Lessons Learned from the Fukushima Daiichi Accident

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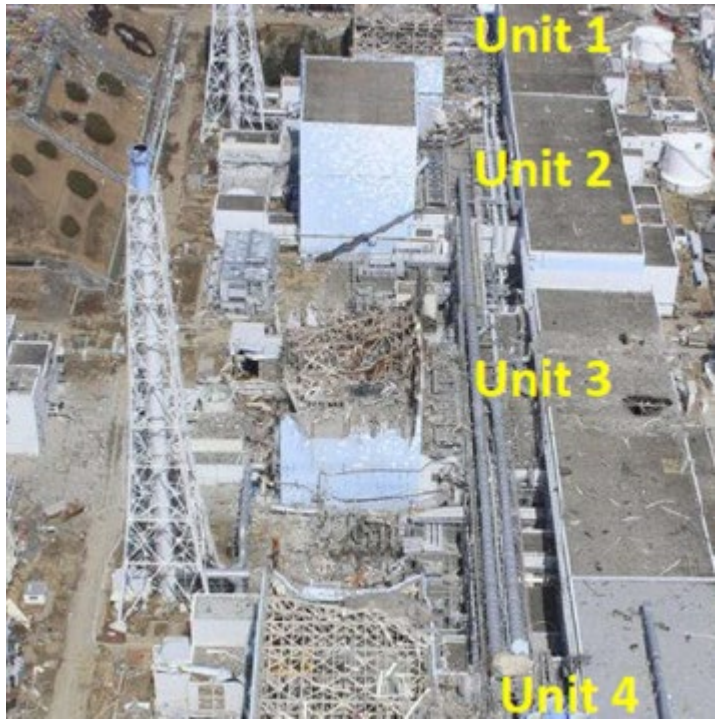
Topics

- ***Radiological situations and protective actions taken***
- ***Lessons on dose prediction system***
- ***New NRA EPR Guide***
- ***Concluding remarks***



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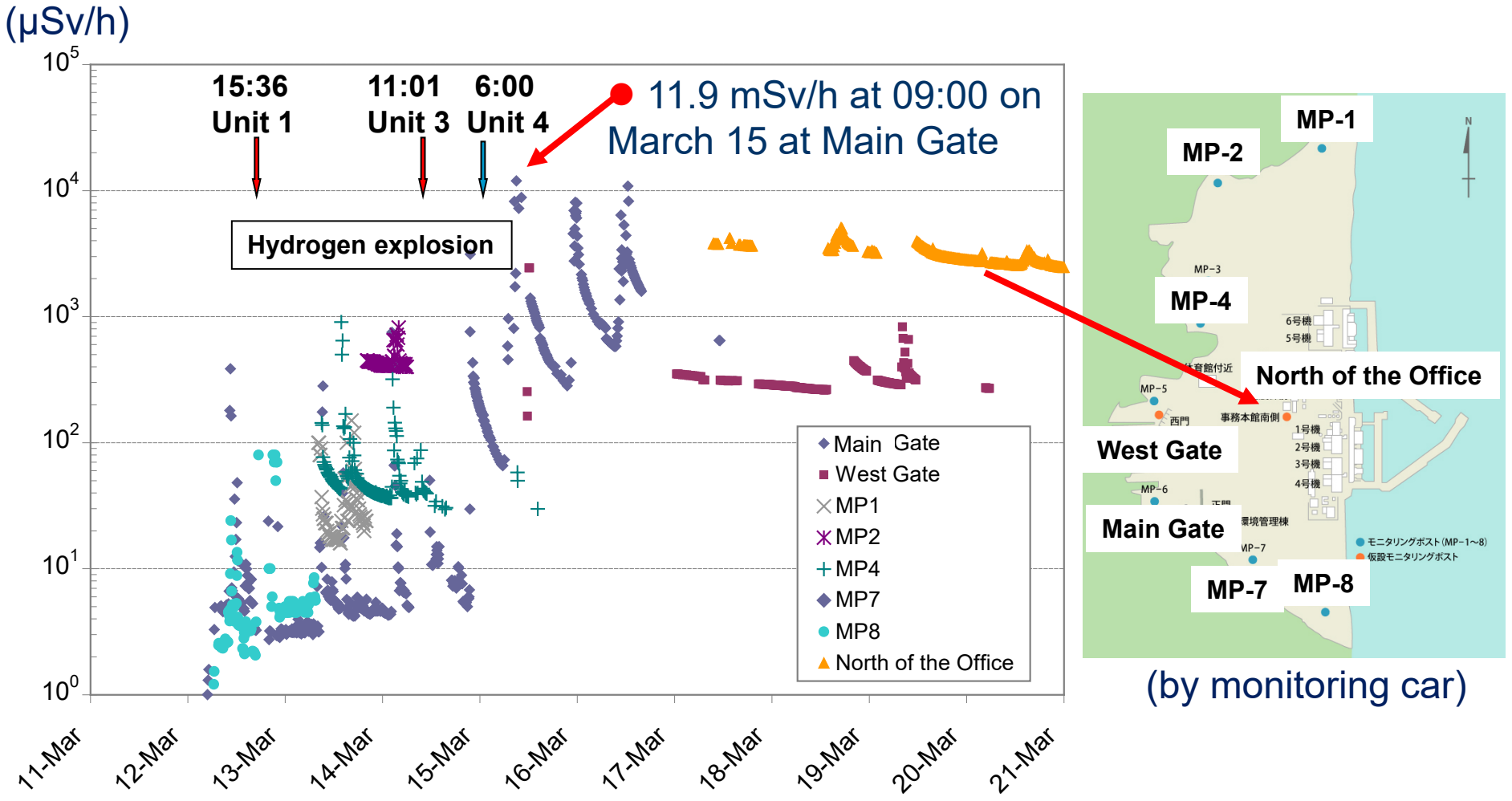
Radiological situation on-site



Changes in ambient dose rates (μSv/h)

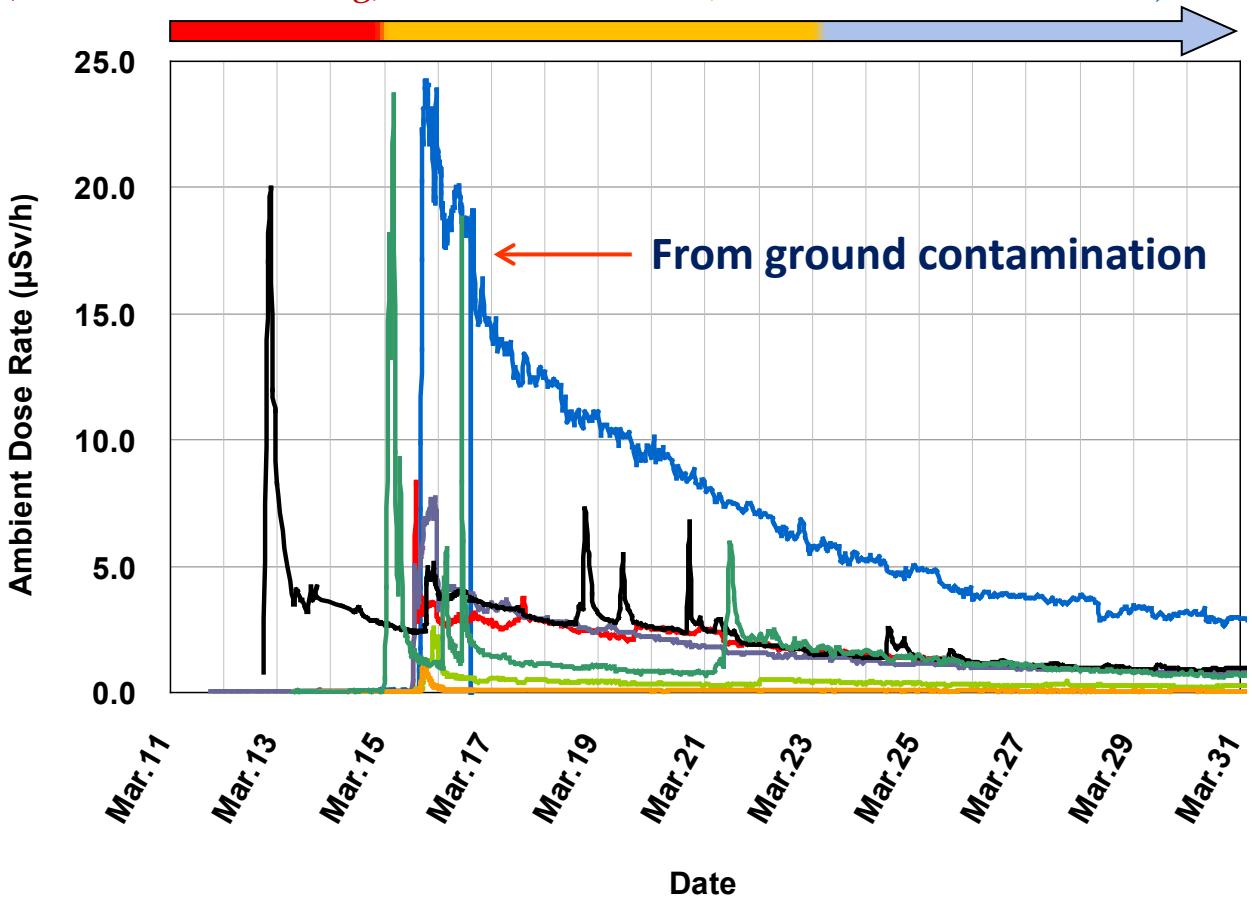
(by monitoring car)

