

# Occupational Radiation Protection during High Exposure Operations

Lessons Learnt from Occupational Radiation Protection  
in Past Accidents

Nuclear Accidents – Fukushima Accident –

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1. Overview of the Fukushima Daiichi Nuclear Accident
2. Radiation control overview
3. Access control of worker
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5. Worker's dose control
6. Remarkable events brought about radiation exposure
7. Efforts to reduce worker's dose
8. Radiation monitoring
9. Lessons learnt

## 2. Radiation control overview

- Off-site Center was expected to be a general headquarters in case of a radiation emergency
- The center was located 4.5km from FDNPS
- However, it was not possible to function because of the interception of all communications and the rise of air dose rate and the infiltration of radioactive substances
- On 14 Mar. withdrawal instruction came out to evade from the high dose plume
- Maximum dose rate outside of the offsite center at 22:07 on 14 Mar. was 1.86mSv/h



## 2. Radiation control overview



## 2. Radiation control overview

- As a result of the tsunami, core damage, and Reactor Building explosions, it became pointless to try to differentiate between controlled area and other area in FDNPS
- Equipment/ systems for Radiation Protection were inundated with water from the tsunami and rendered useless, and with the subsequent power loss, they lost function
- With the SBO, monitoring posts (MPs) failed to function, therefore monitoring cars were started to measure the environment (air dose rate, weather data, etc.) on site
- All radiation control matters would be handled unilaterally by the Emergency Response Centre (ERC) at the seismic isolated build.

## 2. Radiation control overview

- Because of increasing radiation level, it was necessary to wear EPD and protective clothing when leaving the seismic isolated building to engage in work
- The large-scale release of radioactive material led to increase background level, and made it difficult to evaluate internal exposure using installed WBCs
- From March 17, 2011, *J-Village* (outside of the site) became the base of operations for training workers , wearing protective equipment and dosimeters
- *J-Village* functioned effectively as a base of operations for registration procedures for new worker

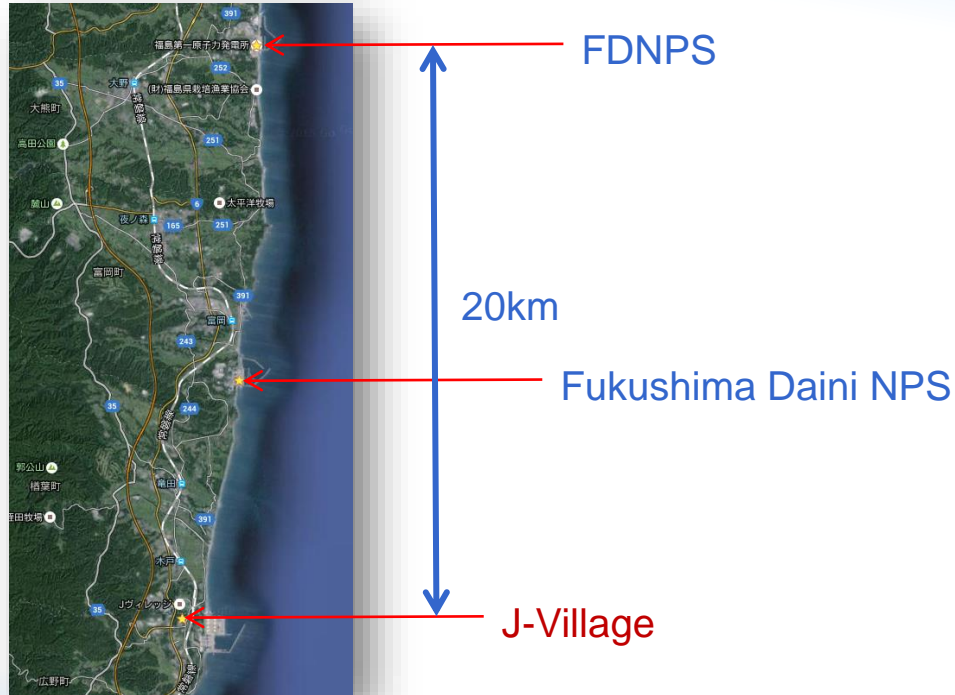
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### 3. Access control of worker

#### Protection of personnel at the NPP





# 3. Access control of worker

## J Village

In dealing with accident a base of operations separate from the seismic isolated building became necessary, so the J Village (football facility) located approx. 20 km to the south of the Fukushima Daiichi NPS was selected for this purpose.



Wearing protective clothing



Body screening



WBC centre

### 3. Access control of worker

#### The Seismic Isolated Building

The seismic isolated building became the base of the worker on site. There were many workers engaged in recovery work who were necessary to sleeping in the seismic isolated building in order to handle the expansive amount of work required following the accident.



Body survey area



Protective cloth storage



EPD rental place

## 4. Radiation protection

### Protection of personnel at the NPP

- The national legislation and guidance in Japan prior to the accident addressed measures to be taken for the protection of emergency worker
- However, the arrangements that were in place addressed these measures only in a general way and not in sufficient detail
- Seismically isolated building was the only usable building in early phase of the accident in FDNPS
- The building was fitted with special features, including an autonomous electrical power supply and ventilation systems with filtration devices and its use enabled mitigation actions to continue at the site during the response to the accident



## 4. Radiation protection

### Protection of personnel at the NPP

- Following the tsunami alert, efforts were made to protect plant personnel (about 6000 people) from the expected impact of the tsunami
- From 11 to 14 March 2011, plant personnel not considered essential for emergency activities were evacuated from the site
- In the morning of 15 March, an evacuation of additional plant personnel took place because of worsening conditions at the site
- An estimated 50–70 staff remained on the site, while approximately 650 people were temporarily evacuated to the Fukushima Daini NPP using buses or private vehicles
- They began to return to the FDNPS from noon on the same day

## 4. Radiation protection

### Protective measures for emergency workers (External exposure)

Before the earthquake

- **Radiation control area (RCA) access management**

- Use access control gate to manage the access to RCA  
for each individual worker



- **Individual dose measurement**

- Use electronic personal dosimeters (EPDs) for each individual worker



- **Radiation work management**

- Use Work information Input Device (WID)  
to register work information at each entry to RCA



## 4. Radiation protection

### Protective measures for emergency workers (External exposure) After the earthquake

- Almost all of the 5000 EPDs and associated readers and chargers became inoperable, because the controlled area access points where EPDs were kept, were flooded
- Only about 320 EPDs remained operable - gathered 50 APDs stored at the seismic building and about 270 available APDs found in the site
- Keep manual log in notebooks for personal register such as name, affiliation, work information and dose information because of the malfunction of access management and dose information system

## 4. Radiation protection

### Protective measures for emergency workers (External exposure) After the earthquake

- Since there were insufficient EPDs available for all the emergency workers on-site, an instruction was issued to share a single EPD for groups of emergency workers devoted to work that could be expected to have homogeneous radiological conditions (group assigned EPD)
- The doses received by emergency workers in the seismically isolated building were controlled by area dose rate monitoring and time spent in the area



## 4. Radiation protection

### Protective measures for emergency workers

- Strict control of access to buildings where high radiation levels were detected or suspected.
- Use of protective clothing and respiratory protection for emergency workers working outdoors or performing continuous work in the vicinity of the reactors, for example in the plant control rooms.
- Emergency workers needed to wear protective equipment before they left the seismically isolated building to carry out their assigned tasks.
- Where possible, the protective equipment consisted of a full mask fitted with a mixed charcoal and particulate filter or a particulate filter.
- When no filters were available, dust masks were provided instead.

## 4. Radiation protection

### Protective measures for emergency workers

- Iodine thyroid blocking (ITB)<sup>38</sup> was implemented as a protective measure for emergency workers from 13 March 2011.
- Notices about the distribution of stable iodine tablets were put up around the site.
- This measure applied to emergency workers under 40 years of age and, to those over 40 years who wished it, who were engaged in emergency work that could result in a projected thyroid equivalent dose of 100 mSv.
- There were a total of approximately 30 000 stable iodine tablets in stock in the main office building at the Fukushima Daiichi NPP.
- During the entire period of on-site implementation of ITB, approximately 17 500 tablets were administered to 2000 emergency workers.
- About 75% of the emergency workers received fewer than ten tablets per individual, although one individual received as many as 87.

## 4. Radiation protection

### Personal protective equipment

- Before the earthquake, the radiation protection equipment had been stored as follows at the several buildings in FDNPS
  - Full-face mask: approx. 1,000 pcs
  - Charcoal filter: approx. 700 pcs
  - Coverall: approx. 6,000 pcs
- However, **80% of them** were unusable due to the Tsunami
- The equipment, therefore, was transported from other NPSs
- Since 17 March, 2011 the equipment had been continuously supplied

## 4. Radiation protection

### Personal protective equipment

- All area of the FDNPS were highly contaminated by radioactive substances, then the radiation protection equipment was indispensable
- The basic personal protective equipment was...
  - Full-face mask with charcoal filter
  - Coverall
  - Socks
  - Shoes
  - Cotton gloves
  - Rubber gloves
  - Caps



# 4. Radiation protection

## Respiratory protective equipment

According to the situation various kind of respiratory protective equipment were used in order to protect the inhalation of radioactive material

Powered hood mask



full-face mask  
with charcoal filter / with dust filter



self-contained breathing mask



Powered air-purifying  
respirator



half-face mask  
with charcoal filter / with dust filter



## 4. Radiation protection

### Protective clothes

- The coverall was commonly used as a cloth for the radioactive contamination protection of the worker
- On the work under the wet condition or high contamination level, a non-permeable anorak suit was used on the coverall
  - Coverall
  - Anorak suit



