

# **Fukushima**

## **First Assessment of the Environment Monitoring**

**Zdeněk Prouza**

**Jiří Hůlka, Aleš Froňka (speaker)**

**National Radiation Protection Institute**

**IRSN report: Assessment on the 66th day of projected external doses for population living in the north-west fall out zone of the Fukushima nuclear accident**

**CTBTO IDC secured web site for authorized users (CRTOOL, PTS Briefings)**

**WGB 37: Lessons learned from Fukushima nuclear accident, CTBTO RN expert group**

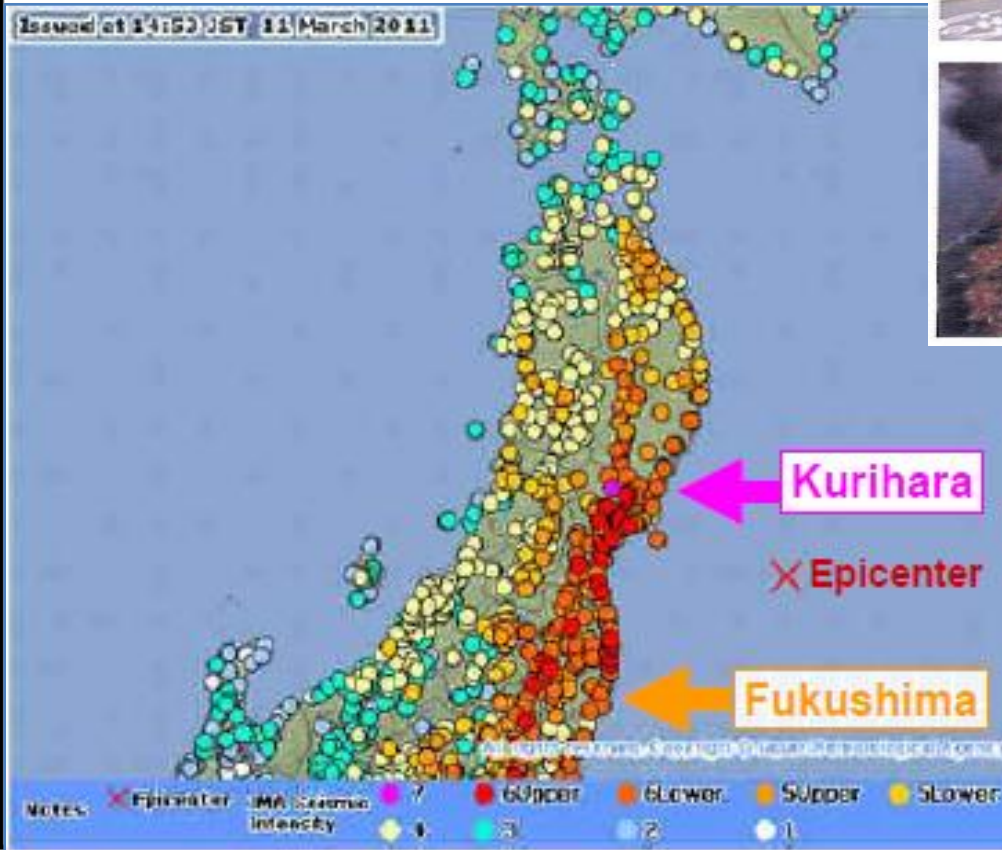
**Matthias Auer: Fukushima – IMS lessons learnt and action planned, IMS Division,  
CTBTO**

**Ludger Mohrbach: Earthquake and Tsunami in Japan on March 11, 2011, VGB  
PowerTech**

**Web sites information: NISA, MEXT**

# Tsunami

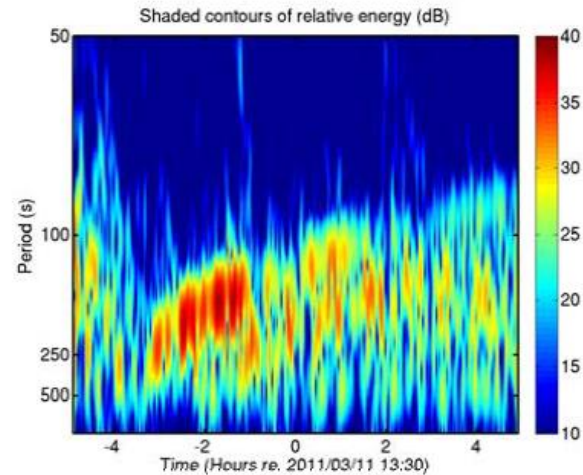
March 11, 2011, 15:41 JST (6:41 UTC) at Fukushima-Dai



atically all damage  
to the tsunami.

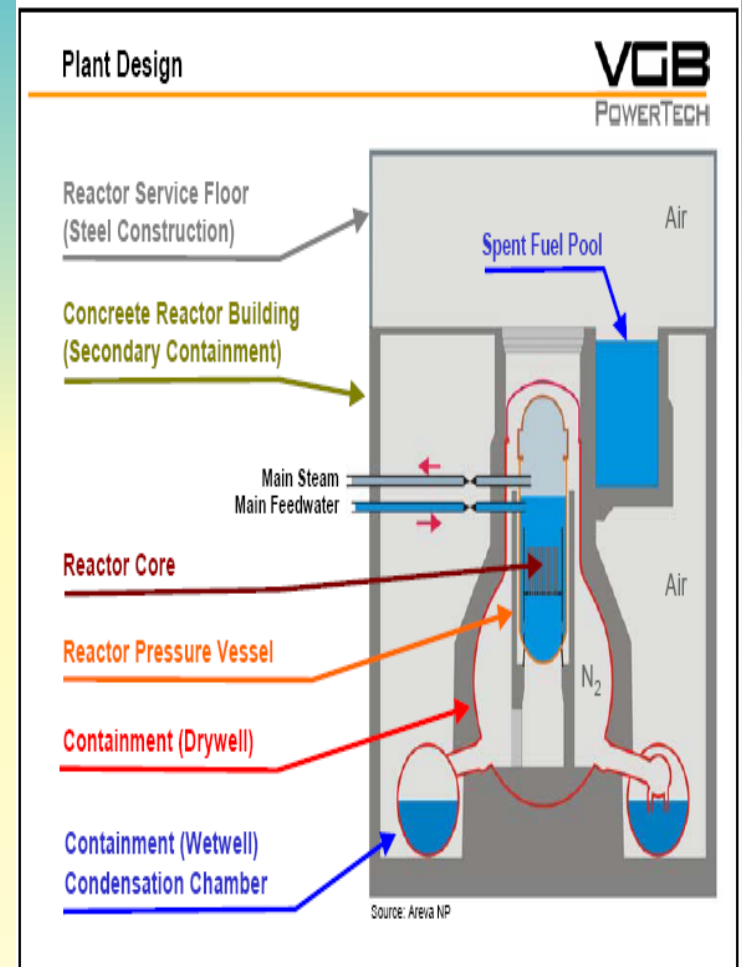
## Tsunami observed on hydrophones

- Image shows pressure on hydrophone as a function of time.
- As tsunami goes over hydrophone, water depth changes and pressure recorded by hydrophone changes
- Red stripe running bottom-left to top-right shows how low-frequency waves arrive first because of high propagation speed.



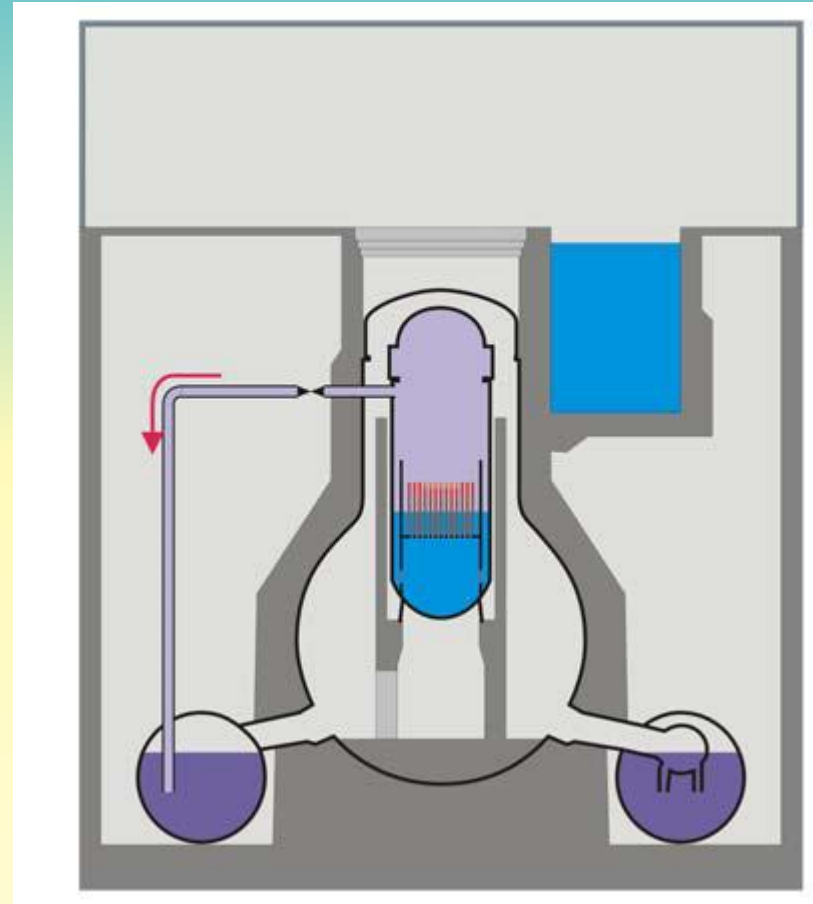
# Fukushima I

- 55 nuclear reactors of different type operated in Japan
- **Fukushima I** – 6 units (1971-79) - BWR 460, 784, 1100 MW - boiled water reactors, without integral containment
- 1. - 3. units operating, 4. – 6. units – temporary shutdown, unit 5 - since 3.1. 2011,  
unit 6 – since 14.8.2010
- Earthquake, tsunami – automatic shutdown of units 1- 3
- Loss of external power supply (black-out)
- Reactors sustained the earthquake, diesel-generators, pumps, batteries – flooded and damaged by tsunami
- damaged/destroyed other systems – monitoring, cooling...