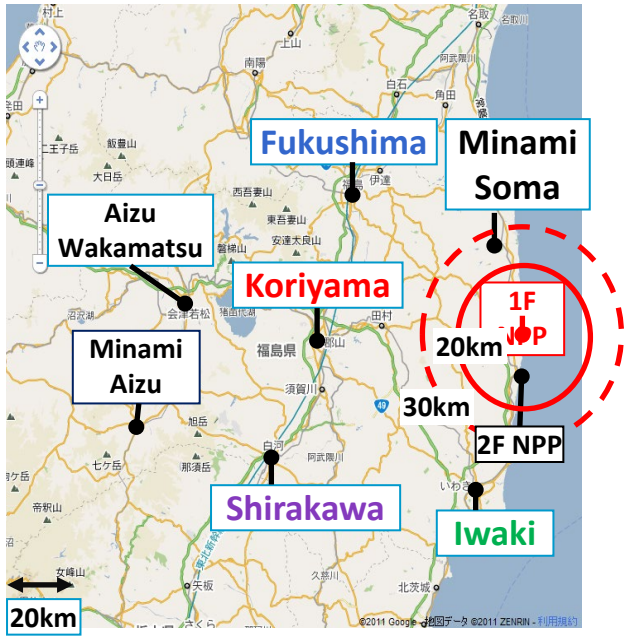
Radiological situation off-site and corresponding protective actions

Precautionary urgent protective actions (evacuation, sheltering)

Urgent protective actions (foodstuff and water restrictions)

Early protective actions (preparation for temporary relocation)





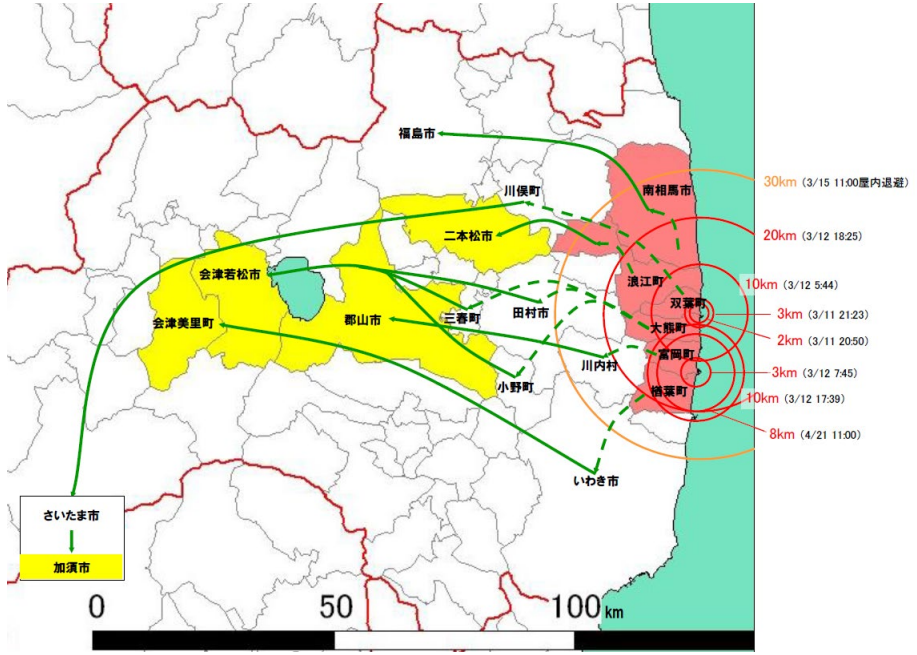
What urgent protective actions were taken?

Events	Response
March 11, 14:46 Earthquake 16:45 Notified Nuclear Emergency at Unit 1, 2 **Inability of water injection**	March 11 19:03 Declaration of Nuclear Emergency 20:50 **Evacuation within 2km** 21:23 **Evacuation within 3km** (6000 people)
March 12 **Pressure in Primary Containment Vessel increased** in Unit 1 15:36 Hydrogen explosion in Unit 1 **Risks at multiple units** March 14, 11:01 Hydrogen explosion in Unit 3	March 12 **Completed at 1:45 on 12th** 05:44 **Evacuation within 10km** (51000 people) 18:25 **Evacuation within 20km** (78000 people) **Completed at 14:00 on 15th**
March 15, 06:00 **Events at multiple units** March 16 Iodine in tap water and milk Iodine and cesium in vegetation March 17 Ambient dose rate (170μSv/h) at 30km north west of Nuclear Power Plant March 22, Considering support for people in sheltering area	March 15, 11:00 **Sheltering** (20-30km) March 16, Directed administration of stable iodine during evacuation March 21 **Drinking water restriction** **Food restriction** March 25, Request of **voluntary evacuation in sheltering area** (20-30km)
	April 10, Nuclear Safety Commission (NSC) recommended temporary relocation April 22, Directed **temporary relocation**

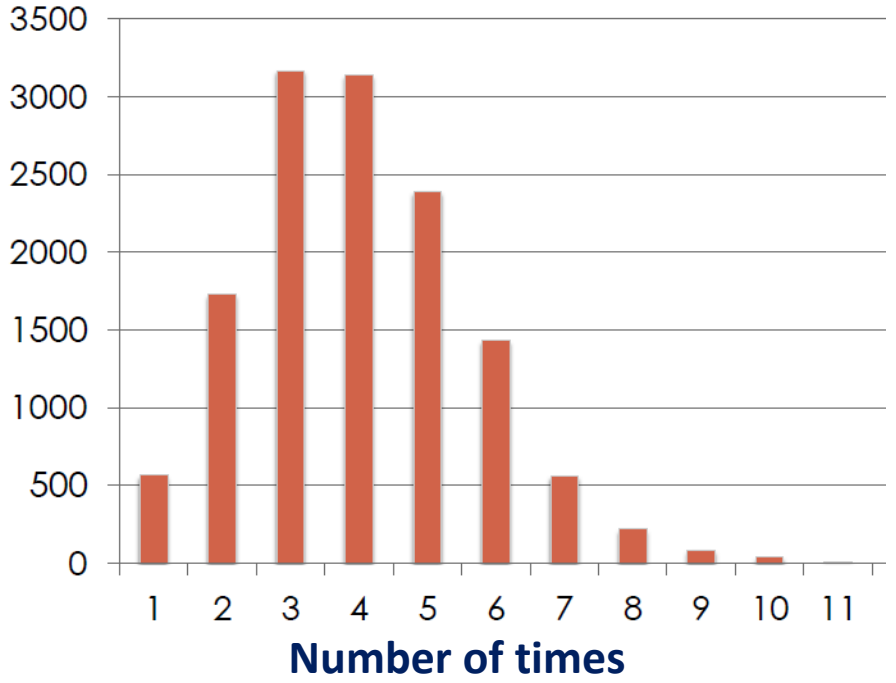
Evacuation with “just the clothes on their backs”

- Prior to the accident
  EPZ (10 km): municipalities had their own emergency plan
  temporary gathering spot ----> Bus ---> evacuation shelter
- Prefecture plan did not provide a wide area evacuation plan across municipalities
- Forcing many residents to relocate multiple times