+



## 4. Radiation protection

### Shielding suit

- The shielding vest and suit were used for the reduction of personal dose depending on the work condition
- The radiation workers were chosen as necessary, such as type of work, environment and physical load
  - Shielding best made by tungsten
  - Shielding best made by rubber
  - Shielding suit made by special material



tungsten vest

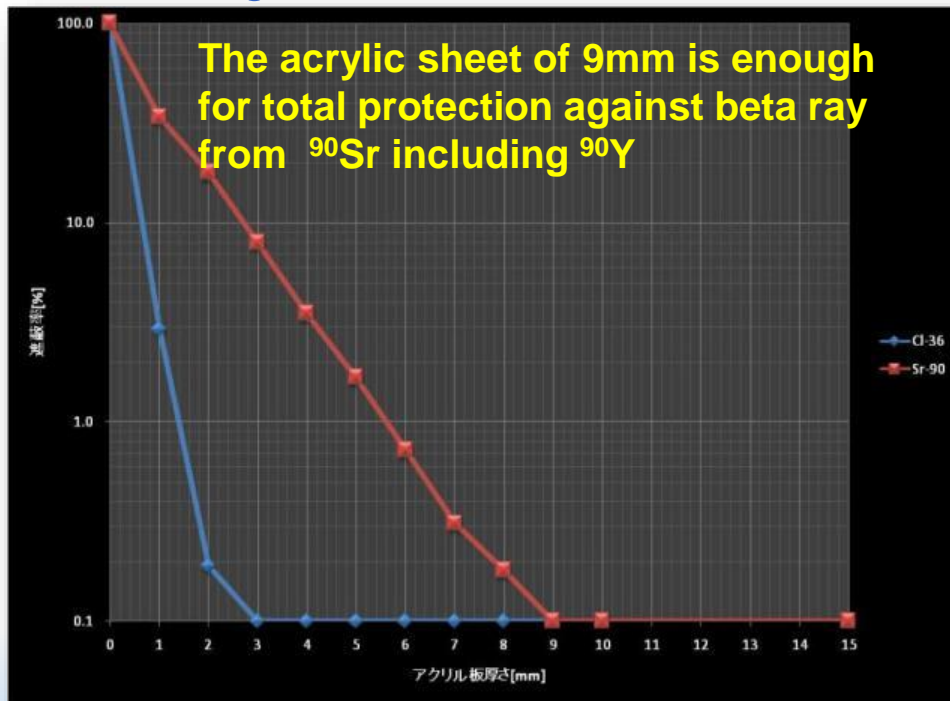


demron suit



# 4. Radiation protection

## Shielding suit



Protective suit made of Zylon



## 4. Radiation protection

### Shielding suit (actual effect)

- The APD was set the outside and inside of the protective suit
- worker A : outside 0.22mSv,    inside 0.17mSv,    (22% shielded)
- worker B : outside 0.24mSv,    inside 0.16mSv,    (33% shielded)
- Shielding effect strongly depends upon the environmental photon spectrum



## 4. Radiation protection

### Shielding suit (actual effect)

- To confirm the performance of fire fighter's shielding suit and military's shielding suit, EPD was put on the tissue equivalent phantom
- The standard irradiation from  $^{137}\text{Cs}$  source was executed to the phantom with and without these shielding suit
- In spite of over 20kg in weight, the penetration of these suits was approx. 90%.

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## 5. Worker's dose control

### Internal dose estimate and control; WBC

- Before the earthquake

Regularly measurement : Once every 3 months (monthly for female)  
Whenever there is suspicion of internal exposure  
Number of WBC = 1F : 4units 2F : 4units

- After the earthquake

All WBCs at 1F and 2F were unavailable by the loss of power,  
contamination and high background  
Installation of mobile WBC (vehicle) borrowed from JAEA  
at Onahama Coal Center

- Priority inspection of workers whose external exposure was in excess of 100mSv
- Priority inspection of female workers who engaged in emergency operations
- It took time to determine the internal exposure because of the uncertain  
of the date of intake and Iodine decay

## 5. Worker's dose control

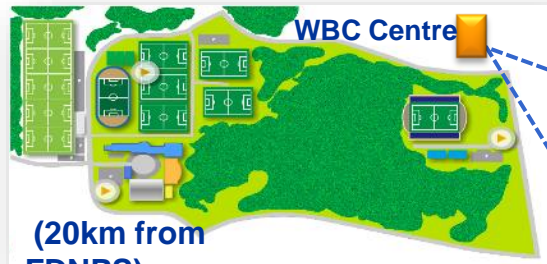
### Mobile WBC

- Practical use of mobile WBC borrowed from JAEA at Onahama Coal Center started from 22 March, 2011 to evaluate internal exposure



## 5. Worker's dose control

### WBC Centre at the Hirono football stadium



(20km from  
FDNPS)

12 WBCs were installed

1 in-vehicle type WBC

- from JAEA

11 stationary type WBCs

- 3:from Fukushima Daiichi
- 1:from Fukushima Daini
- 7:newly provided

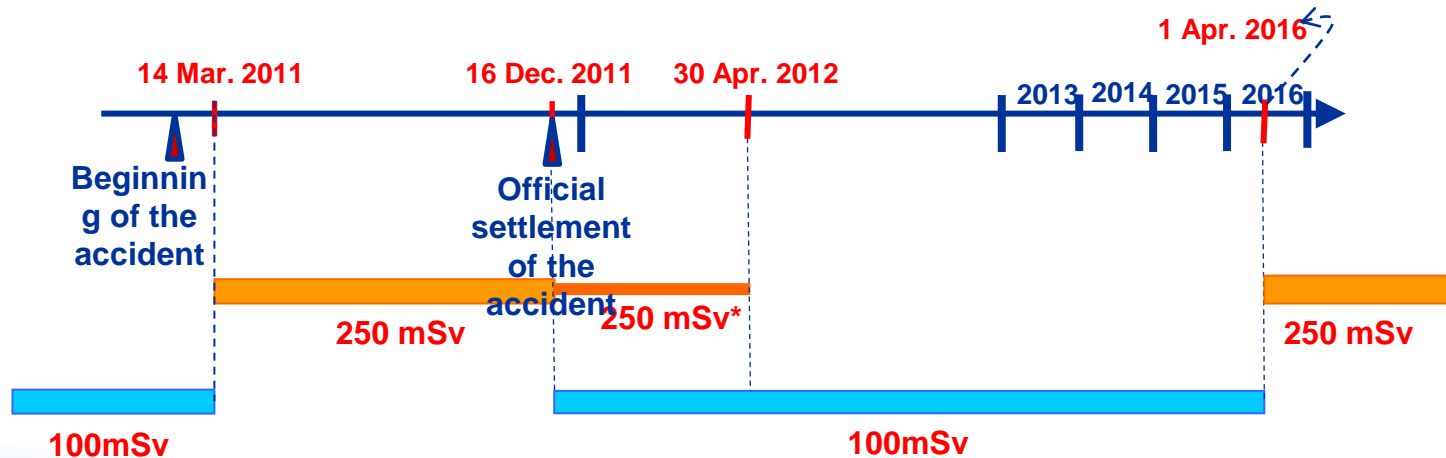




# 5. Worker's dose control

## Dose limit for emergency work

- The dose limit for emergency work was settled 100 mSv.
- Under the Fukushima accident, it became to **250 mSv** from 100 mSv on 14 Mar. 2011



\*applied in part of emergency worker

## 5. Worker's dose control

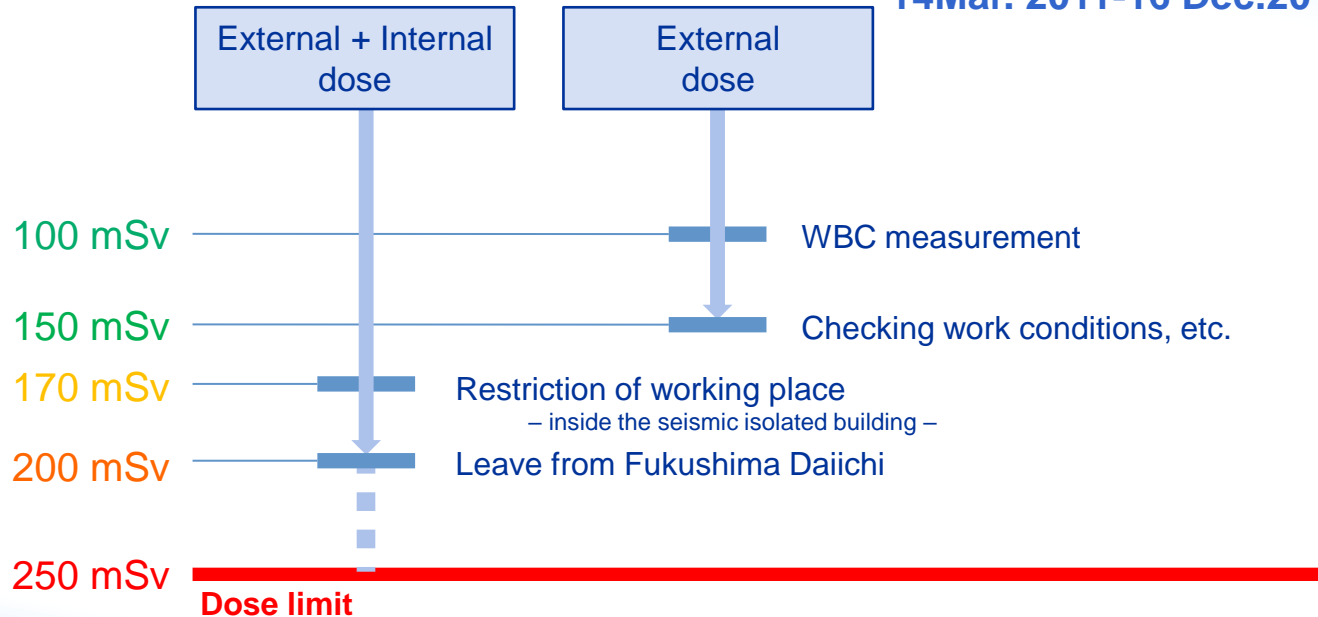
### Dose limit control

- Worker with the external dose of exceed 100 mSv must be examined by WBC to evaluate internal dose.
- Worker with the external dose of exceed 150 mSv have to consider whether to continue work.
- If there is a person whose internal dose exceed 100 mSv by the primary evaluation by WBC (NaI scintillation detector), workers working with the same behaviour are prohibited from working at the field site until the evaluation by detailed WBC is done.
- Worker with the effective dose of exceed 170 mSv must work within the seismic isolated building.
- Worker with the effective dose of exceed 200 mSv must not work at Fukushima Daiichi

# 5. Worker's dose control

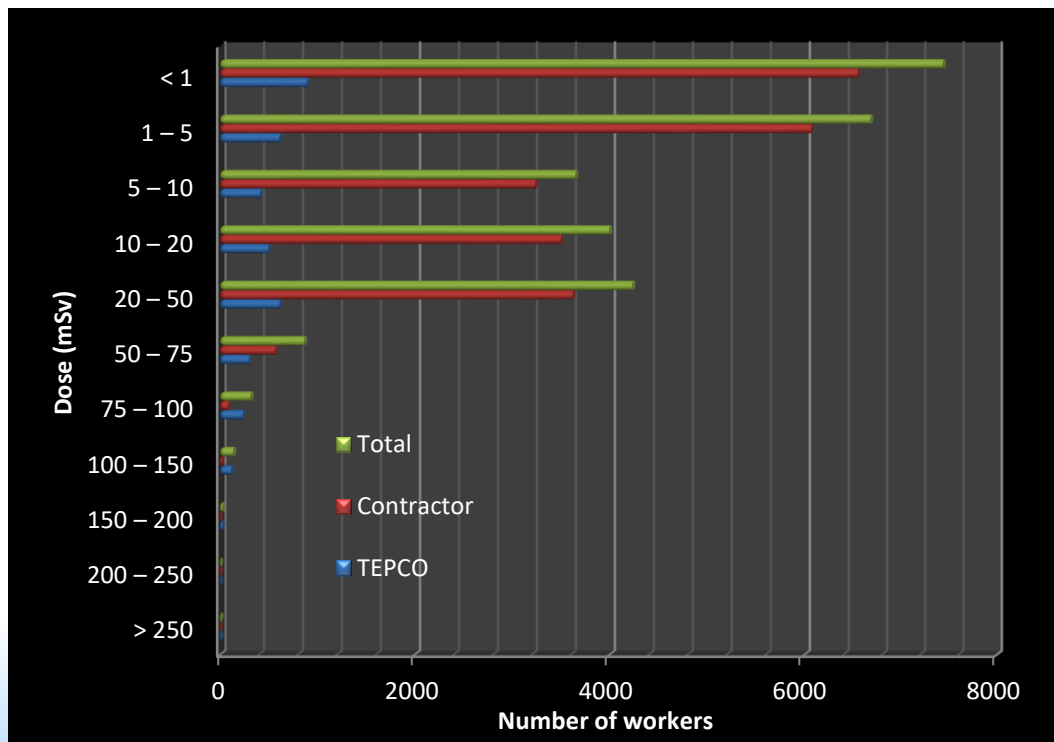
## Individual dose control (cumulative dose)

