

Introduction to the Accident at Fukushima Dai-ichi Nuclear Power Station

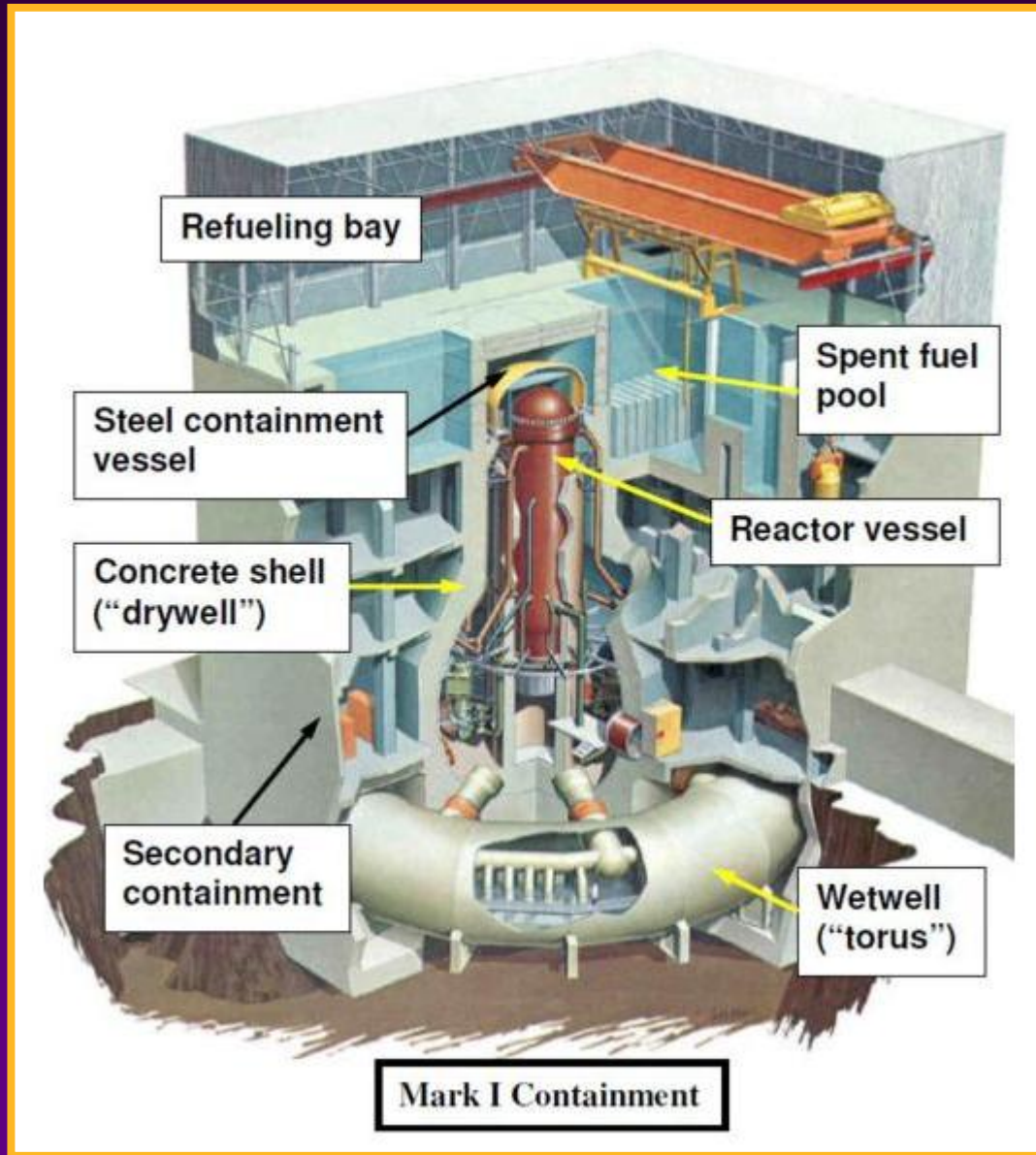
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Fukushima Dai-ichi Nuclear Power Station

- Fukushima Dai-ichi (“No. 1”) Nuclear Power Station (NPS) consisted of six Boiling Water Reactors (BWRs) (Unit 1: ~0.5 GW; Units 2-5: ~0.8 GW; Unit 6: ~1.1 GW).
- First operational during 1970s.
- Three reactors (Units 1-3) operational at the time of a major (magnitude 9.0) earthquake on 11 March 2011.