Evacuation routes and locations



Number of people relocated

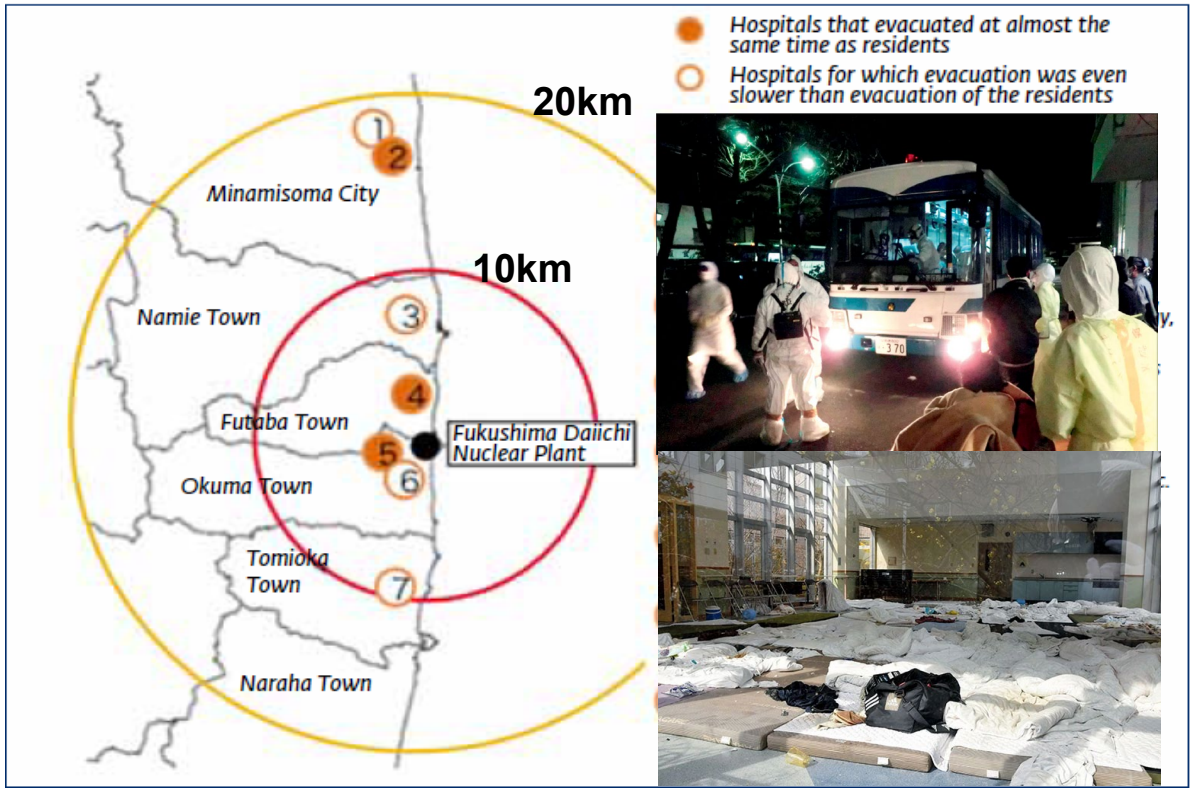


(http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo19/siryo1-1.pdf)

Evacuation of hospital patients

- Approximately 2200 patients and elderly people stayed in 7 hospitals and 17 nursing homes within 20 km evacuation zone.

- No medical support was provided during evacuation or at shelters, resulting in the deterioration of the physical condition of many patients.
- More than 50 patients died either during or soon after evacuation in March 2011.



(Tanigawa, K. et al. Lancet, 2012)

(The National Diet Report, Chapter 4)

Modifying initial urgent protective actions

- March 30: IAEA advised Government to carefully assess the situation.
  (**Operational Intervention Level** for evacuation was exceeded in Iitate village.)

OIL	Default OIL	Relevant OIL for Fukushima
OIL1	1000 μSv/h	Cs-137 : 5×10^6 Bq/m^2 I-131 : 1×10^7 Bq/m^2

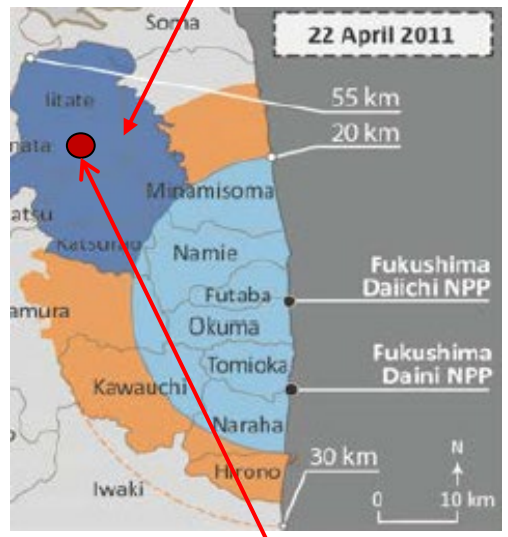
- April 10: NSC applied the ICRP concept of optimisation of protection below a reference level in Emergency Exposure Situation.
- April 22: NERHQ established the areas to be relocated beyond the 20 km evacuation zone as **Deliberate Evacuation Area**.

Deliberate Evacuation Area

- The residents in this area, where annual cumulative dose after the onset of the accident would potentially reach 20mSv, are to be advised to evacuate.

✓ OILs are essential as guides to decision making during an emergency

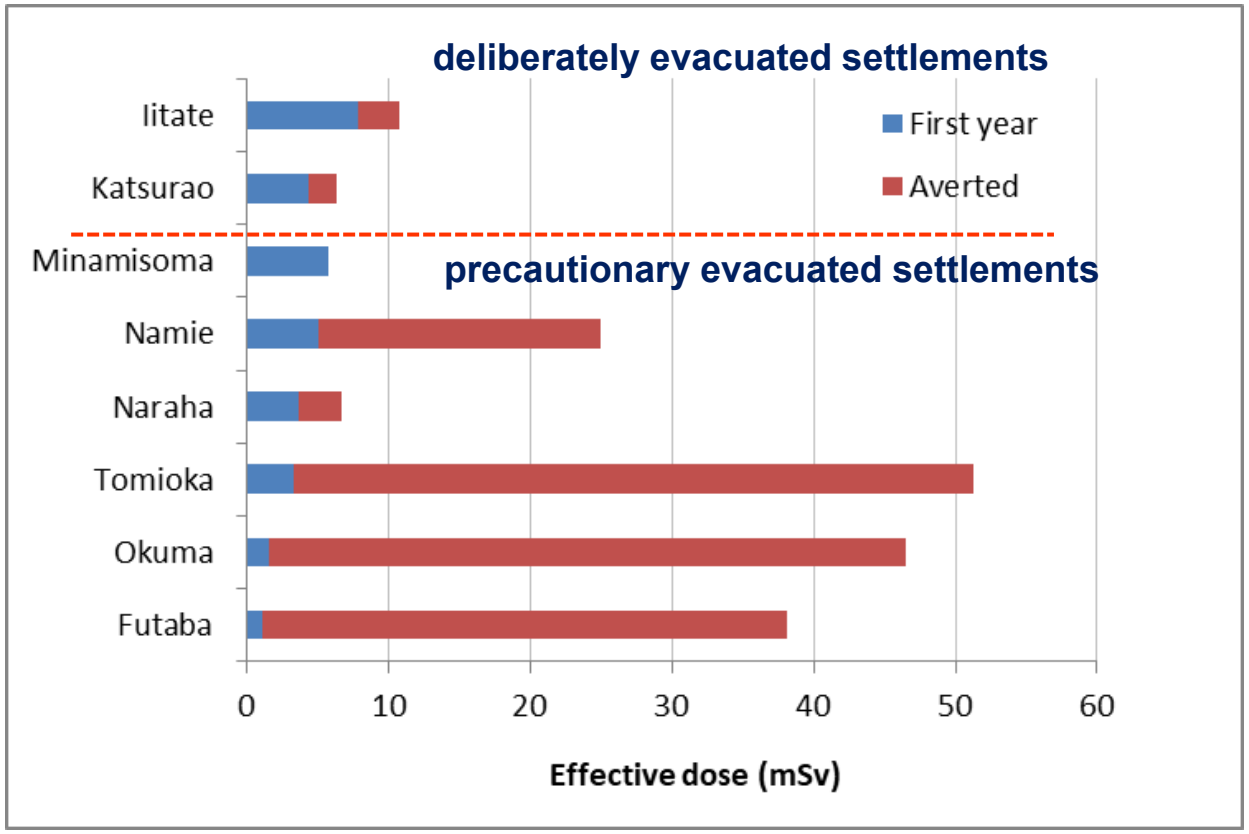
✓ Monitoring (17 March)
170 μSv/h (30km north west)