14Mar. 2011-16 Dec.2011



# 5. Worker's dose control

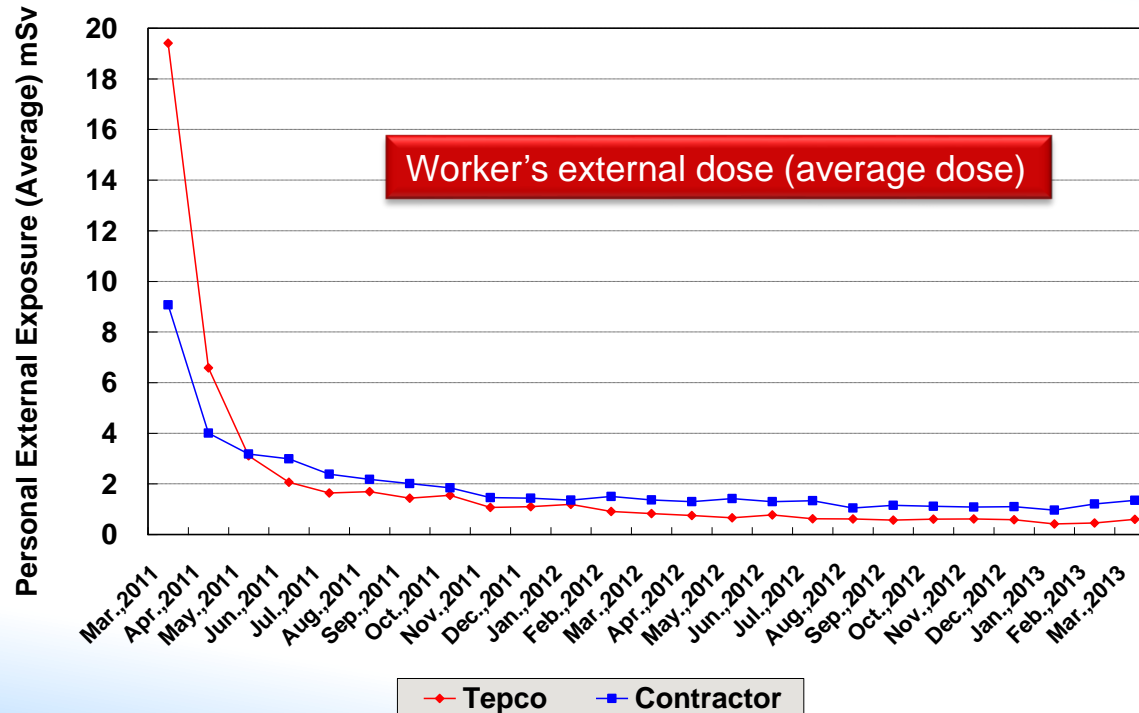
Cumulative dose of radiation worker (March 2011 – September 2013)



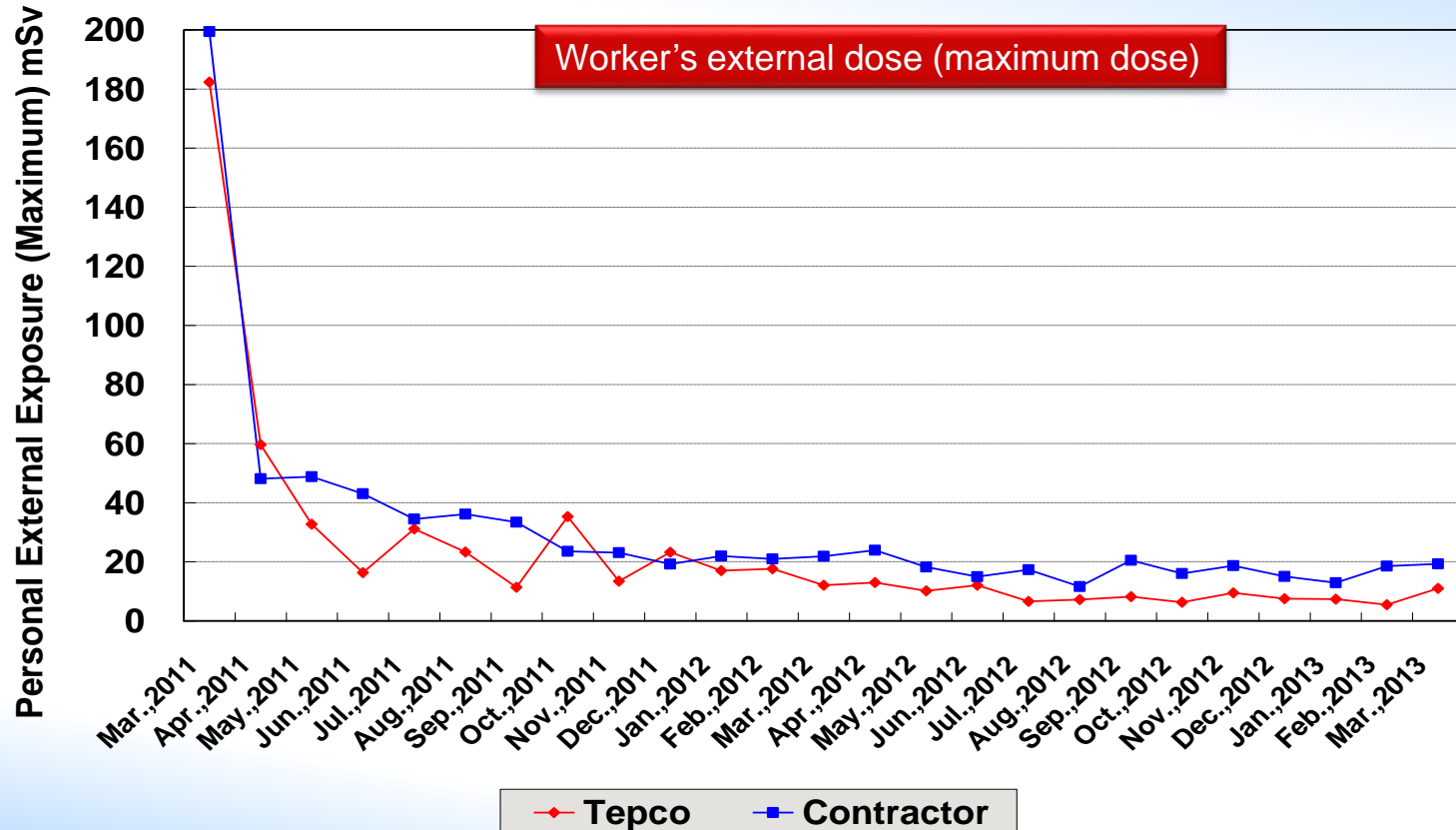
Dose (mSv)	TEPCO	Contractor	Total
> 250	6	0	6
200 - 250	1	2	3
150 - 200	24	2	26
100 - 150	118	20	138
75 - 100	234	84	318
50 - 75	300	566	866
20 - 50	613	3,620	4,233
10 - 20	497	3,499	3,996
5 - 10	413	3,236	3,649
1 - 5	611	6,067	6,678
< 1	893	6,545	7,438
<b>Total</b>	<b>3,710</b>	<b>23,641</b>	<b>27,351</b>

## 5. Worker's dose control

The measurement and evaluation of exposure radiation levels with workers engaged in emergency work at the FDNPS has been implemented continuously since the earthquake.



# 5. Worker's dose control



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## 6. Remarkable events brought about radiation exposure

### Exceeded emergency dose limit (250 mSv)

- The influx of contaminated air into the are Main Control Room (MCR) through the MCR's emergency door that was damaged by the reactor building hydrogen explosions
- There were six cases in which emergency workers incurred doses in excess of the dose limit of 250 mSv. These ranged from the highest dose of 678 mSv (of which 590 mSv was from internal contamination) to the lowest dose of 311 mSv (of which 260 mSv was from internal contamination)



## 6. Remarkable events brought about radiation exposure

### Exceeded emergency dose limit (250 mSv)

- Unavailability of adequate respiratory protection (e.g. too tight, fogging of the mask's glass while breathing smoking, eating and drinking in the contaminated environment) against volatile iodine for the emergency workers in the control room early after the onset of the accident was confirmed
- As the result, these workers ingested radioactive materials.
- However, no radiation damage had occurred among all emergency workers, including workers who exceeded the dose limits. Whereas workers responded under extremely harsh conditions during the initial stages of the accident, substantial safety management had been implemented the perspective of preventing radiation damage.

## 6. Remarkable events brought about radiation exposure

### Exceeded emergency dose limit (250 mSv)

- They (MCR) operators and electrical/instrument related maintenance workers that engaged in operation and monitoring work and also work to restore monitoring instruments, etc..

unit: mSv

	External dose	Internal dose	Total dose
1	88.80	590.00	678.80
2	105.54	540.00	645.54
3	43.49	433.05	477.01
4	32.95	327.90	360.85
5	110.27	241.81	352.08
6	11.31	259.66	310.97

## 6. Remarkable events brought about radiation exposure

### Exposed over 170 mSv from highly contaminated water

- During work conducted in the basement of the Unit 3 Turbine Building on 24 Mar.,2011, three workers were exposed radiation levels of that exceeded 170 mSv during cable laying work
- After examination, they were moved to the National Institute of Radiological Sciences (NIRS) on 25 Mar.,2011
- They were hospitalized for examination until 28 Mar.,2011
- There was no findings, such as a reduction in white blood cells and lymphocytes. It means that no symptoms of beta radiation burns and erythema.

## 6. Remarkable events brought about radiation exposure

### Causes of the over exposure

- Advanced work environment data showed radiation level were approx. 0.5 mSv/h. There was no water accumulated in front of the power panels, and that there was 1 to 2 cm of water accumulated in places under the stairs.
- Based on this information a work plan was created.
- During the work APD alarms sounded, the workers were under the impression from advanced informed that the APD were malfunctioning. And continued to work with a sense of mission that the work had to be completed.
- However, after work was completed when workers met with another workgroup and the RP officer of that workgroup spoke of unforeseen high radiation levels, then quickly returned to the seismic isolated building.
- No one knew about the highly radioactive water that was accumulated in Unit 3.

