Joint seminar of JSPS - Maison Universitaire France-Japonais
Strasbourg, France
25 November, 2013

Contamination of soil with radiocesium emitted from Fukushima Daiichi Power Plant

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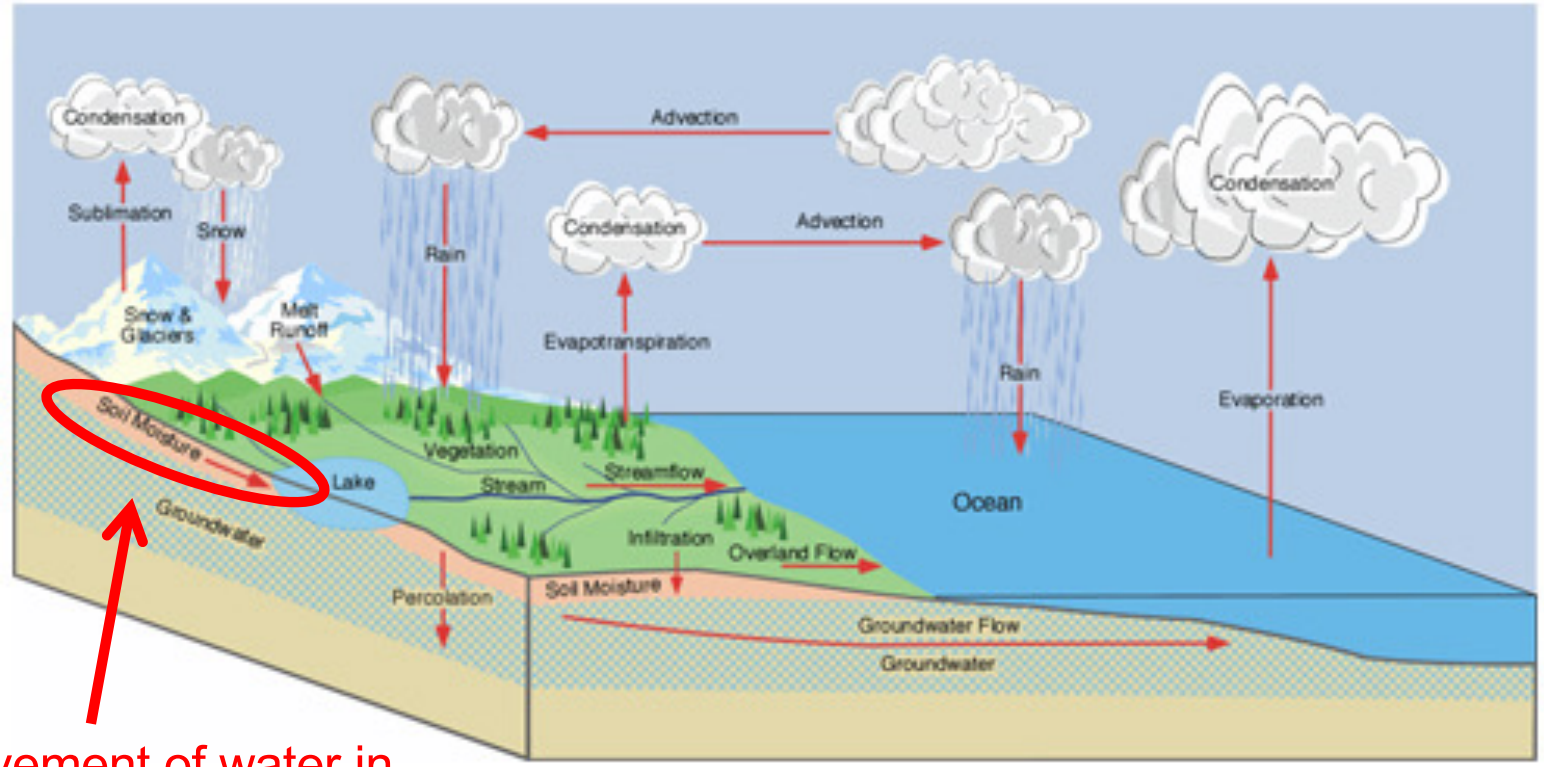
Toyo University, Japan
University of Strasbourg

Hydrology and soil physics



Movement of water in unsaturated zone (vadose zone)

Figure cited from http://www.usask.ca/hydrology/CHOverview.php

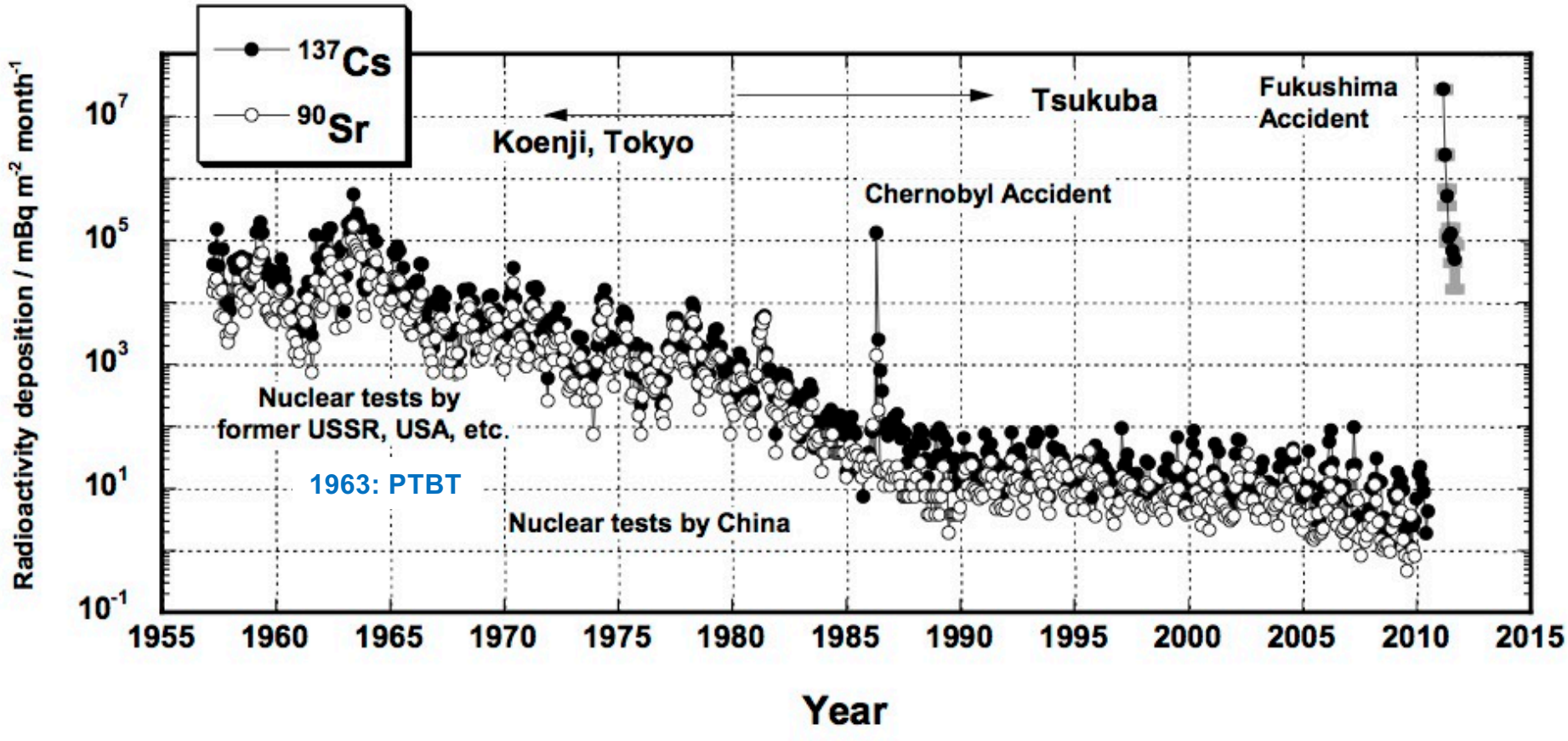
My background

- The University of Tokyo (1989 – 2008)
  Laboratory of soil physics and soil hydrology
  Ph.D. “Effect of microorganisms on soil physical properties” (1998)
- Toyo University (2008 - present)
  Faculty of Business Administration
  Teaching environmental science (liberal education)
- University of Strasbourg (2013.4 – 2014.3)
  Numerical simulation of soil water