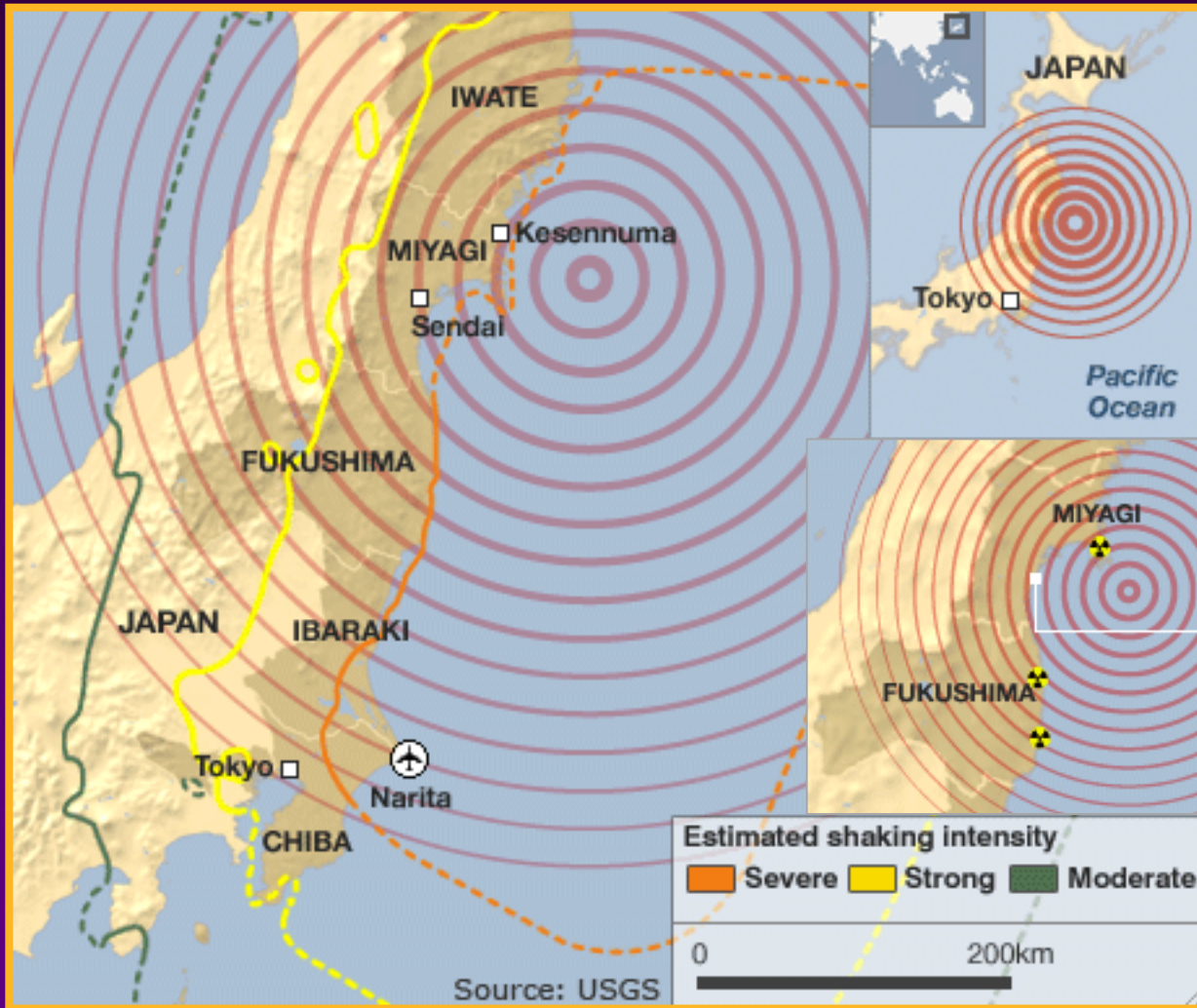
Boiling Water Reactor (BWR)



Fukushima Dai-ichi Nuclear Power Station



2011 Tōhoku Earthquake



After the Earthquake

- The three reactors operating at Fukushima Dai-ichi NPS automatically shut down as designed, apparently with no serious damage that would compromise safety.
- External power supplies severed.
- Emergency diesel generators started-up as designed to maintain electrical power supply to Fukushima Dai-ichi NPS.

11 March 2011



After the Tsunami

- The tsunami damaged the reactor cooling water heat exchangers, and drowned the emergency generators.
- The site was left without electrical power.
- Although the chain reactions in the reactors had been shut down, there was still substantial radioactive decay heat being generated, and no effective means of removing this heat from the cores.

12 March 2011 – Unit 1



14 March 2011 – Unit 3



Late-March 2011



Evacuation

- An area within 20 km of Fukushima Dai-ichi NPS was compulsorily evacuated on 12 March, with sheltering (and then voluntary evacuation) advised within 20-30 km.
