The internal and external dosimetry challenges from past experience : *Fukushima Daiichi accident*

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The beginning

The function of the Fukushima off-site center (OFC) that had the role as the center for emergency response measures in case of nuclear accident had been almost paralyzed on 12th March 2011

Although the emergency power supply had been restored, the multiplex communication network was completely destroyed due to the earthquake

135 telephones and data communication terminals were quite useless except five satellite phones

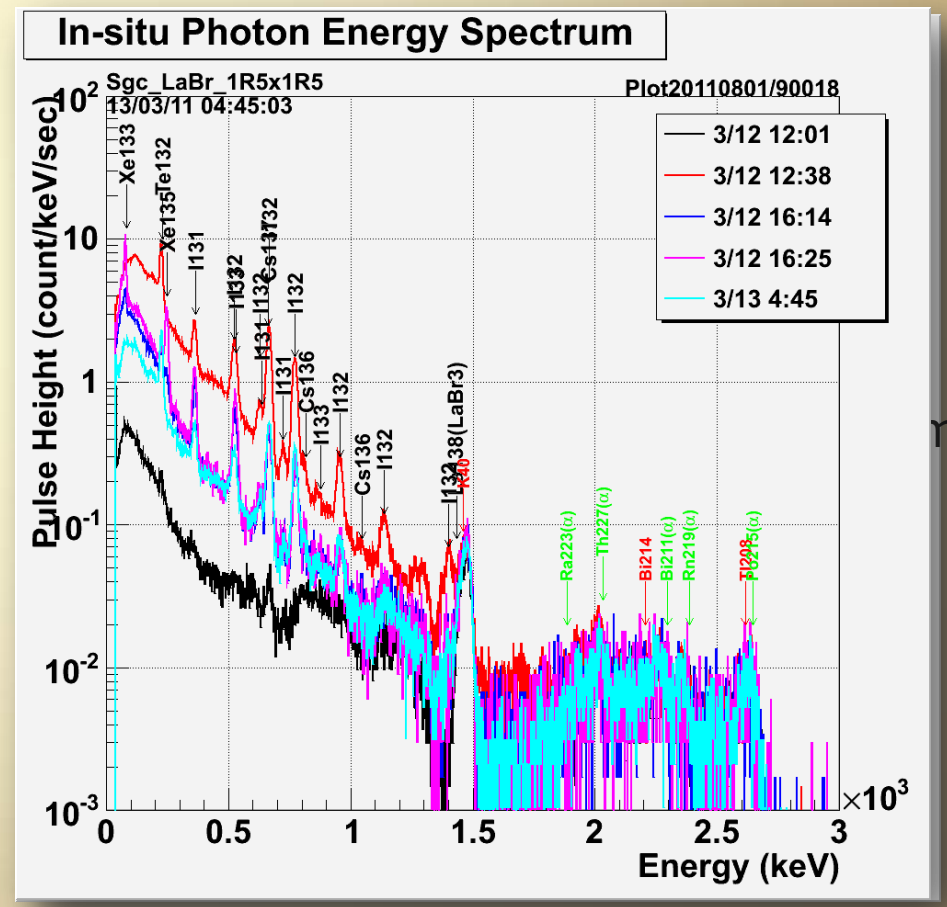
Radioactive plume

It was calm outside and the air dose rate was around 0.06μSv/h
Any anomaly was not found in the gamma-ray spectrum

However, the leakage of radioactive material from the PCV of unit 1 had already begun because of the meltdown which had occurred 16 hours before

Around 12:30pm on the day, Xe-133, Xe-135, Te-132, I-131, I-132, I-133 and Cs-136 were observed in the spectrum

This was the first moment when the radioactive plume had been observed at OFC



Surface contamination

Immediately after that, surface contamination check by a pancake GM survey meter was started for the workers returning from FDNPS at the entrance

The screening level was decided temporary as 13000cpm which meant approx. 40Bq/cm^2

At this point, the contamination of the tire or the shoe sole was already difficult to decontaminate

Self –Defense Force personnel -from the sky-

84 personnel were engaged in discharging water operation for the cooling of the spent fuel pool (SPF) by CH-47JA helicopter on 17th March

Air dose rate at 300ft. above the Unit 3 was approx. 90mSv/h

Lead sheets were spread over the place where the pilot and the mechanic were located

The opening under the aircraft was sealed up with a transparent, acrylic board to prevent radioactive substance from flowing in

The crew wore a lead protective suit under the protective combat suit with a full-face mask, and took iodine tablets in advance

Self –Defense Force personnel -dose evaluated-

Through four times of flight in this mission external exposure of all personnel was below 1mSv

