi Prefecture

E3. Radioactivity concentration in the dust within the atmosphere measured at Tokai

Concentration (Bq/m³)



13. Mar. 2011

16. May. 2011

- **Internal dose derived from the radioactivity concentration**
  - ✓ **Adult: effective dose 0.57mSv, thyroid dose 7.9mSv**
  - ✓ **Infant(1year): effective dose 0.88mSv, thyroid dose 15mSv**

(Source: JAEA review 2011-035)

Personal monitoring

- P1: Situation of workers
- P2: Situation of residents

P1. Situation of workers

- Change of dose limit for emergency worker
- Dose distribution of radiation workers
- Emergency workers exposed over 250 mSv
- Overview of special monitoring for internal exposure of workers supported by JAEA

P1. Dose Limit for Fukushima Emergency Workers

- 2011.Mar.14
  - 100mSv ⇒ 250mSv
- 2011.Dec.16
  - 250mSv ⇒ 100mSv
  - Exception: The workers who already exposed over 100mSv in the past emergency operations can be applied to 250mSv up to 2012.4.30 if next requirement is satisfied.
    - ✓ he should be a specialist who has high revel special knowledge and experience for reactor cooling operation
    - ✓ it should be very difficult to get a successor of him
- 2012.May.1
  - 100mSv
  - No exception

Around 50 TEPCO special workers are predicted

P1. Dose distribution of emergency workers on site (2011.Mar.-Oct.31)

Effective Dose (mSv)	TEPCO staff	Other company staff	Total
＜ 250	6	0	6
200＜－ ≦ 250	1	2	3
150 ＜－ ≦ 200	19	2	21
100 ＜－ ≦ 150	116	23	139
50 ＜－ ≦ 100	354	308	662
20 ＜－ ≦ 50	627	1,686	2,313
10 ＜－ ≦ 20	493	2,320	2,813
10 ＜	1,648	10,175	11,823

K. Sugai; Jpn. J. Health Phys.,47(1),25-29(2012)

Total 17,780

P1. Emergency workers over 250mSv

ID	Internal Dose*	External Dose*	Effective Dose*
A	590	89	679
B	540	106	646
C	242	110	352
D	260	51	311
E	433	44	477
F	328	33	361

*rounded value to double or triple figures
unit: mSv

- TEPCO plant operators or stuffs who engaged in recovery of indication equipment
- Main causes of over exposure are
  1. Severe emergency situation obstructed implementation of adequate radiological protection
  2. High radioactive concentration in air at the control room where the stuffs had to stay and make consumption for plant recovery operation
  3. Inadequate mask fitness of eyeglass workers

K. Sugai; Jpn. J. Health Phys.,47(1),25-29(2012)

P1. Internal exposure monitoring for emergency workers supported by JAEA

Because of lost of power caused by the earthquake and tsunami or because of high B.G., TEPCO WBC was not available.

- **End of Mar. 2011 JAEA sent mobile WBC to TEPCO Onahama coal center in fukushima pref. and started individual monitoring for emergency workers.**
- **20 April – 5 August 2011 Worker whose preliminary estimated dose become over 20 mSv went to JAEA Tokai for additional monitoring.**