My works related to radioisotopes

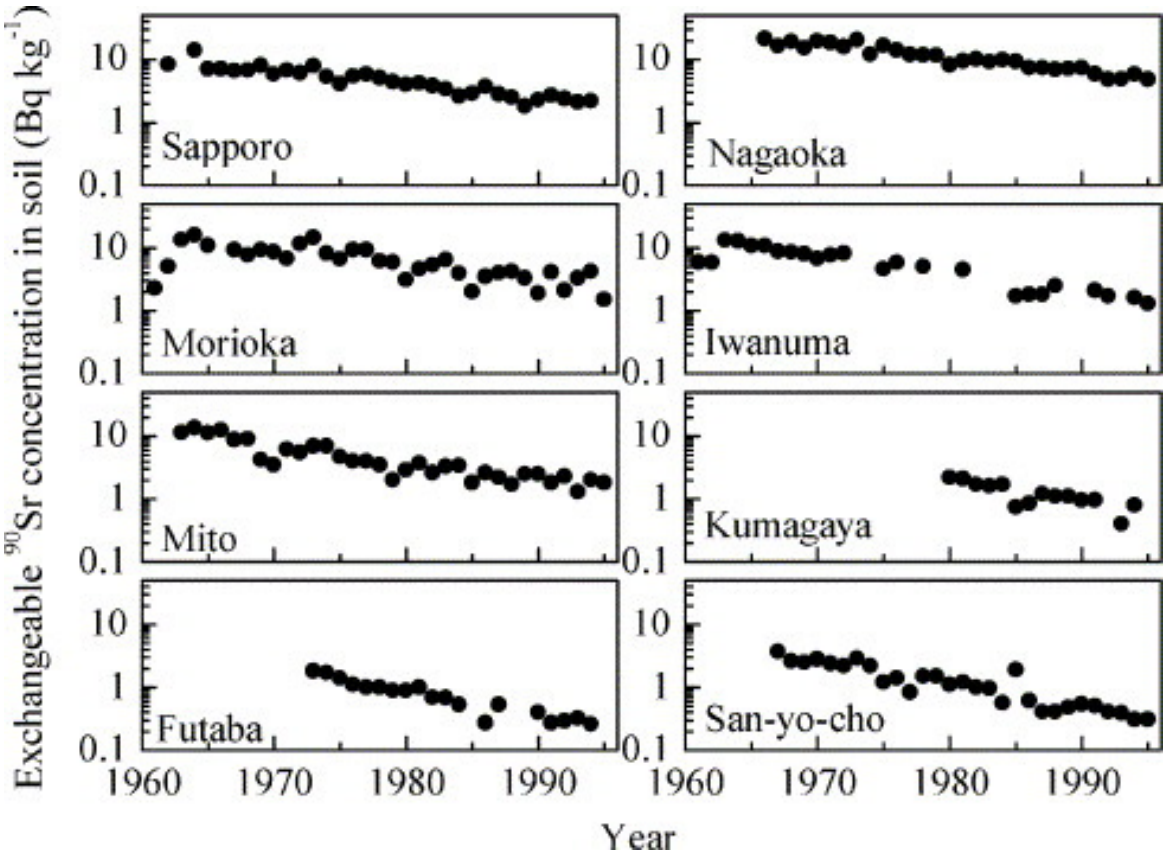
- Yamaguchi, Seki, Komamura and Kurishima (2007) Long-term mobility of fallout 90Sr in ploughed soil, and 90Sr uptake by wheat grain. *Science of the Total Environment*, 372(2-3): 595-604.
- Seki (2011) Remediation of soil contaminated with radionuclides derived from the Fukushima Nuclear Plant accident. *Journal of Business Administraion*, Toyo University 77: 13-26, in Japanese.

Deposition of Cs-137 and Sr-90



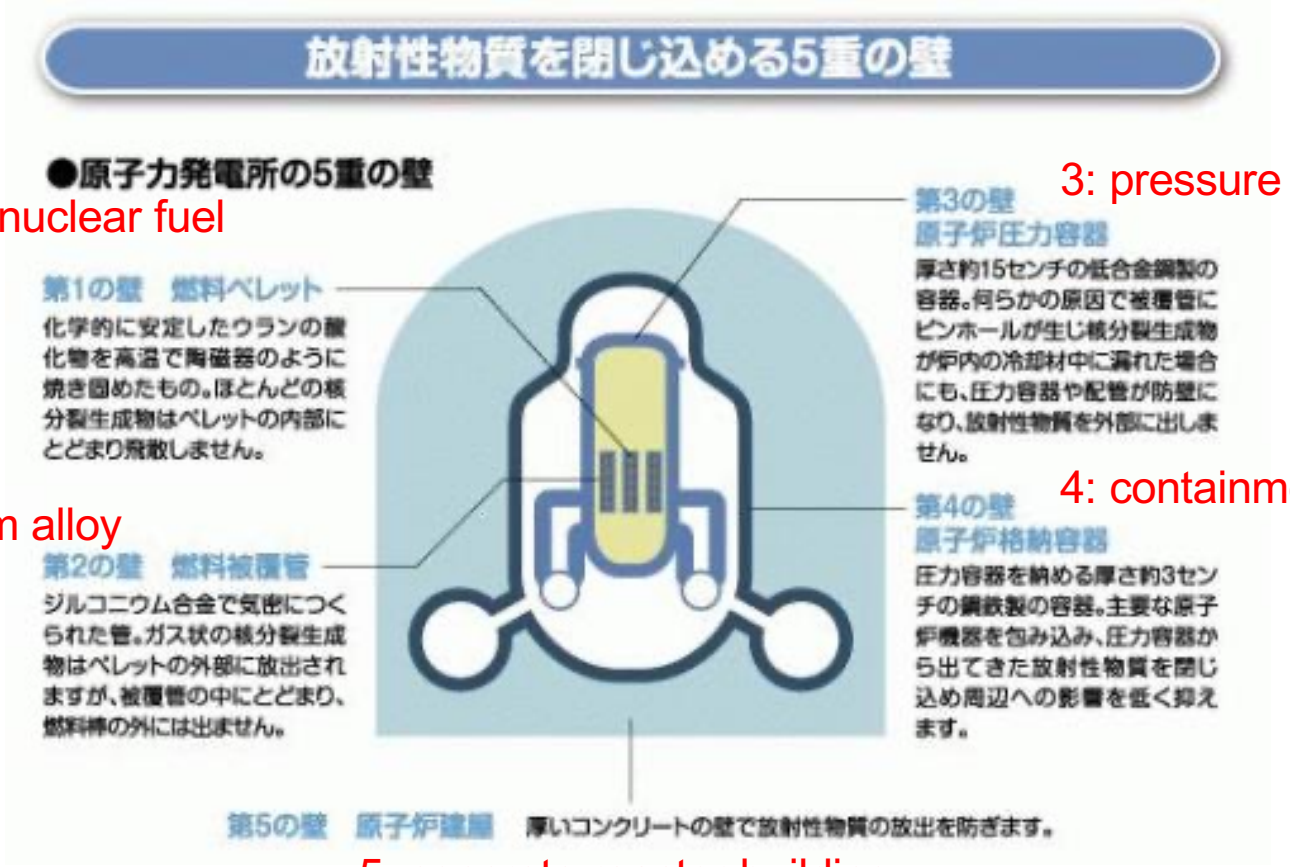
Tsukuba is 150 km away from Fukushima NPP. Until several months after the accident.
PTBT = Partial Test Ban Treaty
(Meteorological Research Institute, 2011)

Yamaguchi et al. (2007)



- Environmental decay factor was calculated.
- CEC was correlated with environmental decay factor and transfer coefficient to wheat grain.
- I didn't believe this research would be so useful, but …

