Radioecology after Fukushima

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Content

- The Fukushima accident: VERY short reminder
- Comparison to post-Chernobyl situation
- Challenges of post-Fukushima radioecology
- Technical innovation
- Monitoring
- Remediation work
- Challenges to the radioecological community

- Issues can be addressed only very superficially!
- No discussion of individual results

The accident at Fukushima Daiichi NPP

11 March 2011:
- "Great Tohoku Earthquake" → loss of external power
- tsunami → blocks 1-4 inundated → electrical equipment fails
- loss of heat removal → core melting within hours
- H explosions, ventings, containment failure of block 2 → large emissions of radionuclides

Causes:
- design shortcomings,
- insufficient "safety culture"

Consequences: ~10^3 km² contaminated, evacuations, moderate thyroid doses (some cases of high doses), socio-psychological, economical and political consequences

from Wikipedia

Comparison with Chernobyl

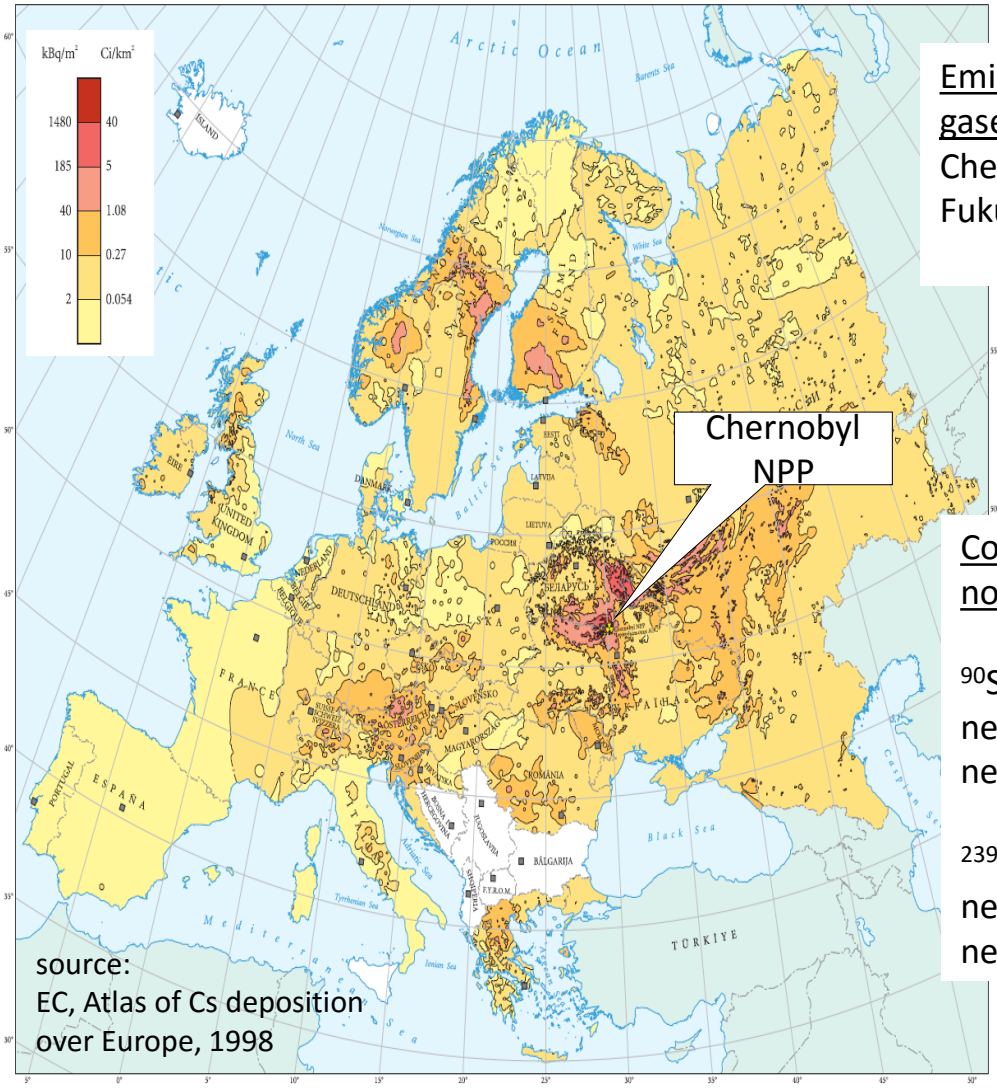
Chernobyl, 26 April 1986
- badly conducted experiment
  → criticality, reactor excursion
- explosion, loss of cooling, core melting, graphite fire
- large emissions of radionuclides