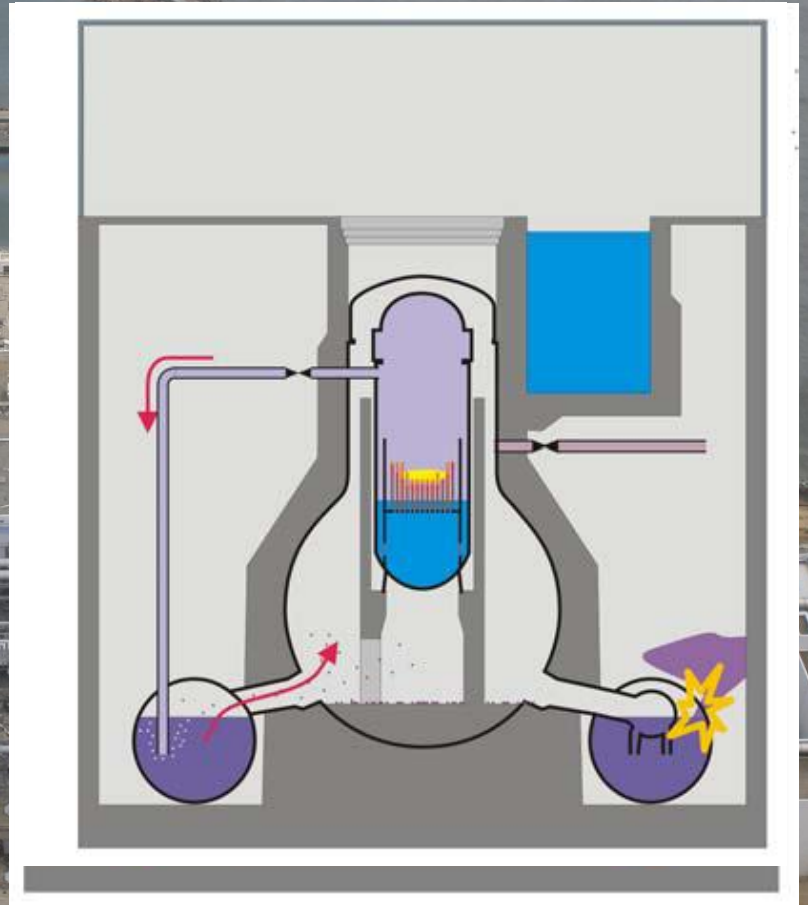
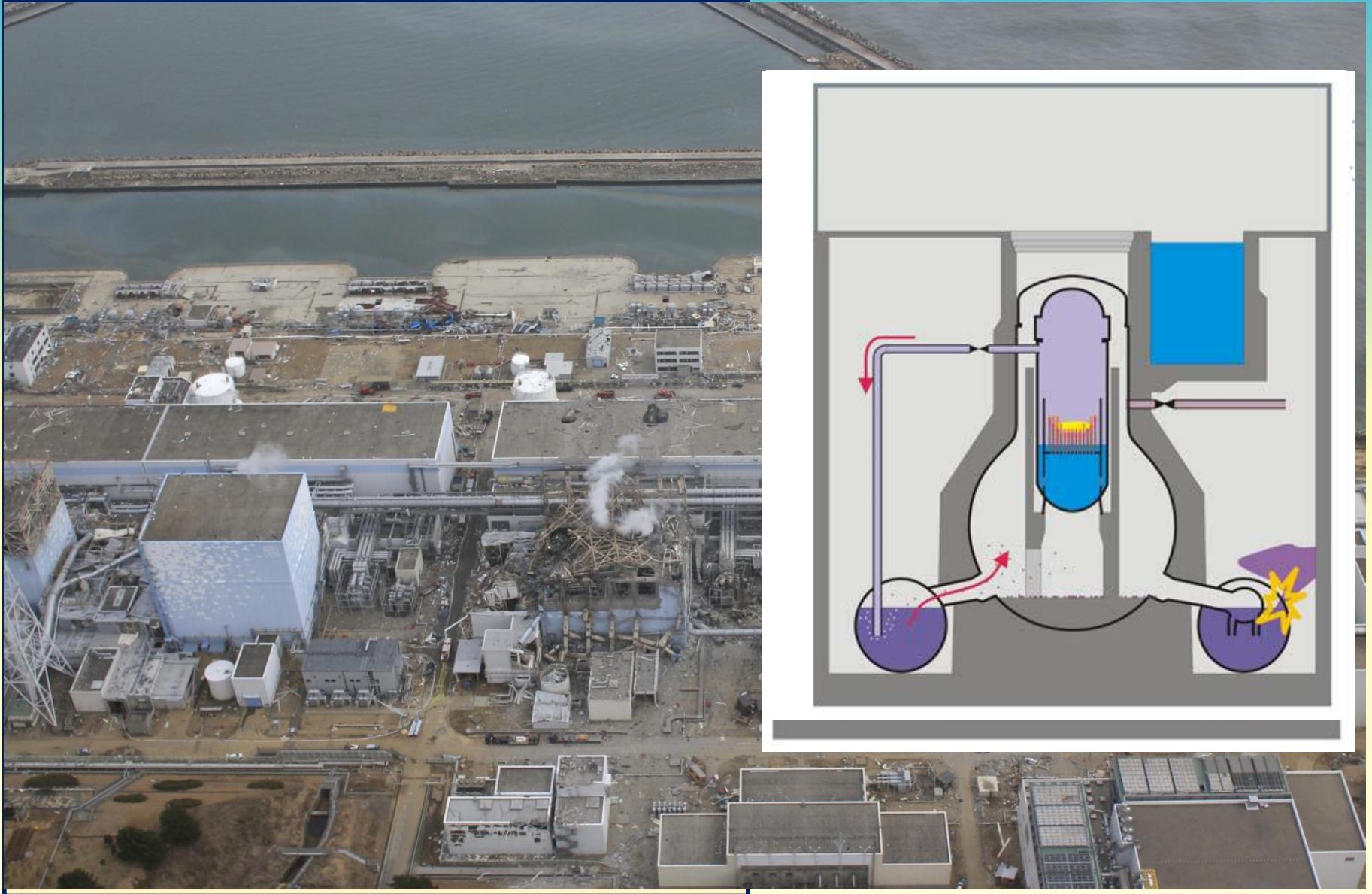


# Fukushima I

- **Heat removal failure – increase in temperature and pressure – reactor vessel decompression using wet well (RN material captured in water)**
- **Ballooning and bursting of claddings (local damage), temperature rise up to 2700°C**
- **Zirconium reaction with water steam - H generation and core heat up and melt progression**
- **Re-flood phase of reactors and spent fuel pools (helicopters, water cannons, car pumps) using seawater**