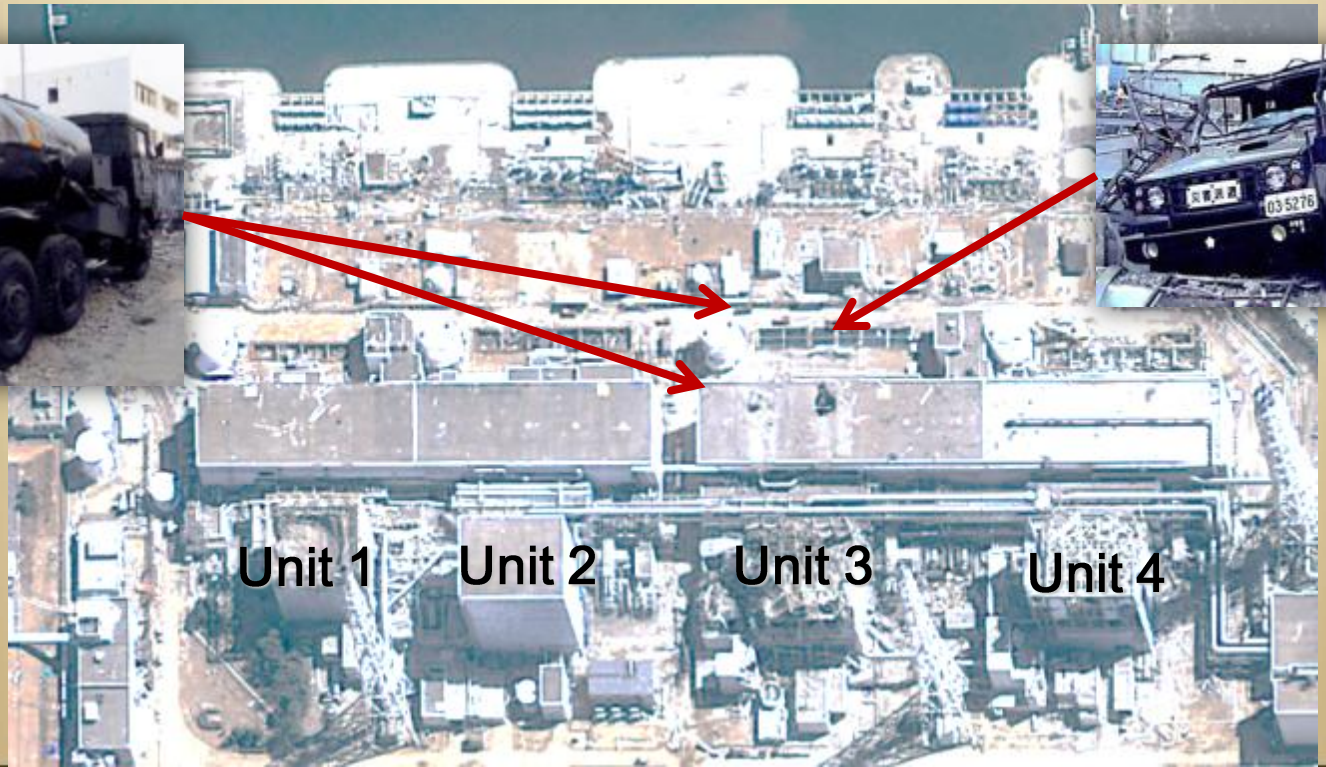
Internal contamination of them all was below the detection limit, which was measured by chair-type WBC installed in central military hospital

Self –Defense Force personnel -on the ground-

The other 84 personal were engaged in SPF cooling operation from the ground side by using water cannon truck

At 11:01am on March 14th three vehicles were rolled in the hydrogen explosion with six CNBC personnel

Water canon trucks



Commander's vehicle

Self –Defense Force personnel -situation-

90 minutes before the hydrogen explosion they took potassium iodine (130mg)

Their equipment was APD, TLD, Tyvek® suit on the battle suit and full-face mask with charcoal filter