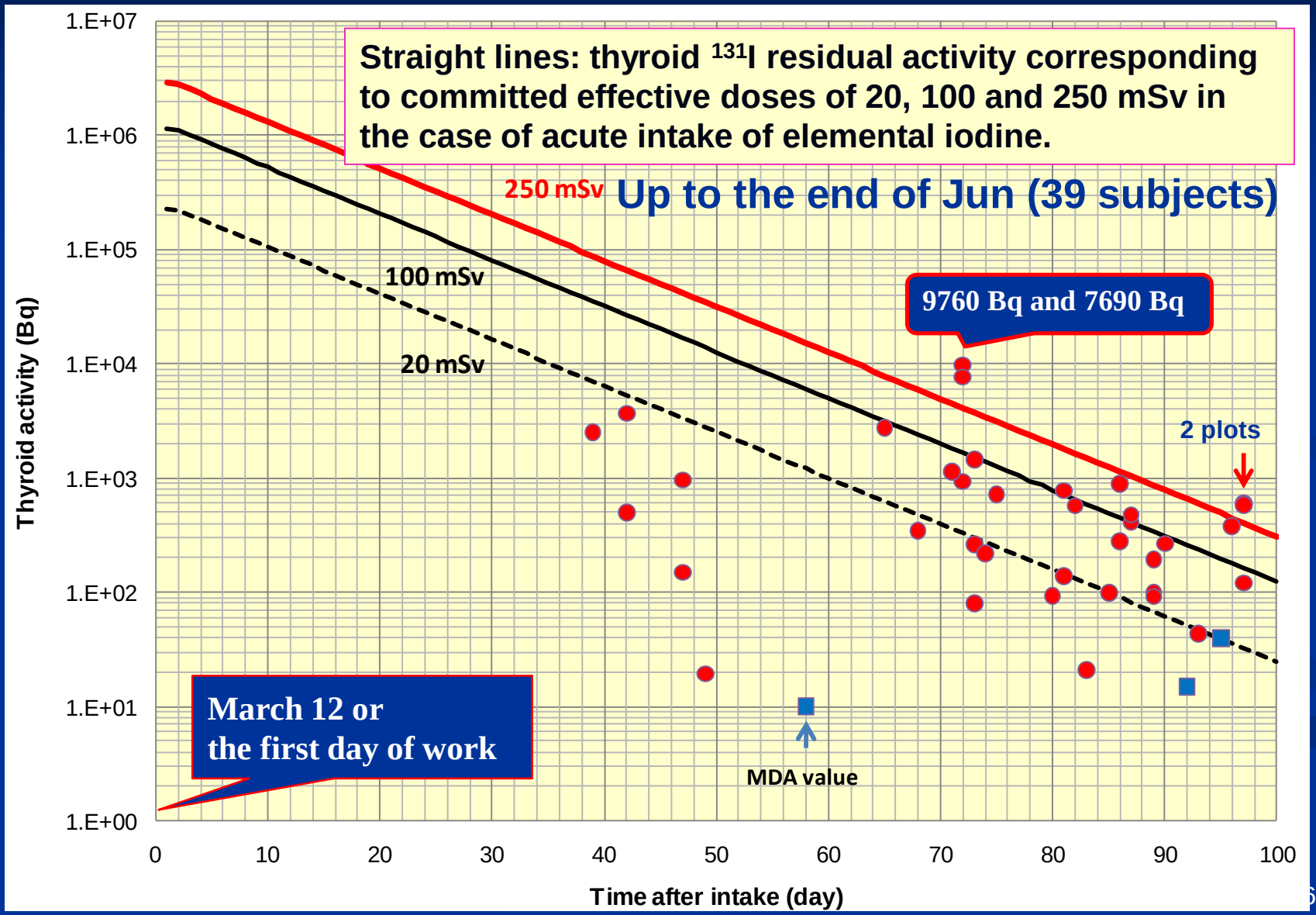
P1. Special monitoring for emergency workers at JAEA

- 23 April - 5 August 2011
- Whole body monitoring
  - Ge detector in the shielding room with 20 cm thickness iron
  - Canberra FASTSCAN NaI(Tl) detector
- Thyroid monitoring
  - Ge detector in the shielding room
- Number of measured workers
  - Female 6
  - Male 560