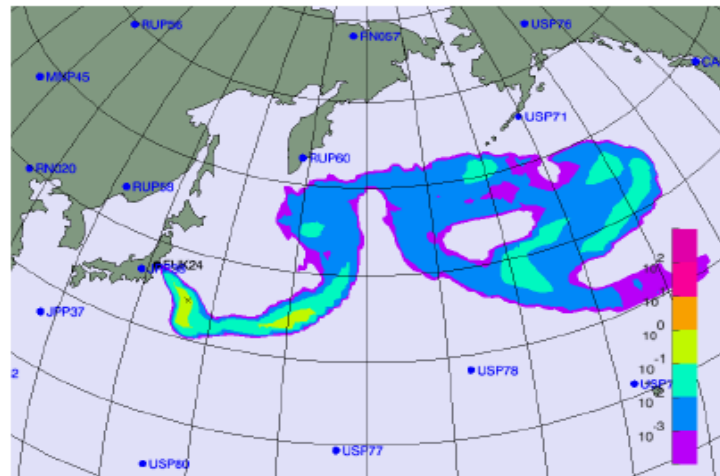
# Fukushima I



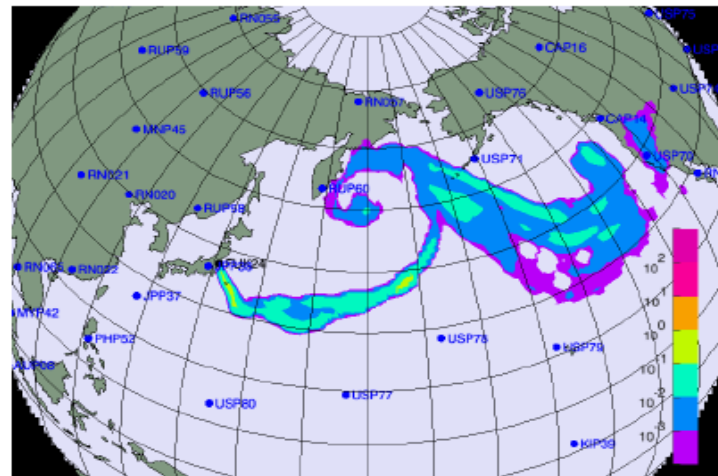
## Accident evolution

- **8:30 (UTC) 11.3. 2011** IAEA published information about the earthquake (8.9 magnitude) in the vicinity of east coast of Honshu island; Japanese Ministry of Economy, Trade and Industry (METI) has been asked by the IAEA to provide details related to the NPP
- During the day IAEA announced the nuclear accident at the NPP Fukushima I (FI) - **05:46 (UTC)** – loss of power supply
- IAEA was informed by WMO about prevailing wind direction (east direction from affected area)
- 7 h after the accident outbreak preventive evacuation was announced within the radius of 3 km from NPP FI; taking shelters within the radius of 10 km – evacuation zone was progressively extended up to 20 km; taking shelters up to 30 km
- IAEA issued information on the daily basis „Status of the Fukushima I NPP and related environmental conditions“

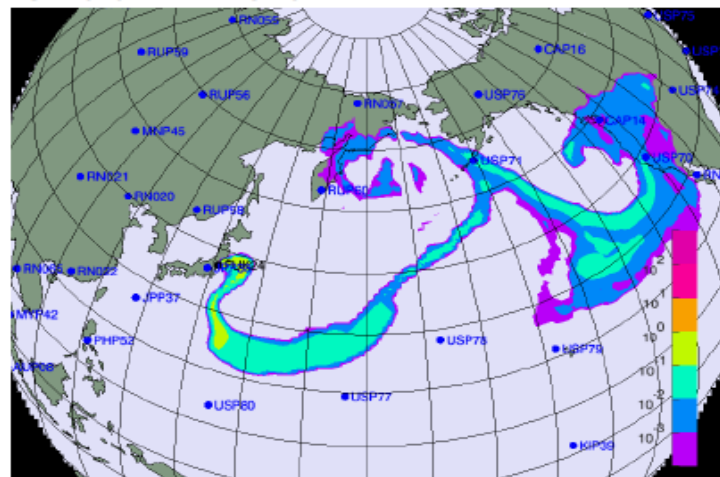
16 March 21-24 UTC



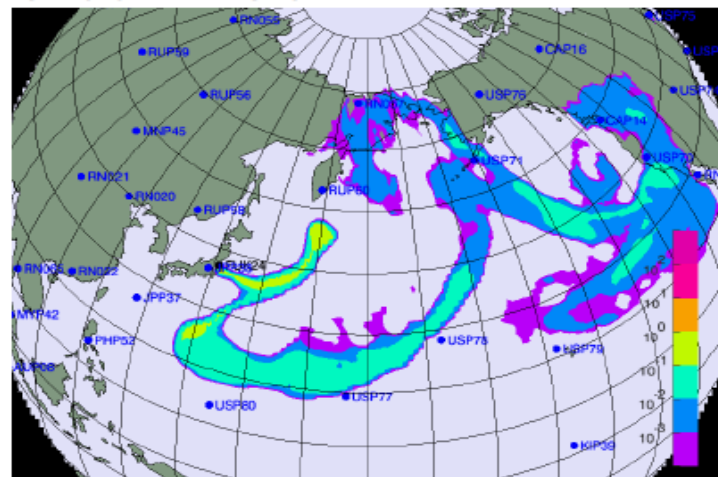
17 March 21-24 UTC



18 March 21-24 UTC



19 March 21-24 UTC



# Particulate network detections, Stations detected radioactive Particles originating from Fukushima



*Network  
availability  
90-95%*

*All these  
stations  
detected  
at least  
radioactive  
iodine  
end of March  
to the middle  
of April*

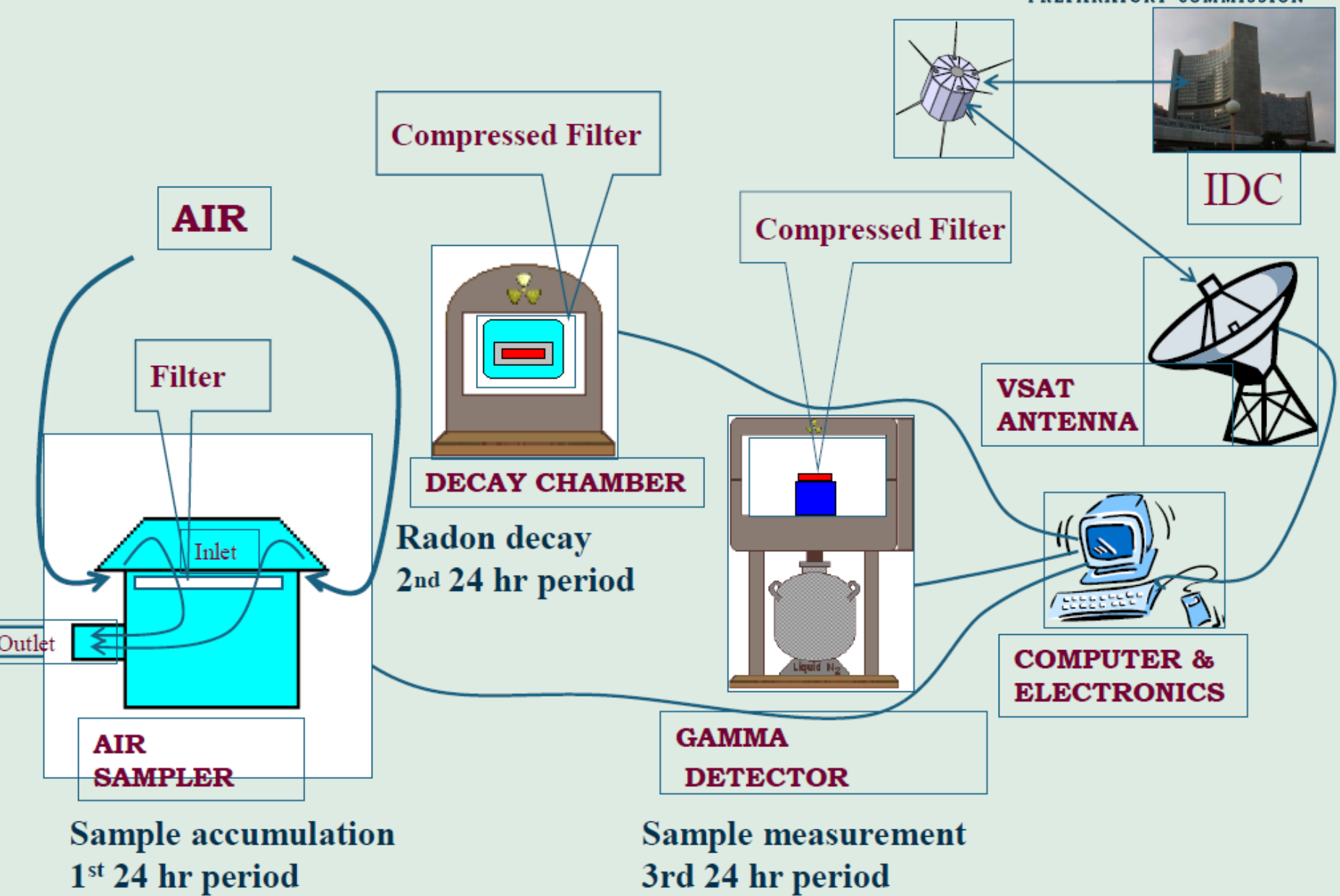
# Noble gas network detections, Stations detected radioactive Xenon originating from Fukushima



*Network  
availability  
85-90%*

*All these  
stations  
detected  
at least  
radioactive  
Xe-133  
end of March  
to the middle  
of April*