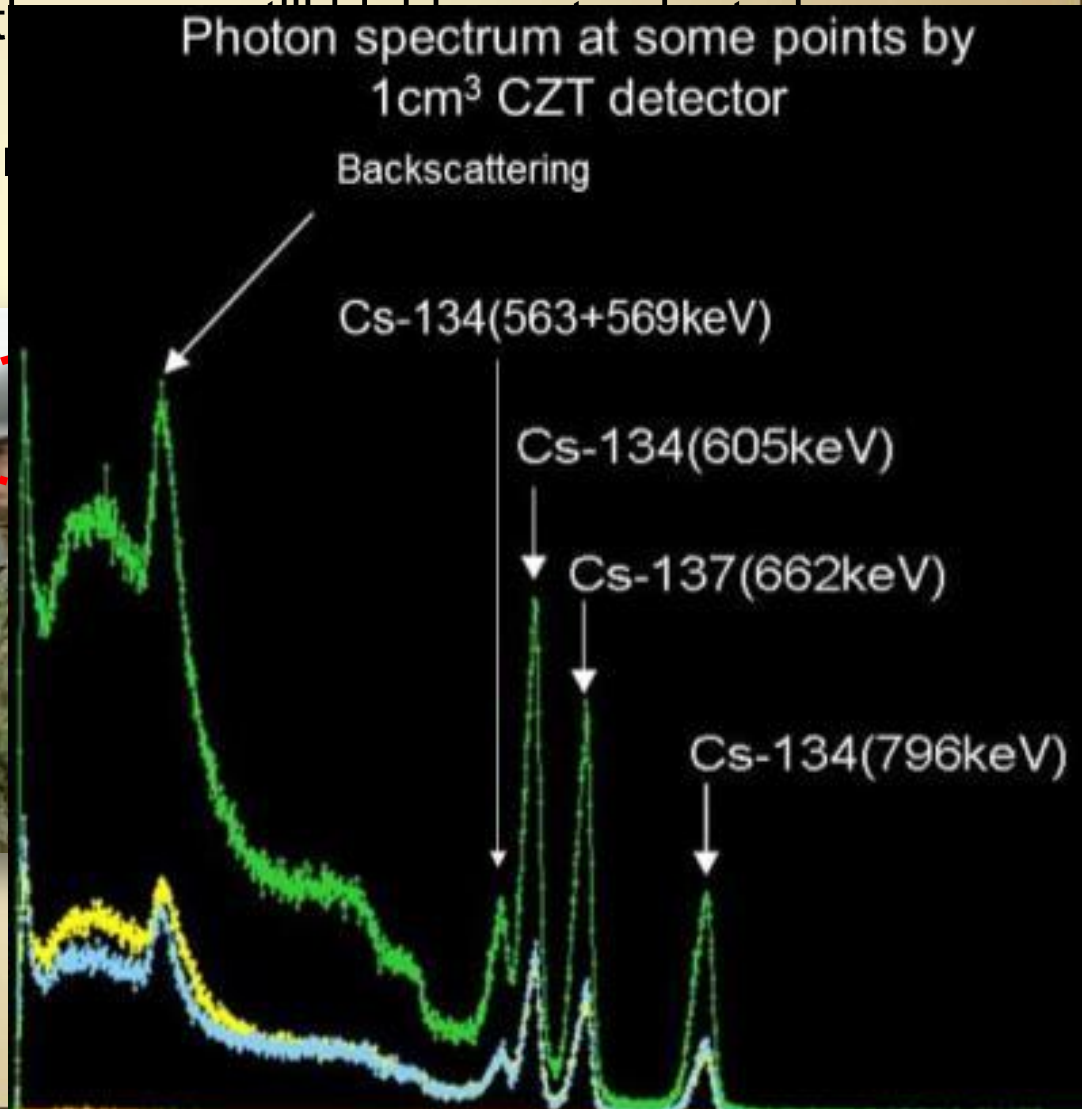
The blast of the hydrogen explosion directly pierced through their Tyvek® suit and the battle suit

Surface contamination level at the distance of 10cm was 1.0mSv/h when they reached the OFC by walk

For the quick decontamination their Tyvek suit was cut by a medical scissors, during this treatment the APD sounded. As the alarm setting value was 20mSv, their external exposure was evaluated as 20mSv