## 6. Remarkable events brought about radiation exposure

### Exceeded the dose limit for female worker (5 mSv / 3 month)

- 19 female were engaged in emergency work of FDNPS
- Among them, 2 female exceeded dose limit stipulated by regulation

### Effective dose

1) 17.55 mSv (external: 3.95 mSv / internal: 13.6 mSv)

2) 7.94 mSv (external: 0.78 mSv / internal: 6.71 mSv)

- Female workers were not allowed to work within the FDNPS after 23 Mar.,2011

## 6. Remarkable events brought about radiation exposure

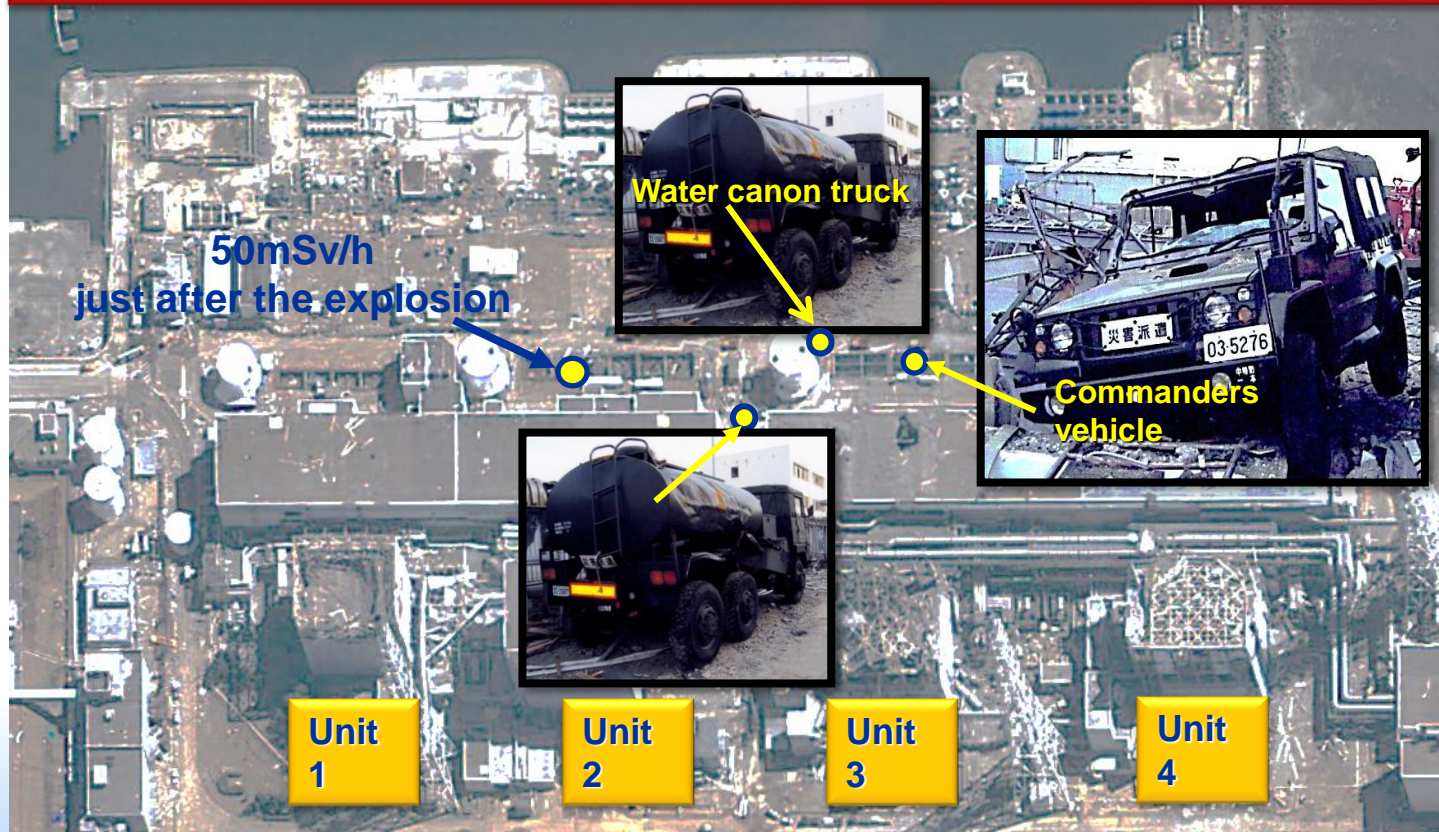
### Military personnel exposed by hydrogen explosion

- On 14 March 2011, six military personnel encountered the hydrogen explosion just in front of Unit 3
- 90 minutes before hydrogen explosion they took potassium iodine (130mg)
- The blast of the hydrogen explosion directly pierced through their Tyvek® suit and battle suit.
- Surface contamination level was 1 mSv/h at 10cm distance when they escaped from the site



## 6. Remarkable events brought about radiation exposure

Arrangement of the military vehicle just before the hydrogen explosion





## 6. Remarkable events brought about radiation exposure

- As soon as the heavy contamination was confirmed, their Tyvek suit and battle suit were cut and removed immediately
- The activity of the clothes was too high to analyze the spectrum on the day
- Two days later radio nuclides were detected from their battle suits

Measured on 16 Mar. 2011



### Nuclides

Te-129

Te-129m

Te-132

I-131

I-132

I-133

Cs-134

Cs-136

Cs-137

La-140

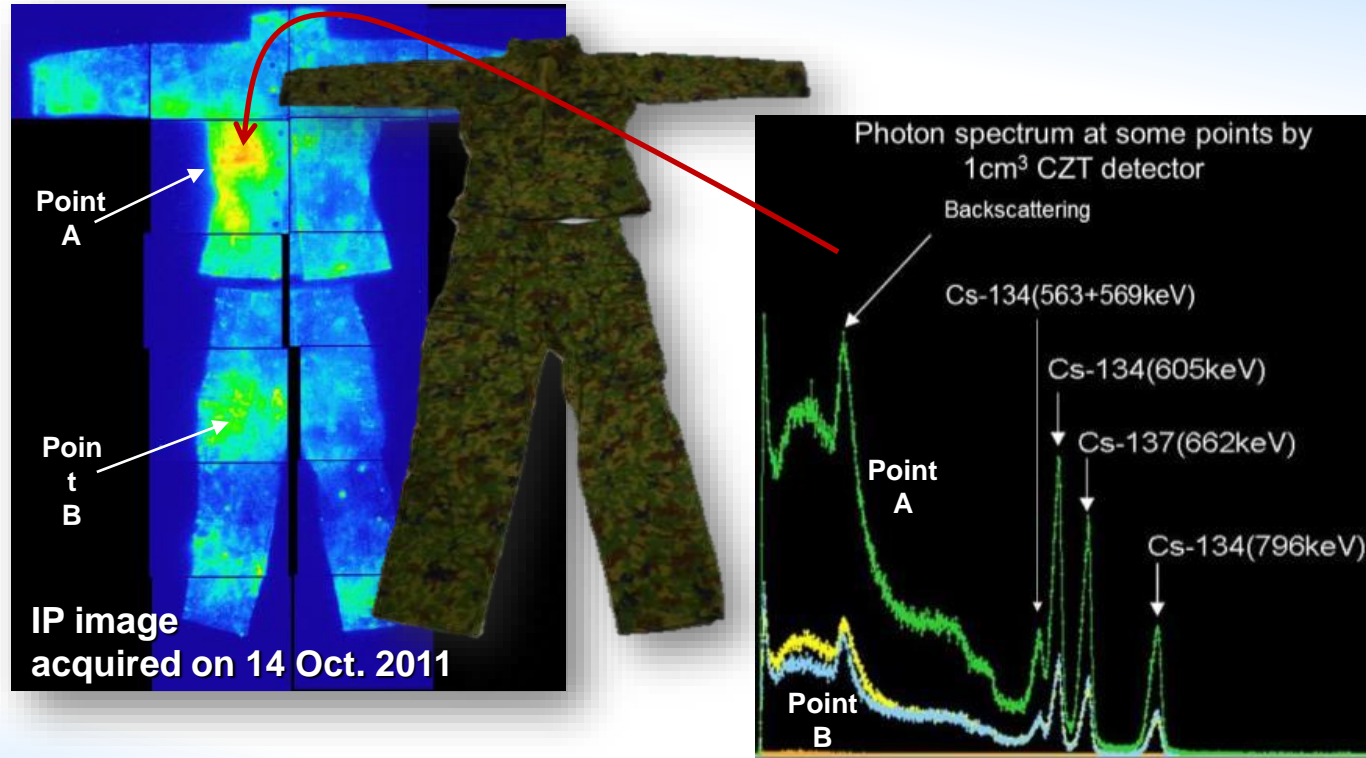


## 6. Remarkable events brought about radiation exposure

6 months later, the surface contamination of the battle suit was reduced to 1/20 of the initial level because of the half life of Tellurium and Iodine, but was still 30 times of legal regulation