# Example of a RN station layout



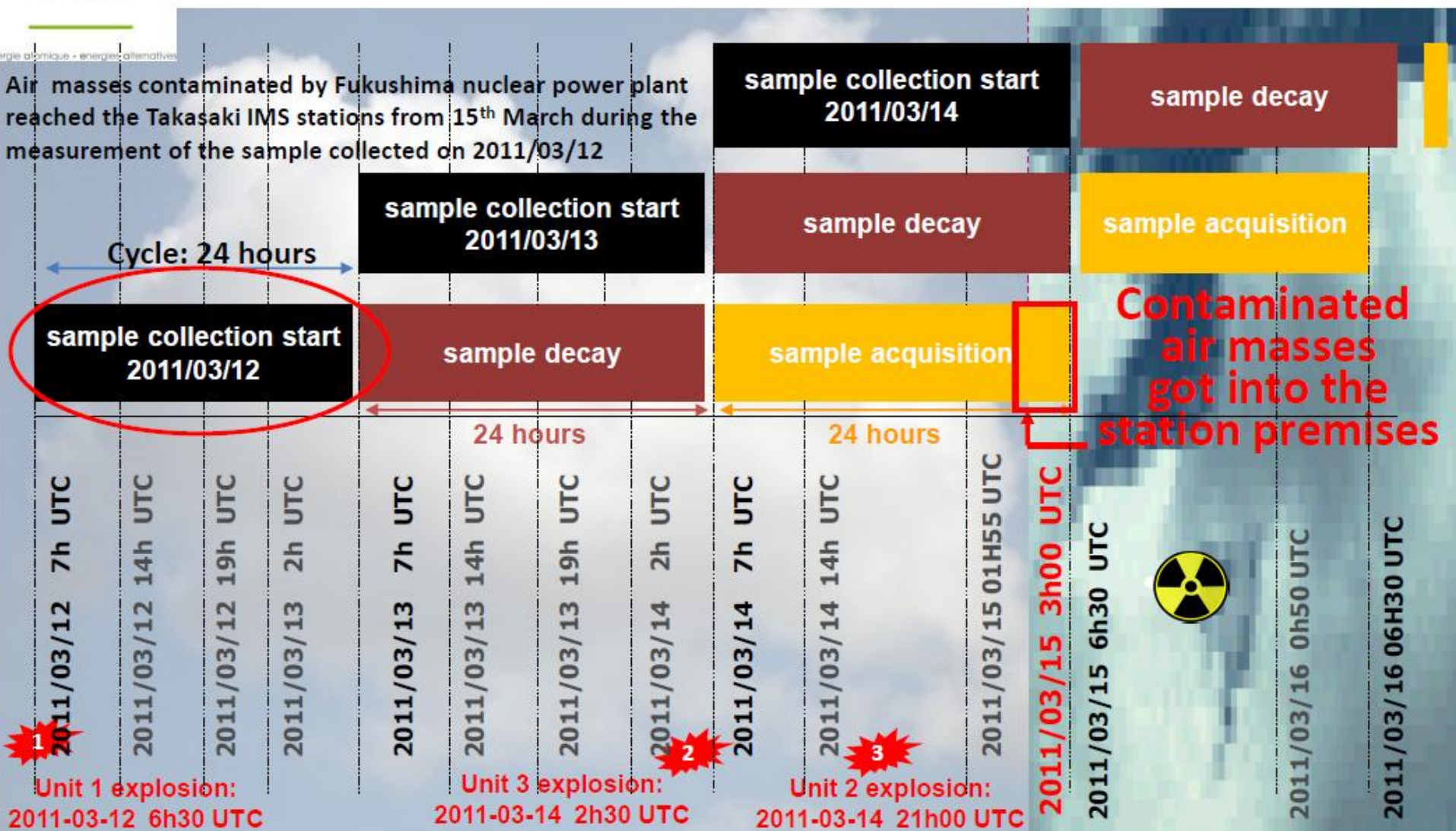
# Fukushima's contaminated air masses arrival at the Takasaki IMS

particulate station, JPP38, about 200 km from Fukushima site



nergie atomique • energie alternatives

Air masses contaminated by Fukushima nuclear power plant reached the Takasaki IMS stations from 15<sup>th</sup> March during the measurement of the sample collected on 2011/03/12



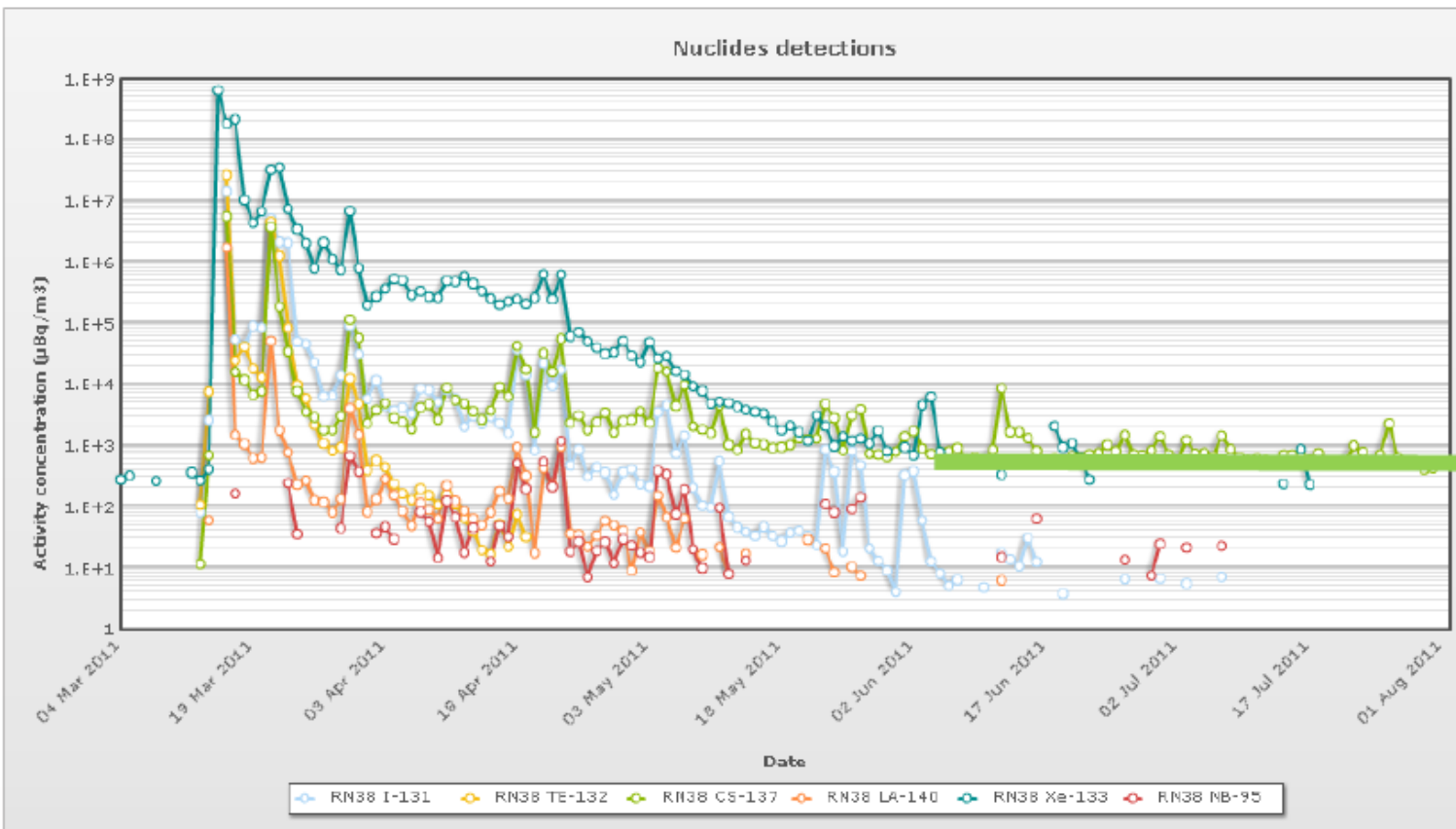
# Detected isotope concentrations on JPP38, Takasaki, Japan