Self –Defense Force personnel -contamination-

Eight months later, their clot
by Cs-134 and Cs-137
The maximum contaminatio

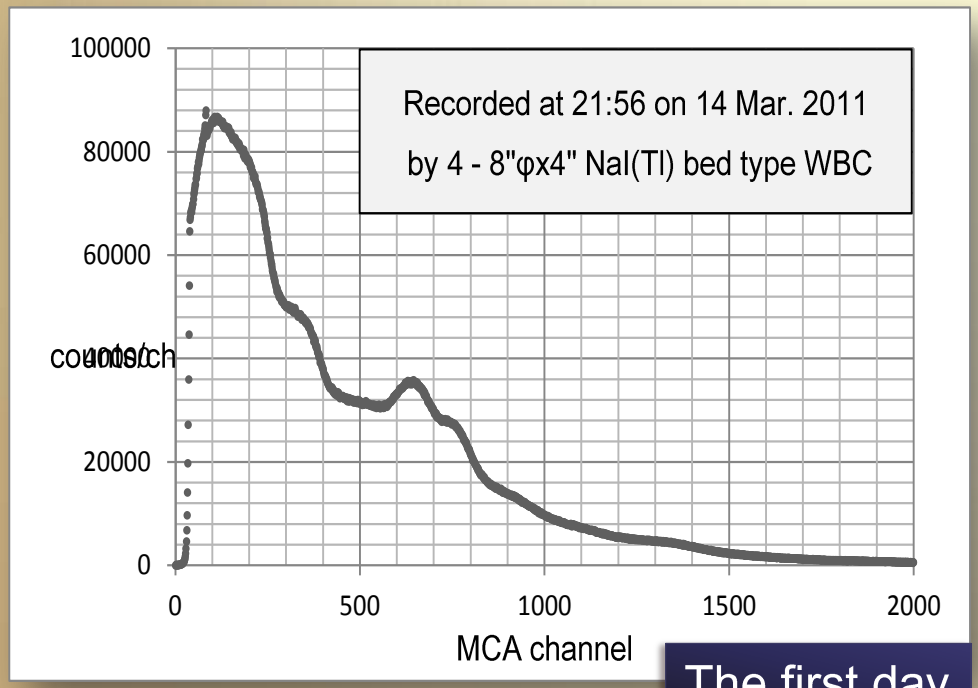


Self –Defense Force personnel -internal contamination-

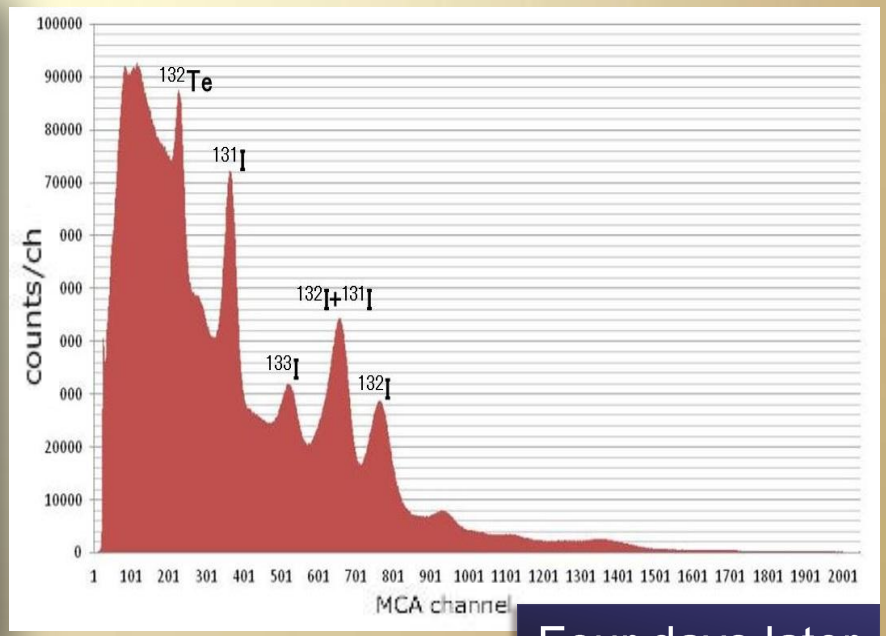
whole body counting

Their medical treatment and internal dose evaluation was executed at the NIRS soon

Because of the remaining high surface contamination and the gamma-ray pile-up, the quantification by WBC was difficult at the early stage



The first day



Four days later

Self –Defense Force personnel -internal contamination-

whole body counting

For this measurement,
NIRS's main WBC could not be used because of its high sensitivity and evasion of cross-contamination

(MDA is below 10Bq to Cs-137)

Self –Defense Force personnel -internal contamination-

whole body counting

For the emergency screening, four channel open air WBC was adopted, which was always energized to keep the stability

The calibration was carried out by using ANSI 13.35 BOMAB phantoms

In order to compensate the contribution of ambient background and shielding effect of human body, K-40 water BOMAB phantom was applied

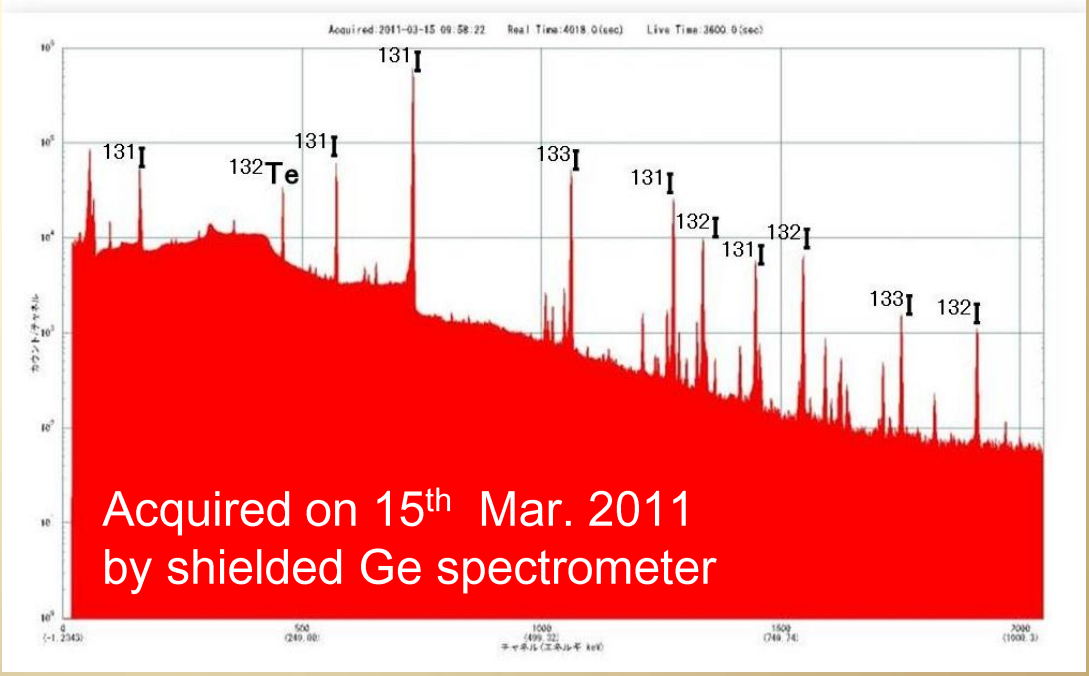
8”φx4” shielded NaI(Tl) scintillator

Self –Defense Force personnel -internal contamination- bioassay

Because high surface contamination had remained, in-vitro measurements were not able to be used in the first stage

Urine diluted five time was measured by Ge detector for 60 minutes in U8 container