Causes:
- design shortcomings,
- insufficient “safety culture”

Consequences: acute radiation fatalities,
~10^5 km² contaminated, evacuations,
high thyroid doses, medical, socio-psychological,
economic and political consequences

from Wikipedia

Comparison 2

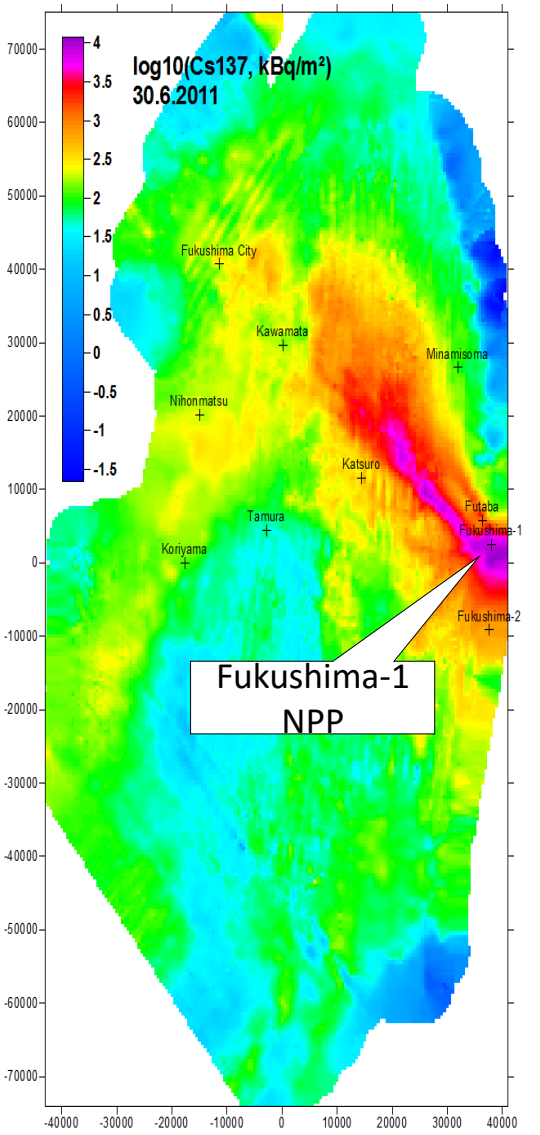


Emissions excl. noble gases:
Chernobyl ~ 5300 PBq,
Fukushima ~ 520
(340-800) PBq

Contribution of non-volatile elements:

$^{90}Sr/^{137}Cs$:
near Chernobyl ~ 0.3
near Fukushima ~ 0.01

$^{239+240}Pu/^{137}Cs$:
near Chernobyl ~ 0.01
near Fukushima ~ 10^{-7}



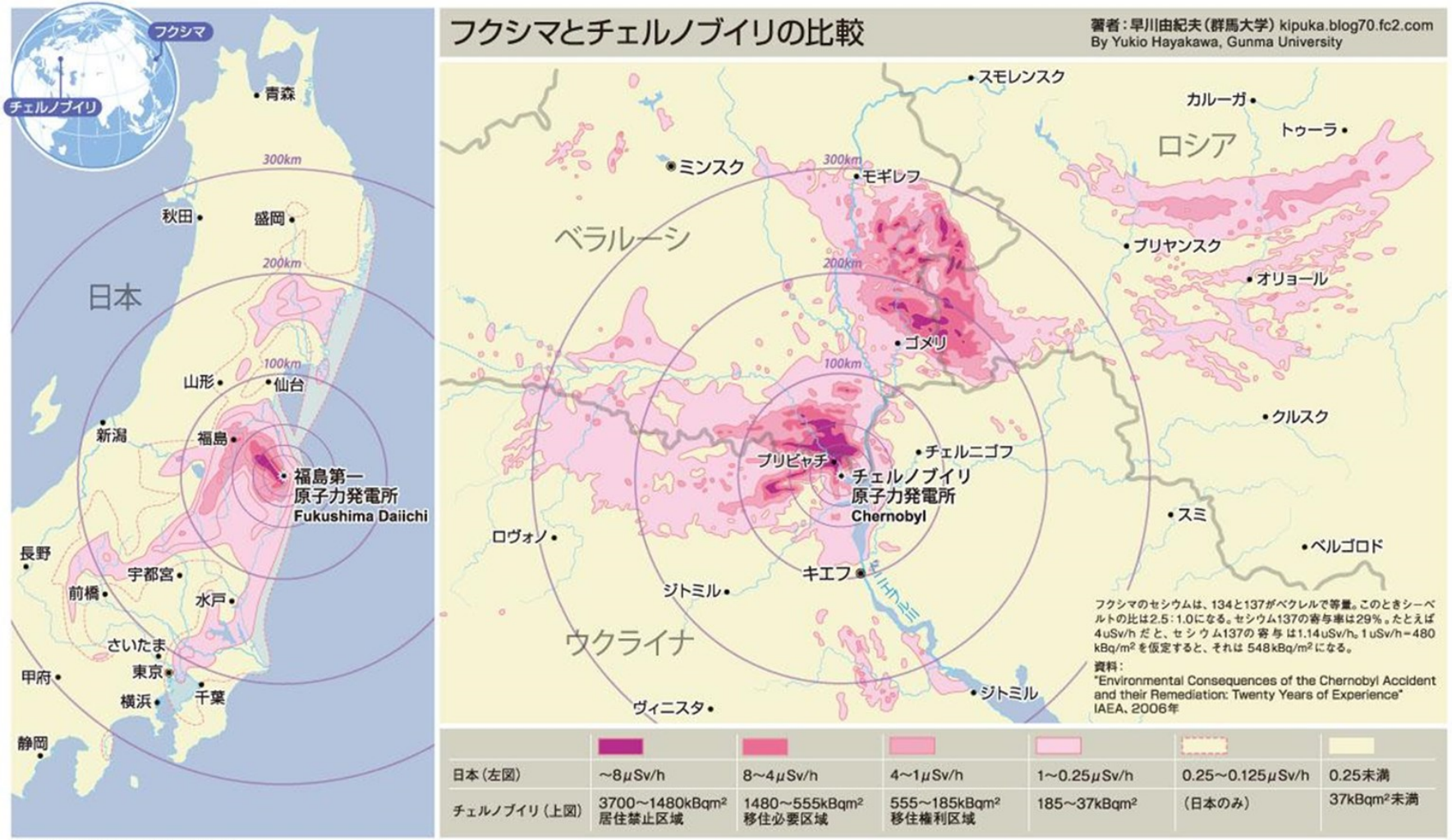
from airborne gammaspec. data

thyroid cancer: *Chernobyl* incidence ~10^4, fatalities ~20; *Fukushima* incidence maybe a few, fatalities 0
total fatalities: *Chernobyl* observed ~10^2, estimated up to 10^4-10^5; *Fukushima* observed 0, estimated up to 10^2-10^4

(earthquake: 2303, tsunami 20159 dead or missing)

Comparison 3

Extent of contaminated areas in same scale



改訂版 2011年12月9日（初版4月15日）
この地図の作成には、文部科学省科学研究費補助金「インターネットを活用した情報共有による新しい地学教育」（番号23501007）を使用しました。
地図製図：萩原佐知子（TUBE graphics）

Specific situation in Fukushima

- emission: long lasting, variable composition, variable deposition mechanism → very patchy deposition pattern
- topography: steep hills and valleys → particular run-off and erosion characteristic; topography enhances patchiness
- soil types: mainly volcanic → migration properties to be assumed different from soils which have been mainly studied in the past in Europe and N America
- climate: very humid → migration of radionuclides in hydrosphere; erosion
- vegetation: very dense evergreen forests → act as radioactivity reservoir
- nutrition habits: rice, soy, tea, seafood, fruits such as loquat → partly little investigated in the past
- sociological: rural population, strong emotional ties to their traditional land → particular problems with resettlement and remediation