## Nuclides detections

**Nuclide(s):** CS-137; I-131; LA-140; NB-95; Xe-133; TE-132

**Station(s):** RN38, Japan

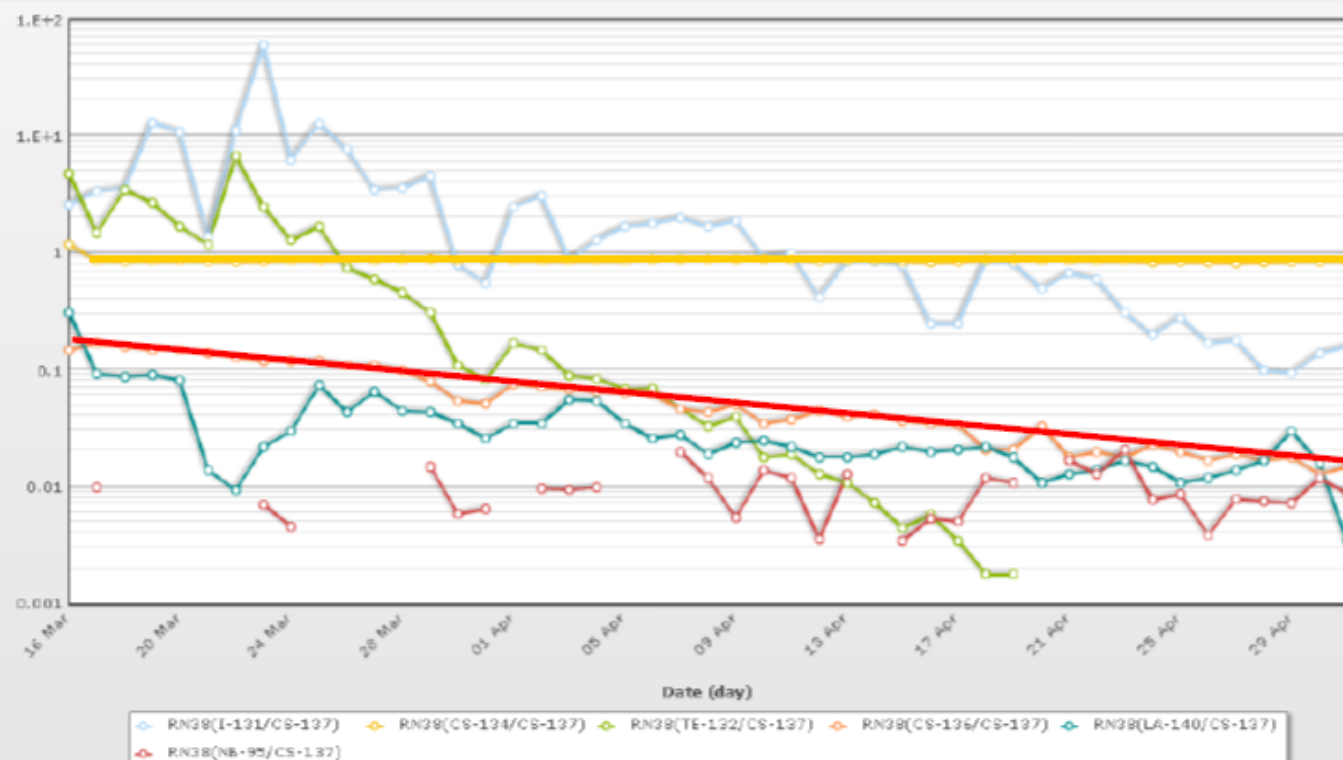
**Period:** 04 Mar 2011 - 03 Aug 2011; **Units:**  $\mu\text{Bq}/\text{m}^3$



*Cs-137 contamination level inside the system measured from blank*

*The station is 200 km SW from Fukushima. The radiation levels detected are generally low in the global scale, these are the highest values measured at the IMS network.*

# Isotope ratios, JPP38, Takasaki, Japan



Cs-134 to Cs-137 is behaving smoothly: predominantly same type of source material.

Cs-136 to Cs-137 ratio has some variation, this may indicate that source material has a mixture of different irradiated batches of fuel.

Cs-134/Cs-137

I-131/Cs-137

Cs-136/Cs-137

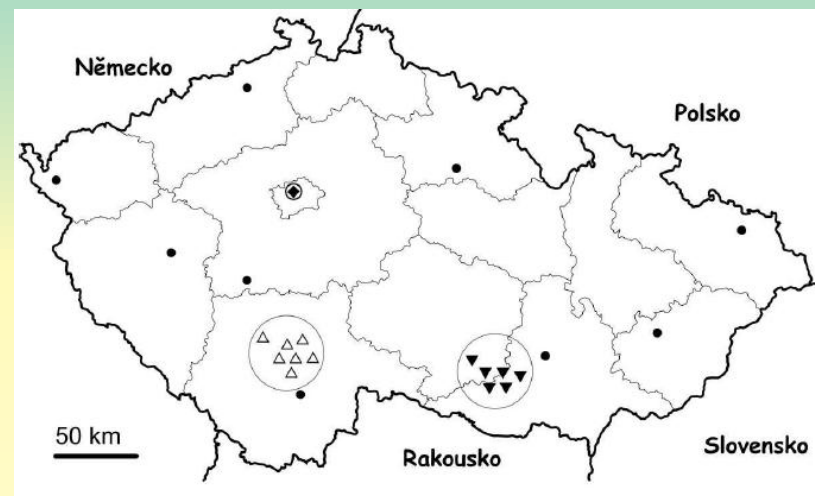
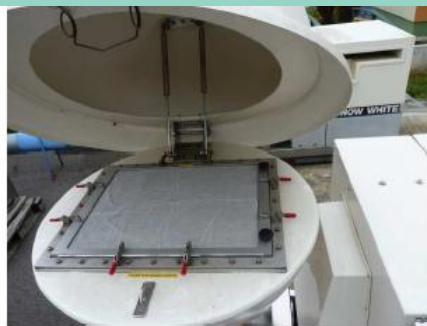
Nb-95/Cs-137

La-140/Cs-137

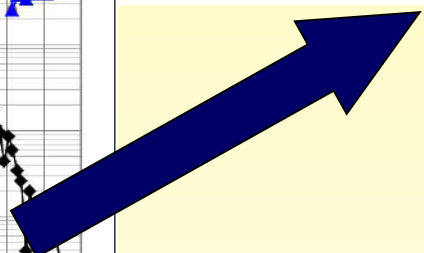
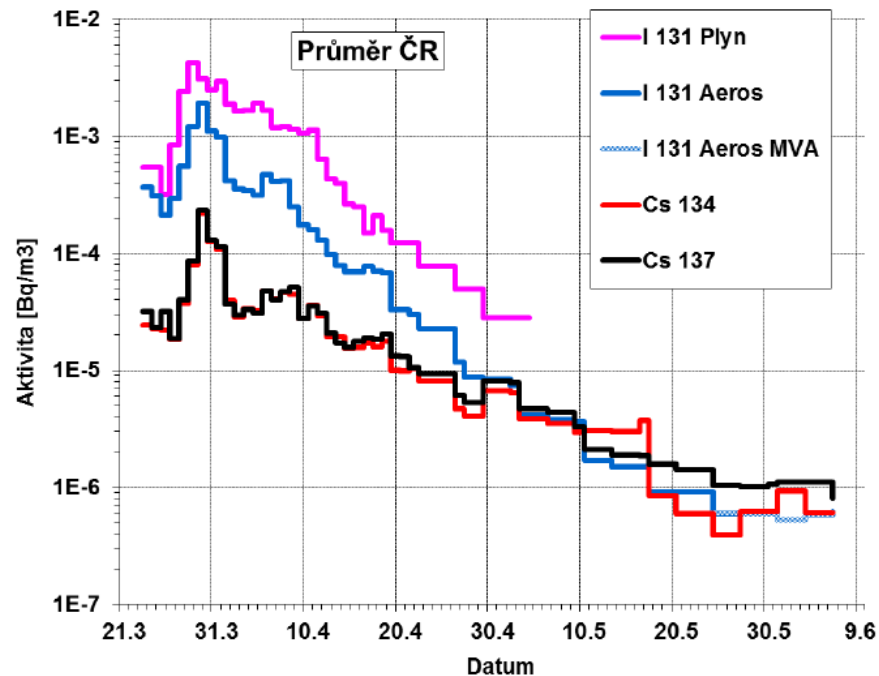
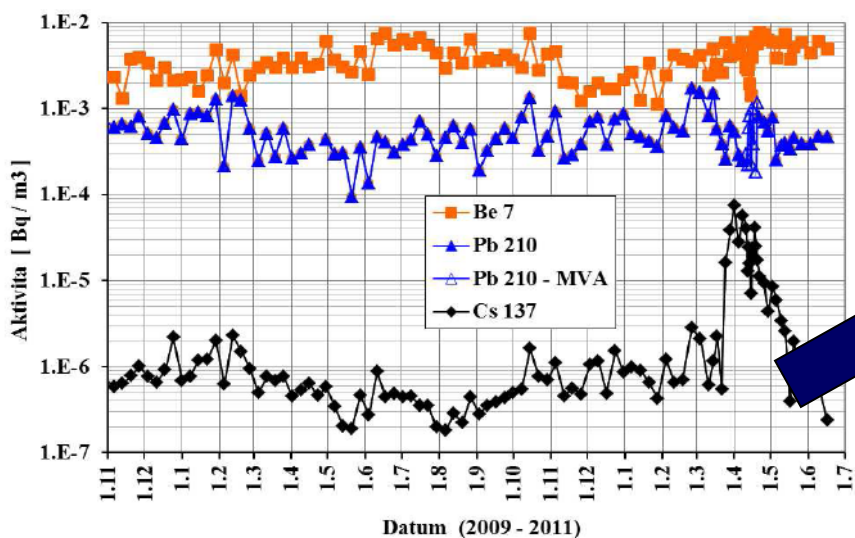
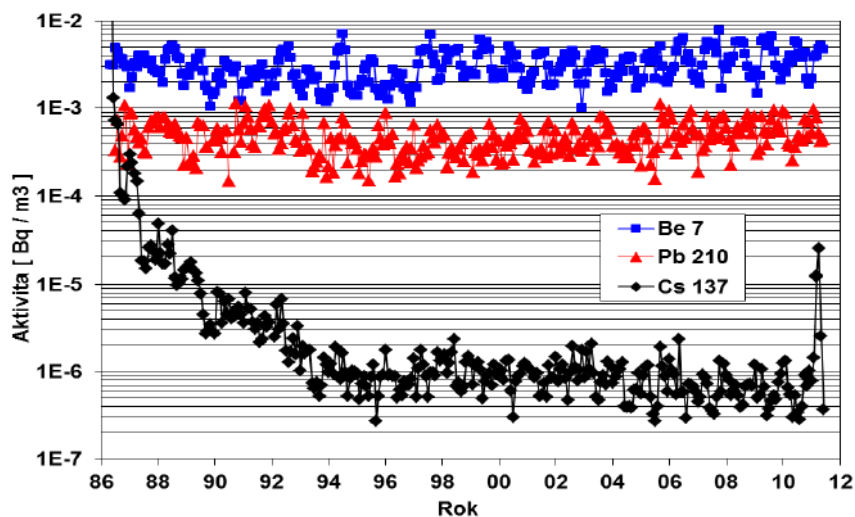
Te-132/Cs-137

No significant change in metallic elements vs. Cs-137 ratio, gaseous fission products are dominating.