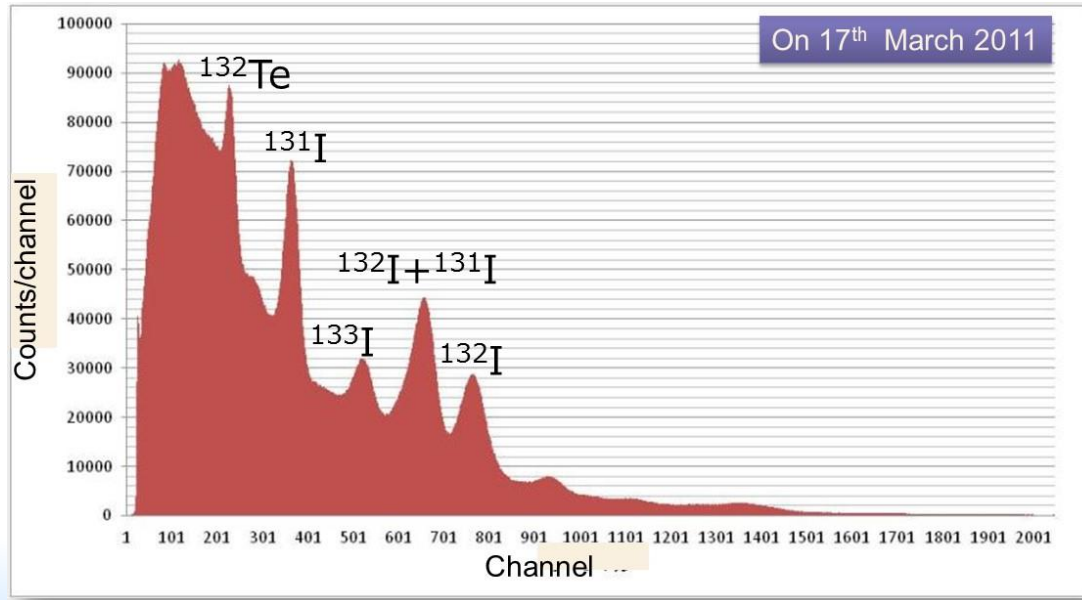


## 6. Remarkable events brought about radiation exposure



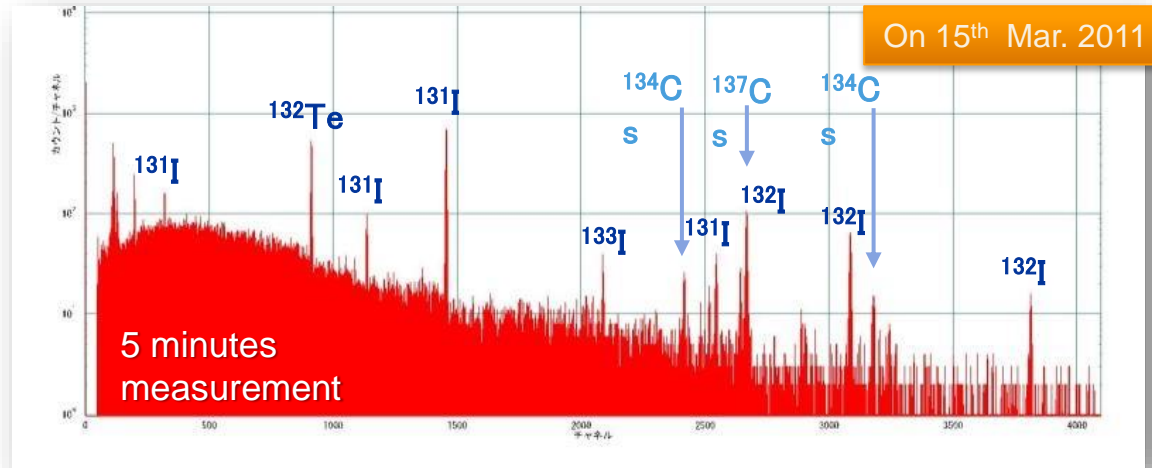
## 6. Remarkable events brought about radiation exposure

- On 15 Mar. one injured soldier who suffered injury was carried to NIRS
- It was impossible to measure his internal contamination on the day because of the saturation of the WBC (NaI(Tl)-8"Φx4)
- Two days later the in-vivo measurement was carried out as below



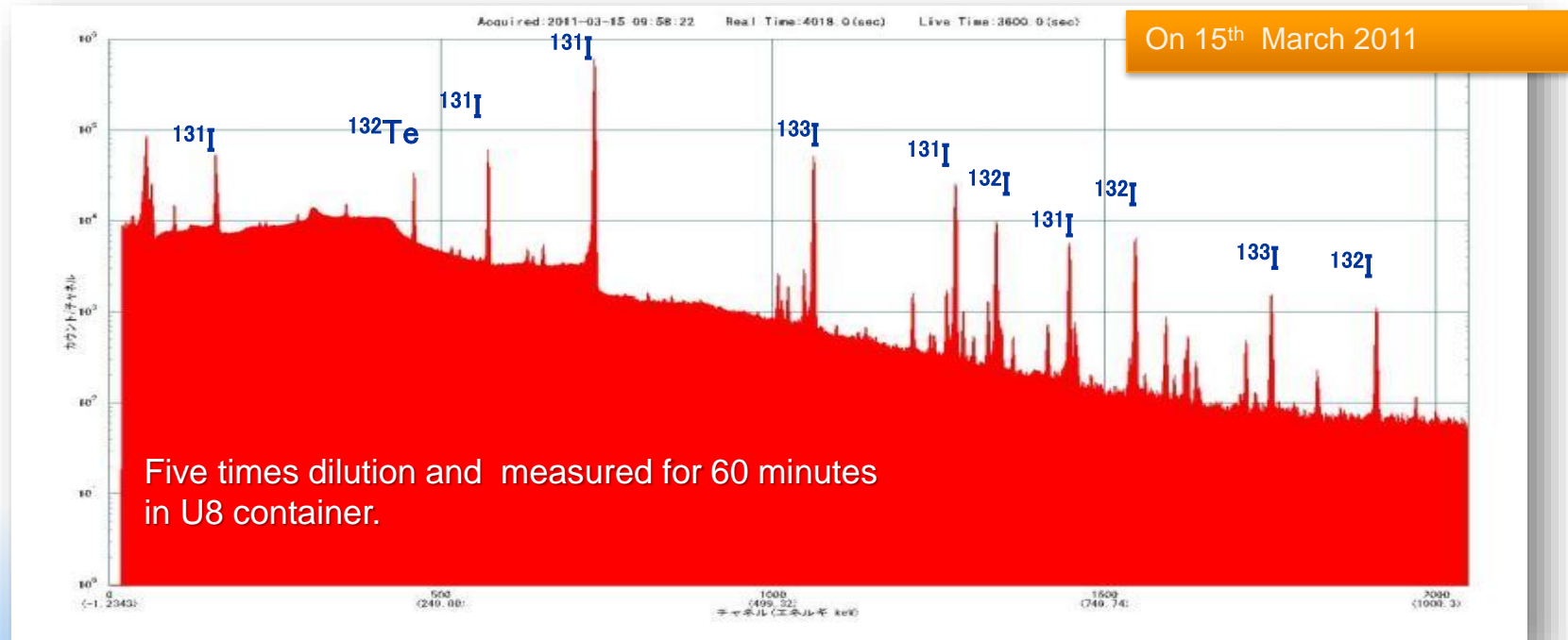
## 6. Remarkable events brought about radiation exposure

- There was an incorporation to the thyroid gland though the overall mask had been worn based upon the measurement by Ge thyroid monitor
- It was thought that not only  $I_2$  and CsI but a large amount of methyl iodide were existing
- Considering the collection efficiency of the iodine filter and specific activity it may be reasonable to assume the penetration of some methyl iodide.



## 6. Remarkable events brought about radiation exposure

- Nuclide observed in urine
- A large amount of iodine shows the blocking effect by the iodine tablet



## 6. Remarkable events brought about radiation exposure

### Dose evaluation of the six personnel

- Fortunately, the maximum exposure was following our assumption.
  - Effective dose: 20mSv
  - Committed effective dose: 4.2mSv  
(Mainly thyroid)
- Slight  $^{90}\text{Sr}$ - $^{90}\text{Y}$  was detected in urine but the dose contribution can be disregarded.

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## 7. Efforts to reduce worker's dose

### Application of the state of the art equipment

- When engaging in the work in zone with high radiation levels, robots and gamma cameras were used in advance to measure atmospheric dose rates inside the Reactor Buildings (R/Bs) in order to reduce exposure
- When removing highly radioactive debris outside efforts were being made to reduce exposure by employing remote control unmanned heavy equipment



# 7. Efforts to reduce worker's dose

## Robots for exploration



**Quince**



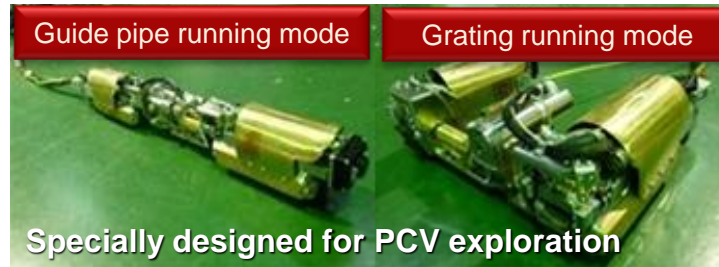
**Packbot**



**FRIGO-MA**



**Rosemary**



Guide pipe running mode

Grating running mode

Specially designed for PCV exploration

**Shape changeable robot**

# 7. Efforts to reduce worker's dose

## Robots for decontamination



Water jet  
**Arounder**



Shot blast  
**MEISTeR**



Cleaner  
**Raccoon**



Dry ice blast

## 7. Efforts to reduce worker's dose

### Robots for removal work



**Warrior**

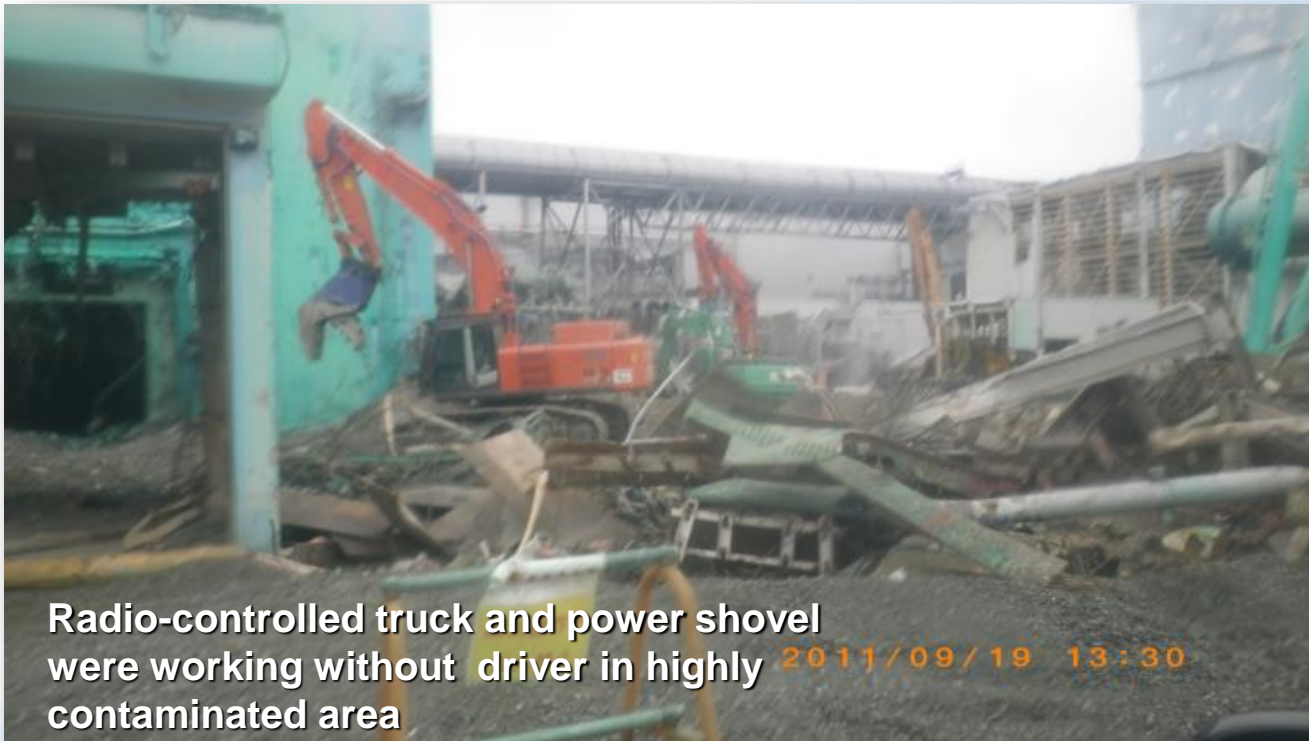


**ASTACO-SoRa**



**DXR-140**

## 7. Efforts to reduce worker's dose



## 7. Efforts to reduce worker's dose

### Dose reduction in the seismic isolated building and MCRs

- Since there were many workers engaged in recovery work who were sleeping in the seismic isolated building in order to handle the expansive amount of work required following the accident, it became necessary to reduce exposure dose during their stay