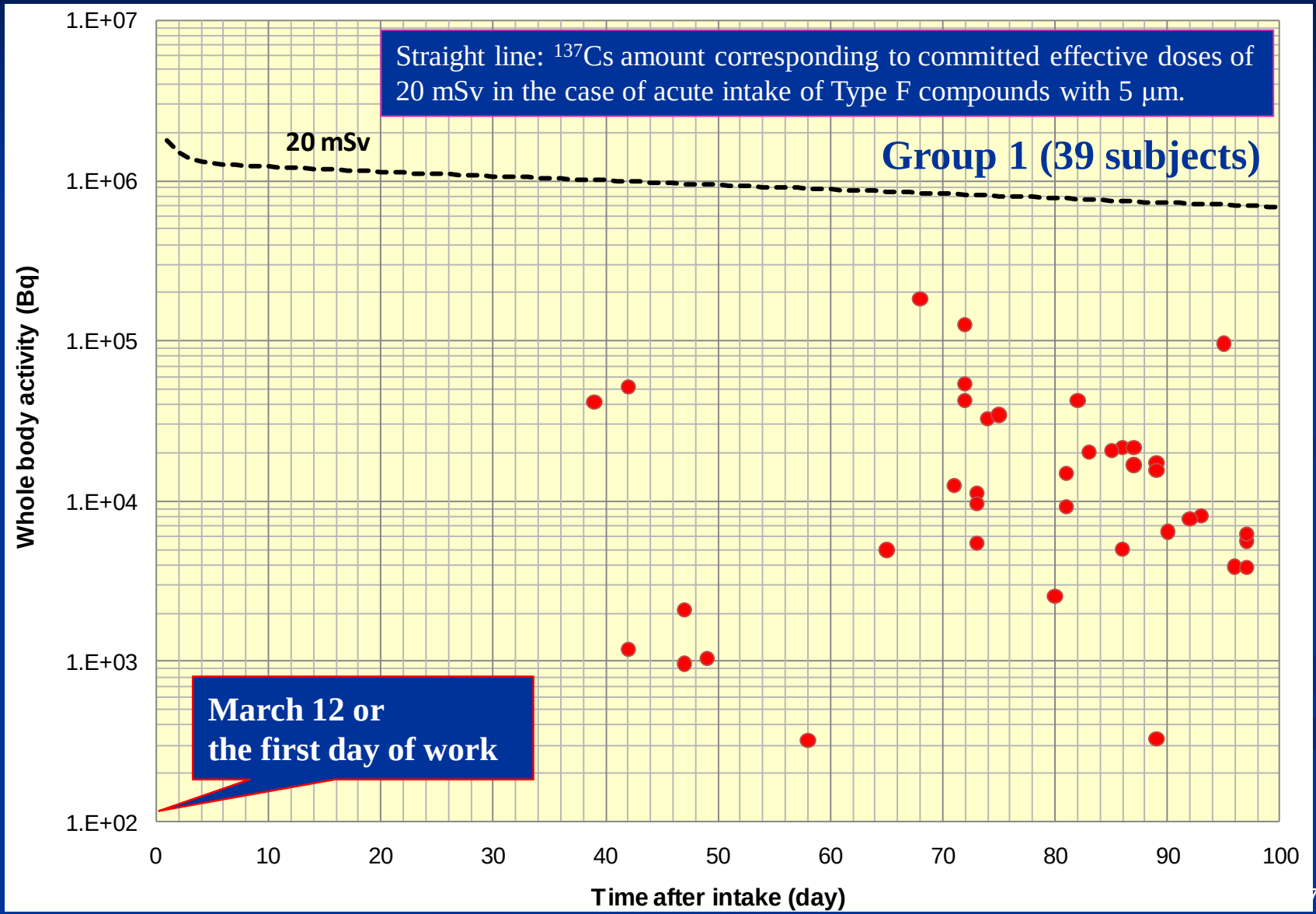
Ge detector in the shielding room

C. Takada et al.; IRPA13 P12.22

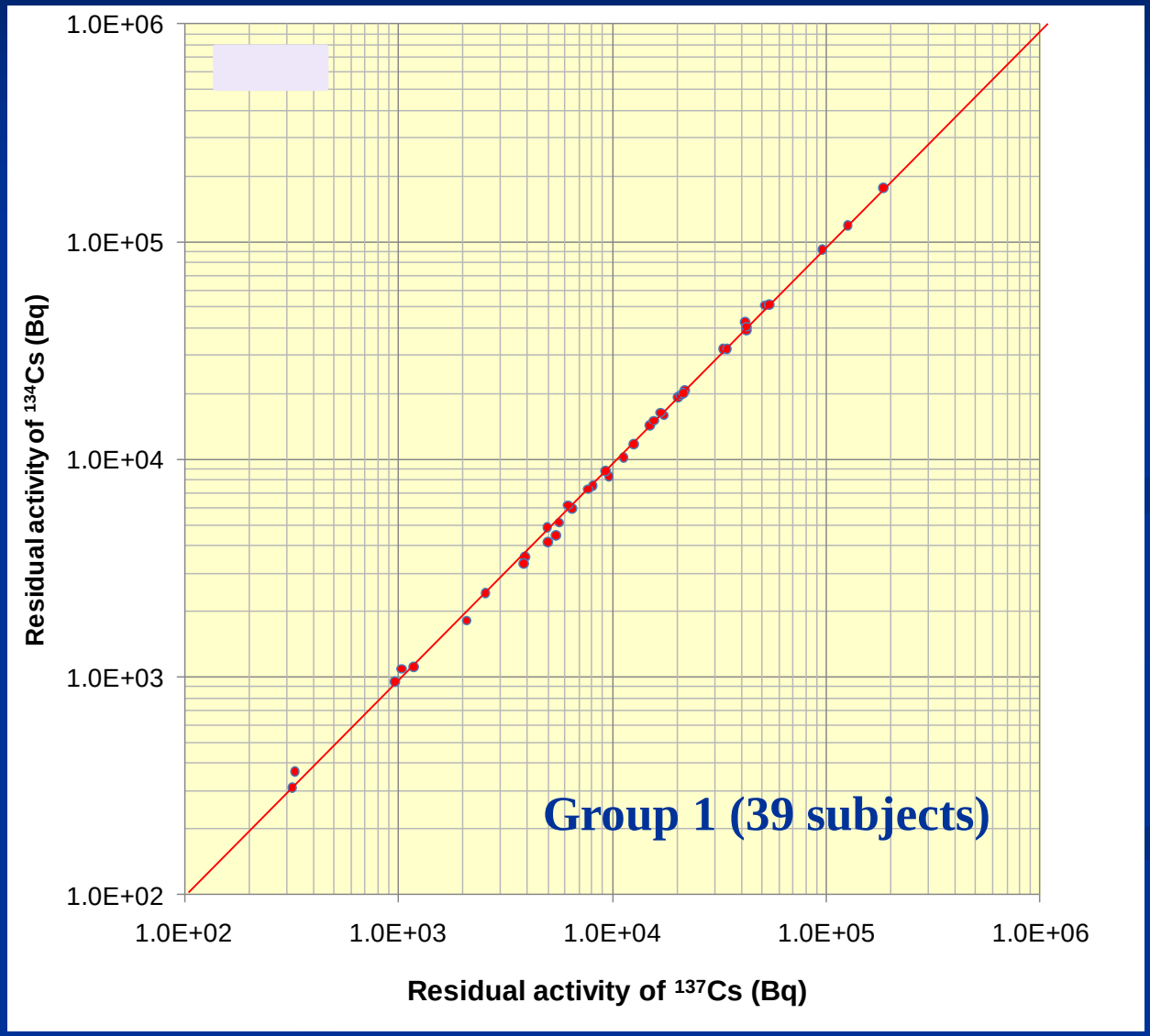
P1. Thyroid monitoring (^{131}I)