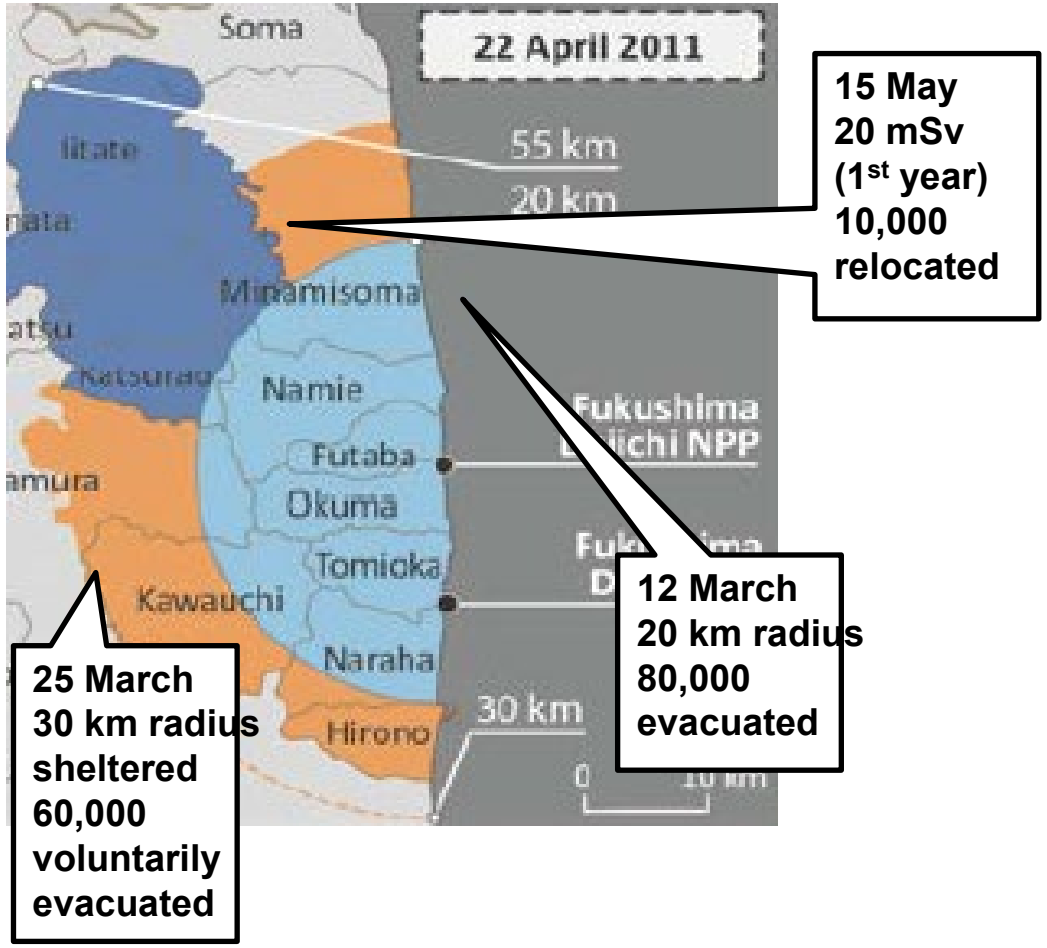
Iitate village more than 30 km far from the Fukushima Daiich NPP
I-131 : 2.5×10^7Bq/m^2

Radiological impacts with evacuation

- The average effective doses evacuated in March 2011 were estimated to be less than 6 mSv and to those evacuated in April to June 2011 less than 10 mSv in the first year.

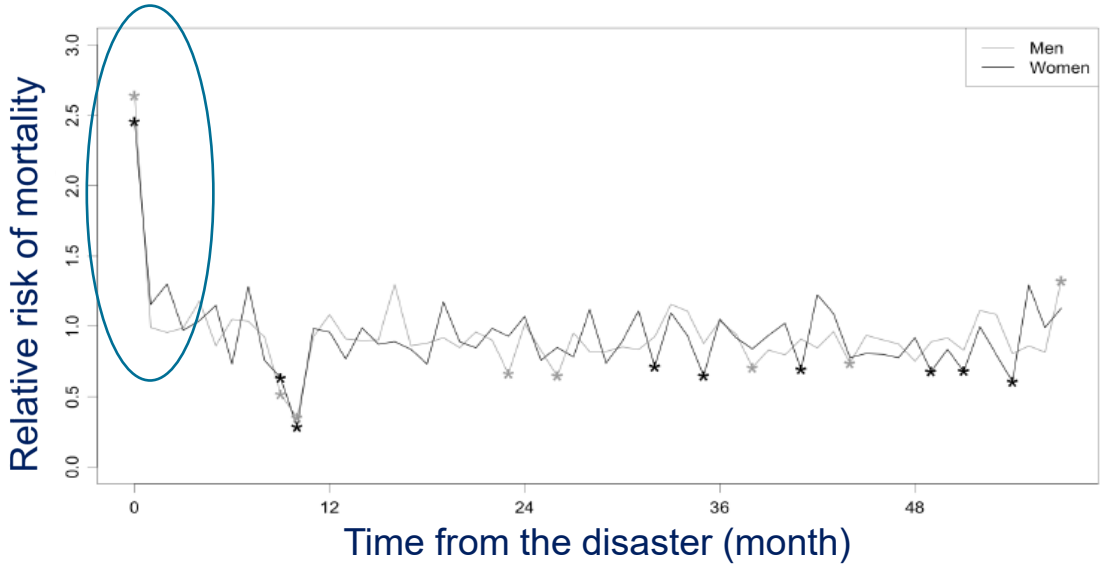


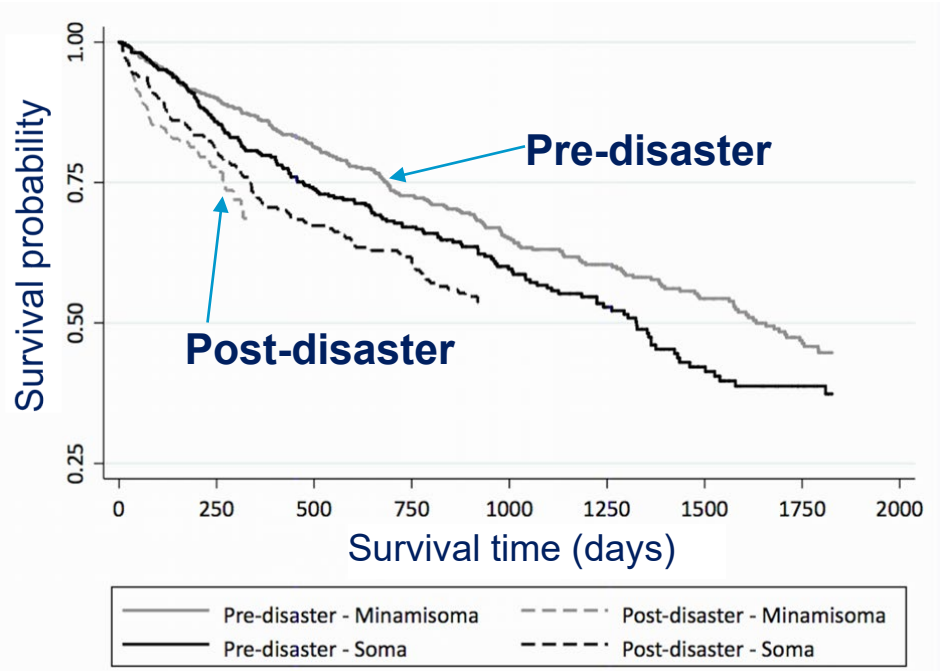
(UNSCEAR 2013 Report, Vol.1 ANNEX A, Appendix C.)



Health effects with evacuation

- There is a wide range of health issues after the accident, and many of them are triggered by evacuation (Tsubokura, 2018).
  - It is important to consider health issues as being defined **by society and the surrounding environment**, rather than as a consequence of individual intentions and actions.
  - The risk of death increased the most in **the first month** of the triplet disasters (Morita, et al. 2017).
  - The risk of death among the elderly in institutions was particularly high after **the initial evacuation** (Nomura, et al. 2016).
  - It is essential to maintain the number of staff to maintain the hospital functions in the early stage of the accident.





Key experience from the accident

- The lessons learned call for reconsideration of implementing immediate evacuation and relocation
  - Significant difficulties encountered in evacuating people from hospitals and nursing facilities resulted in more than 50 deaths.
  - Disaster related deaths*: 1632 in total (761 in Fukushima, 636 in Miyagi, 193 in Iwate) for the first 12 months after the earthquake (March 31, 2012)
    - ✓ Most of the cases became weak gradually due to fatigue, stress, lack of exercise, and medical conditions caused by evacuation (movement) and living in evacuation place (Reconstruction Agency, 2012).

***Disaster related deaths (DRD)** are defined as deaths which occurred due to aggravation of injury as a result of the Great East Japan Earthquake, and who qualified for condolence money pursuant to the Act on Payment of Condolence Money due to the natural disaster.*

Practice for preparing recovery

◆17 May **2011**, **Roadmap** to return to normality by NERHQ

- June: Arrangements for long-term **health surveillance** (The Fukushima Health Management Survey);
- August: Comprehensive **monitoring plan** by the MEXT;
- August: **Long-term management of radioactive waste**;
  - ***Act on Special Measures*** *concerning the Handling of Environmental Pollution by MOE (enacted on 26 August)*
- 30 September: **Lifting the recommendation to former shelter areas** by NERHQ;

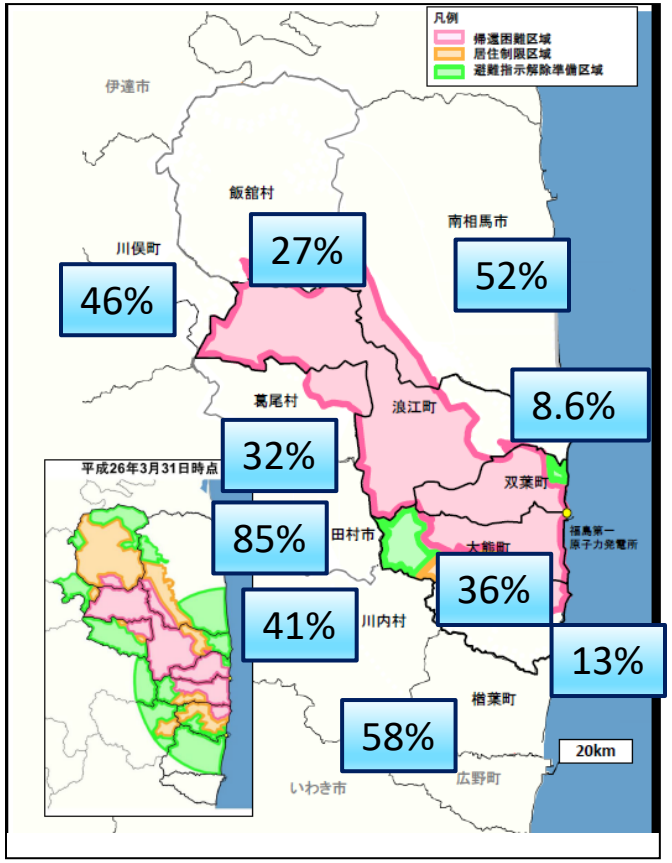
◆16 December: **Control of the situation** at NPP has been regained