Local exhauster



Replacement of  
floor tiles

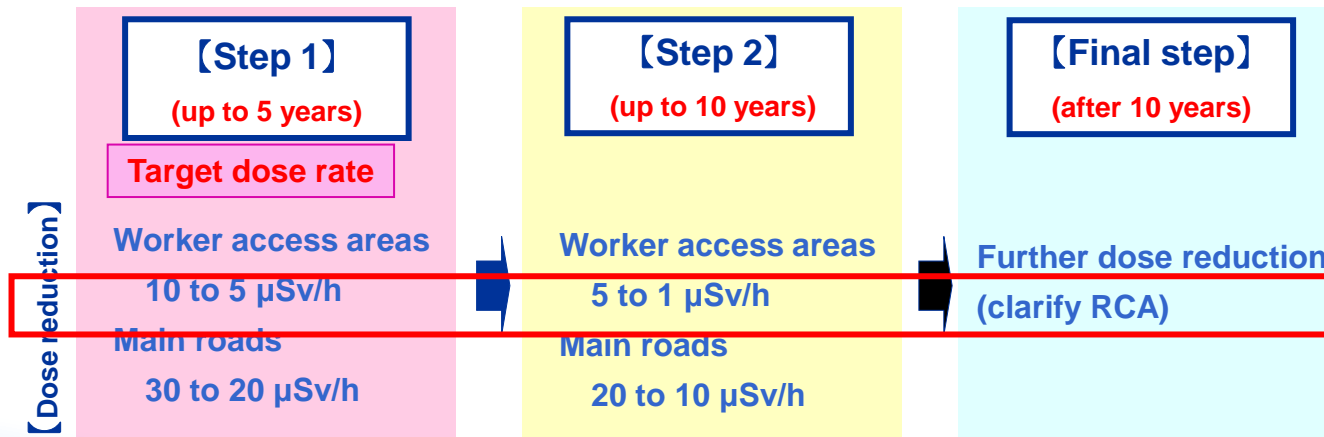


Lead board to shield  
glass windows

## 7. Efforts to reduce worker's dose

### On-site decontamination

- On-site decontamination has proceeded for the purpose of reducing doses in area where many workers enter, the locations subject to decontamination are selected and target dose rates are set for each step.





## 7. Efforts to reduce worker's dose

### Dose reduction per task

- When engaging in this type of work in zones with high radiation levels were used in advance to measure atmospheric dose rates within the reactor buildings in an effort to ascertain the conditions and reduce exposure.



Wiping work with a robot



Removal of concrete  
on admin. building



Ultra high pressure  
water peeling

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## 8. Radiation monitoring

### On-site air dose rate monitoring

- Due to loss of power supply monitoring systems such as fixed 8 monitoring posts (MPs) were unusable.
- Monitoring cars and mobile monitoring posts were applied to ascertain the state of the release of radioactive materials near the borders of the site.
- Gathering the data was very difficult because all communication devices were unusable.
- Under high background workers in the seismic isolated building had to retrieve handwritten notes from the monitoring cars periodically.
- From 9 April 2011 all monitoring posts had been restored and the air dose rate was monitored and publicly disclosed.

## 8. Radiation monitoring

### On-site air dose rate monitoring

- As of the evening of 11 Mar., dose rates exceeding 1 mSv/h were detected in the reactor building of Unit 1

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- At 15:29 on 12 Mar., radiation dose rates at a station monitoring post along the site boundary showed 1.015 mSv/h
- The radiation level measured near a monitoring post (MP4) was 0.569 mSv/h at 15:31

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- On the afternoon of 13 Mar., the site radiological conditions deteriorated
- At 14:15, an 'abnormal rise in the site boundary radiation dose rate' was declared, upon a radiation level measurement of 0.905 mSv/h at one of the site monitoring posts near the site boundary

## 8. Radiation monitoring

### On-site air dose rate monitoring

- At 15:28, dose rates exceeded 12 mSv/h at the Unit 3 side of the common MCR of Units 3 and 4, causing the shift team to move to the Unit 4 side.
- At 14:31, the radiation dose rate exceeded 300 mSv/h at the north side and 100 mSv/h at the south side RB doors
- At 11:01 on 14 March, an explosion occurred in the upper part of the Unit 3 RB, destroying the building structure above the service floor
- At about 08:25 on 15 Mar., white smoke (or steam) was observed being released from the Unit 2 RB near the fifth floor
- A radiation dose rate measurement of 11.93 mSv/h was recorded at the main gate at 09:00, the highest measurement since the beginning of the accident.

## 8. Radiation monitoring

### On-site monitoring of environmental sample

- Measurement samples were carried from FDNPS to Fukushima Daini NPS and measured since 21 March, 2011
- Photon spectrum analysis was applied as below;
  - Dust (air)
  - Seawater (coastal, offshore, harbour)
  - Sub-drain water (on-site)
  - Well water (on-site)
  - Soil (on-site)
  - Etc.
- Measurement of alpha and beta-ray (since 1 July)