P1. Whole body measurements (^{137}Cs)



P1. Whole body measurements (^{134}Cs vs.^{137}Cs)

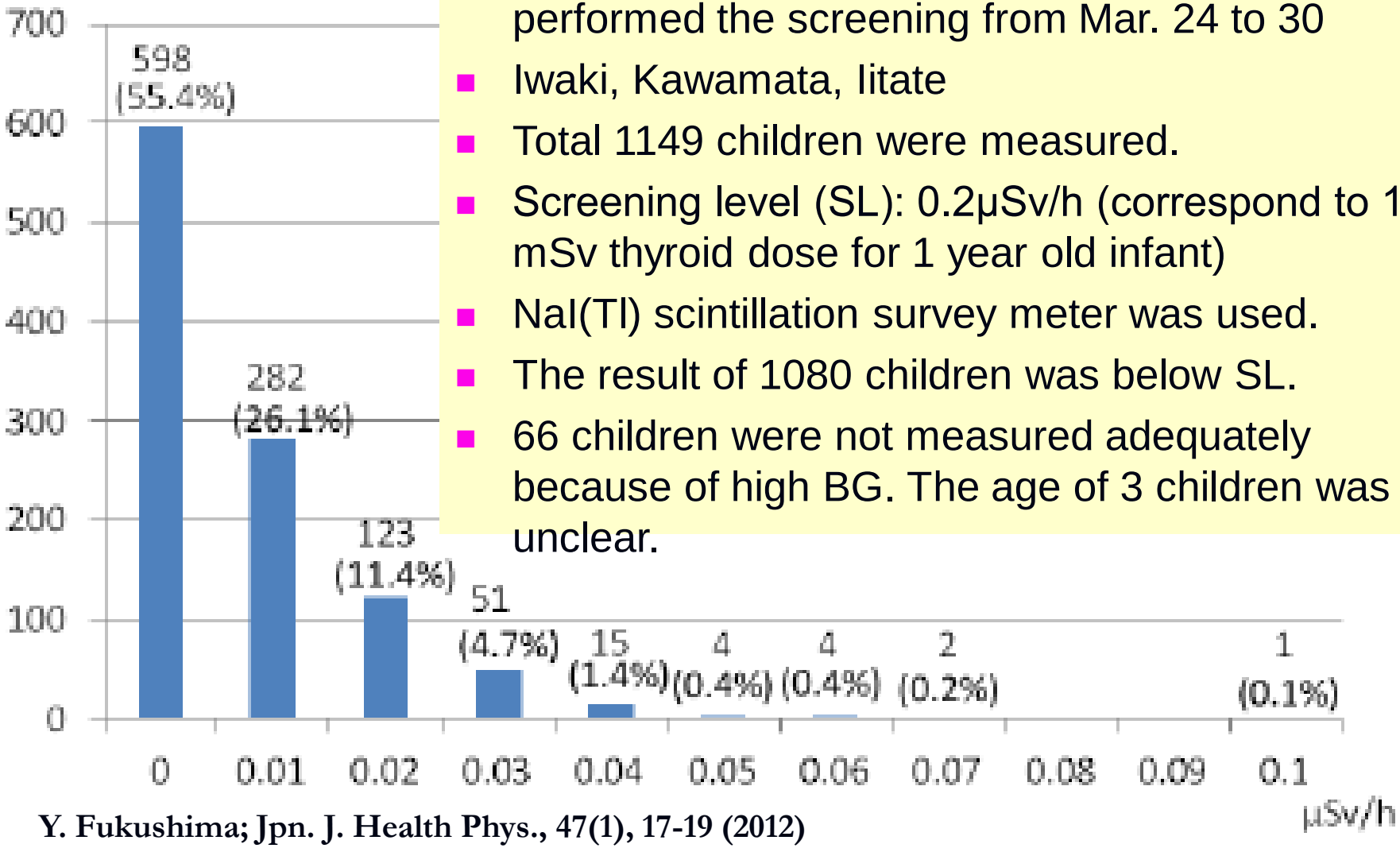


P2. Situation of residents

- Screening survey for thyroid internal exposure of children
- Health management survey for the residents in Fukushima prefecture
- WBC for residents performed by JAEA under the assignment of Fukushima prefecture.