Important research topics

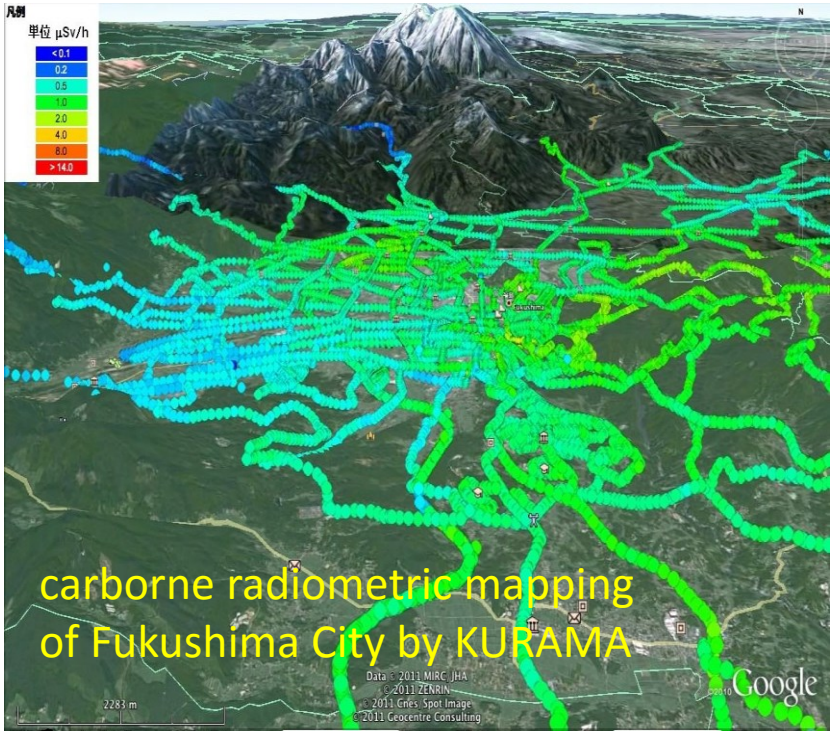
- soil: Cs retention, sorption and migration properties, radio-Cs interception potential (RIP) as measure of soil vulnerability
- plants: Cs uptake for nutritional plants (rice, soy!) in dependence of soil chemistry; how to reduce uptake
- forest: Cs inventories, balances, fluxes, peculiarities of forest soils
- marine environment: dispersion in the Pacific Ocean, fixation in sediments, impact to marine life; uptake by and depuration from fish
- freshwater environment: groundwater contamination, freshwater biota
- catchments: Cs transport by run-off, dispersion by streams, sorption by sediments, rice paddy irrigation water
- area contamination: reconstruction of ^{131}I deposition, which in the initial stressful days could not be assessed properly; assessment of temporal development
- atmospheric transport modelling: reconstruction of source term, model validation
- efficiency of decontamination: reduction of gamma dose rate (target: < 1mSv/a), possibility to resettle affected areas; decontamination of forest edges; secondary unwanted consequences?

Technical innovation

- Mobile detectors:
  - novel materials: $LaBr_3$, CdZnTe, etc.
  - carriers: drones carrying detectors
- Connecting data sources:
  - geo-referencing during measurement, send data to databases in real time
  - data not individual data but "arrays" of quantities (actual measurement result, location, meteo,…)
- "Citizen scientists":
  - "Democratization" of monitoring → credibility
  - efficient acquisition of large amounts of data
- Mass spectrometry:
  - increasingly available on an affordable commercial base
  - high sensitivity: e.g. Pu: LLD (AMS): 10^6 Pu atoms vs. α-spectrometry: 10^8-10^9 atoms
  - separate ^{239}Pu / ^{240}Pu
  - "difficult" and "exotic" radionuclides: ^{129}I, ^{237}Np, ^{135}Cs, etc.
- Atmospheric transport modelling
  - development of models
  - increasing calculation power

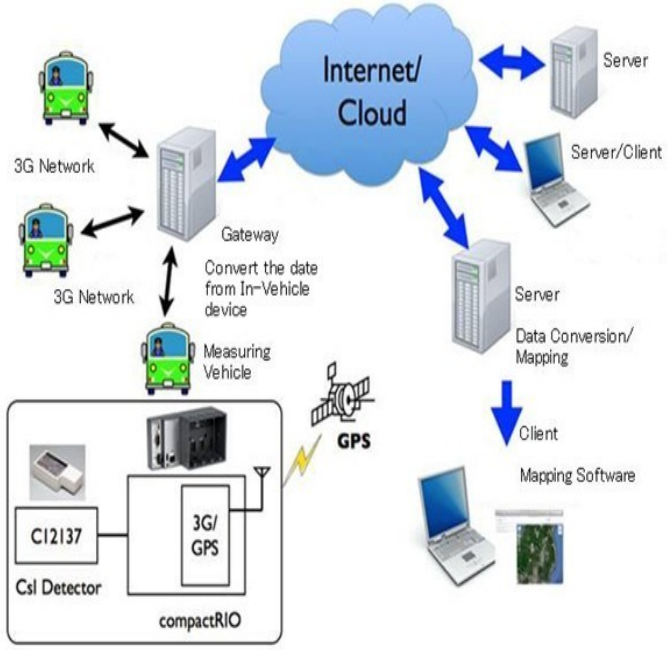
Example 1

KURAMA-2 mobile monitoring system, developed by Kyoto uni., now commercial
recurrent surveying of same route → temporal development