Safety of 5 walls for NPP



1: pellet of nuclear fuel

2: zirconium alloy

3: pressure vessel

4: containment building

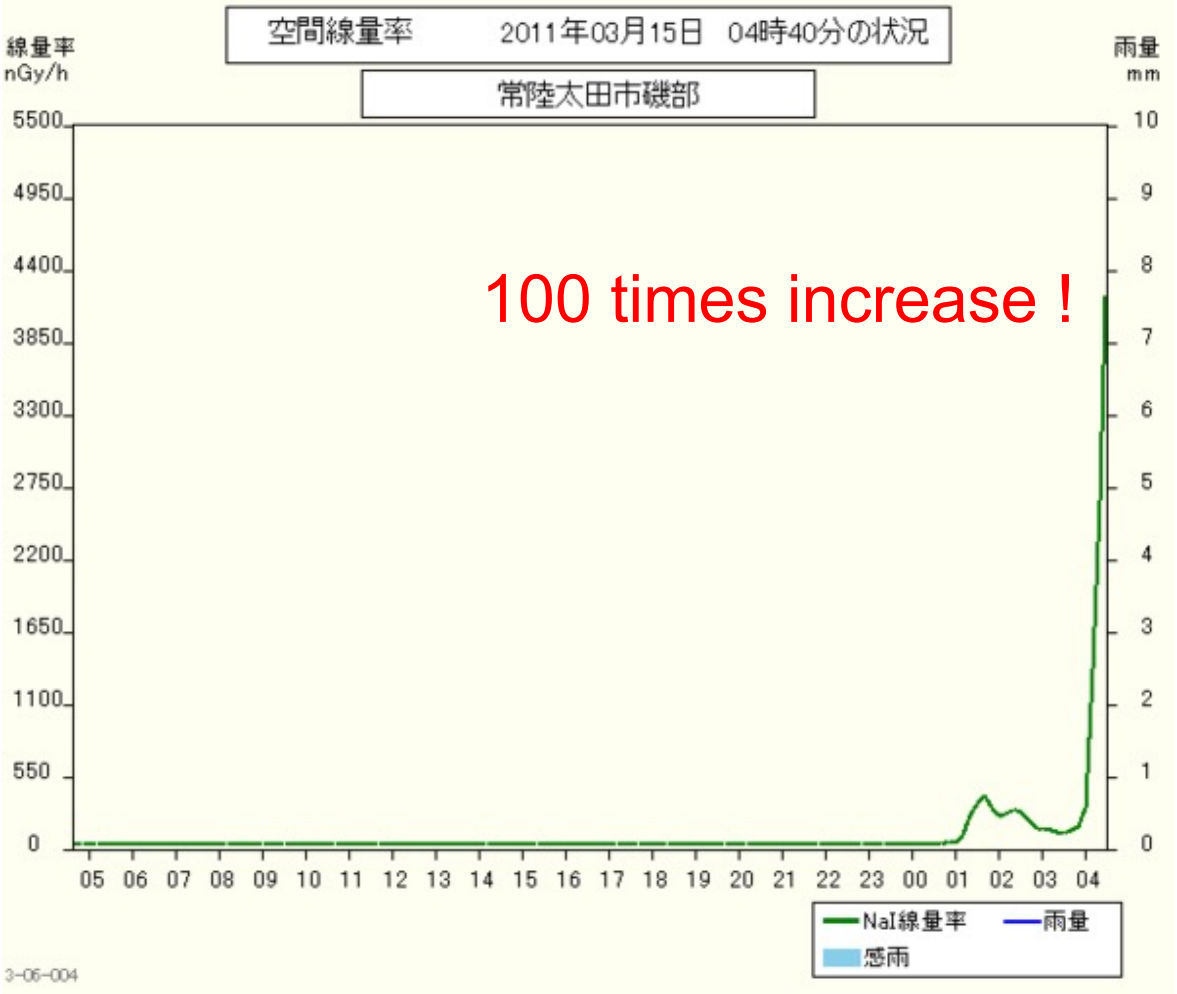
5: concrete reactor building

- It was believed (or explained) that radionuclide will not be emitted in the environment.

Cooling

- After the accident, chain reaction was stopped safely, as expected.
- The decay heat from fission products had to be cooled down. However, the cooling system was broken by earthquake and tsunami. Backup electricity was also broken by tsunami.
- They poured water in nuclear reactors to cool down, but TEPCO said the water level was not rising on TV (14-15 March, 2011). I was scared …

Radiation at Isobe, 100 km from Fukushima



I was looking at this data on time, and understood that radionuclide was actually emitted to environment, and traveled 100 km from Fukushima.
http://www.houshasen-pref-ibaraki.jp/present/result01.html

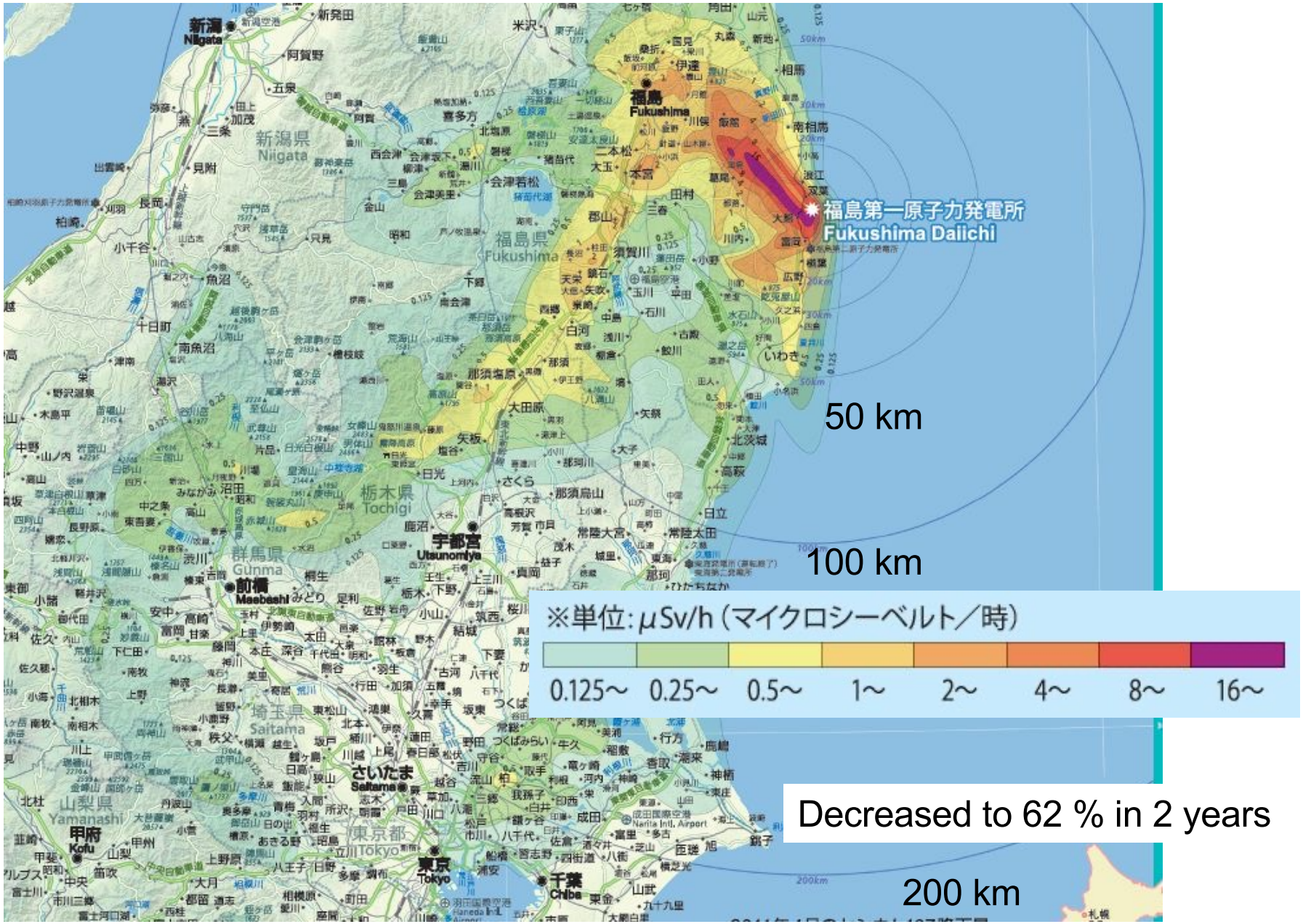
Kyoto, May 15, 2011

Kinkaku-ji (Temple of the Golden Pavilion)

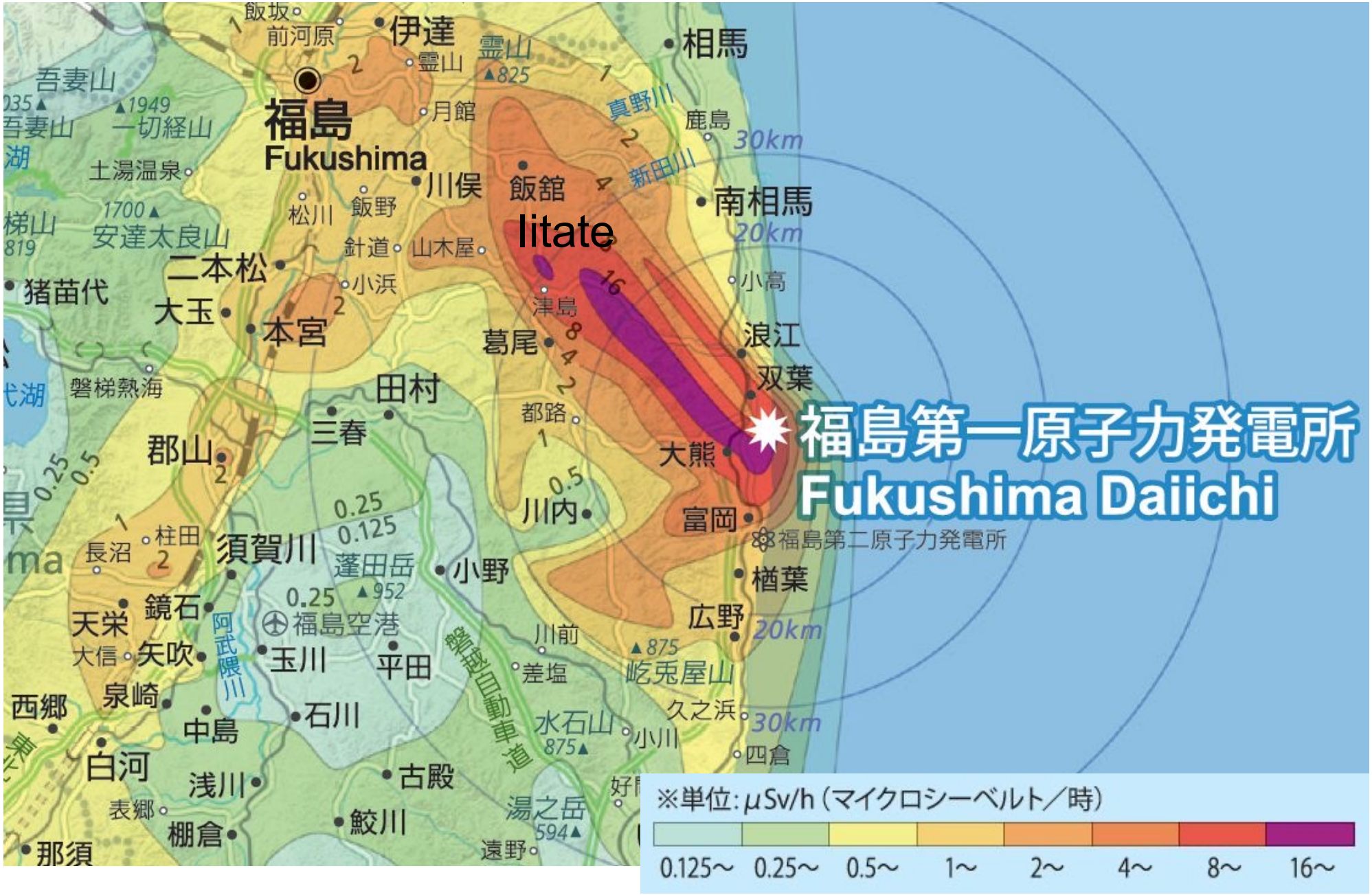
Explosion of 3rd reactor, 11am March 14

Actually it was not the only source of emission.