P2. Screening survey for thyroid internal exposure of children

- The local emergency response headquarters performed the screening from Mar. 24 to 30
- Iwaki, Kawamata, Iitate
- Total 1149 children were measured.
- Screening level (SL): 0.2μSv/h (correspond to 100 mSv thyroid dose for 1 year old infant)
- NaI(Tl) scintillation survey meter was used.
- The result of 1080 children was below SL.
- 66 children were not measured adequately because of high BG. The age of 3 children was unclear.

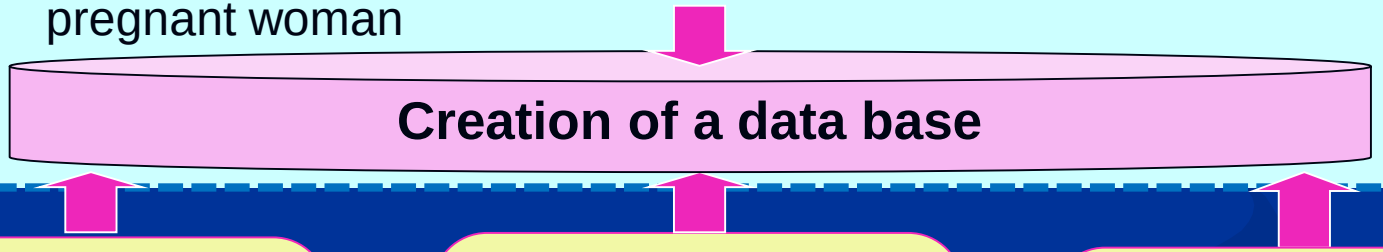


Y. Fukushima; Jpn. J. Health Phys., 47(1), 17-19 (2012)

P2. Health management survey and individual monitoring for the residents in Fukushima pref.

Health Management Survey

1. **Basic survey: estimation of exposure dose based on action records**
   - Subjects: All residents in Fukushima pref. (total: ~ 2 millions)
   - Methods: Self-consumption questionnaire for evacuation behavior
   - August 2011～
2. **Detailed survey: ascertain health conditions**
   - Subjects: Residents in the evacuation areas and persons who needs survey (~ 200 thousands)
   - Items: Thyroid ultrasonography for children. Medical checkups, mental health care, medical questionnaire and consultation to pregnant woman



Thyroid monitoring with NaI survey meter
Residents supporting team in Japanese gov.

Whole body counter
Fukushima pref., JAEA, NIRS

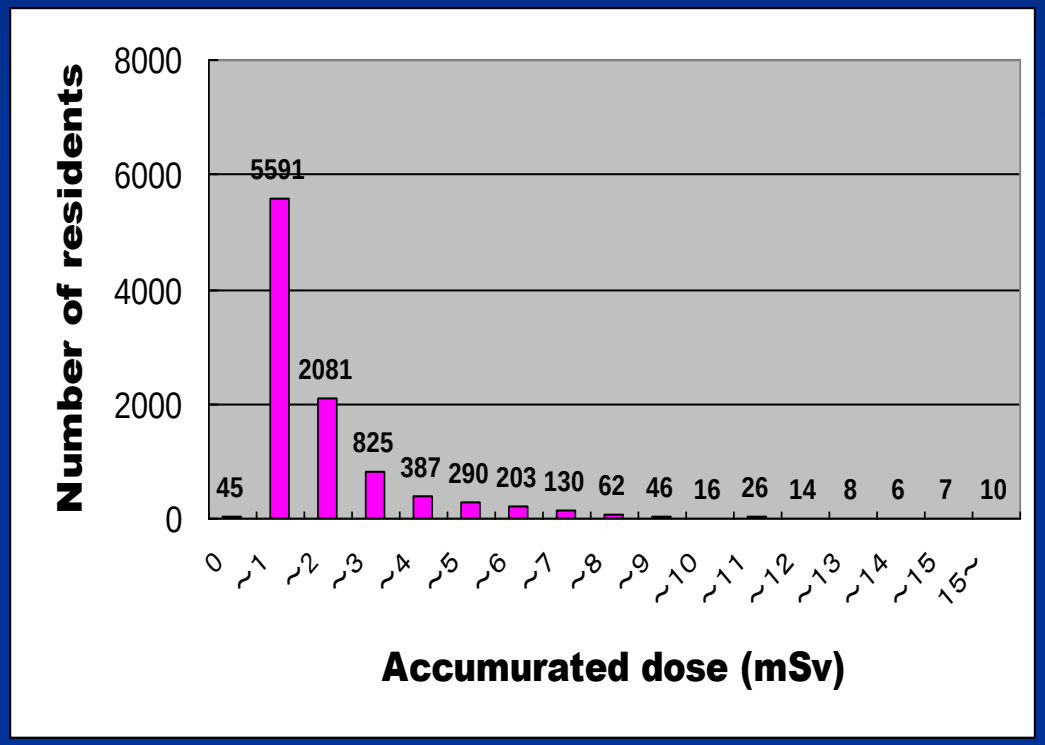
Personal dosimeter
Fukushima pref., other community