- ~100 000 people were initially evacuated.
- Evacuation has (non-radiological) health consequences: early deaths due to the evacuation (mainly in the elderly and chronically ill) have been reported.

An Irresponsible Statement

- On Tuesday, 15th March 2011, the then EU Commissioner for Energy, Günther Oettinger, said of the situation at Fukushima:

“There is talk of an apocalypse and I think the word is particularly well chosen. Practically everything is out of control. I cannot exclude the worst in the hours and days to come.”

- How many deaths might this public statement by an EU Commissioner have caused by promoting panic in, and flight from, Tokyo?

Nuclear Reactor Accidents

A comparison of the activities (PBq) of radionuclides released to atmosphere as a consequence of the Fukushima and Chornobyl accidents.

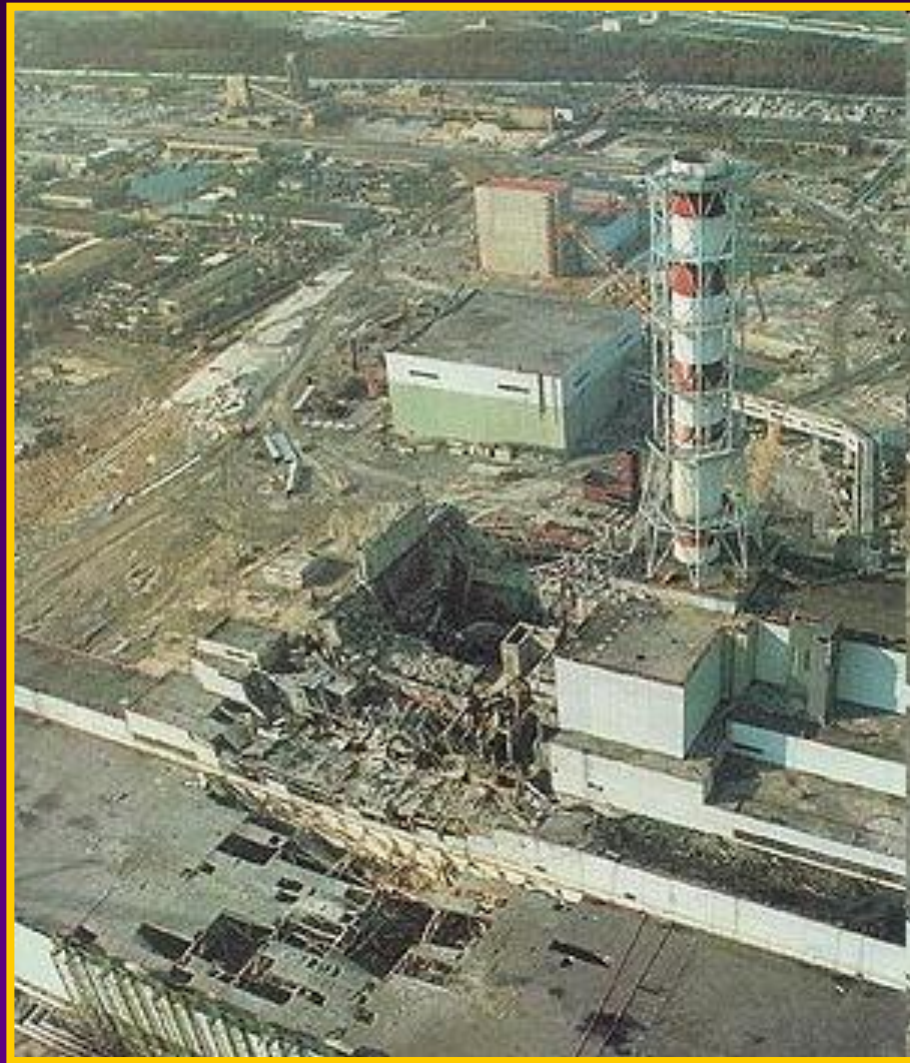
Radionuclide	Fukushima Accident (PBq)	Chornobyl Accident (PBq)
Noble Gases (mainly Xe-133)	500	6500
I-131	500	1800
Cs-134	10	50
Cs-137	10	85