- 26 December: **Basic concept for rearranging** the evacuation areas by NERHQ
- January 2012: Act on Special Measures was fully enforced
- 30 March: **First rearrangement of the evacuation areas** started by NERHQ
- April: New **food regulation** came into effect by MHLW

Status of the areas under evacuation order

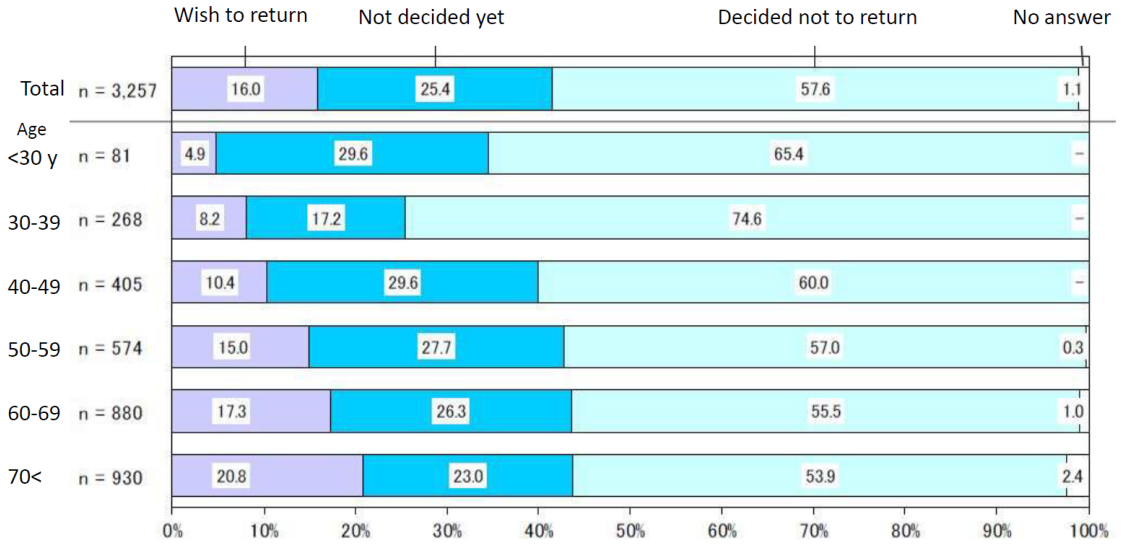
- **Lifting conditions (Dec. 2011)**

✓ Dose level < 20 mSv/y
✓ Infrastructures and live services
✓ Consultation with local gov. and residents

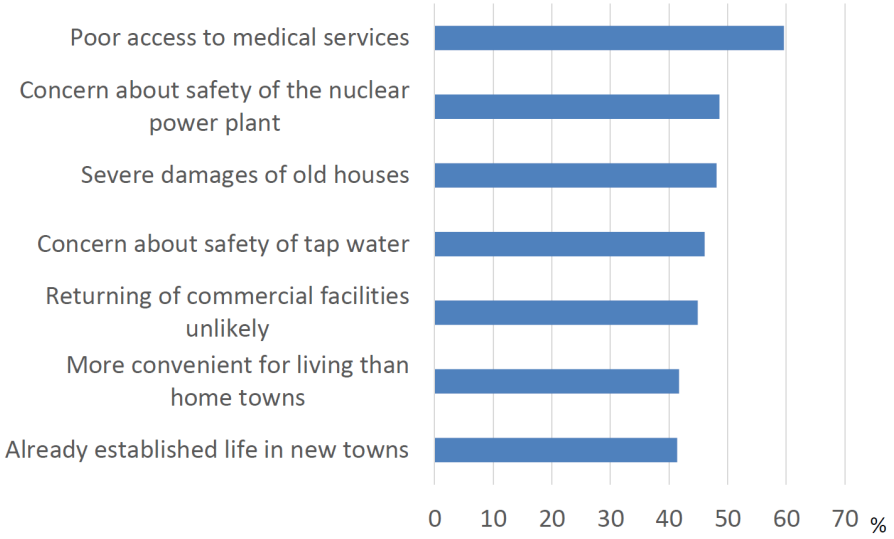


1 April 2017

Intension about returning



Major reasons for “decided not to return” and “not decided yet”



Key lessons on implementation of protective actions

- Arrangements should be established for taking **predetermined** urgent protective actions **before a release on the basis of plant conditions**.
- Advance preparation needs to be in place for **safe evacuation of special facilities** (designation of medical teams and hospitals, methods of transportation in advance).
- Predefined criteria based on **operational intervention levels** concerning relocation and other early protective actions are needed to ensure timely response.
- Sheltering should be implemented only for **a short period** until either safe evacuation or termination of sheltering is possible.
- Instructions explaining radiation hazard and grounds of need of early measures should be prepared in advance to clarify the situation to population, those directly affected but also to those not directly affected by decisions.

- ***Radiological situations and protective actions taken***
- ***Lessons on dose prediction system***
- ***New NRA EPR Guide***
- ***Concluding remarks***

Regulatory Guide on EPR prior to the accident

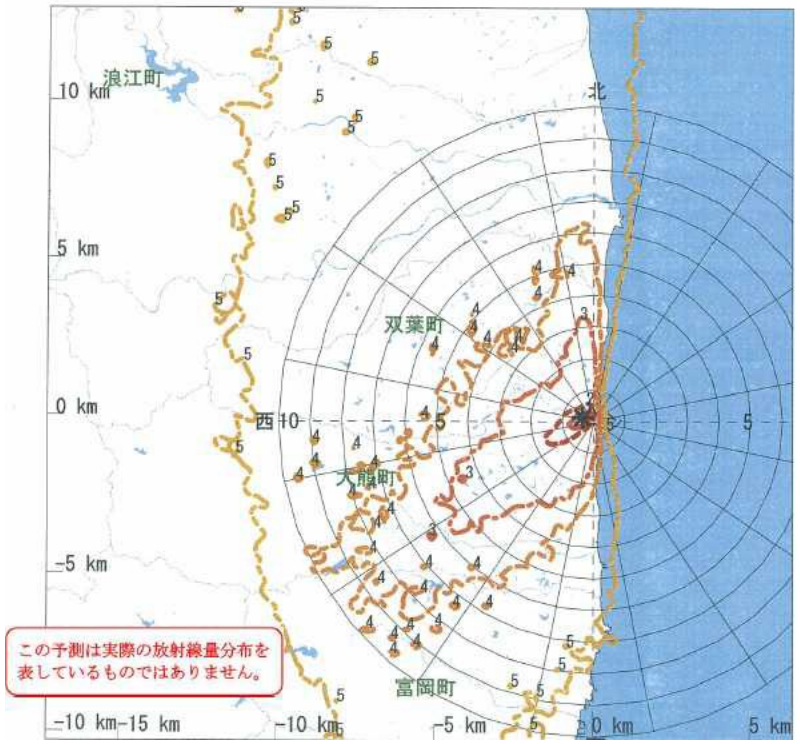
- "**Regulatory Guide: Emergency Preparedness for Nuclear Facilities**" by the Nuclear Safety Commission (1980)
  - EPZ (Emergency Planning Zones) : 8 – 10km
  - IL (Intervention levels) : Sheltering: 10mSv, Evacuation: 50mSv
- Clear "**Protection strategy**" or "**Concept of operations**" in emergency response planning has not been established and shared by relevant response organizations.
  - "Predicted doses as indicators for taking protective actions are estimated based on the plant situation, the expected releases of radioactive material, monitoring information, meteorological information, and **the SPEEDI network system**, etc."
- Decision making to initiate off-site protective actions **heavily relied on computer-based prediction systems**.
  - **ERSS/MAAP** for severe accident (SA) progression / **source term** analysis based on the plant data from **SPDS**
  - **SPEEDI** for atmospheric dispersion simulation

SPEEDI: System for Prediction of Environmental Emergency Dose Information
ERSS: Emergency Response Support System
SPDS: Safety Parameter Display System