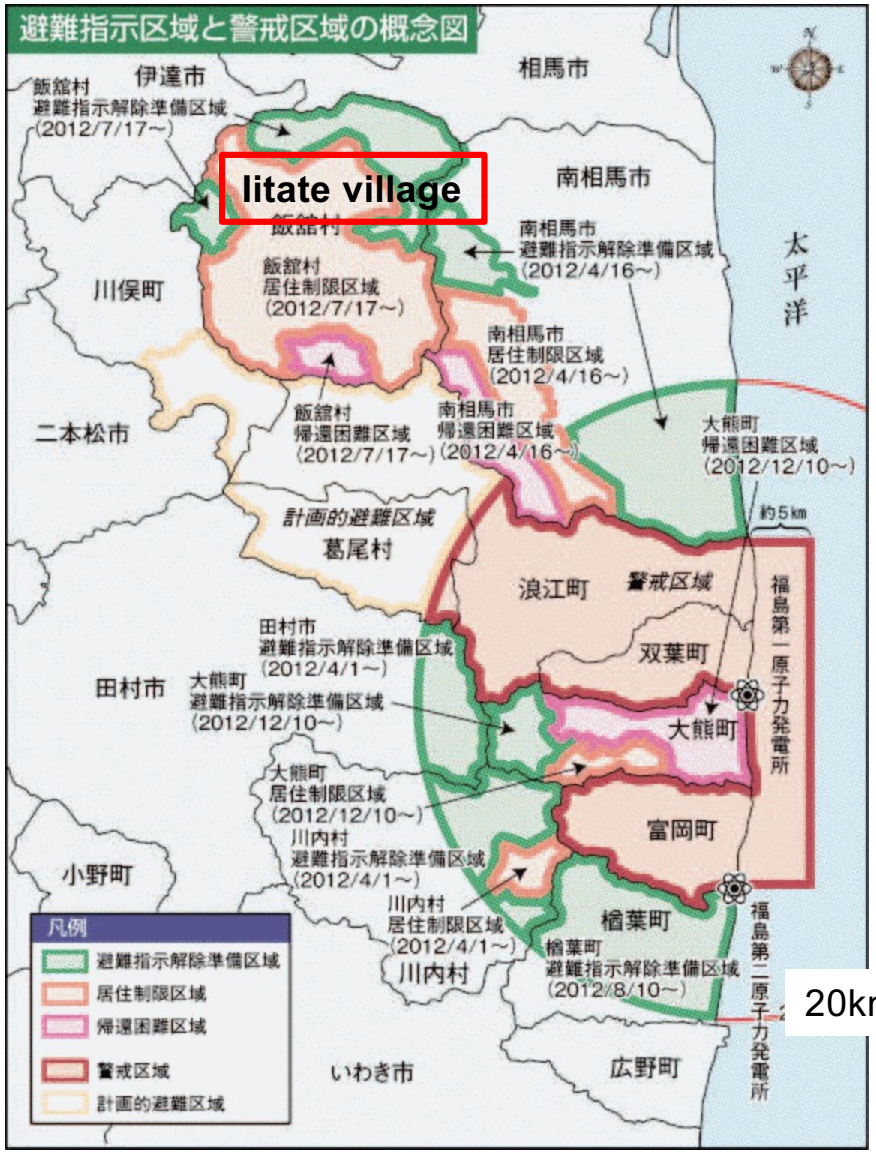
Radiation contour map of Cs-134 and Cs-137 at September 2011 (Yukio Hayakawa)



Evacuation (20 km) Stay in door (20 - 30 km)



Evacuation

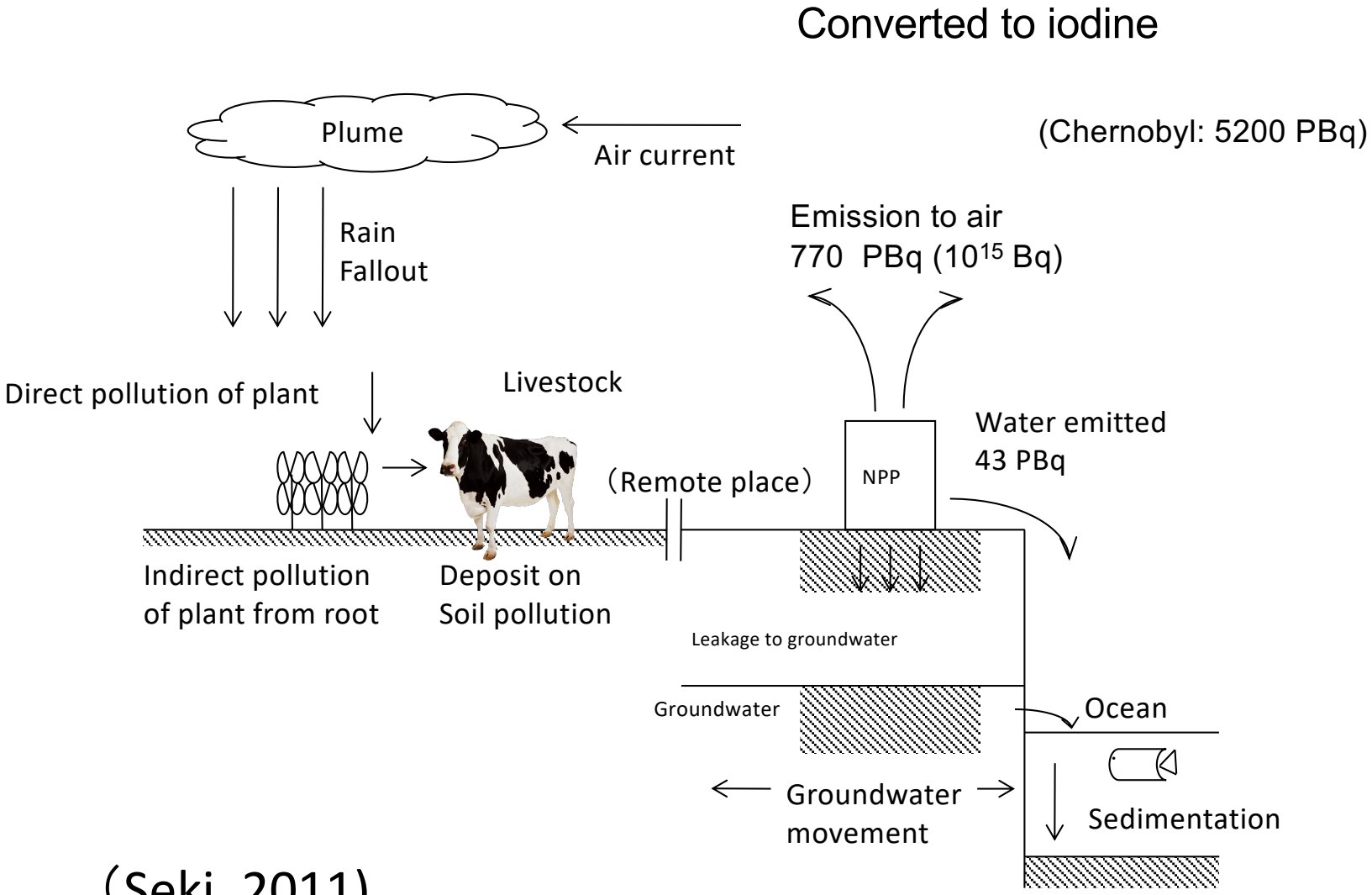


- 160,000 people are evacuating (December 11, 2012, Fukushima Minpo news)
- Warning region
- Hard to return region
  > 50 mSv / year
- Residence restriction region
  > 20 mSv / year
- Preparing for termination of evacuation

Seki (2011)

- Reviewed emission of radionuclides
- Reviewed soil contamination
- Reviewed remediation strategies