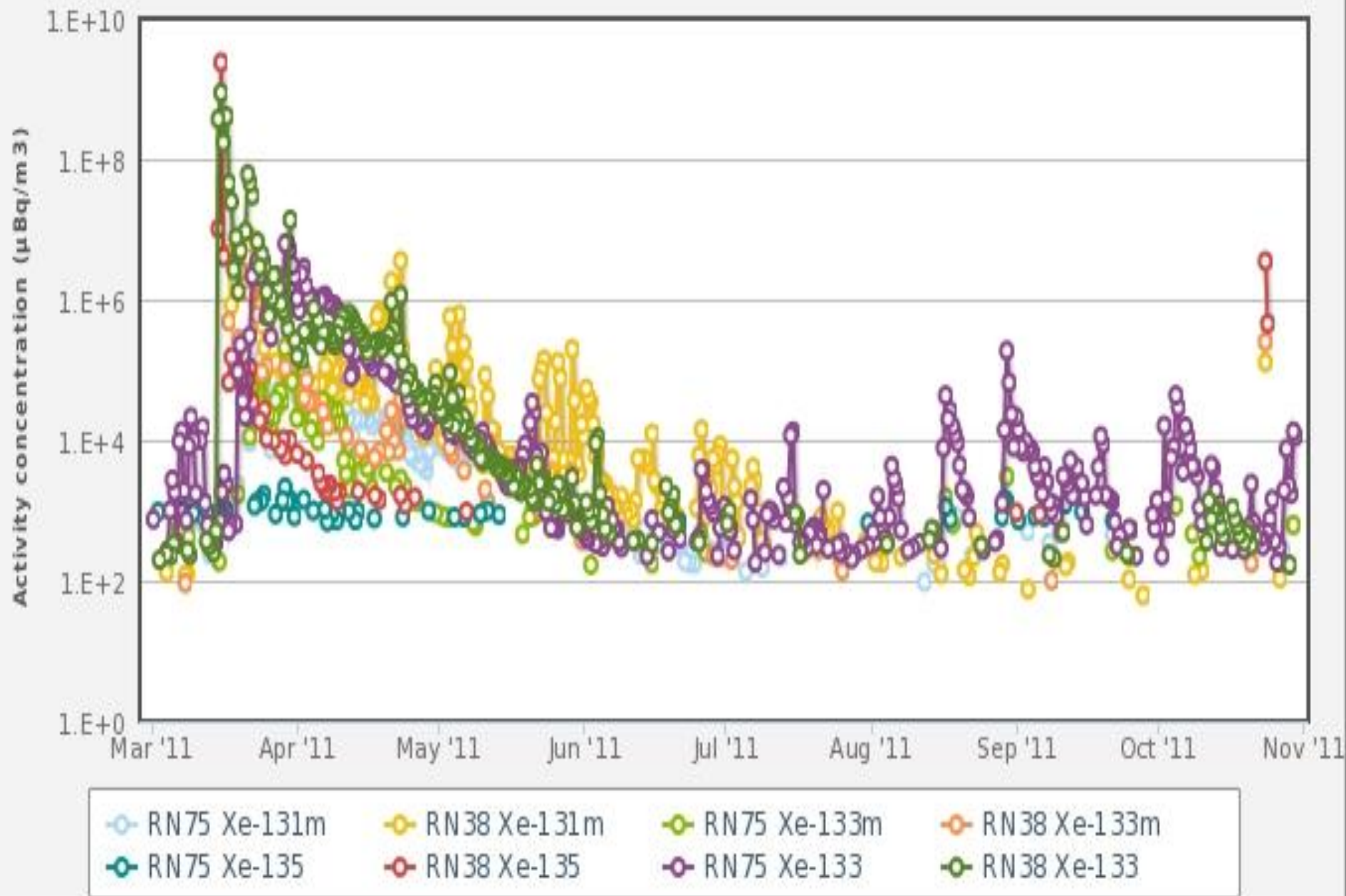
# Aerosol monitoring in the Czech Republic



# Results of aerosol measurement – comparison of long term monitoring with Fukushima measurement campaign



# Nuclides detection



**Current Status of "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station, TEPCO" (Revised edition)**

August 17, 2011  
Nuclear Emergency Response Headquarters  
Government-TEPCO Integrated Response Office

Appendix 3

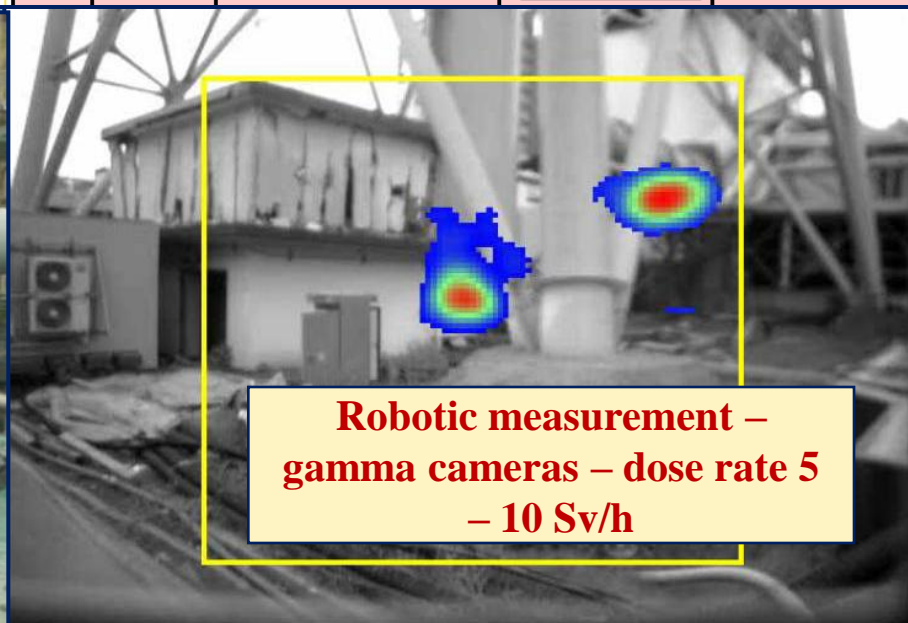
Red colored letter: newly added to the previous version. ☆: already reported to the government. Green colored shading: achieved object

Issues	As of Apr. 17	Step 1 (around 3 months)	Step 2 (around 3 to 6 months after achieving Step 1 current status (as of Aug. 17))	Mid-term issues (around 3 years)	
I. Cooling	(-) Reactor Fresh water injection	Cooling by minimum injection rate (injection cooling)	Stable cooling Circulating water cooling (start) ☆	Cold shutdown condition Continuous cold shutdown condition	
		Consideration and preparation of reuse of accumulated water			
	(-) Spent Fuel Pool Fresh water injection	Nitrogen gas injection ☆	Stable cooling Remote-controlled injection operation	Warm stable cooling Start of removal work of fuels	
		Improvement of work environment ☆			
II. Mitigation	(-) Accumulated Water Transferring water with high radiation level	Installation of storage / processing facilities ☆	Secure storage phase Expansion ☆ / consideration of full-fledged processing facilities	Reduction of total amount of contaminated water Installation of full-fledged water processing facilities	
		Storing water with low radiation level			
	(-) Ground water Mitigation of contamination of groundwater	Installation of storage facilities / decontamination processing	Mitigate ocean contamination Sub-drainage management with expansion of storage / processing facilities	Mitigate ocean contamination Design / implementation of impermeable wall against groundwater	Mitigation of contamination in the ocean Mitigation of contamination of groundwater
		Mitigation of contamination of groundwater			
	(-) Atmosphere / Soil Dispersion of inhibitor	Removal of debris	Mitigate scattering Dispersion of inhibitor (continued)	Mitigate scattering (continued)	Dispersion of inhibitor Removal / management of debris
		Removal of debris (top of Unit 3&4 R/B)			
	Consideration of reactor building container			Start of installation work of reactor building container	

**Current Status of "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station, TEPCO" (Revised edition)**

Red colored letter: newly added to the previous version. ☆: already reported to the government. Green colored shading: achieved object