A large amount of radio iodine was observed in the urine



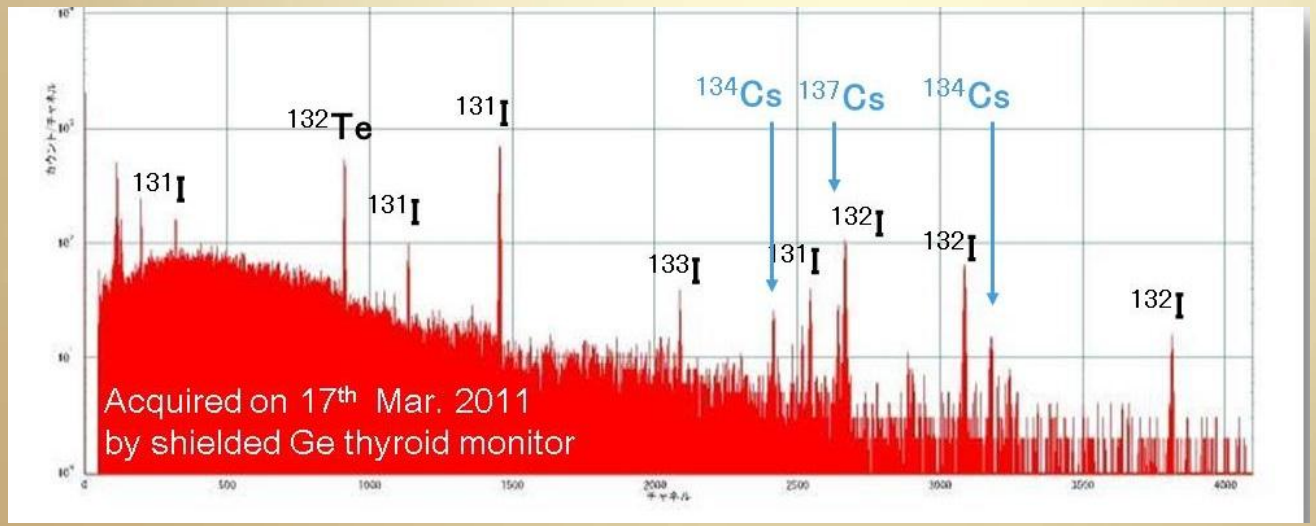
Self –Defense Force personnel -internal contamination-

thyroid measurement

There was an incorporation to the thyroid gland though the full-face mask with charcoal filter was worn

The personnel was not using glasses, and the possibility of the leakage from the temple was few

It is thought this was caused by the filtering efficiency (99.9%) of the charcoal filter, considering large specific activity of I-131 (4.6E15 Bq/g)



Self –Defense Force personnel -internal contamination- dose evaluation

The maximum exposure among the six personnel was;

- Effective dose: *20mSv* -from APD-
- Committed effective dose: *4.2mSv* -calculated by MONDAL-
  (Thyroid committed equivalent dose: *27.4mSv*)
- Total dose: *24.2mSv*

Slight ^{90}Sr-^{90}Y was detected in the urine but the dose contribution could be disregarded.

Emergency measure for thyroid measurement

This technique stayed in use to the infant this time,
it's thought to be useful for screening in the emergency
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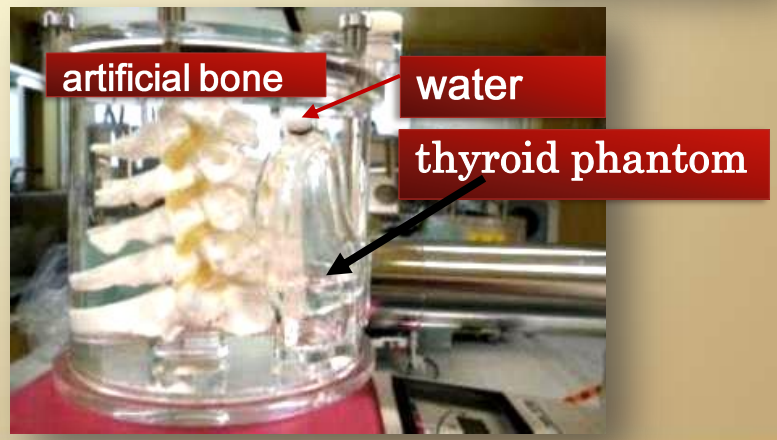
1. Only one thyroid monitor was left in high contaminated area

2. NaI(Tl) scintillation survey meter was applied as the substitution

3. Conversion coefficient between μSv/h and Bq was decided by neck phantom which included thyroid phantom filled with standard Ba-133



4. The value is 1μSv/h=22kBq

Fire-fighters -private-

In the early phase, the small number of private fire-fighters who belonged to the subsidiary of TEPCO played the most important role for reactor cooling

The maximum external exposure of them was *88mSv* evaluated by the same personal dosimeter as TEPCO worker

The maximum thyroid equivalent dose was estimated as *230mSv*

calculated conditions: inhaled iodine for 3 days uniformly
examined 8 days later

Fire-fighters -Tokyo Fire Department -

139 fire-fighters of Tokyo Fire Department were sent from 19th March 2011

The air dose rate where they worked was approx. 400μSv/h

Their maximum external exposure did not exceed 30mSv

Returning back to 19th March

Radio nuclides detected from the surface of their personal dosimeter on 3rd June 2011

Nuclide	Activity (Bq)	Ratio to total
Cs-134	1.93E+02	9.87%
Cs-136	1.99E-01	0.01%
Cs-137	2.61E+02	13.32%
Ag-110m	3.00E+01	1.53%
I-131	4.34E+00	0.22%
Te-129	6.39E+02	32.58%
Te-129m	8.18E+02	41.73%
La-140	9.35E-01	0.05%
Sb-125	1.34E+01	0.68%