from www.pref.fukushima.lg.jp.e.od.hp.transer.com/sec/16025c/genan28.html

from Tanigaki et al.: Current status of a carborne survey system, KURAMA;
http://accelconf.web.cern.ch/AccelConf/ICALEPCS2013/papers/tucoca06.pdf



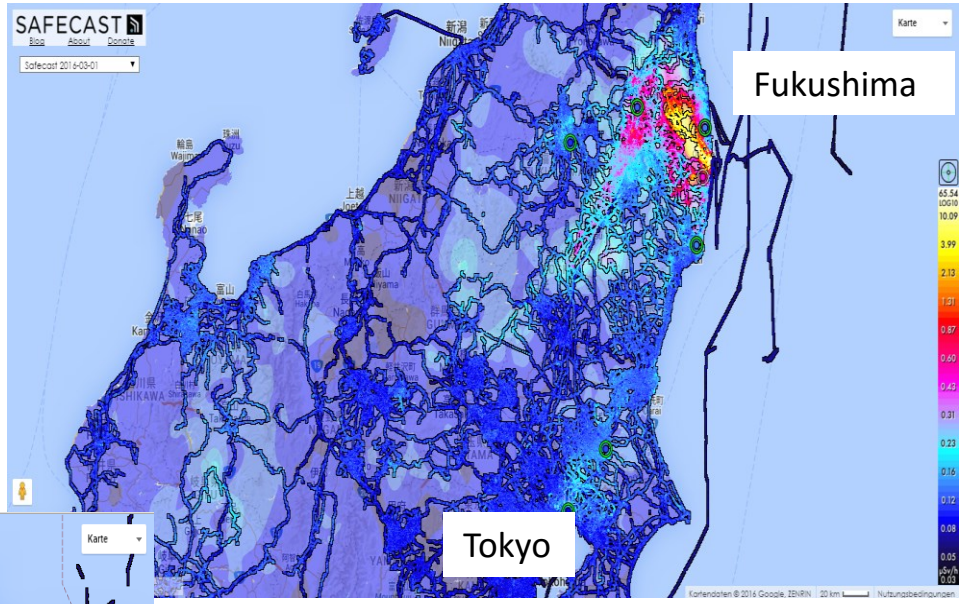
from
http://sine.ni.com/cs/app/doc/p/id/cs-14802#