Issues	As of Apr. 17	Step 1 (around 3 months)	Step 2 (around 3 to 6 months after achieving Step 1 current status (as of Aug. 17))	Mid-term issues (around 3 years)
III. Monitoring / Decontamination	(u) Water level, R, Dose rate Expansion, enhancement and disclosure of radiation dose monitoring in and out of the power station		Decommissionation Consideration / start of full-fledged decontamination	Continuous environmental monitoring Continuous decontamination
IV. Countermeasures for aftershocks, etc.	(-) Tsunami, Reinforcement, etc. Enhancement of countermeasures against aftershocks and tsunami, preparation for various countermeasures for radiation shielding		Mitigate disasters Consideration / implementation of reinforcement work of each Unit	Continue various countermeasures for radiation shielding Reinforcement work of each Unit
V. Environment Improvement	(u) Life work environment, Medical care Improvement of workers' living / working environment		Environment of workers' living / working environment Improvement of radiation control / medical system	Improvement of workers' life / work environment Improvement of radiation control / medical system
Measures for Mid-term issues			Government's concept of securing safety Establishing plant operation plan based on the safety concept	Response based on the plant operation plan



**Robotic measurement – gamma cameras – dose rate 5 – 10 Sv/h**

# Radiation monitoring

## Monitoring program:

- External and internal radiation exposure of critical population – existing situation and trends
- Radiation protection measures planning and implementation – radiation doses reduction
- Set up of evacuation and resettlement zones
- Long term evaluation of health risk
- Evaluation of radionuclides transport processes in the environment

## Individual responsibilities:

- State institutes and private subjects involved – ministries, municipalities, NPP operator, schools, public institutes

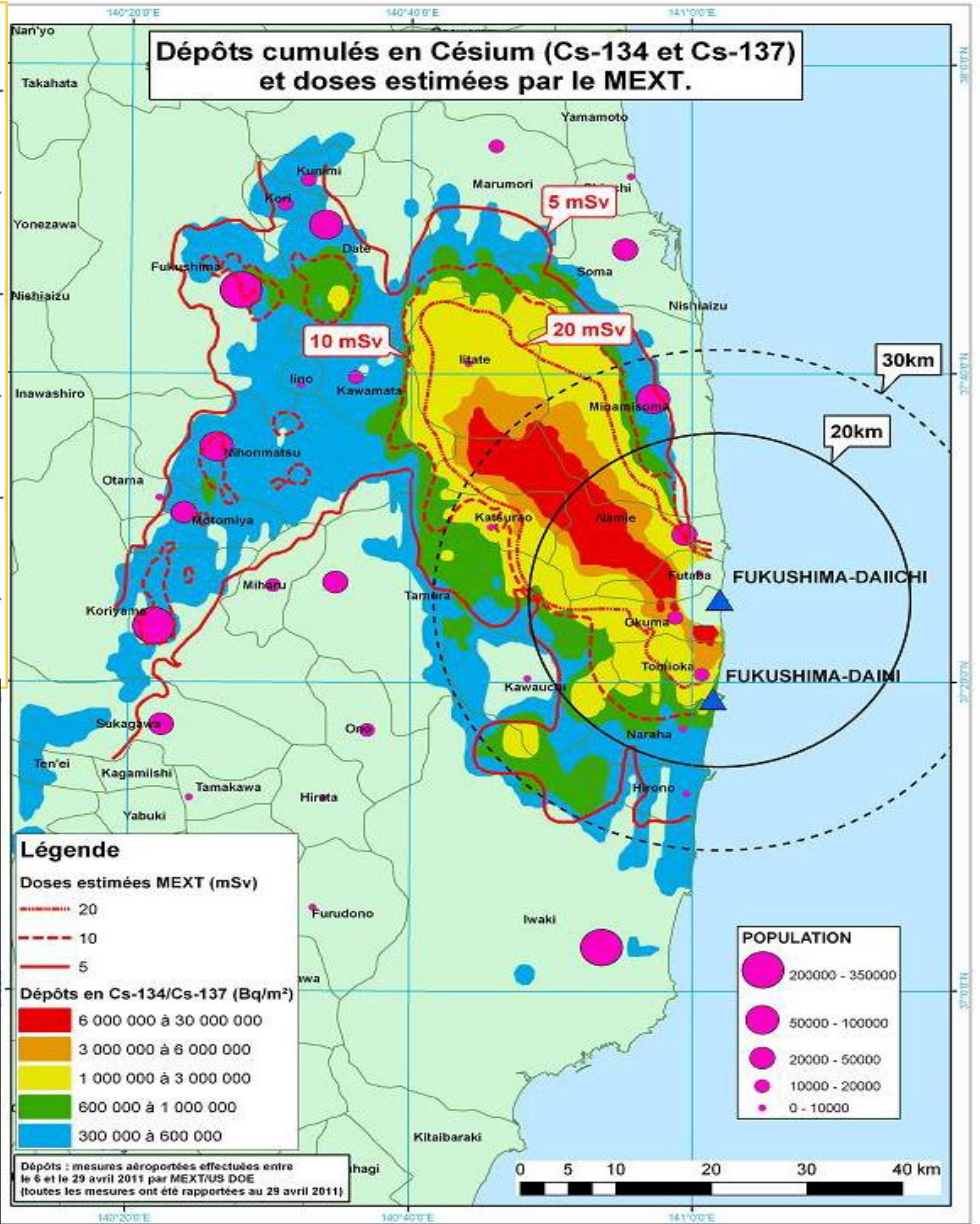
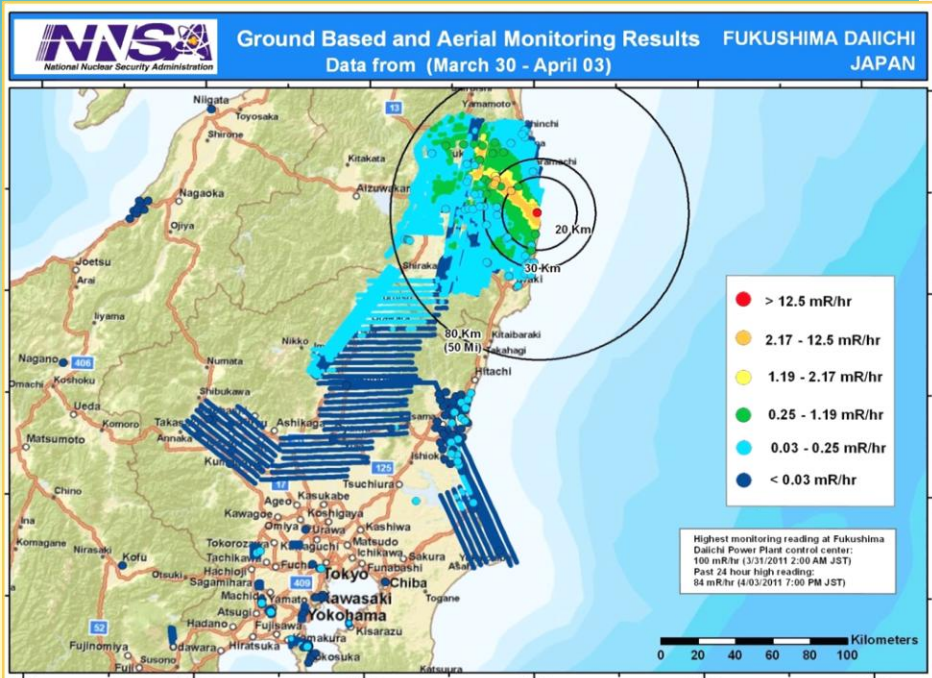
## Structure of monitoring:

- NPP Fukushima – facilities, workplaces and the vicinity
- Radiation survey – ground based, airborne – environmental sampling (air, airborne particles, soils, water (sea, rivers, other water bodies))
- indicators (selected plants)
- Special location and equipment

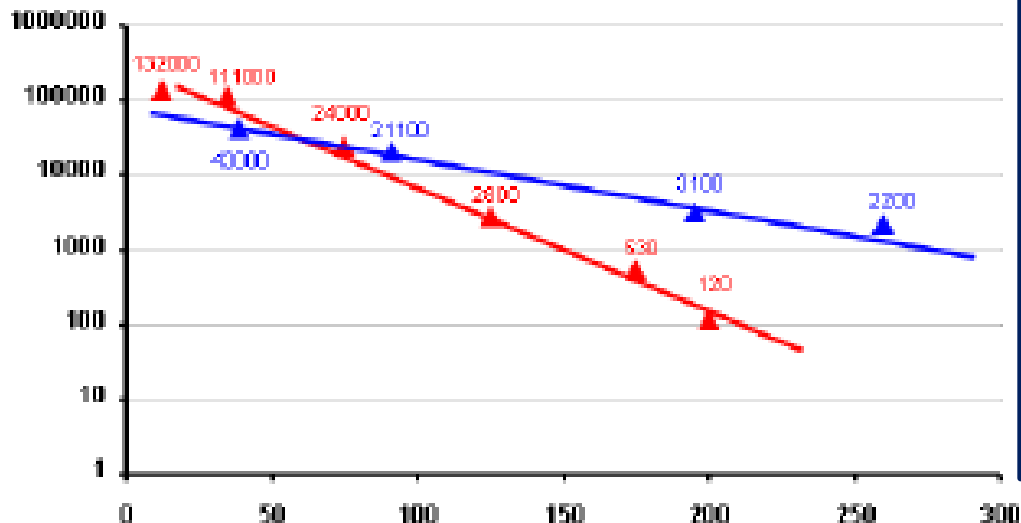
## Special radiation monitoring

- **NPP Fukushima and the vicinity** – dose rate measurement (airborne monitoring – area coverage up to 80 km from NPP), integral doses – trends/maps – Fukushima prefecture - 59 municipalities equipped with meter, total 350 meters operated, neighboring prefectures - 130 „meters“ – radiation survey maps and trends – MEXT, TEPCO
- **Evacuation zone/zone of potential relocation** – dose rate measurement (250 monitoring points) – resident units, industrial facilities, infrastructure; „superficial“ dose rate – kindergartens, schools, medical facilities, gardens, parks – basis for soil sampling (2x2km<sup>2</sup> grid), specific activities assessment – selected locations – rivers, lakes, wells, underground water (up to 100 km from NPP), channels, grazing land, agricultural land, fall out (high resolution gamma spectrometry)
- **Sea** – volume activity assessment (up to 30 km, high seas ocean water up to 280 km), sediments, seafood; coast line – Fukushima, Miyagi, Ibaraki (30 - 90 km along the coast) – Fisheries Agency, Japan Coast Guard
- **Special localities** – airports, seaports, touristic areas, natural reservations, water cleaning facility, dump sites, sewage water pools, waste disposal facilities (incineration plant, waste repository) – frequency, range – monitoring results