Nuclear Weapons Testing

Comparison of Activity Releases (PBq) from Atmospheric Nuclear Weapons Testing and the Chornobyl Accident

Radionuclide	Nuclear Weapons Testing (PBq)	Chornobyl Accident (PBq)
I-131	675 000	1 800
Cs-137	948	85
Sr-90	622	10
Pu (α -activity)	11	0.1

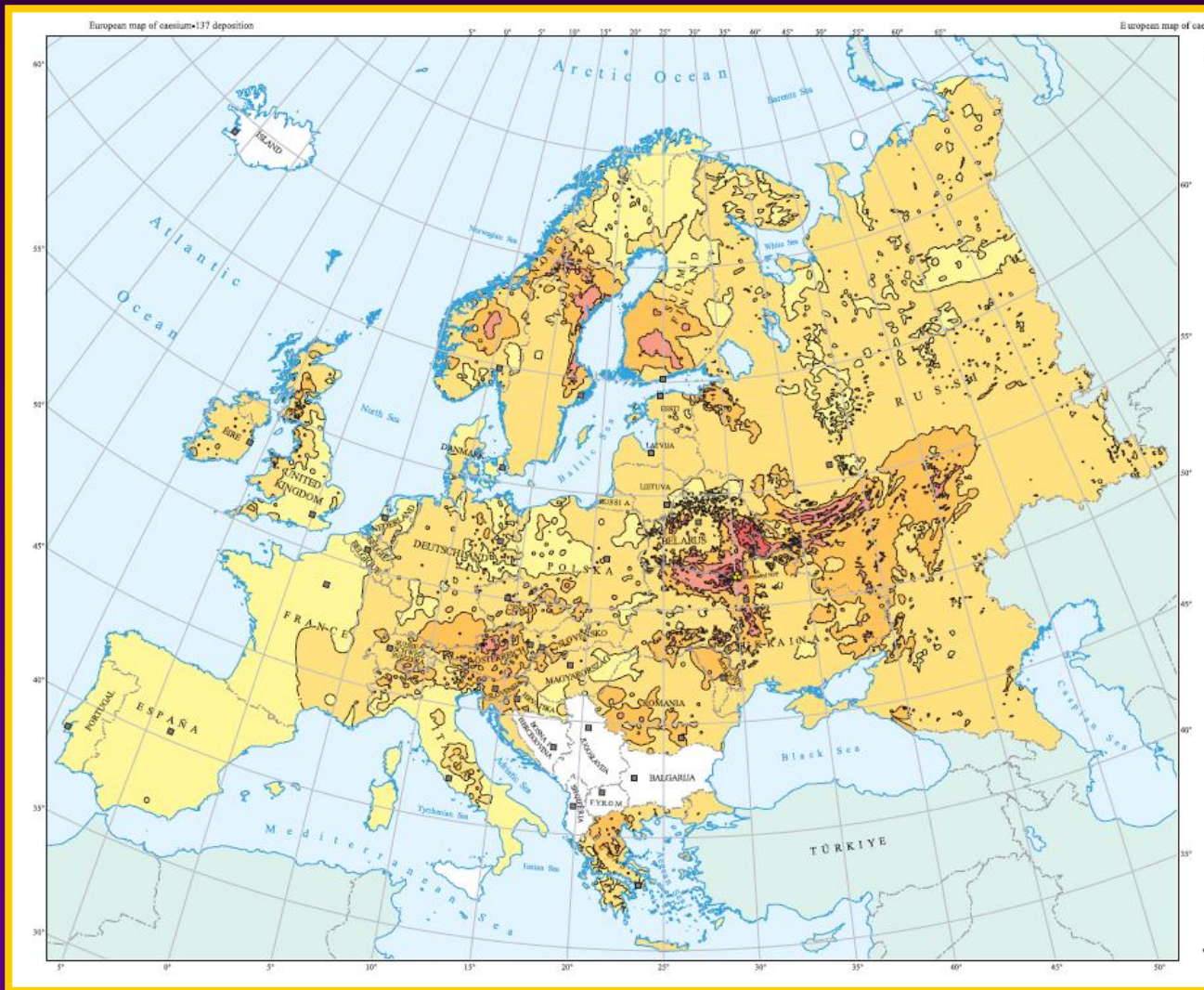
Chornobyl Unit 4 – 26 April 1986



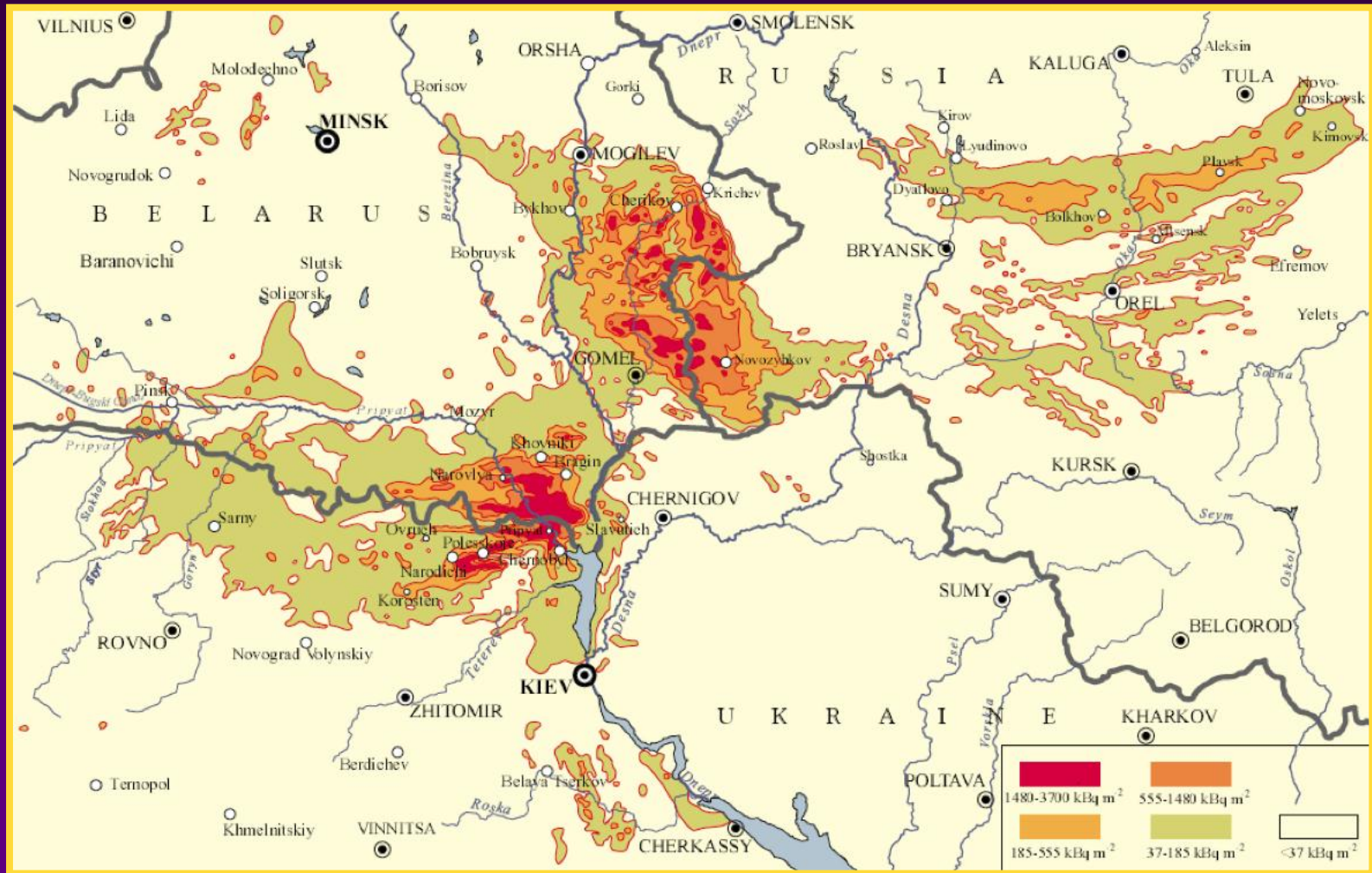
Acute Radiation Sickness

- Acute Radiation Sickness (ARS) was diagnosed in 134 emergency workers attending the Chornobyl accident.
- 28 of these workers died in 1986.
- 19 more workers died during 1987-2004, although not necessarily as a result of exposure to radiation.