Application of real-time dose predictions, I

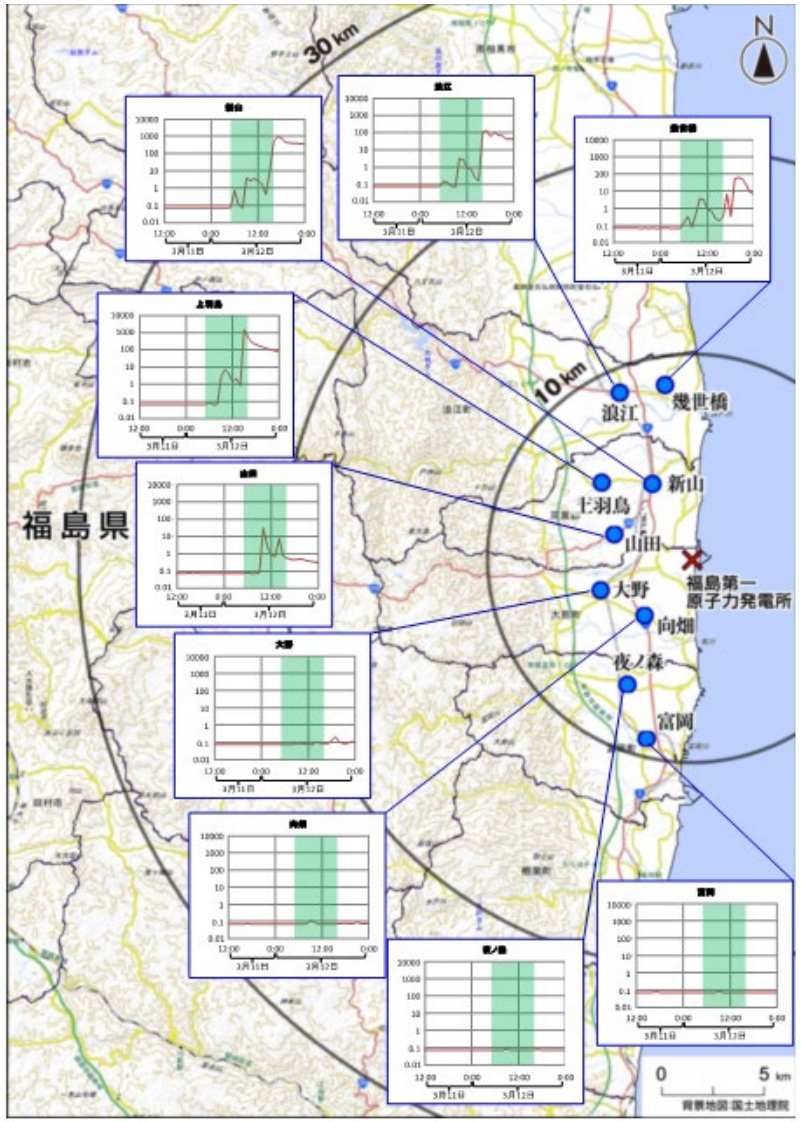
- On **March 12**, 2011, a SPEEDI calculation was done by using **source terms of a SBO scenario which had been calculated prior to the accident.**

Cumulative effective dose due to external exposure (1300 – 1900 on March 12)



(http://www.nsr.go.jp/archive/nisa/earthquake/speedi/erc/05-03120607.pdf)

Air dose rate (μSv/h) (March 11:1200 – 12:2400)



Application of real-time dose predictions, II

- On March 23, a SPEEDI projected dose estimate was made available to the public.
- There was no adequate explanation that the estimates was inversely made based on environmental data.

Lack of this explanation resulted in misunderstanding and confusion.

内部被ばく臓器等価線量
日時＝ 2011/03/12 06:00 -
2011/03/24 00:00 の積算値

領域 ： 92km X 92km
核種名 ＝ ヨウ素合計
対象年齢 ＝ 1歳児
臓器名 ＝ 甲状腺

【凡例】
線量等価線 (mSv)
1= 10000
2= 5000
3= 1000
4= 500
5= 100

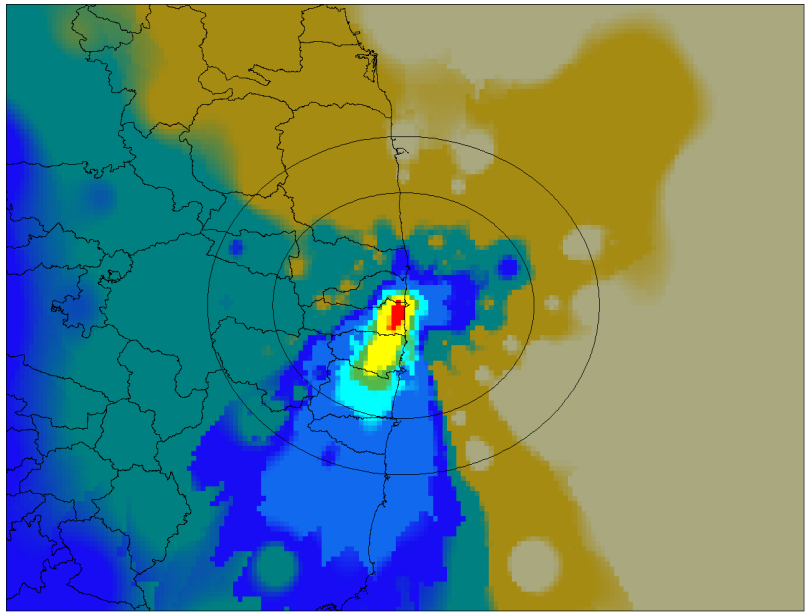
（評価）
本試算は、福島第一原子力発電所の事故発生後、連続して一日中屋外で過ごすという保守的な条件を仮定して、甲状腺の被ばく線量を試算した

(https://warp.da.ndl.go.jp/info:ndljp/pid/9483636/www.nsr.go.jp/archive/nsc/info/110323_top_siryo.pdf)

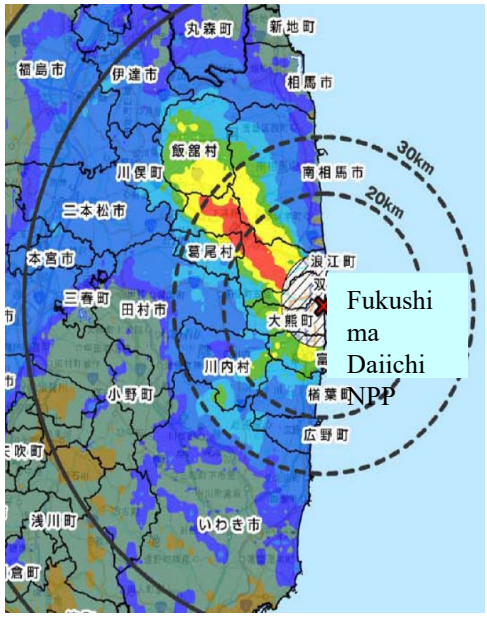
Strategy of precautionary urgent protective actions

- In emergency exercises, recommendations of taking urgent protective actions have been made based on **real-time dose predictions** by computer-based models (ERSS, SPEEDI) compared with intervention levels.
- In the Fukushima case, Government implemented protective actions based on **plant conditions**.

Comparison of Cs-137 contamination



Post-accident model predictions



Airborne monitoring

◆ The difference highlights the difficulty of protective action recommendations solely based on computer-based dose predictions.