# Source term estimation



Number of people

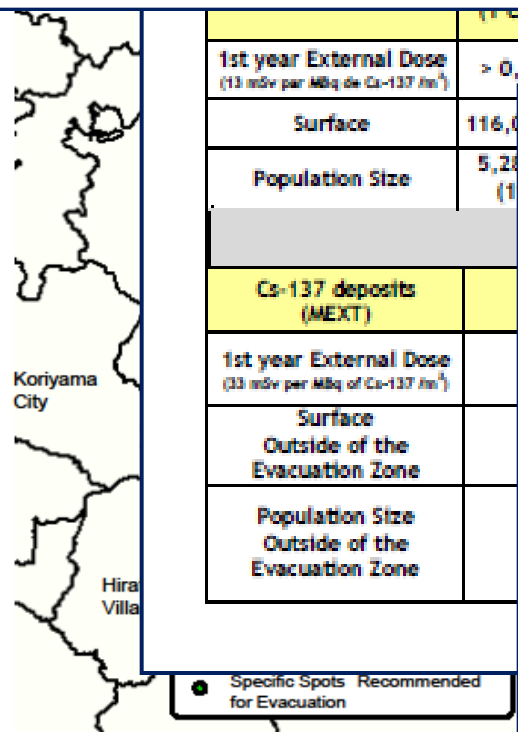


## Chernobyl:

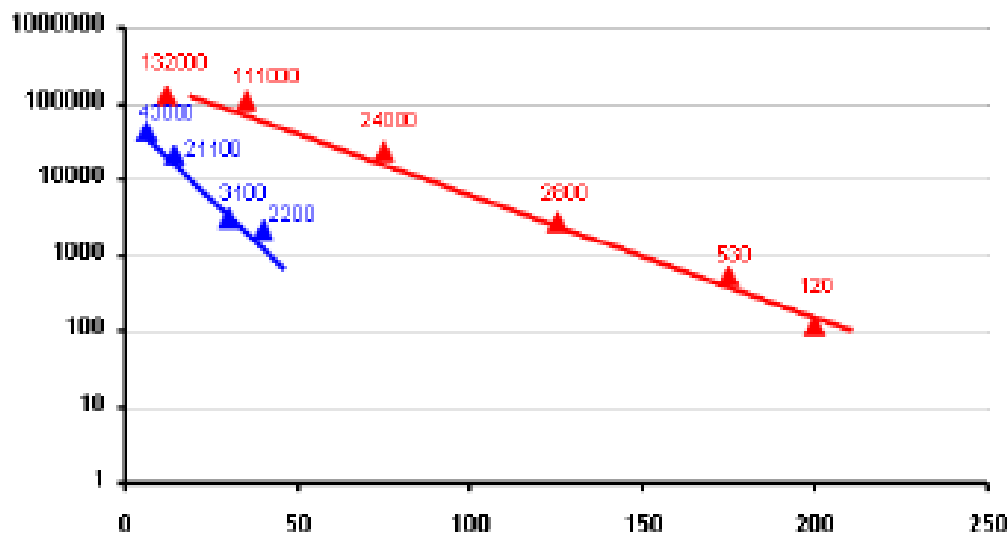
- taking shelters, iodine prophylaxis - Pripjat' 2nd day (27th of April 1986)
- evacuation – from 27th to 6th of May 1986 (Pripjat' cca 30 000 persons within 3 hours, 1200 buses from Kiev and the vicinity) - 30 km zone - 135 000 people (< 5% of people with effective dose > 100 mSv)

External doses (mSv) in Chernobyl (1986-1989) and in Fukushima (2011-2014)

		30 km	
EVACUATION ZONE			
10 km	7,4 millions Bq/m <sup>2</sup> (200 Ci/km <sup>2</sup> )	Up to 37 millions Bq/m <sup>2</sup> (1,000 Ci/km <sup>2</sup> )	



Number of people



External doses (mSv) in Chernobyl (1986-1989) and in Fukushima (March 2011- June 2014)

▲ Tchernobyl  
▲ Fukushima 3 months

## Personal monitor



### **NPP workers and contractors:**

- **Intervention level = 250 mSv – external exposure assessment;**
  - **250 mSv (total dose) 6 persons**
  - **351 persons – dose exceeding 20 mSv**

### **General population:**

- **1080 children in age of 0 – 15 years have been monitored for the content of I-131 in thyroid gland by the 5th of August – all measured values have been lower than criterion 0,2  $\mu$ Sv/h;**
- **23 women – breast milk monitoring – insignificant values of I-131 concentration**
- **195 354 persons have been monitored by the 31st of May, hundreds of them have been decontaminated – no relevant health effects are assumed**
- **prefecture Fukushima official representatives decided in collaboration with NIRS that the state of health of more than 2 mil. persons would be checked and examined with regard to low dose effects**

# Agriculture and foodstuff monitoring

D.R.: Distribution Restricted C.R.: Consumption Restricted		Fukushima pref.		Ibaraki pref.	Tochigi pref.	Chiba pref.	Kanagawa pref.	Gunma pref.	Miyagi Pref.	Iwate pref.
		D.R.	C.R.	D.R.	D.R.	D.R.	D.R.	D.R.	D.R.	D.R.
raw milk		3 cities, 14 towns and 9 villages	—	—	—	—	—	—	—	—
vegetables	Non-head leafy vegetables (spinach, komatsuna)	2 cities, 7 towns and 3 villages	2 cities, 7 towns and 3 villages	—	—	—	—	—	—	—
	head leafy vegetables (cabbage)			—	—	—	—	—	—	—
	flowerhead brassicas, (broccoli, cauliflower)			—	—	—	—	—	—	—
	turnip			—	—	—	—	—	—	—
	log-grown shiitake (grown outdoor)	6 cities, 7 towns and 3 villages	1 village	—	—	—	—	—	—	—
	log-grown shiitake (grown in facilities)	2 cities and 1 town	—	—	—	—	—	—	—	—
	bamboo shoot	4 cities, 3 towns and 1 village	—	—	—	—	—	—	—	—
	ostrich fern	1 city and 1 town	—	—	—	—	—	—	—	—
Ume	4 cities and 1 town	—	—	—	—	—	—	—	—	
Fishery products	sand lance (juvenile)	all areas	all areas	—	—	—	—	—	—	—
	cherry salmon yamame (excluding farmed fish)	some areas	—	—	—	—	—	—	—	—
	Japanese dace	some areas	—	—	—	—	—	—	—	—
	Ayu (excluding farmed fish)	some areas	—	—	—	—	—	—	—	—
Meat/Egg	Beef	all areas	—	—	all area	—	—	—	all area	all area
Others	tea leaf	—	—	all area	3 cities	6 cities and 1 town	3 cities, 6 towns and 1 village	2 cities	—	—

# Lessons learnt from Fukushima accident

## ❑ Emergency preparedness system:

- Regional Crisis Staff (flexible and expeditious decision making)
- Preventive measures – taking shelters, evacuation included
- Set up of the entering regime into the zones (transportation means)
- Resettlement – needs to be optimized – surface contamination – trends in integral dose assessment (meteorological conditions) – 3 MBq/m<sup>2</sup> Cs-137 → dose rate ~ 55 mSv/y
- Food chain – restriction of distribution and consumption effectively regulated
- Decontamination and waste disposal management

## ❑ Monitoring:

- Express and robust methods of measurement – gamma dose rate measurement (monitoring area, trends, density of measurement points, operator (remote control x simple technique – municipalities, fire squads, schools, etc.)
- Relation of dose rate and surface contamination – mobile emergency teams – car-borne system + airborne radiation survey (stand-by ≤ 1 h – military forces, police)
- Measurement technique – unmanned means, cameras



**People affected by the Great East Japan Earthquake wrote „ARIGATO“  
on the shore using pine trees for the US Armed Forces which had  
supported with the restoration of Sendai Airport.**

**"ARIGATO" = „THANK YOU“**

**13.3. → 13.4. (the first landing)**