P2. Present status of personal dosimetry for Fukushima residents

- Basic survey 9747 persons reported
  - ✓ <1mSv: 57.8%, <10mSv: 99.3%, Max. 23 mSv/4month
- WBC
  - ✓ 15,383 persons measured (up to Jan. 31 2012)
  - ✓ <1mSv: 99.8%, Max.: 3mSv(two persons)
- Personal dosimeter
  - ✓ 70,400 persons reported from 22 communities
  - ✓ Terms 1 month – 3 month
  - ✓ Median: <1mSv (0.01mSv - <1mSv)
  - ✓ Max.: 46.6 mSv/annual (include X-ray diagnosis),2nd 7.66mSv/annual
- Radiological analysis on food stuff
  - ✓ Estimated dose from ingestion: 0.244mSv/annual(all nuclides), 0.01 – 0.04 mSv/annual (radio cesium)

Data from Fukushima pref. HP
http://www.pref.fukushima.jp/imu/kenkoukanri/240426shiryou.pdf

P2. External Dose Estimation based on the action records (Basic survey)



Progress report

- Evaluation term
  2011.Mar.11 – Jul.11
  (4 month)
- Objects
  KAWAMATA 553
  NAMIE 7,250
  IIDATE 1,944
  Total 9,747
  (except worker on site)
- Dose distribution
  <1 mSv 57.8%
  <5 mSv 94.6%
  <10 mSv 99.3%
  Max. 23mSv

Data from Fukushima pref. HP
http://www.pref.fukushima.jp/imu/kenkoukanri/240426shiryou.pdf

P2. Whole body counters at JAEA

- Canberra FASTSCAN
- Detector: 16” ×5”×3” NaI(Tl) 2 Units
- Shield: low BG steel sheets 10 cm
- D.L.*: 300 Bq (^{137}Cs, 2 min)
- Calibration phantom: Canberra transfer phantom, BOMAB phantom

- Aloka co. WBC
- Detector: 8”ϕ*4” NaI(Tl) 2 Unit
- Shield: Pb 5 cm
- D.L.*: 300q (^{137}Cs, 3 min)
- Calibration phantom: Block phantom, BOMAB phantom

* After the accident

P2. Flowchart of whole body measurement

Registration

Guidance

Check of surface contamination

WBC

Explanation

Dose assessments

P2. Dose evaluation

- **Only ^{134}Cs and ^{137}Cs were detected.**
- **Acute inhalation scenario was applied for dose evaluation to the measurement before 30 Jan. 2012.**
  - ✓ **Date of inhalation was assumed to be 12. Mar. 2011 to all residents.**
- **Continuous ingestion scenario has been applied to the measurement after Feb 1, 2012.**

P2. Internal exposure of residents caused by ^{134}Cs, ^{137}Cs

(July 27, 2011 ~ Jan 31, 2012)

(source: Fukushima Pref. Web site)

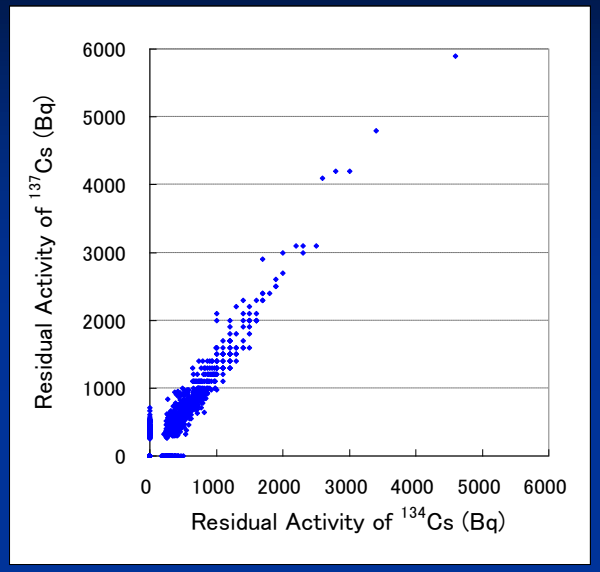
Community	<1mSv	1 mSv	2 mSv	3 mSv
Kawamata	632	0	0	0
Namie	3,043	5	2	0
Iitate	1,425	0	0	0
Hirono	645	0	0	0
Naraha	1,067	1	2	0
Tomioka	1,814	0	0	0
Kawauchi	302	0	1	0
Okuma	1,959	3	1	0
Futaba	1,155	2	2	2
Katsurao	181	0	0	0