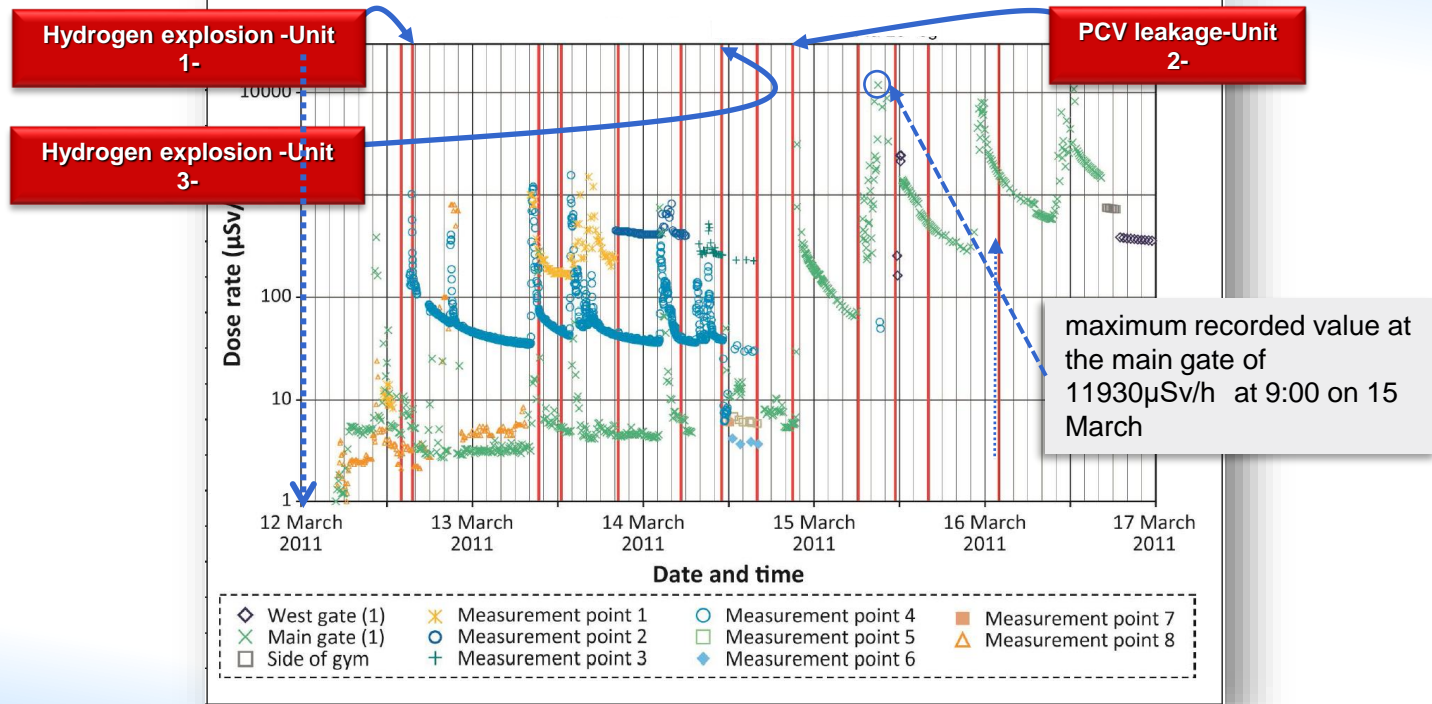
# 8. Radiation monitoring

## Layout of Monitoring Post (MP), Portable MP, Monitoring car



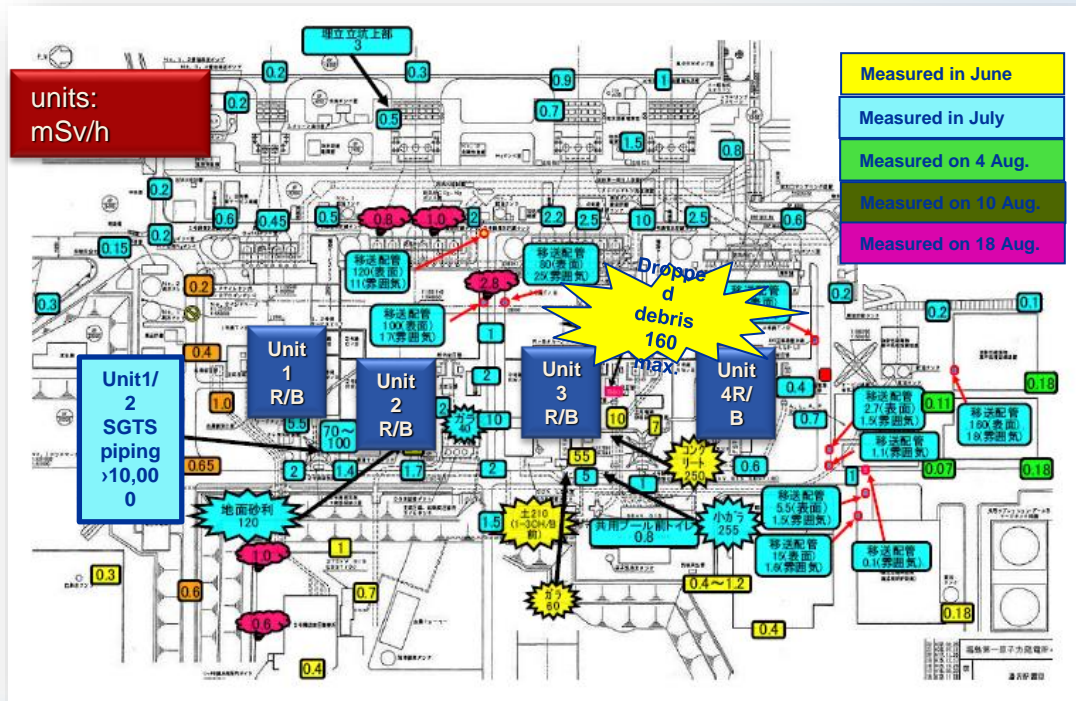
# 8. Radiation monitoring

## On-site air dose rate



# 8. Radiation monitoring

## On-site dose mapping on 18 August, 2011





# 8. Radiation monitoring

## Monitoring measures in the high dose rate zone





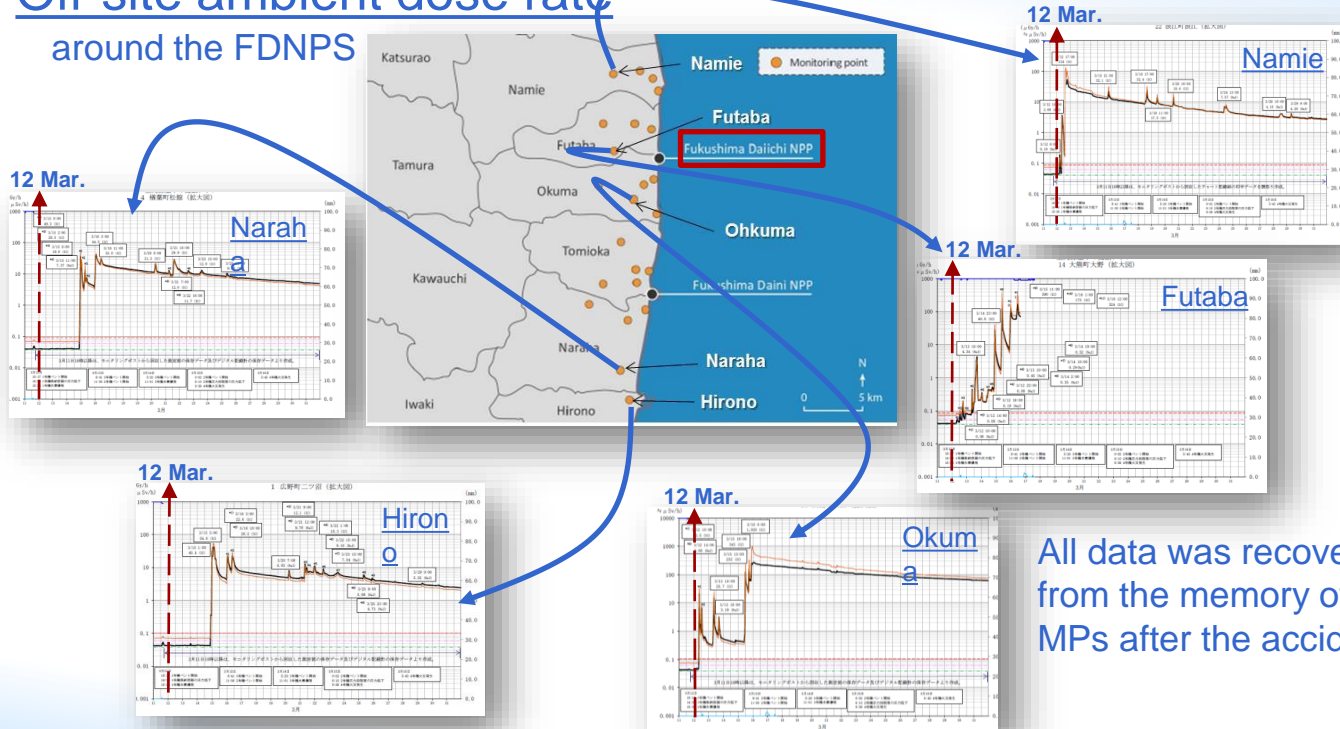
## 8. Radiation monitoring

### Off-site ambient dose rate monitoring

- Prior to the accident, monitoring posts, under the responsibility of Fukushima Prefecture, were located within about 5 km of the FDNPS.
- However, as a result of earthquake and tsunami, only one of these was functioning at the time of the accident.
- The local government had 12 monitoring vehicles and four germanium semiconductor detectors as well as a number of NaI scintillation detectors.
- The 12 vehicles ran out of fuel and were abandoned, along with most of the monitoring equipment.
- Two of the four germanium semiconductor detectors were not functioning due to the damage caused by the earthquake.

# 8. Radiation monitoring

## Off-site ambient dose rate around the FDNPS

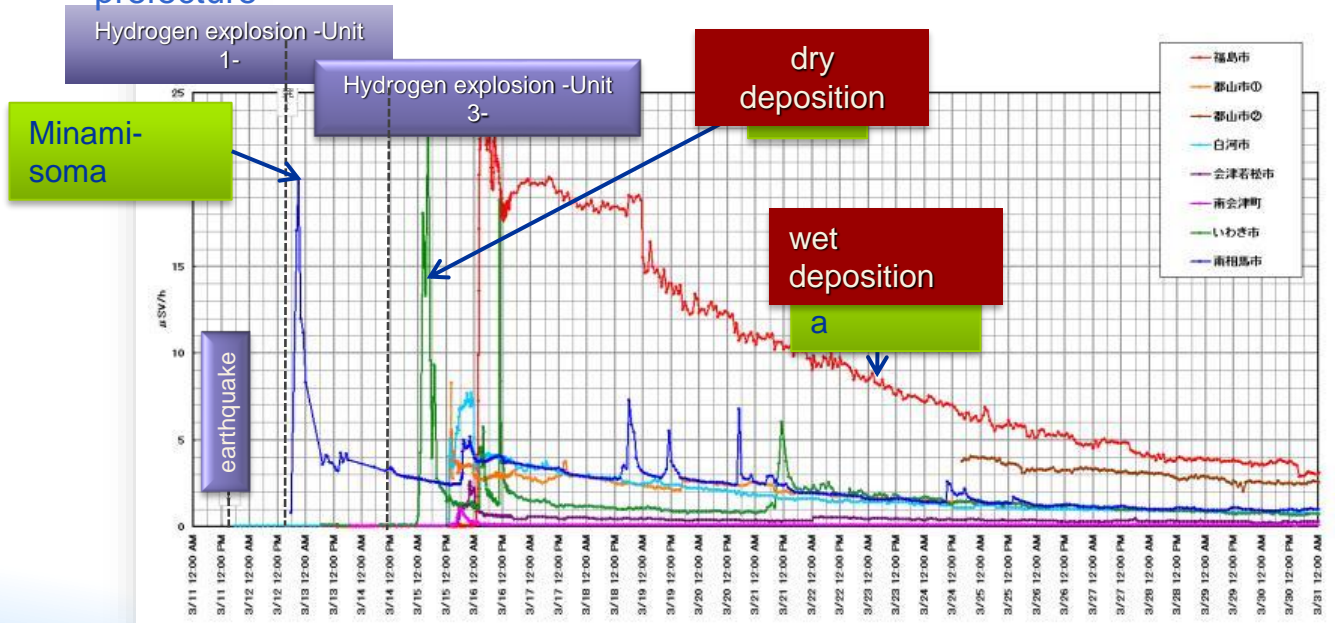


All data was recovered from the memory of MPs after the accident

# 8. Radiation monitoring

## Off-site ambient dose rate in Fukushima prefecture

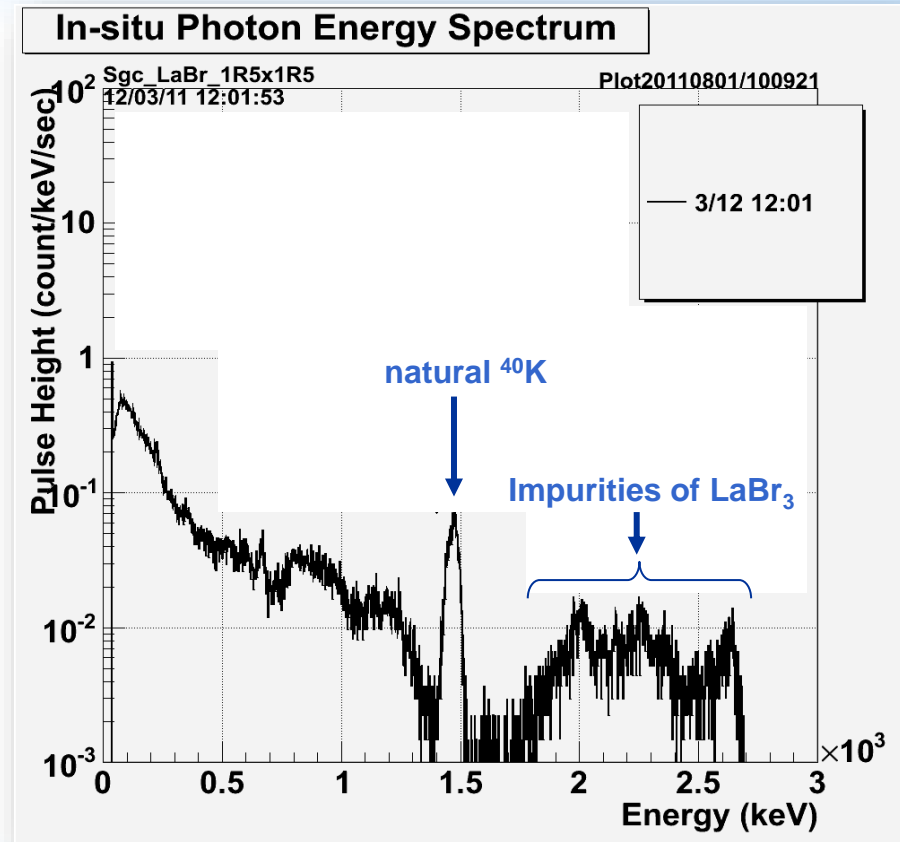
## Observed ambient dose rate by local government's MP



## 8. Radiation monitoring

[γ-ray spectrum measured by LaBr3 spectrometer at Okuma off-site center](#)

- It was calm, and the background was around  $0.06\mu\text{Sv/h}$  at Okuma Off-Site center at noon on 12 March, 2011
- However, plume had not yet reached this measuring point