Chornobyl Contamination



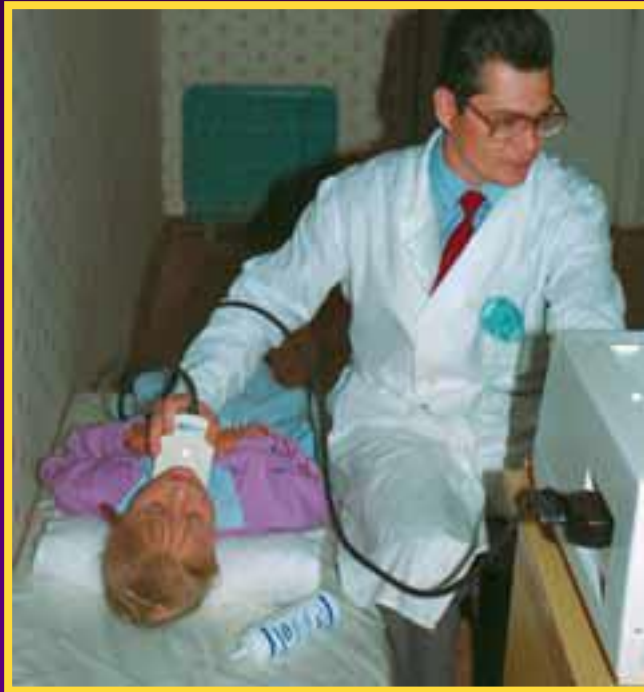
Chornobyl Contamination



Chornobyl Countermeasures

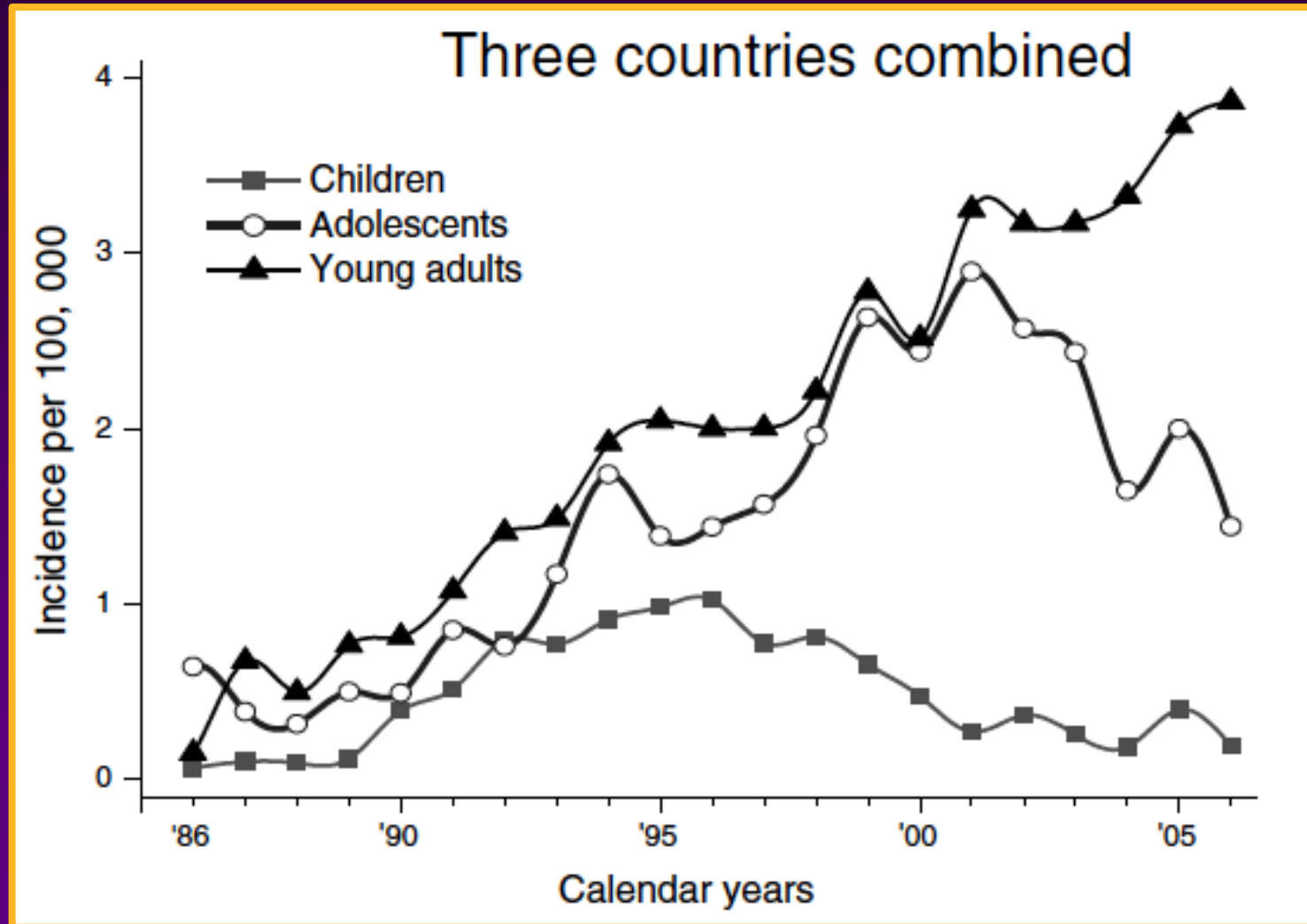
- Evacuation of heavily contaminated areas was delayed.
- Food restrictions were delayed.
- In particular, children were permitted to consume milk heavily contaminated by I-131, which is concentrated in the thyroid gland, leading to many children ($>10^4$) receiving high thyroid doses (>1 Gy).