Emission of radionuclides from Fukushima Daiichi NPP

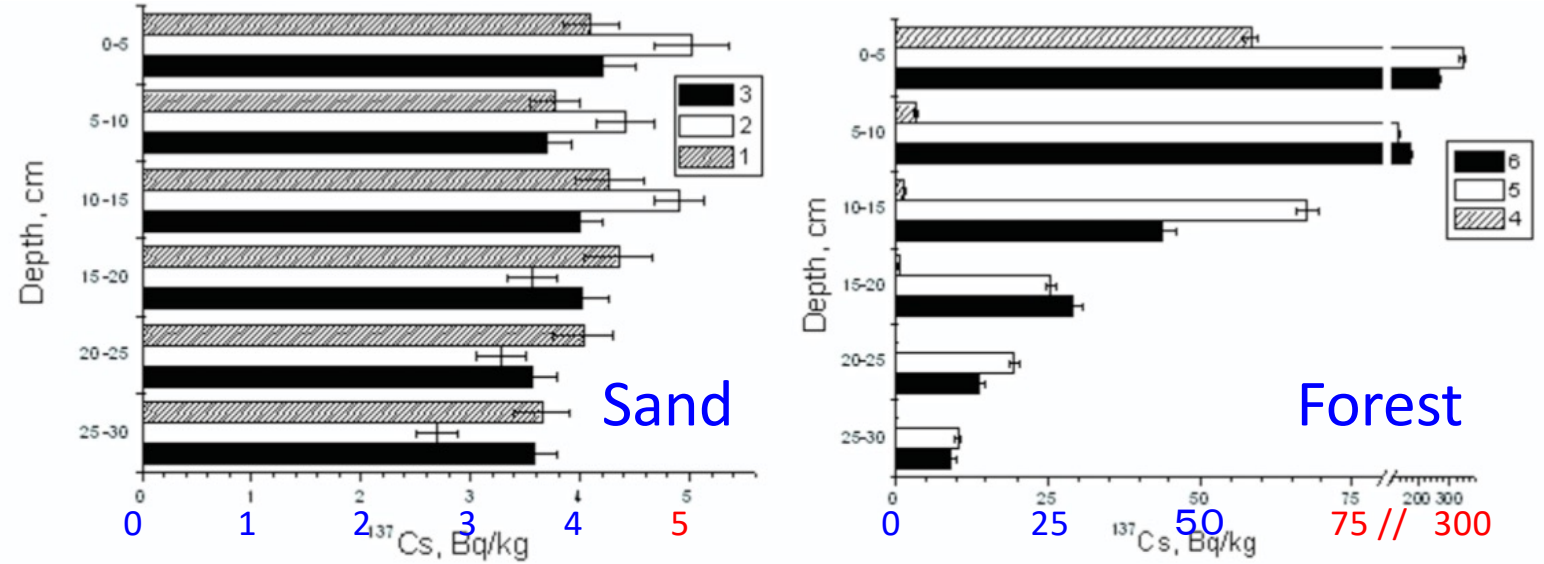


(Seki, 2011)

Radioisotopes

Radioisotope	Half life
I-132	2 hr
Te-132	3 day
I-131	8 day
Sr-89	50 day
Cs-134	2 year
Sr-90	29 year
Cs-137	30 year

Radiocesium movement in soil



Cs–137, Bq/kg

- Cs-137 concentration at Lithuania 17 years after Chernobyl accident (Druteikiené et al., 2011）

Cs-134 and Cs-137 profile at paddy field at Fukushima after 2 months from accident

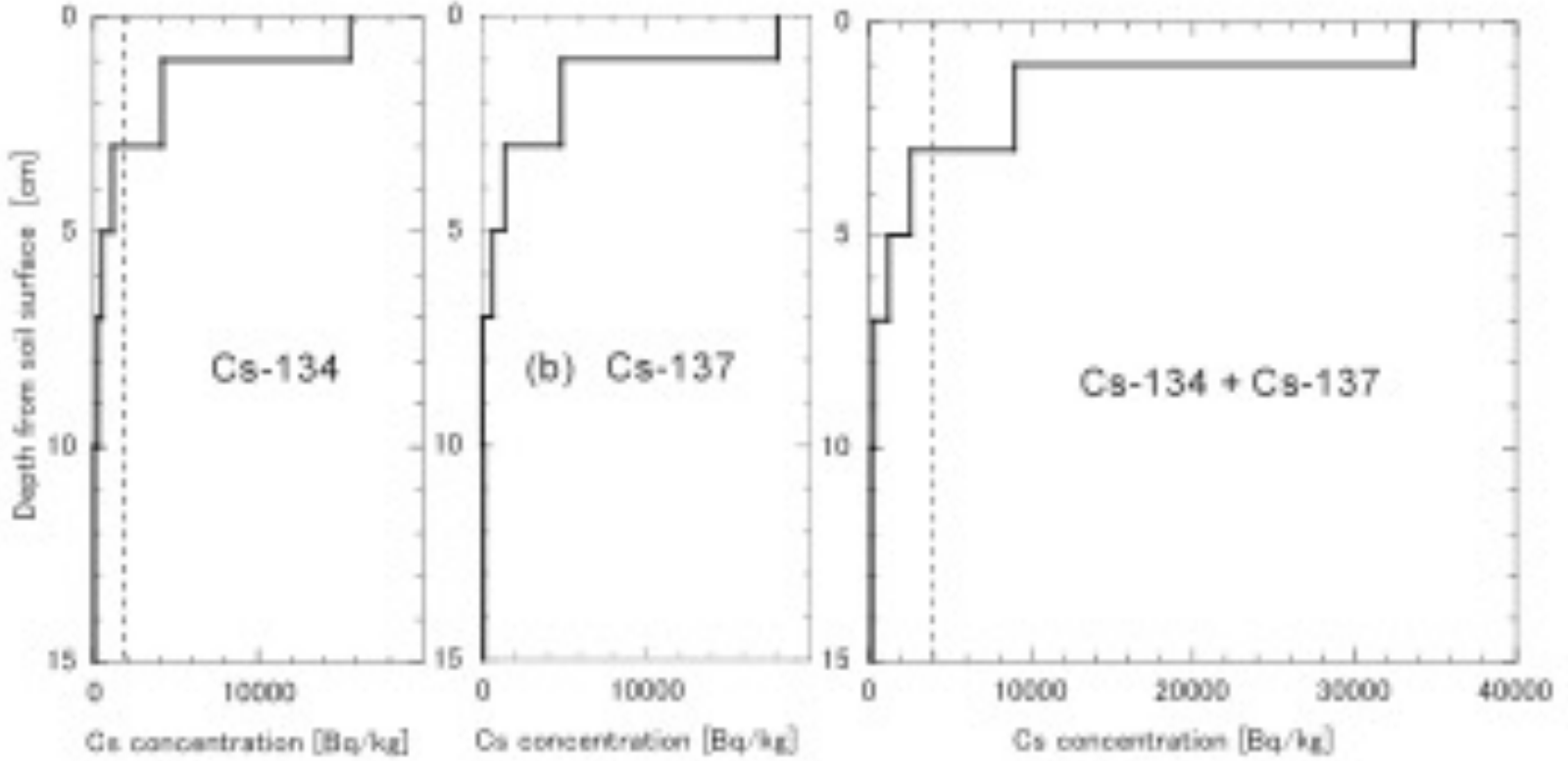
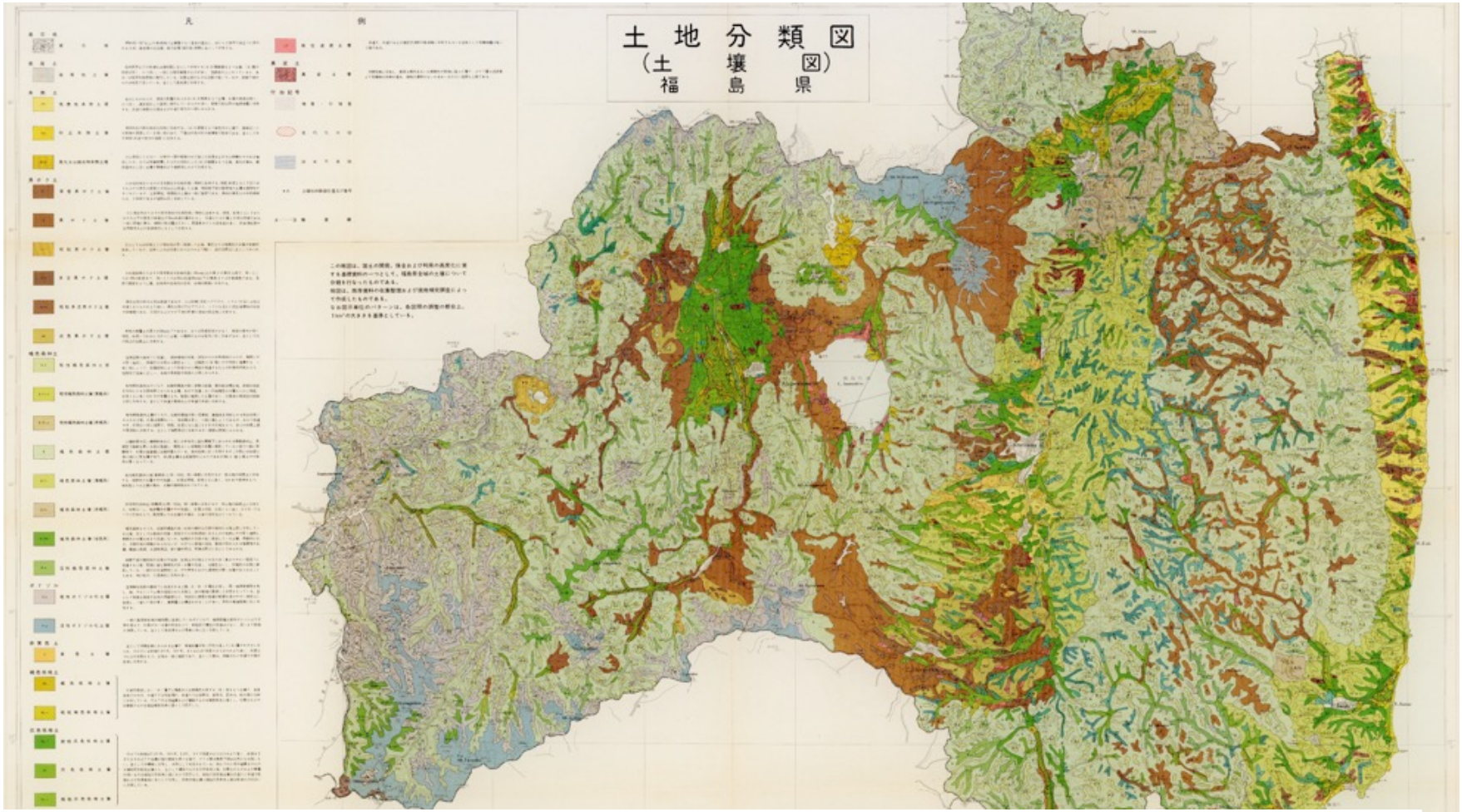


Fig. 1 Radioactive Cs concentration profiles in soil on may 24th, 2011 in undisturbed paddy field (solid line) and plowed paddy field (dashed line).