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Cs-136	1.99E-01	0.01%
Cs-137	2.62E+2	2.09%
Ag-110m	3.00E+01	1.53%
I-131	4.36E+3	34.64%
Te-129	6.39E+02	32.58%
Te-129m	4.27E+3	33.98%
La-140	9.35E-01	0.05%
Sb-125	1.34E+01	0.68%

TEPCO and contractor's worker -External exposure -

Approx. 5000 APDs were unusable because of inundation by the tsunami

Only 320 APDs gathered from buildings in FDNPS were available until 1st April 2011

Panasonic APDs using a silicon semiconductor were used both by Self-Defense Force and TEPCO

The APDs were allocated only to the representative of same working group whose planned exposure was below 10mSv

The dose records were made by handwriting because of the malfunction of access control and dose management system

This might cause some uncertainty to the evaluation of individual dose

TEPCO and contractor's worker -internal exposure -

In the early phase, *in-vivo* monitoring was carried out by using WBC installed at Kashiwazaki-kariwa NPS, which was calibrated by Co-60

From the end of March 2011, the JAEA sent mobile WBC in which Canberra FASTSCAN was installed

During 20 April to 5 August 2011, worker whose preliminary estimated dose become over 20 mSv went to the JAEA Tokai for additional monitoring

The JAEA reported only the internal activity, and TEPCO evaluated the committed effective dose by MONDAL

TEPCO and contractor's worker -internal exposure additional monitoring at JAEA -

560 subject April to
5 August 20

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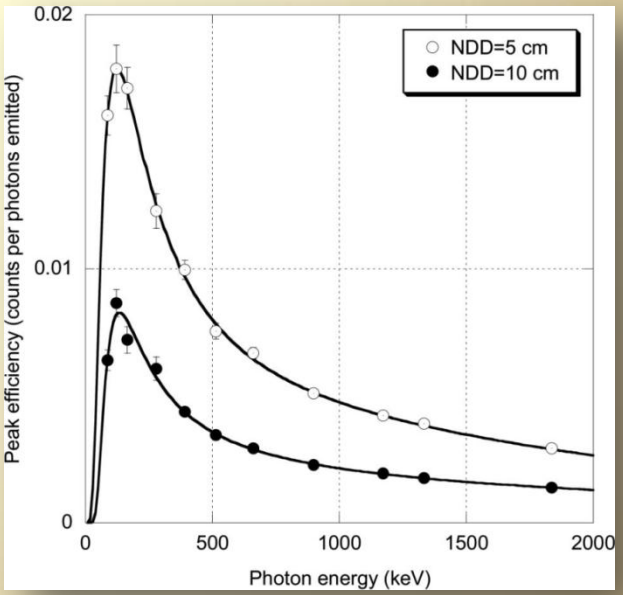
be reduced

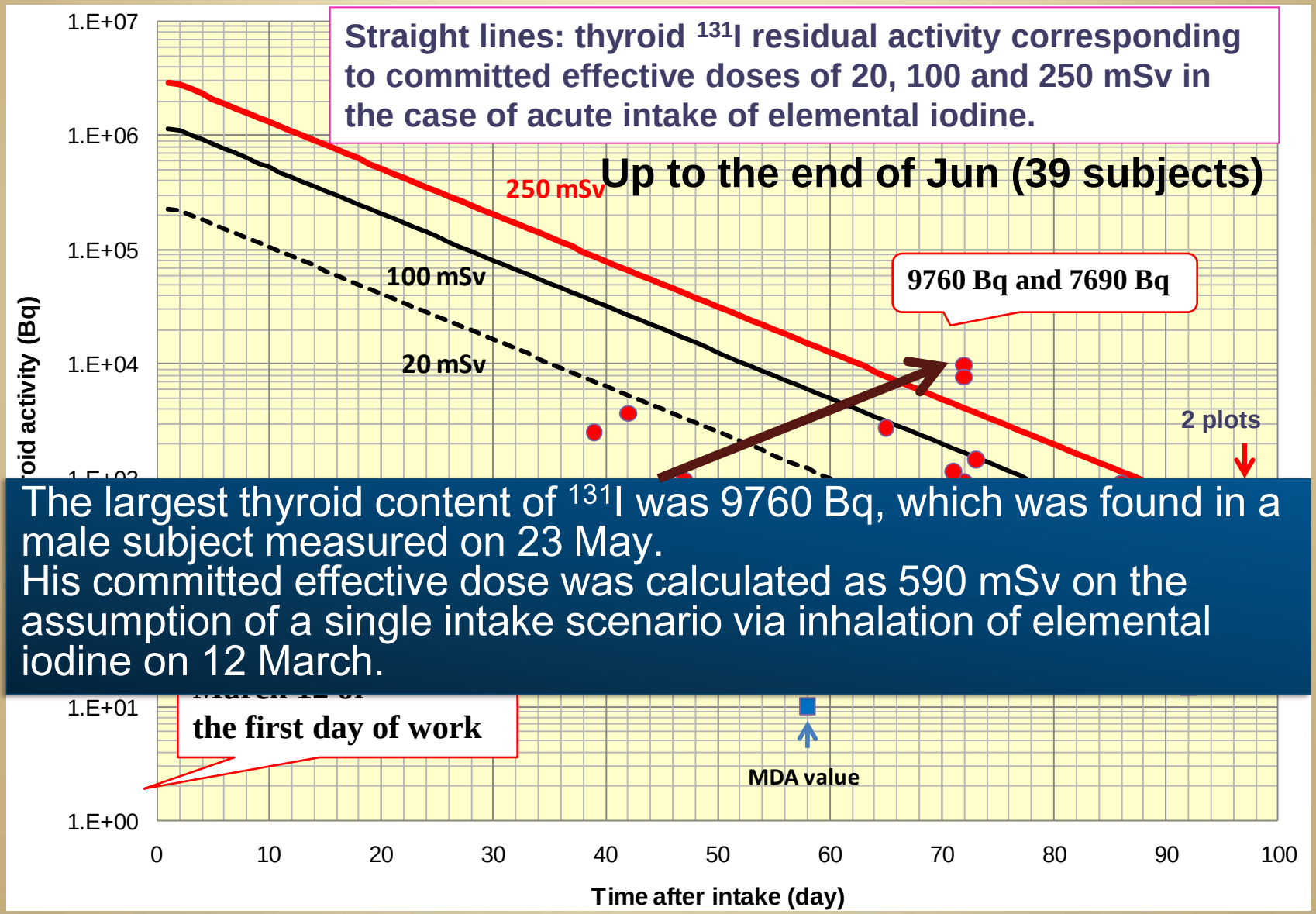
TEPCO and contractor's worker -internal exposure additional monitoring at JAEA -