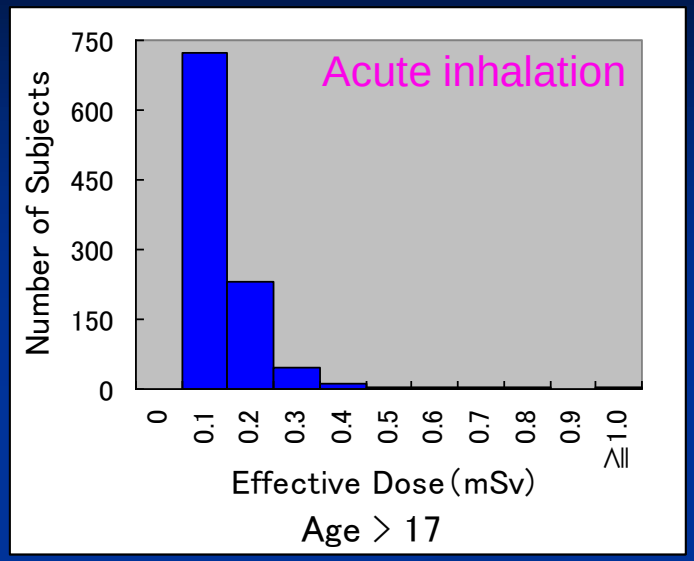
Community	<1mSv	1 mSv	2 mSv	3 mSv
Soma	2	0	0	0
Minamisoma	21	0	0	0
Date	1,208	2	1	0
Iwaki	799	0	0	0
Tamura	200	0	0	0
Shirakawa	10	0	0	0
Fukushima	430	0	0	0
Sukagawa	490	0	0	0
Total	15,383	13	10	2

http://wwwcms.pref.fukushima.jp/pcp_portal/PortalServlet?DISPLAY_ID=DIRECT&NEXT_DISPLAY_ID=U000004&CONTENTS_ID=26211 (Japanese)

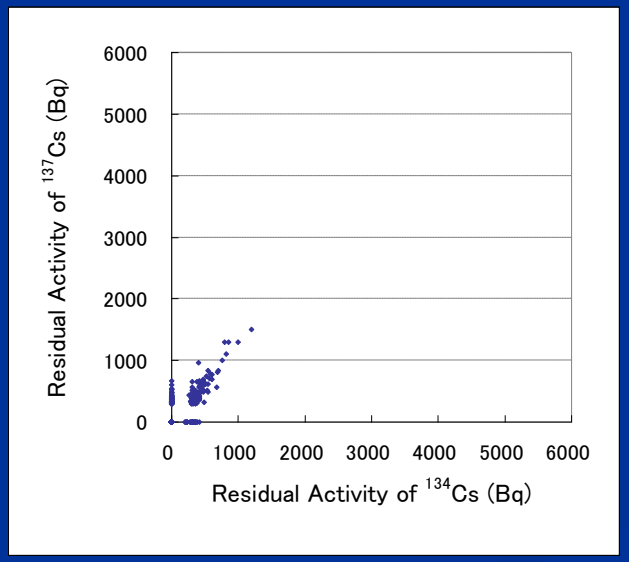
Evaluated dose distribution

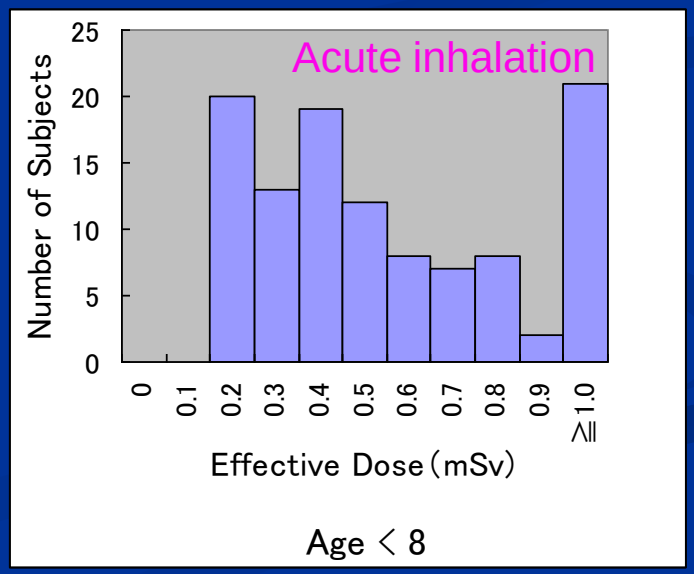
Adult





Infant





Significant value (over MDA) is plotted.