- ***Radiological situations and protective actions taken***
- ***Lessons on dose prediction system***
- ***New NRA EPR Guide***
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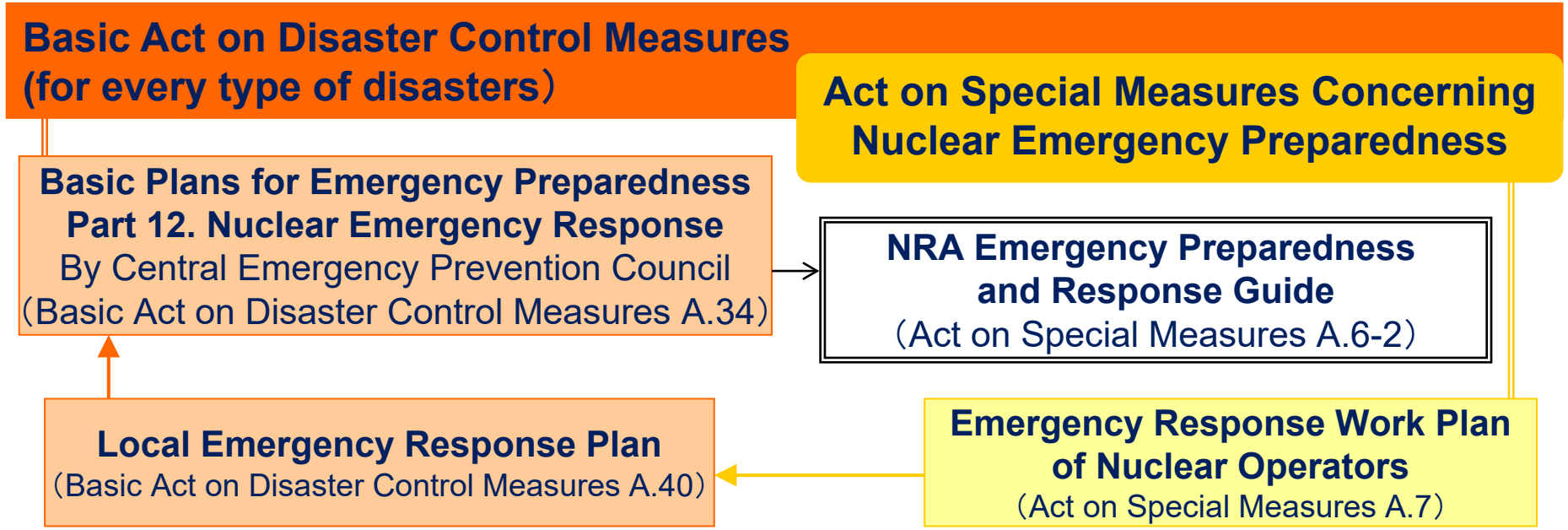
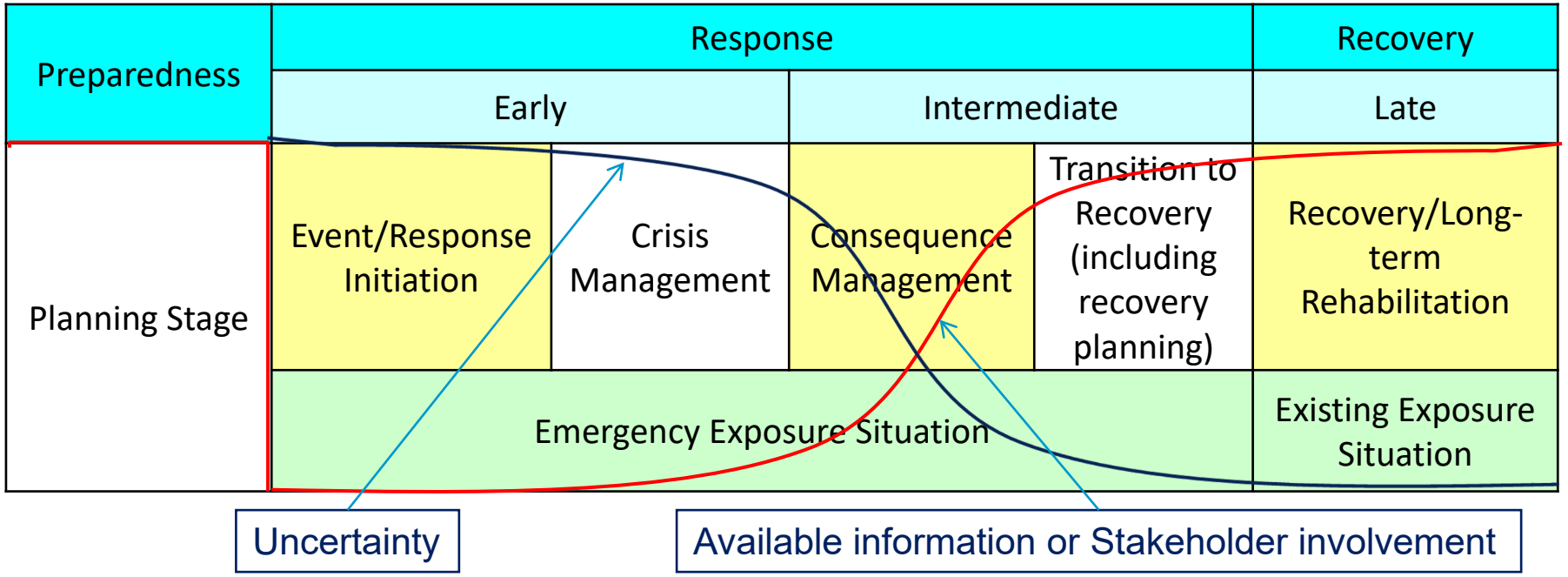
Legal system of EPR and role of NRA



- Establish NRA EPR Guide that provides specialized and technical matters for the implementation of preparedness, response and recovery measures
- Primary responsibility for decisions on safety issues on site in the Response Headquarters
- Provide the Prime Minister (head of Headquarters) with necessary information on the status of the event, the areas for protective actions, proposed instructions on protective actions

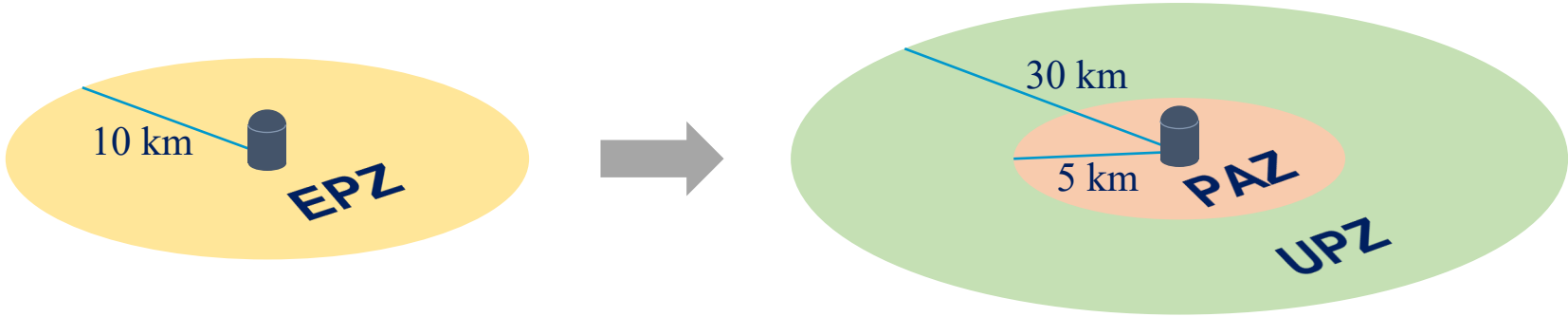
New concept of operation



- Early: The response should be undertaken in accordance with **predetermined** procedures and criteria. The participation of relevant stakeholders in the **planning stage** is essential.
- Intermediate and late: The response should be undertaken by step by step, taking the **prevailing circumstances** into account. It is necessary to make an agreement between different stakeholders, to coordinate a unified response.

EPR Strategy based on EALs and OILs

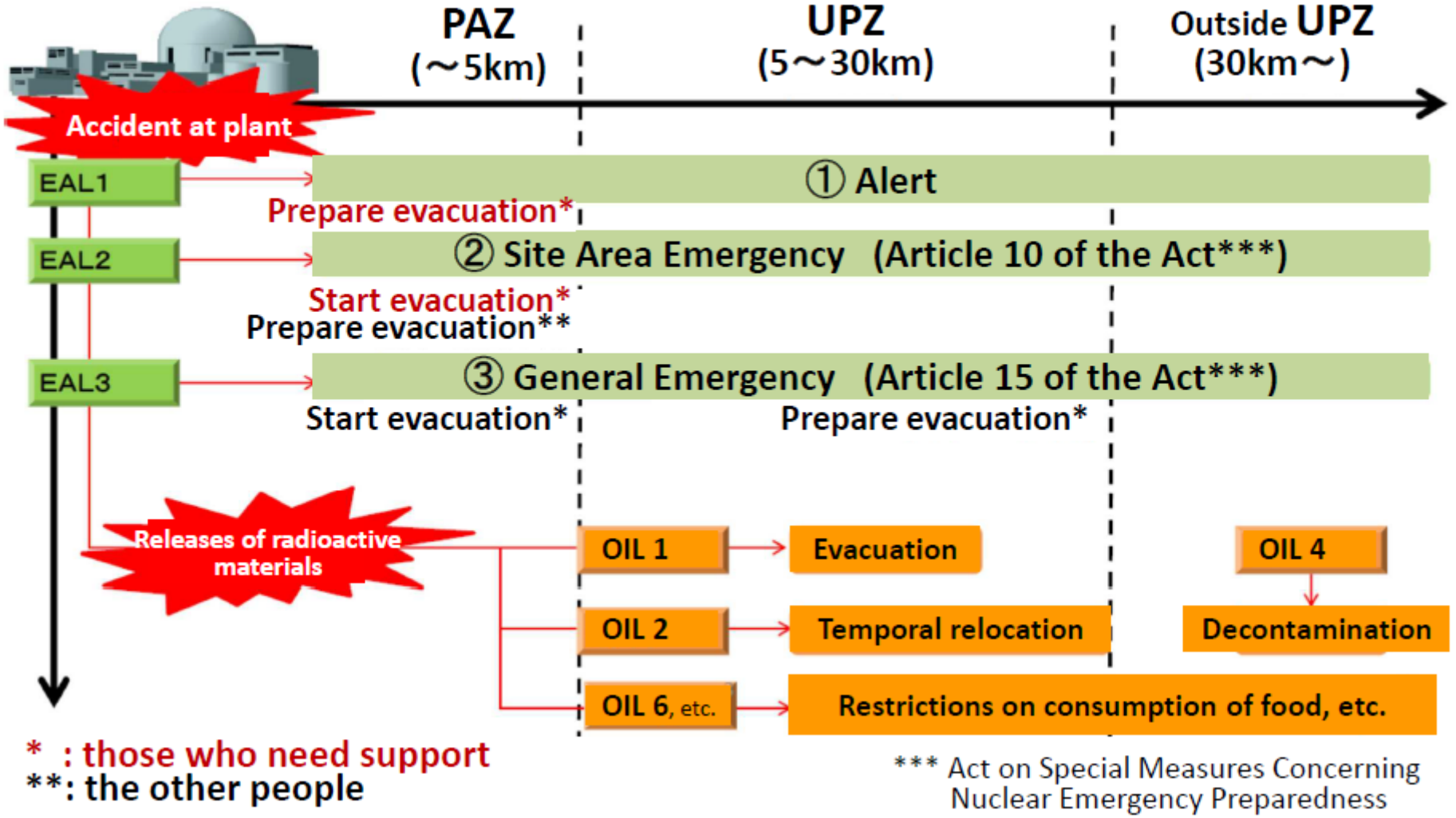
- Emergency Planning Zones expanded to 30 km defined by PAZ and UPZ
- Judgments based on observables(EALs) and measurements(OILs), not on simulation
- Protective actions to avoid or to minimize deterministic effects, evacuation from PAZ
- Protective actions to reduce the risk of stochastic effects, ITB in PAZ and sheltering in place, staged evacuation, temporary relocation in UPZ