(Shiozawa et al., 2011)

Soil in Fukushima

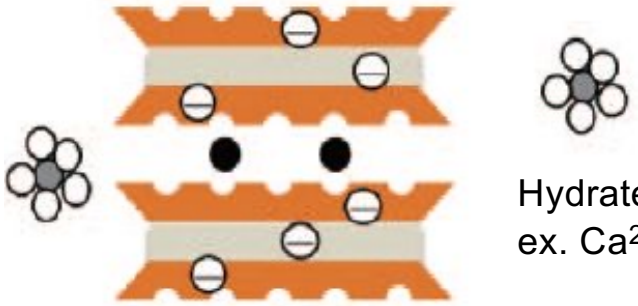


Mostly brown forest soil and lowland soil. Also volcanic ash soil (Andisol).

Ministry of Land, Infrastructure, Transport and Tourism, Japan

Cesium adsorption on Clay particle

(1) Beidellite

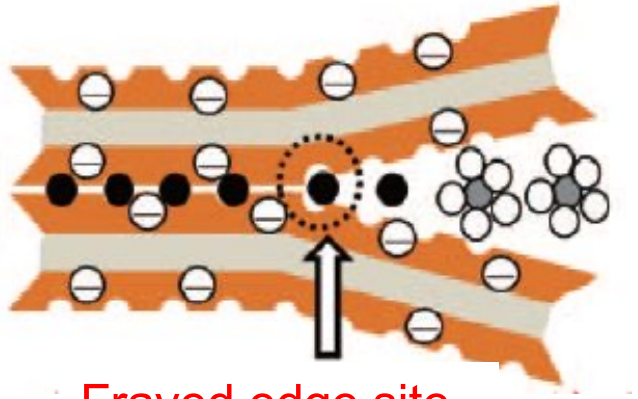


Hydrated ions
ex. Ca^{2+}

It can swell, but when Cs^{-} enters between sheets, it shrinks and Cs^{-} is trapped.

Phyllosilicate (Sheet of SiO_4 tetrahydra) has siloxane ditrigonal cavity similar to the size of Cs^{-}

(2) Vermiculite, illite

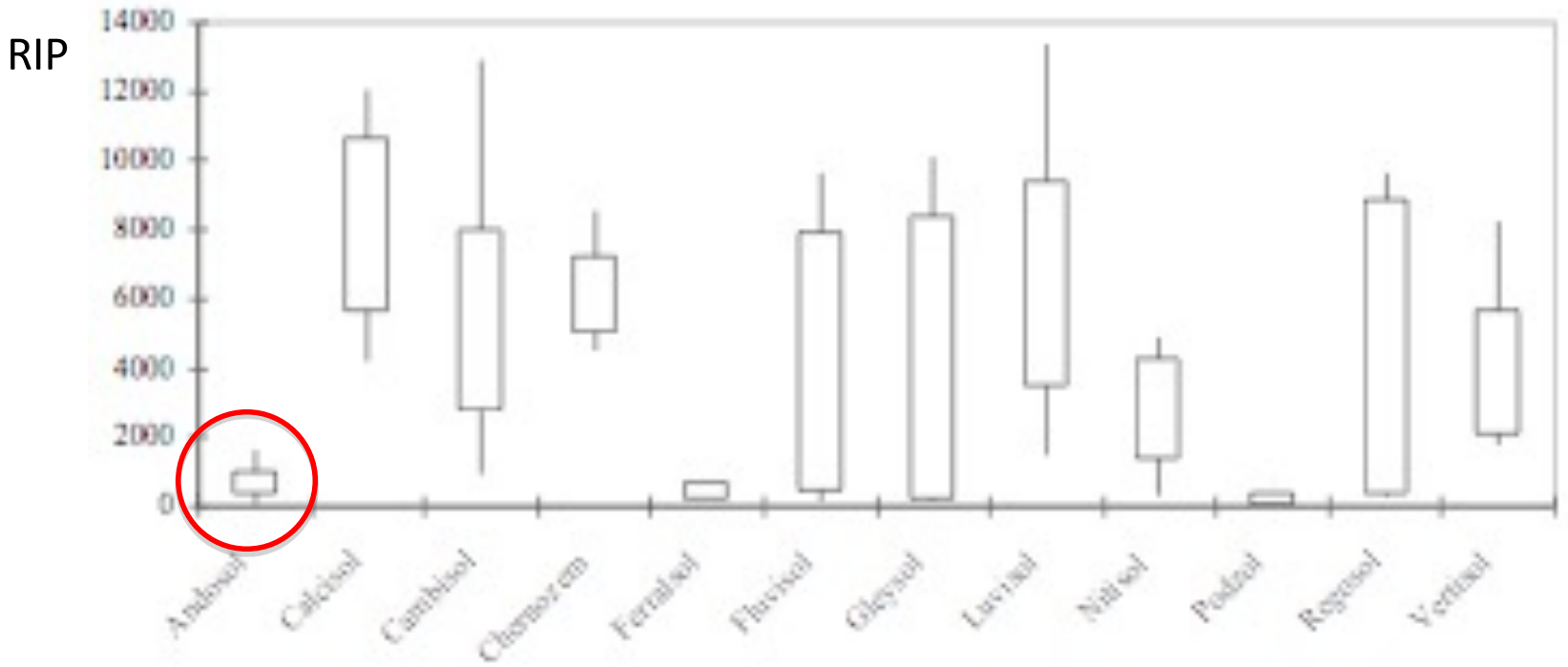


Frayed edge site

- Takes long time to access
- Once Cs^{-} is trapped, no escape
- Small ratio to whole charge
- Main cause of Cs^{-} entrapment

(Yamaguchi et al., 2012)

RIP (Radiocesium Interception Potential)



(Vandebroek et al., 2009)

Andisol has small RIP

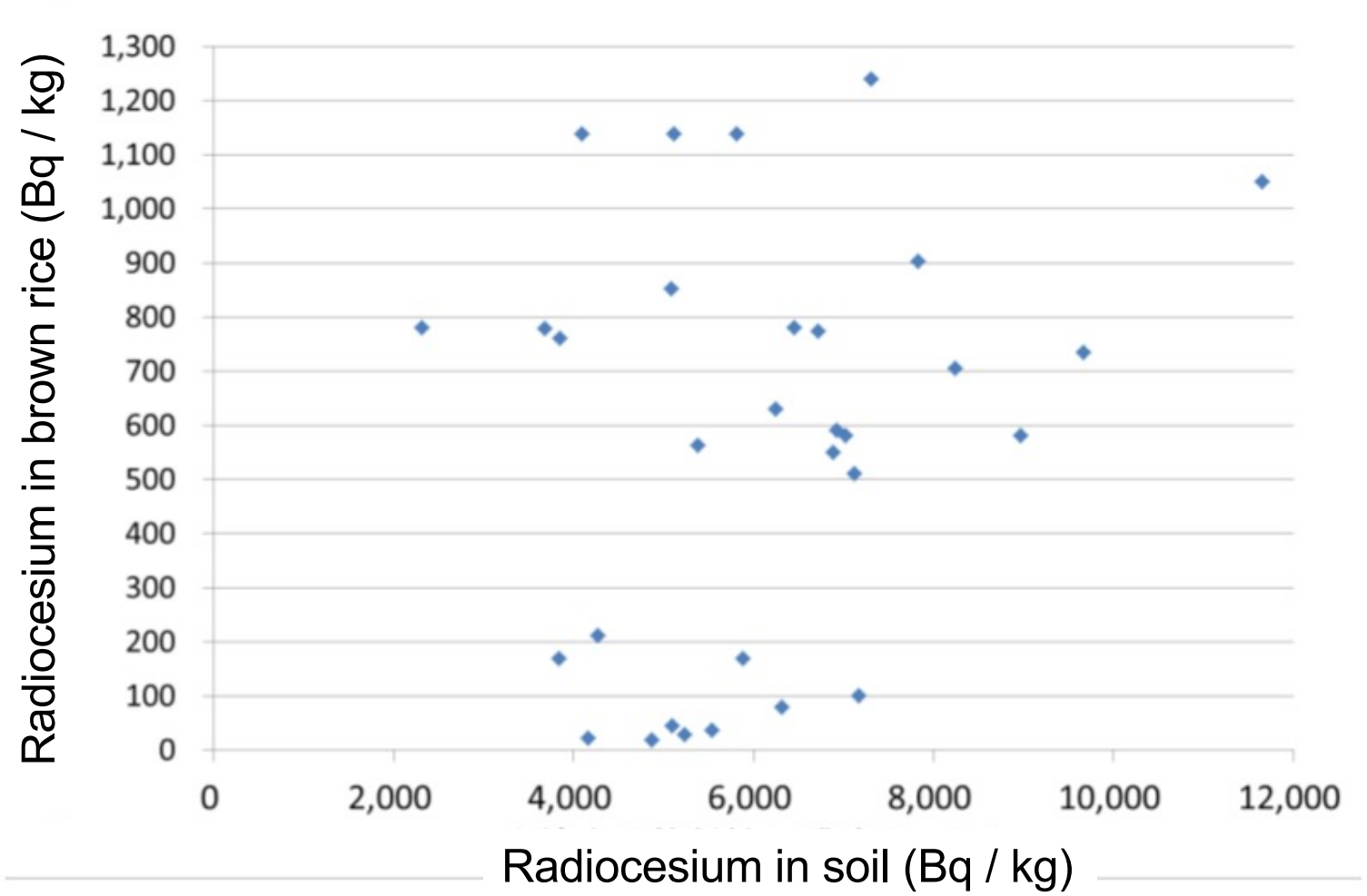
Transfer coefficient (TC)