Chornobyl –Thyroid Cancer

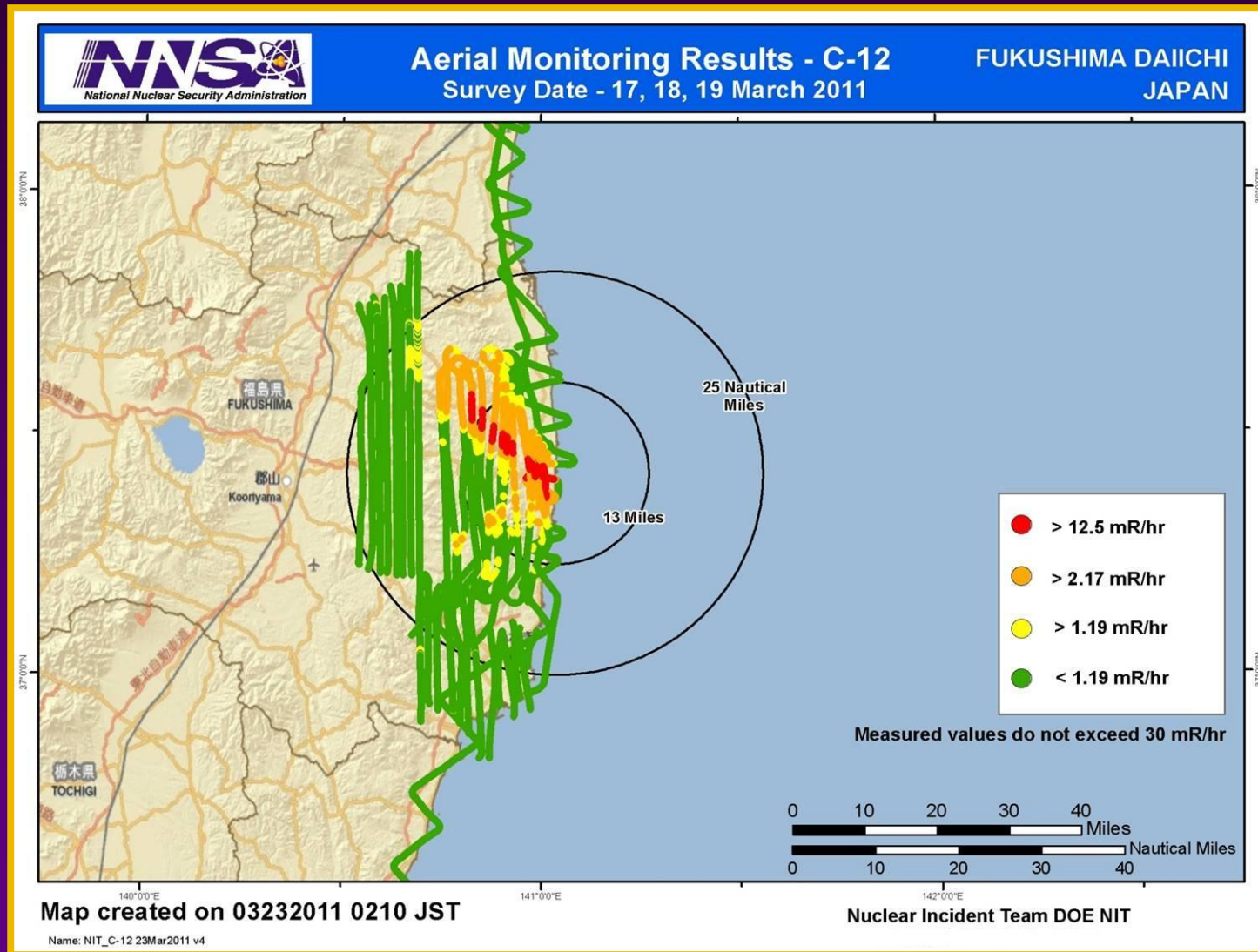


Chornobyl – Thyroid Cancer

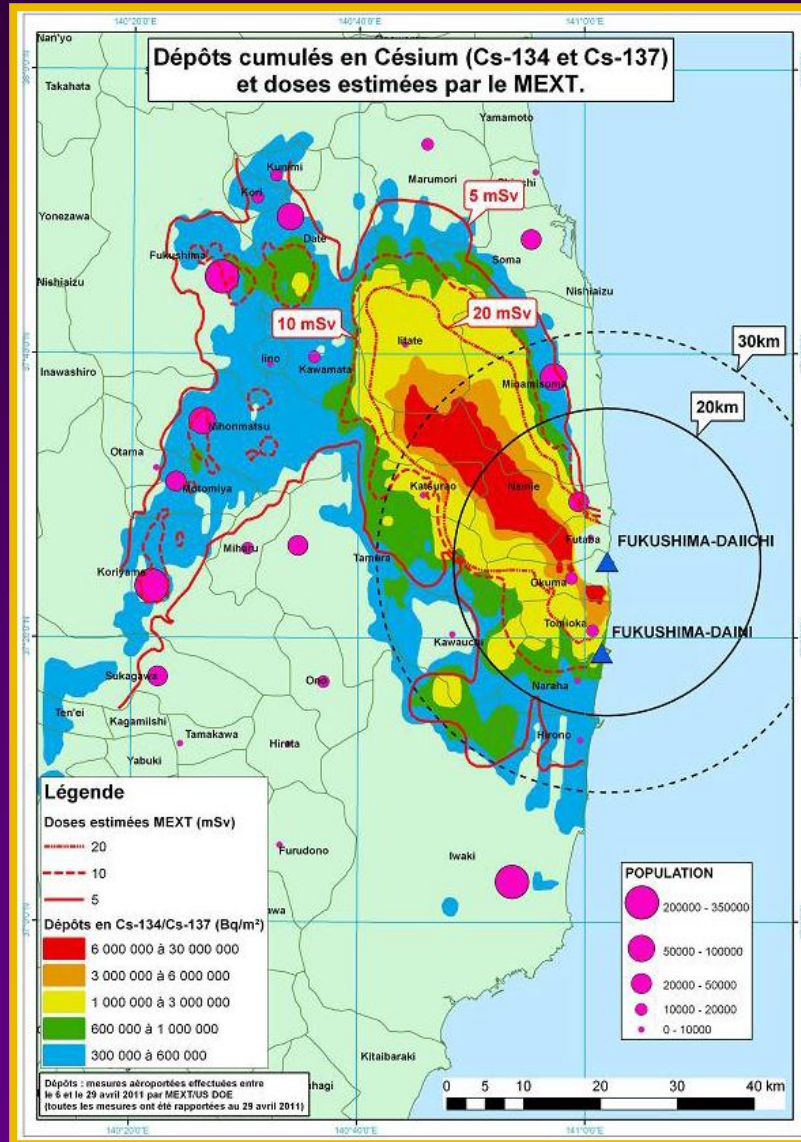
(Yamashita, *Health Phys* 2014; **106**: 166-80)