Strategy for implementing protective actions

- **Those who need support should start earlier**

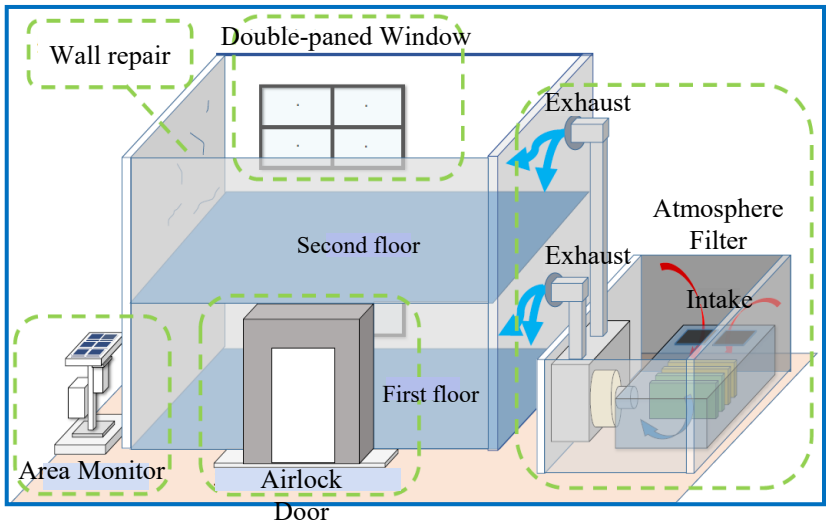
PAZ: Precautionary Action Zone
UPZ: Urgent Protective Action Planning Zone



Temporal shelters

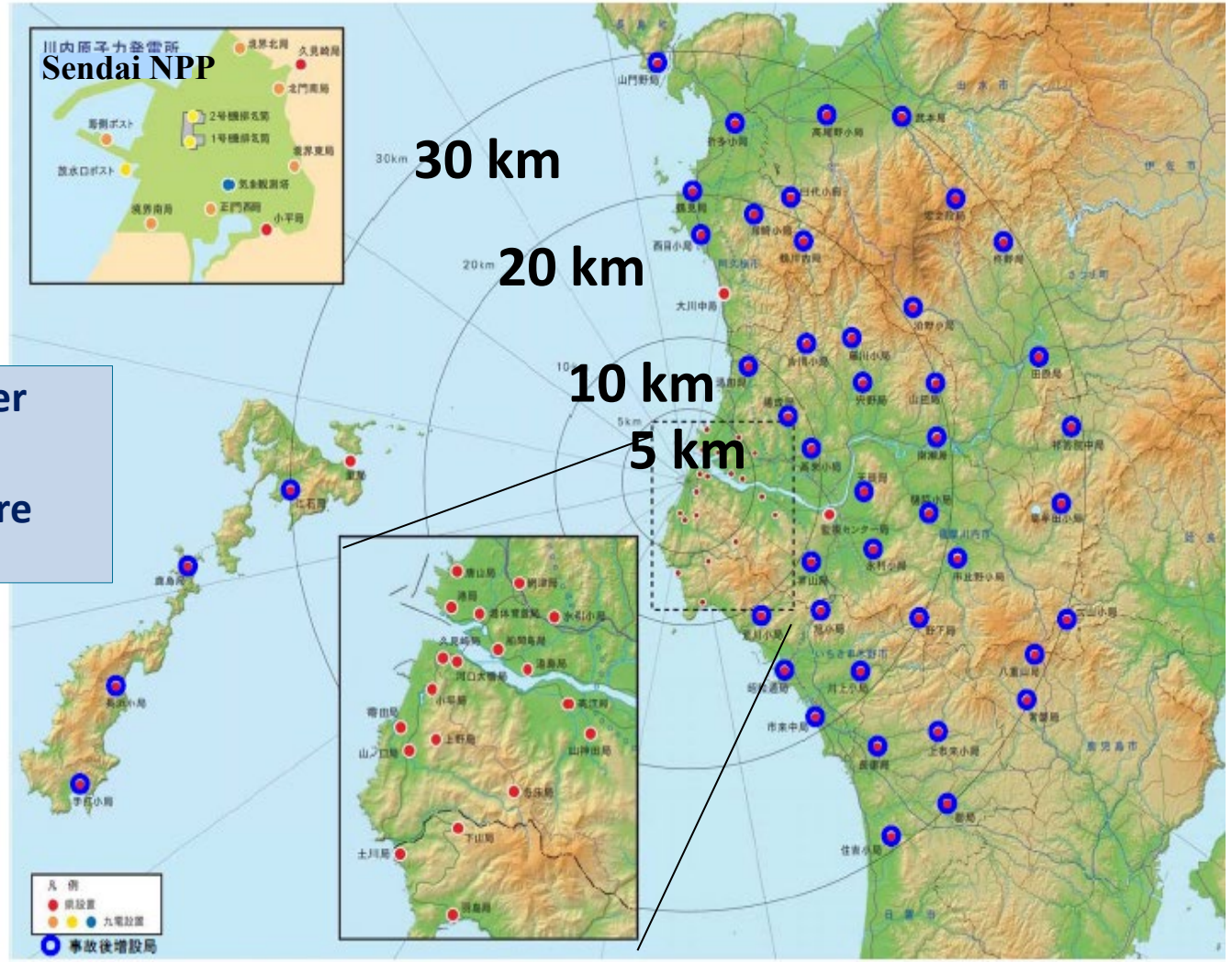
- The government has supplied financial support to local governments for implementing **temporal shelters,** including additional protective measures:

  - ✓ **Enhancement of airtightness** of the buildings,
  - ✓ Installation of **air conditioning system with filter** to the existing facilities:
  - ➢ Long-term care health facilities, and Community halls, hospitals, school, etc.



Emergency radiation monitoring

- Surrounding the Sendai NPP, there are **67** monitoring stations:
  - ✓ **22** before the Fukushima accident, **45 added**



Monitoring post with PV generator

Portable monitoring post with PV generator and cellular phone communication function

Portable dust iodine sampler

Nuclear emergency exercise

	National Exercises	Local Drills	Operator Drills
Plan	National Government	Prefecture	Operator
Main Participants	National Government Local Government First Responder Residents Operators	Local Government First Responder Residents Operators	Operator Regulatory body(NRA)
Activities	Off-site and On-site	Off-site and On-site	On-site
Act	Nuclear Emergency Act	Disaster Countermeasure Act	Nuclear Emergency Act Reactor Regulation Act
Period	Once a year	Once a year /Prefecture	Once a year /site

Future issues

- Arrangements for protective action recommendations taking into account non-radiological effects are not currently explicitly incorporated in the NRA EPR Guide.
- Considerations to be taken into account include:
  - The need to balance between **radiological risks and evacuation-induced health risks**
  - Preparedness for the implementation of **safe evacuation for vulnerable populations** is of particular importance.
  - Arrangements should be in place for **communication with the public** at the preparedness stage and throughout an emergency to deal with mental health and psychosocial impacts
  - Experiences and lessons from **non-nuclear emergencies** should be learned, as all activities (risk reduction, emergency preparedness, response actions and community recovery activities) will be implemented in a similar way, regardless of the cause.

Conclusions

- A general lesson is that there was an **implicit assumption** of both the operators and the regulatory authorities that such **severe accidents could not happen** and thus enough attention had not been paid to preparedness for such accidents.
- NRA issued the “EPR Guide” in 2012 in which a new protection strategy was established based on **lessons learned from the TEPCO Fukushima Daiichi accident** and **international guidance**.
- Further actions still need to be prepared and implemented with respect to arrangements for the **emergency response** and **recovery process**.
- It will be important to **continuously improve** emergency response arrangements based on feedback from exercises.