- $$TC = \frac{\text{Cs-137 in agricultural product}}{\text{Cs-137 in soil}}$$
- TC of brown rice was set as 0.1 on April 8, 2011 by MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan)
- MAFF published transfer coefficient of vegetables and fruits on May 27, 2011 http://www.maff.go.jp/j/press/syouan/nouan/110527.html

Rice in Fukushima

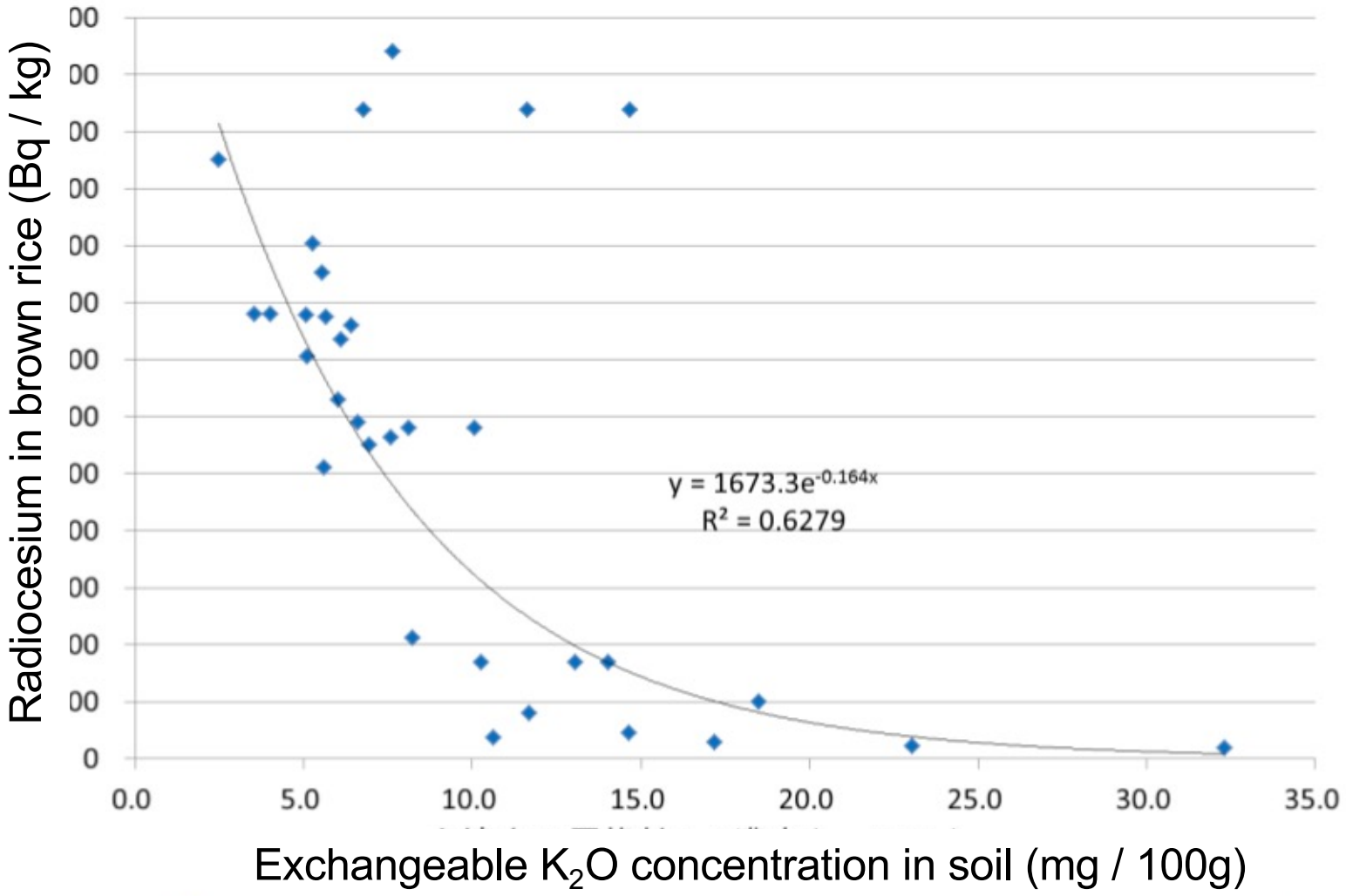
- Plantation of rice with soil more than 5000 Bq/kg was prohibited. Temporal regulation was 500 Bq/kg, and TC of 0.1 was assumed.
- At first, most rice was below 500 Bq/kg, but some rice exceeded 500 Bq/kg.
- Regulation changed to 100 Bq/kg on April 1, 2012, based on the limit of radiation exposure of 1 mSv / year.

Radiocesium in soil and rice (2011)



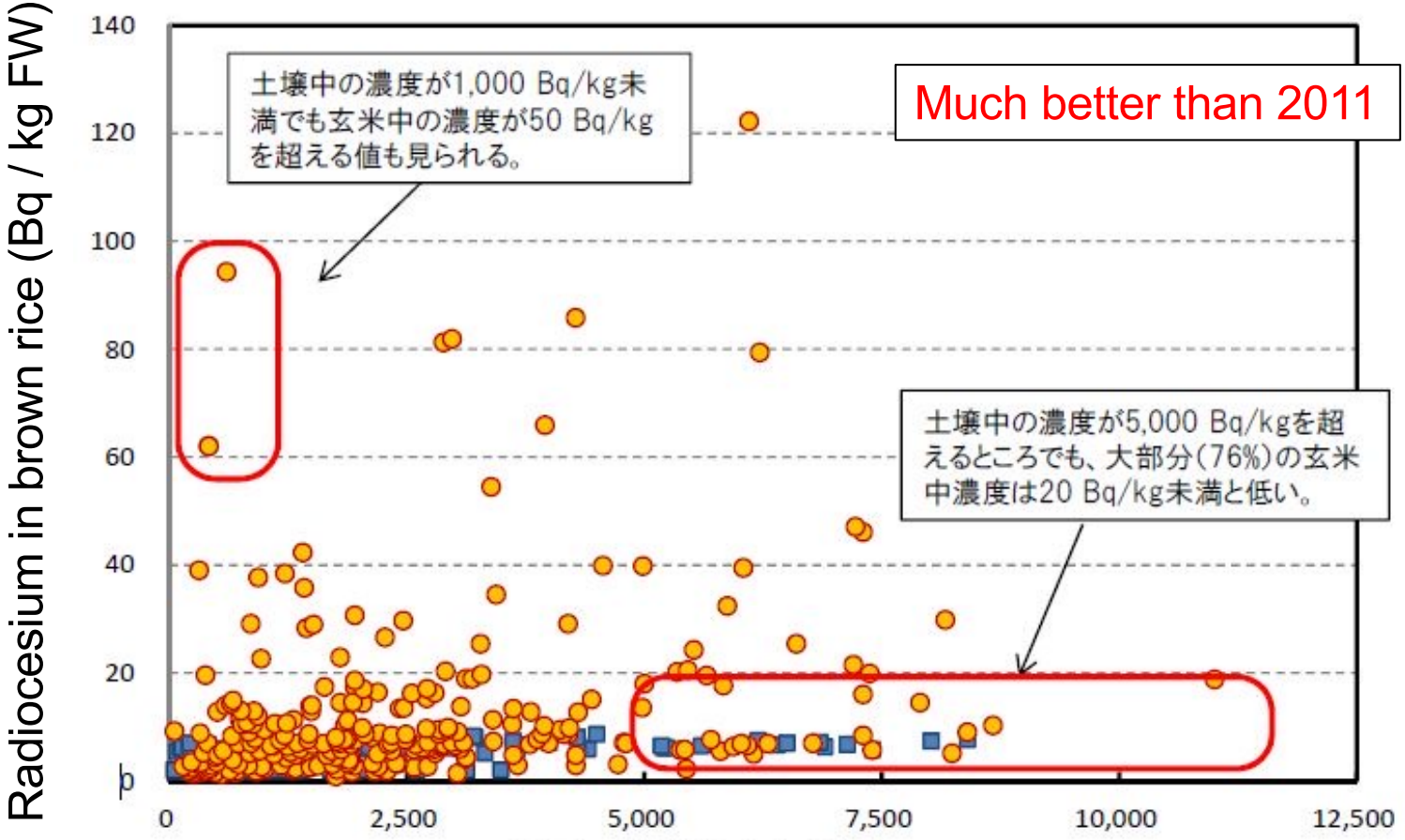
(Fukushima Prefecture and MAFF, 2011)