US DOE Monitoring



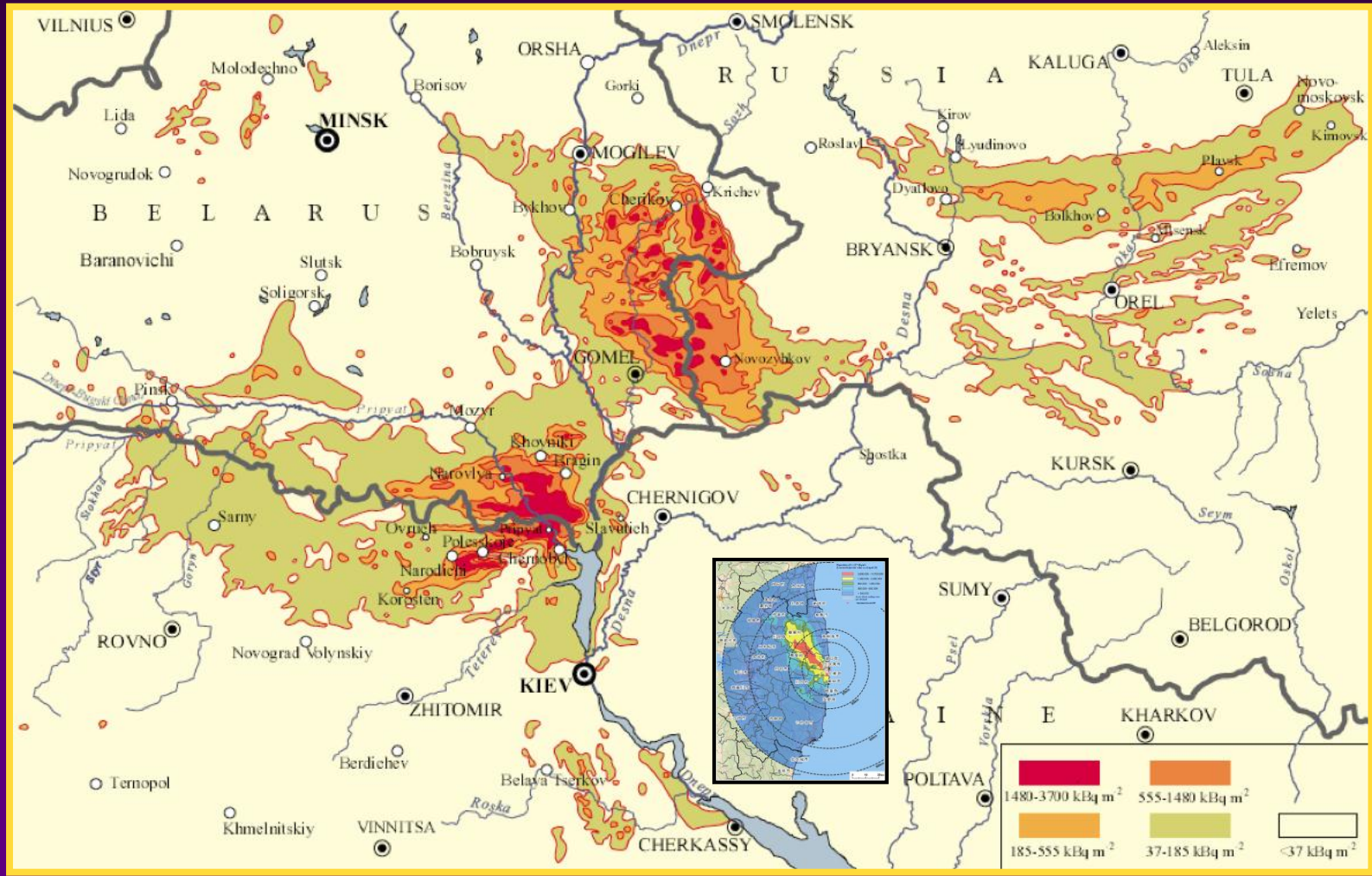
Fukushima Contamination



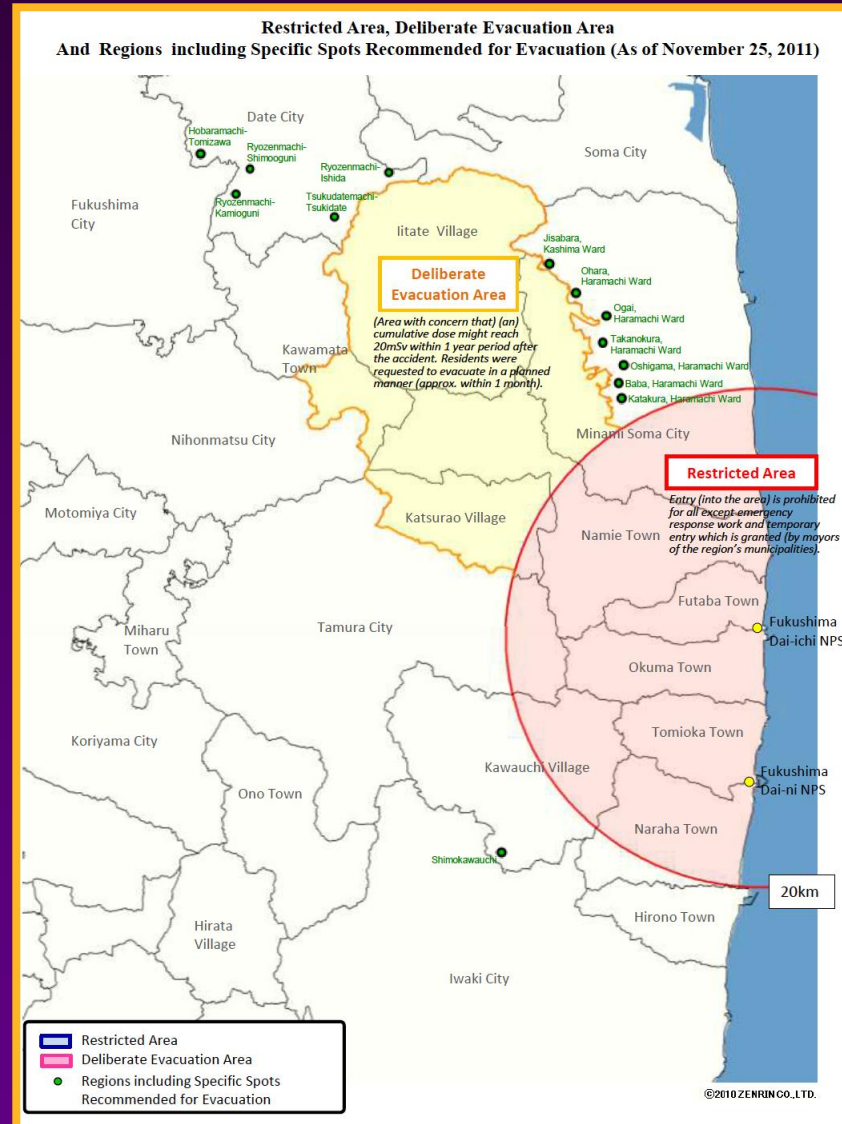
Comparison of ^{137}Cs Contamination around Chernobyl with that around Fukushima (inset)

The two areas shown are approximately to the same scale.