The HPGe detector was calibrated with the neck part of
a Transfer phantom (Canberra) based on the specifications of ANSI



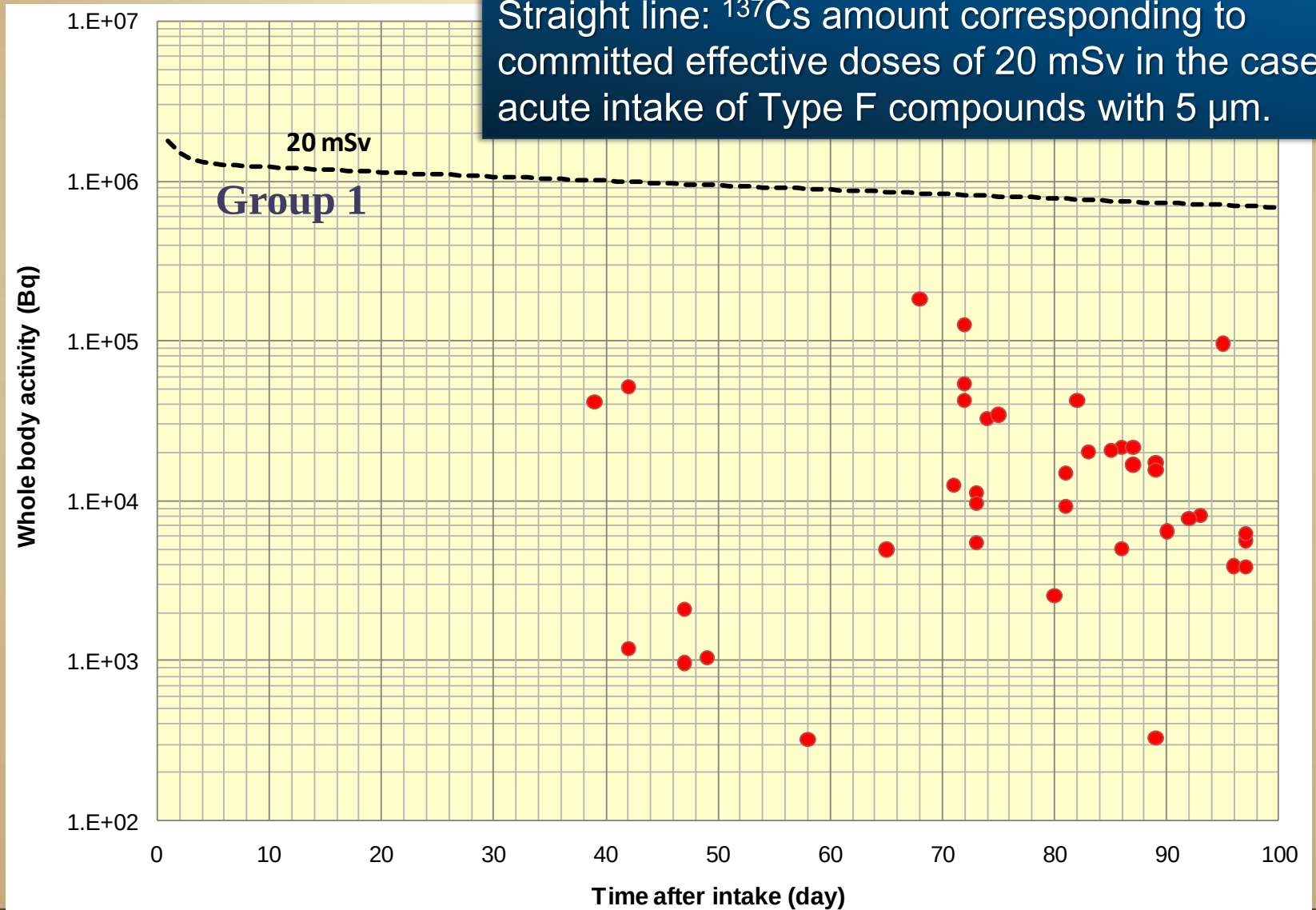
Peak efficiency values and fitted curves