P2. Result of WBC

- 99.8% residents who measured with WBC were exposed less than 1mSv from internal contamination of ^{134}Cs and ^{137}Cs.
- No excessively exposed residents have been found to the present (Max. 3 mSv).
- Most of the subjects with internal doses above 1 mSv were children. But a large discrepancy in the dose between child and his/her families can be observed. This suggest that a small amount of contamination on clothes has affected to dose estimation as background mainly for children.
- Internal exposure of residents which was caused by short half life radionuclides such as ^{131}I will be considered by the dose reconstruction project in near future.

P2. Report and Risk communication

Report Form

平成 23 年　月　日

検 査 結 果

検査実施機関：（独）日本原子力研究開発機構
原子力科学研究所（東海村）

氏　名：　　様（顧・職　年　月　日生、男　女）

検査日：　平成 23 年＿＿月＿＿日

検査結果：

1）体表面検査　　体表面汚染の有無：　　有（　　cpm）・無

2）全身検査

測定器	測定時（秒）	核種	測定値（Bq）	預託実効線量（mSv）[注1,2]
座位型 WBC	180	Cs-134	有効数字 2 桁	例）1 未満
		Cs-137	例）1300	

（Cs-134，Cs-137　放射性セシウム）

今回の検査の結果、あなたの体内にある放射性物質から、概ね一生の間に受けると思われる線量[注1,2]は、

例）約 1 mSv 未満

と推定しました。

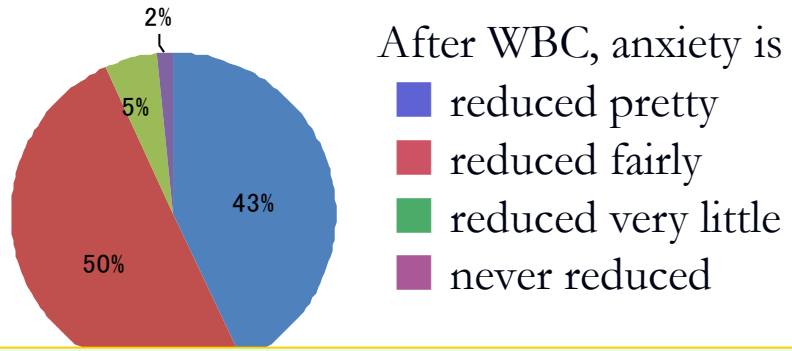
注1）　成人では 50 年間、子供では 70 歳までに体内から受けると思われる内部被ばく線量を表す

注2）　線量推定においては、線量が最大となる摂取条件（3 月 12 日に全量を吸入摂取）で推定

裏面に検査結果の見方と解説を示します。裏面もご覧下さい。

The result was explained to a residents by JAEA expert in a manner of interview or phone consultation.

Reduction of anxiety on health effect



Many residents replied that WBC and consultation is effective for reduction of anxiety on radiological health effect.

P2. Present status of WBC in Fukushima

- **Monitoring capability for residents is being enhanced.**

New five mobile whole body counters are operated.

12 WBCs concerned to Fukushma pref. are operating for residents now

Present issues on WBC for residents

✓Development of human resources for internal dosimetry

✓Measurement and calibration for infant

Recent Practical and/or Research Issues on Dosimetry

- Synthetic dose reconstruction for residents in 2011 including thyroid dose
- Development of practical remote position sensitive radiation detector which can be applied to area remediation
- Verification system for radiation measurement
- Validation of dosimetric models with individual monitoring (personal dose meter, WBC)
- Establishment of integrated individual dose recording system

Conclusion-1

- In spite of severe condition caused by wide area earthquake and tsunami, environmental and individual monitoring in emergency situation was performed adequately and quickly by means of cooperation among many participants in Japan.
- The radiological distribution map (2nd or 3rd dimensional image) is effective for planning of Fukushima reconstruction.
- Detectable health effect in the public have not been observed and predicted so far, mostly due to adequate early countermeasures for radiological protection.

Conclusion-2

- Individual monitoring such as WBC and direct consultation with radiation protection experts are effective for affected people to reduce elevated anxiety on health effect of radiation.
- Standardization of radiation monitoring and synthetic dose reconstruction for residents are important for radiation protection and health care for public.
- Japan health physics society will continue to organize open symposium and training course focused on practical issues of radiation protection to enhance cooperation with all concerned.