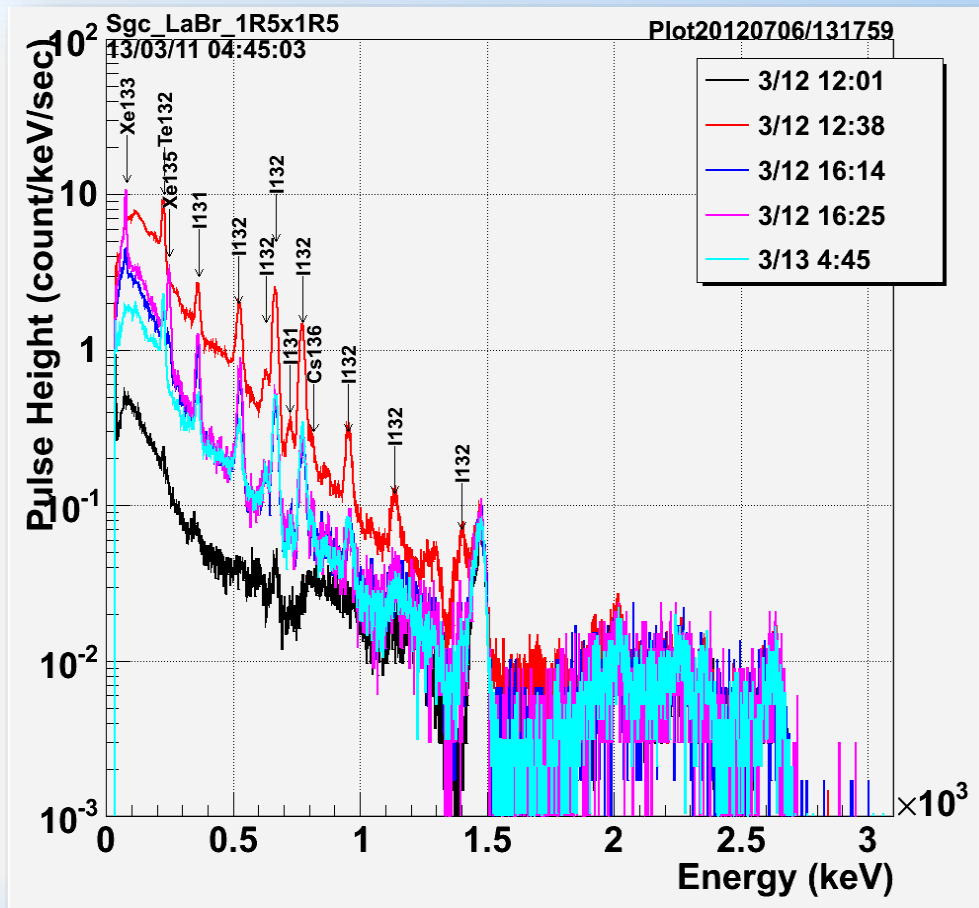


## 8. Radiation monitoring

### [γ-ray spectrum](#)

at Okuma off-site center

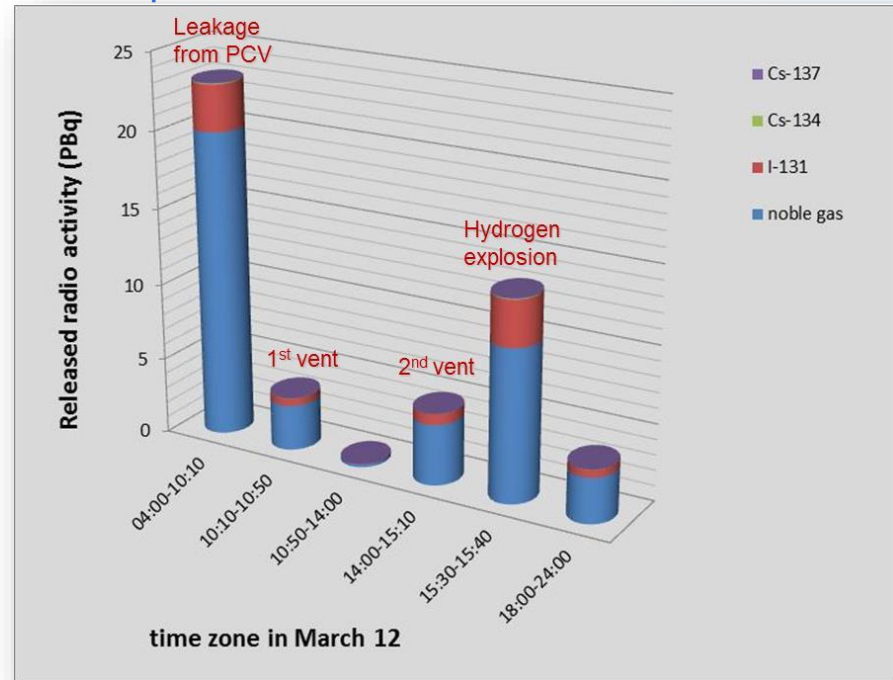
- 30 minutes later, radioactive plume had come just above the center
- Xe-133, Te-132, I-131, I-132, I-133 were mainly observed



## 8. Radiation monitoring

### The first release of the radioactive material

- The origin of this plume must be the wet-well vent operation in unit 1 at 10:17 on March 12 and continuous leakage from the PCV
- Window direction had changed from north to southwest during this 30 minutes at a velocity of 2m/sec, then the plume was coming above the off-site center.
- According to TEPCO's announcement dated in Sep. 2012, 3.5PBq including noble gas, Iodine and Cesium released at this vent.

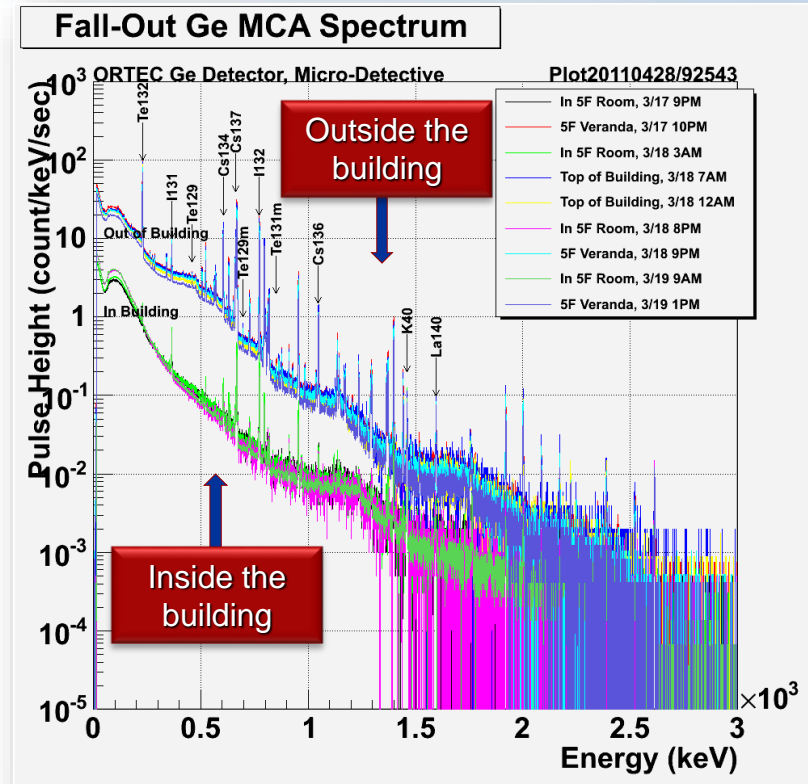


## 8. Radiation monitoring

### $\gamma$ -ray spectrum

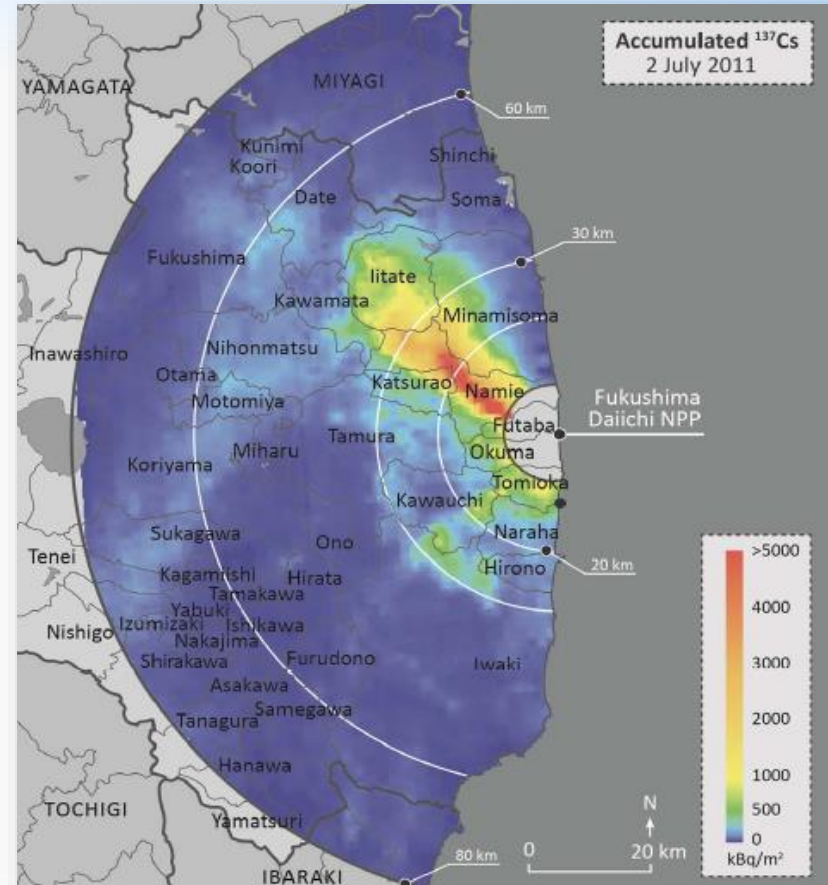
at Fukushima Local Government Office

- Early phase photon spectrum measured by portable Ge spectrometer from 17-19 March, 2011
- Approx. one order of magnitude of shielding effect by concrete building was confirmed



## 8. Radiation monitoring

- The contamination map of the Fukushima prefecture was made by an actual soil radioactivity analysis in addition to the aircraft survey and the car survey
- The prime cause that the strong distribution's being seen on the north-northwest side was raining when a radioactive plume reached the area





# Contents

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2. Radiation control overview
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6. Remarkable events brought about radiation exposure
7. Efforts to reduce worker's dose
8. Radiation monitoring
9. **Lessons learnt**

## 9. LESSONS LEARNT

The valuable experience gained from this accident

1. Reinforcement of environmental radiation monitoring system:

- It is necessary to reinforce the radiation measurement system equipped by self-sustainable power supply such as solar panel with water-proof battery,
- Promotion and organizing of radiation monitoring team for emergency preparedness in addition to RPOs.

# 9. LESSONS LEARNT

The valuable experience gained from this accident

## 2. Enhancement of protective equipment:

- It is necessary to regularly provide a sufficient number of equipment in appropriate, comprehensive locations. Such protective equipment should include protective clothing (normal gear and radiation shielding suit), masks, Active Personal Dosimeters (APD), and portable air purifiers to improve Main Control Room (MCR) environment;
- It is important to have waterproof alarm APDs with standard battery supply;
- Alternative emergency ventilation equipment for the MCR where is the forefront in emergency response is indispensable.;
- As the seismic isolated building functions as a center for accident responses, it should be designed in advance to protect the indoor contamination and the external radiation from released radioactive materials.

## 9. LESSONS LEARNT (cont'd)

### 3. Preparation of radiation control tools:

Management tools for easy dose calculation should be prepared in advance

### 4. Preparedness of mobile WBC:

It is effective to prepare a WBC car for internal exposure assessment of workers in nuclear disasters

### 5. Development of evaluation approach on internal exposure and the response procedures:

It is necessary to establish a plane manual for internal dose assessment and to develop training material for nuclear disasters

### 6. Method to Review Emergency Dose Limits:

The nuclear accident is very rare event. So, the government is requested to make the standard by taking international rules based on wide findings without a delay

## 9. LESSONS LEARNT (cont'd)

7. Development on radiation protection approach for female workers:  
Basic approach should be developed to evacuate female workers engaged in work at the station as early as possible when a nuclear disaster occurs

8. Establishment of an access control center:  
Establishment an access control centre as well as transport relay centre should be considered in advance (pre-selection of locations, radiation education for support workers, providing decontamination equipment)