Thyroid monitoring (^{131}I)

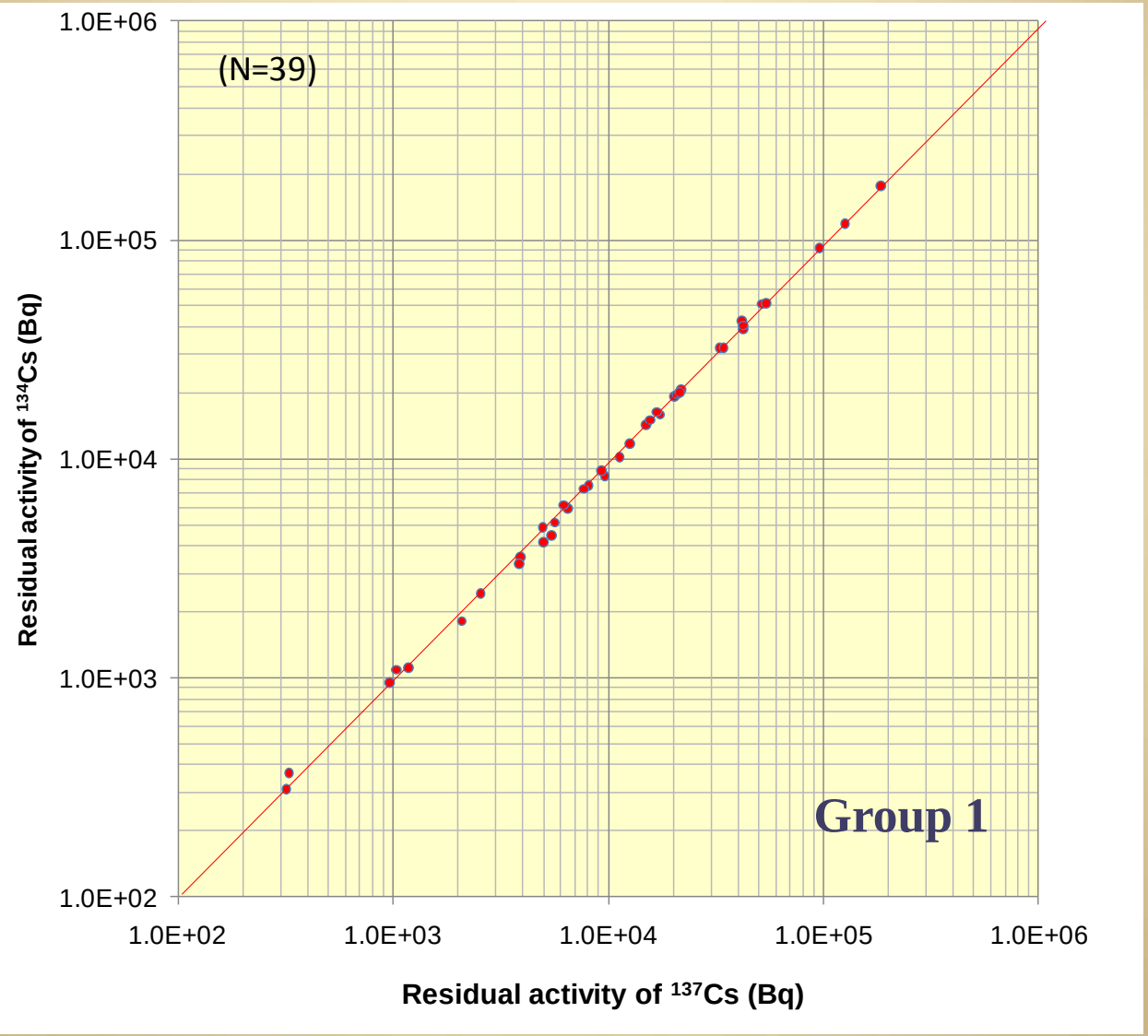


Whole body measurements (^{137}Cs)

Straight line: ^{137}Cs amount corresponding to committed effective doses of 20 mSv in the case of acute intake of Type F compounds with 5 μm.



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



Conclusion

The personal dosimeter of the waterproofing type is indispensable considering worker's sweat as well as the inundation

Administration of iodine tablet in advance and fitting of full-face mask with charcoal filter is effective in the environment where the radioiodine exists. As for the charcoal filter it is necessary to examine the filtering efficiency of radioiodine because of its high specific activity.

Evaluated dose is changed depending on scenario of intake. Data on workplace monitoring and interview to workers is important for adequate dose evaluation.

Further studies are still needed for the improvement of internal dose estimations especially for subjects who were suspected to have extremely high internal exposure, considering more realistic intake scenarios and the intake of other short-life radionuclides (e.g., ^{132}I, ^{133}I, and ^{132}Te).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