Potassium in fertilizer (2011)



(Fukushima Prefecture and MAFF, 2011）

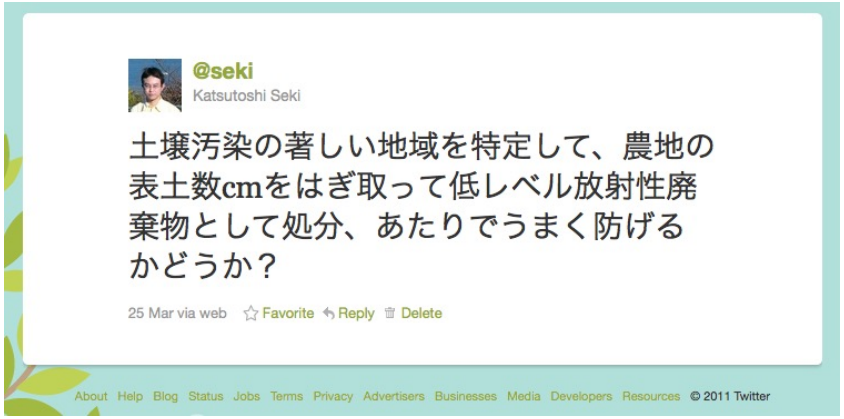
Radiocesium in soil and rice (2012)



(Fukushima Prefecture and MAFF, 2013)

Countermeasures (Seki, 2011)

- Stripping of surface soil
- Turn over surface soil with subsoil
- Application of K fertilizer
- Change to crops of low transfer coefficient
- Phytoremediation
- Chemical remediation



Identify the contaminated area, remove soil of several cm at the surface, and discard it as radioactive waste. Does it work ?

(Twitter @seki, March 25, 2011)

Stripping of surface soil

- As long as radiocesium is in a few centimeters, it can be removed.
- Planned for paddy field uncutivated after 2011 (> 5000 Bq/kg, ex. Iitate). Once cultivated, it is ieffective.
- Depth of contamination should be examined.
- Massive amount of soil as radioactive waste disposal.

Radioactive waste disposal site

- Final disposal site is not determined.
- Not enough temporal storage site.

Temporal temporal storage site at Iitate village

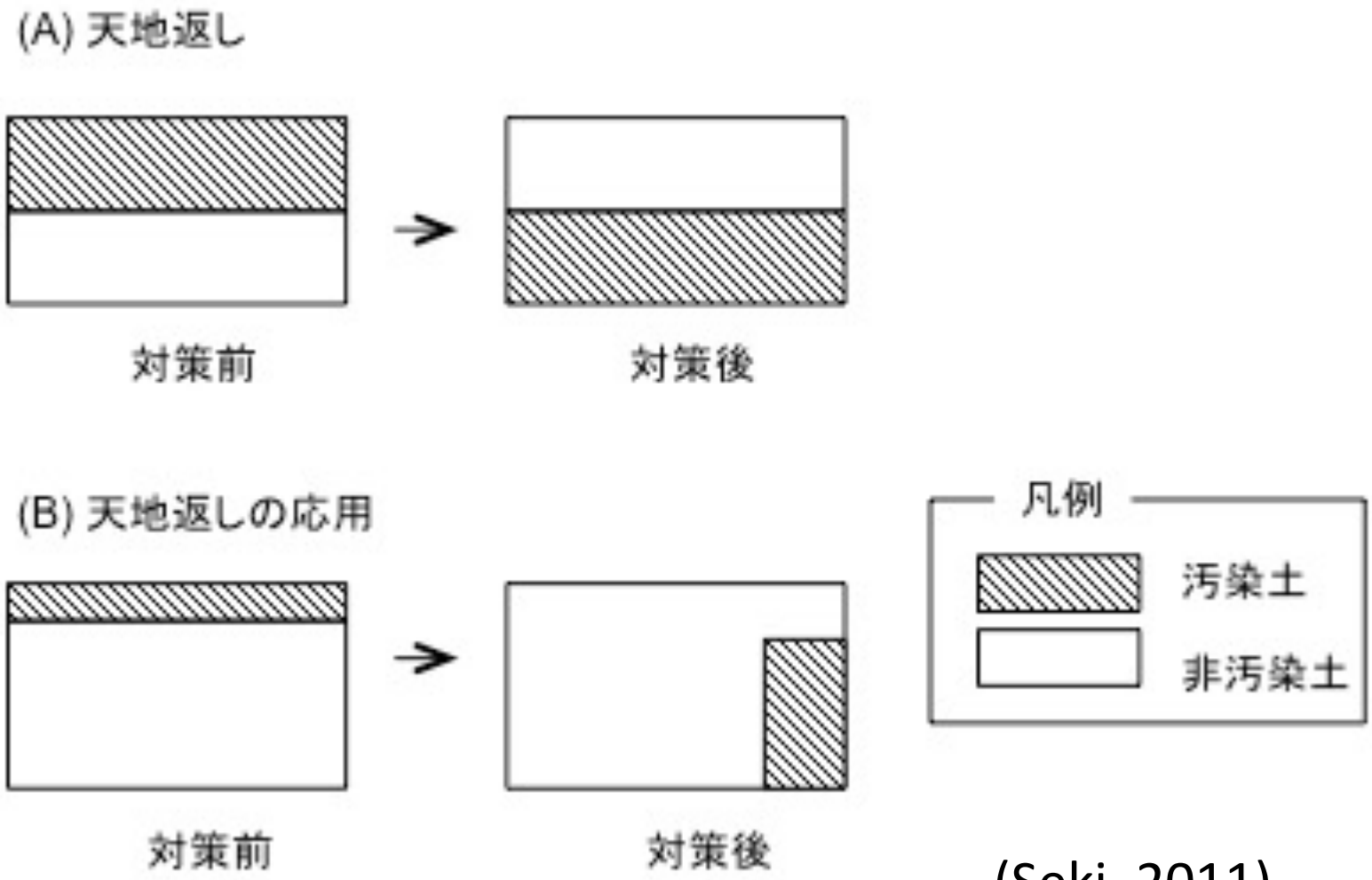
Osamu Ieda
http://www.kyoten.org/top_seminar12.html

Stabilizer of soil

- Difficult to remove surface soil of paddy field.
- Stabilizer with magnesium can be used before removal.
- Contaminated soil can be easily identified.

http://www.s.affrc.go.jp/docs/press/110914.htm

Turn over



(Seki, 2011)

Change crops

- Change to crops with lower transfer coefficient.

Phytoremediation

- Make plant absorb contamination.
- Experiment with sunflower showed that it is not very effective.
- Plant should be safely disposed.
- Depth of root and depth of contamination should be examined.

Chemical remediation

- No efficient way of chemical remediation now.
- Cesium is too strongly adsorbed on clay.
- Besides, concentration is less than 10000 times lower than cadmium contamination.
  - 100 Bq/kg of radiocesium = 0.032 ppb
  - 400 ppb for Cd

Problem for decontamination

- High cost – 100 trillion yen or more, to attain < 1mSv / year.
- Final disposal site is not determined.

Battle of soil scientists in Fukushima, Japan

ASA, CSSA and SSSA Annual Meeting, Tampa, Florida, November 4, 2013

- Enhancing vertical transport with artificial macropore
- Device to measure radiocesium concentration
- Cooperation of NGO with researchers to resurrect Fukushima
- Field monitoring system for sediment and radiocesium runoff
- Colloid facilitated transport of radioactive cesium
- Role of clay mineral in radioactive Cs transport
- Recovering soil fertility after stripping
- Burial experiment of soil contaminated by radiocesium
- http://www.iai.ga.a.u-tokyo.ac.jp/mizo/edrp/fukushima/ASA13/

Still long way for safeguarding Fukushima

- Nuclear fuel is melt down, how can we take out? We have no plan yet.
- Nuclear fuels in the pool of 4^{th} reactor are now transported to safer place.
- Stop the leakage of contaminated water
- Water cleanup system of ALPS (France) – until the end of 2014
- 40 years is enough?

Problems

- Many workers get limit radiation 100 mSv / year and cannot work any more. They work in very bad condition.
- Earthquake probability is always high in Japan. If “unpredicted” accident happens again, who can do the recovery work ?
- Risk for big earthquake is always large in Japan.

Energy in future

- In Japan, all NPP is stopped now for regular maintenance. They are waiting for safety judging.
- Government still wants to promote nuke, but strong movement of anti-nuke in citizens.
- We need to seek for transition to other energy sources.
- How about in France ?

Final remark

- We are still in the process of recovering from the disaster.
- This talk focused on soil contamination and remediation. I would like to contribute something in this field as a soil scientist.
- France and Japan can share our knowledge and techniques for better future of our countries.

Merci