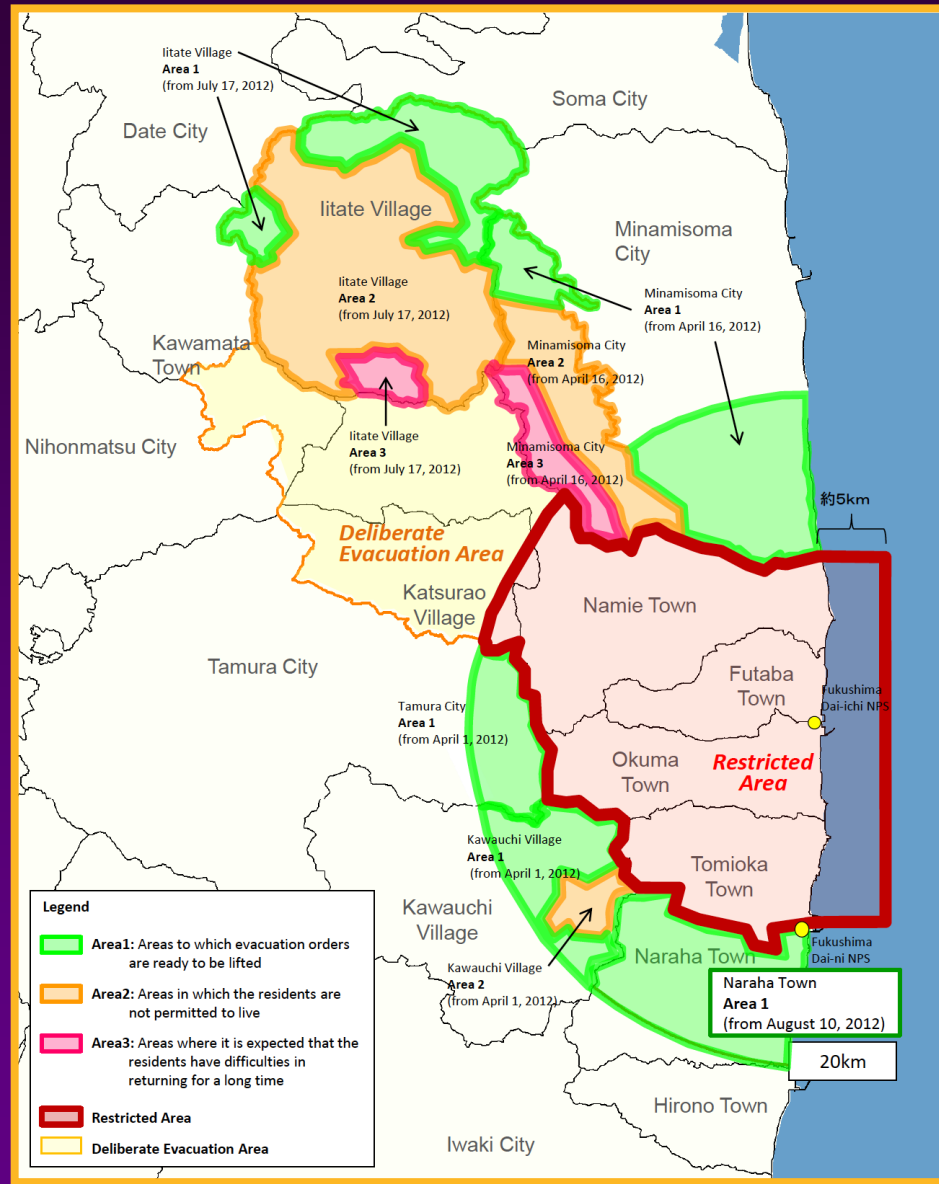
The orange/red areas around Chernobyl correspond approximately to the green/yellow/red areas around Fukushima in level of contamination.



Areas in Fukushima Prefecture



Areas as of 31 July 2012



1896 Meiji Sanriku Tsunami



Japanese “Tsunami Stones”



Sumatra Tsunami, December 2004



International Repercussions

- Serious international concern that a major accident of this sort could occur in a technologically advanced country.
- What happened to design, operational and regulatory safety controls?
- Serious public concern in countries with nuclear power programmes, and in neighbouring countries.

Japanese Inquiries

- “Hatamura Committee” established by Cabinet and reported in July 2012.
- “Kurokawa Commission” established by Diet and reported in July 2012.
- Both reports *highly critical* of the Japanese system – “Kurokawa Report” spoke of “collusion between the government, the regulators and TEPCO [the operators]” and a “disaster ‘Made in Japan’”.

The Way Forward?

- If nuclear power is to remain a viable option, public confidence must be restored.
- Strong and independent regulation is essential.
- Trust in operators of nuclear facilities.
- A role for international audit of national operational and regulatory systems?
- A role for insurers and shareholders?

Kaliningrad, Russia



Baltic NPP Project



Acton & Hibbs

(Carnegie Paper, March 2012)

“In the final analysis, the Fukushima accident does not reveal a previously unknown fatal flaw associated with nuclear power. Rather, it underscores the importance of periodically reevaluating plant safety in light of dynamic external threats and of evolving best practices, as well as the need for an effective regulator to oversee this process.”

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