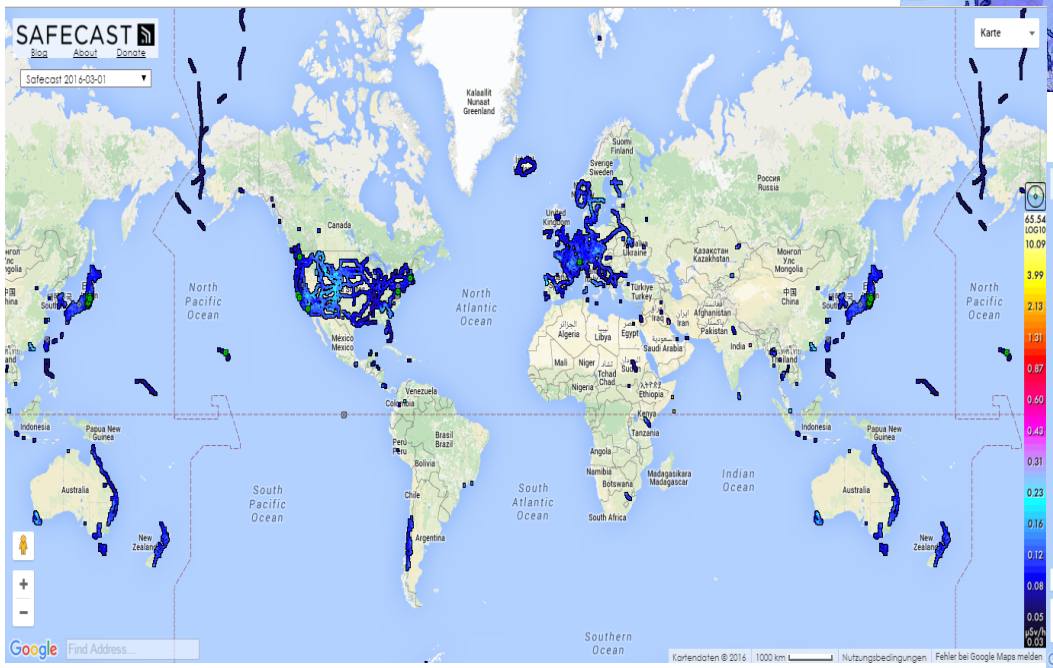
Example 2

Citizen scientists –

SAFECAST (http://blog.safecast.org/) standardized G-M counter, QA, connected to GPS; data log → transfer to central. Data are open accessible (~5 GB).

Maps: 1 Mar. 2016

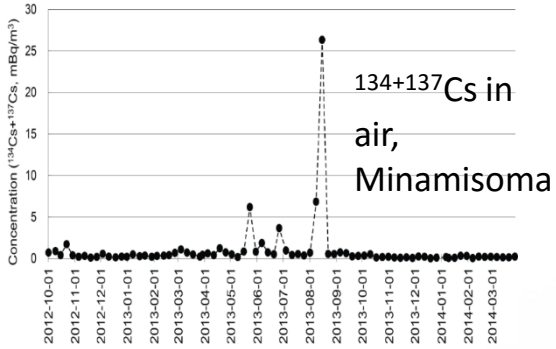




Remediation

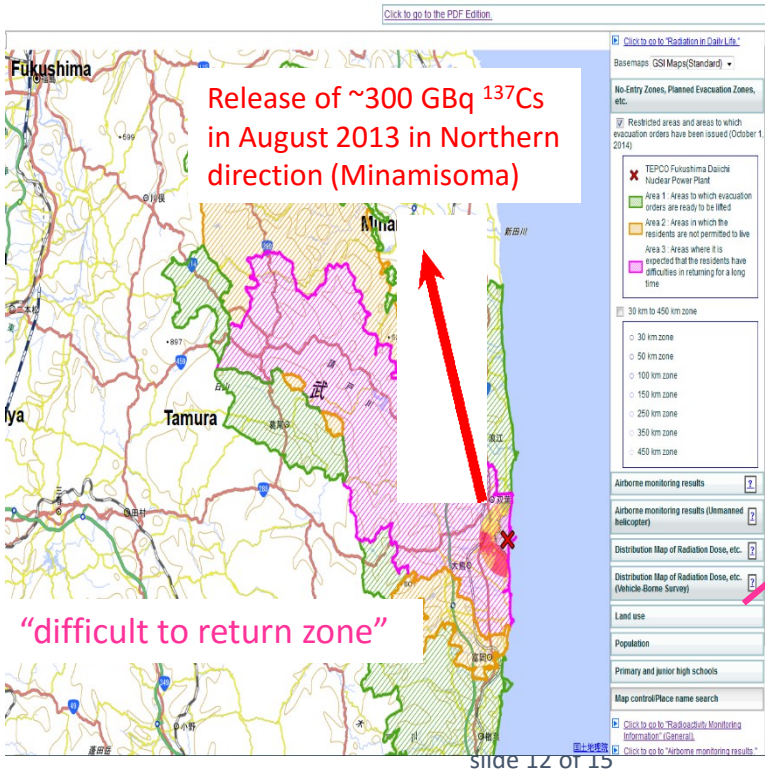
- Contaminated zones shall be successively remediated (target: <1 mSv/a)
- By mid 2015: ~ 1.4×10^{12} Yen $\approx 10^{10}$ Euro spent for remediation
- Removal of top soil, down to 50 cm!
- Enormous volume of low-contaminated soil, treated as waste → storage problem
- Secondary radioprotection issues arising from remediation work:
  Releases in the course of debris removal operations on the NPP site: Previously scarcely contaminated Minamisoma area faced contamination through resuspension

G. Steinhauser et al.
Environ. Sci. Technol.
2015, 49,
14028−14035



$^{134+137}$Cs in air, Minamisoma

storage of removed soil in large plastic bags



“Hot spots”

- small areas where radionuclides have concentrated due to ecological processes, in corners, gullies, sinks etc.
- do not contribute much to collective dose, but can be local problems
- have been found as far away as Tokyo

A decontamination team

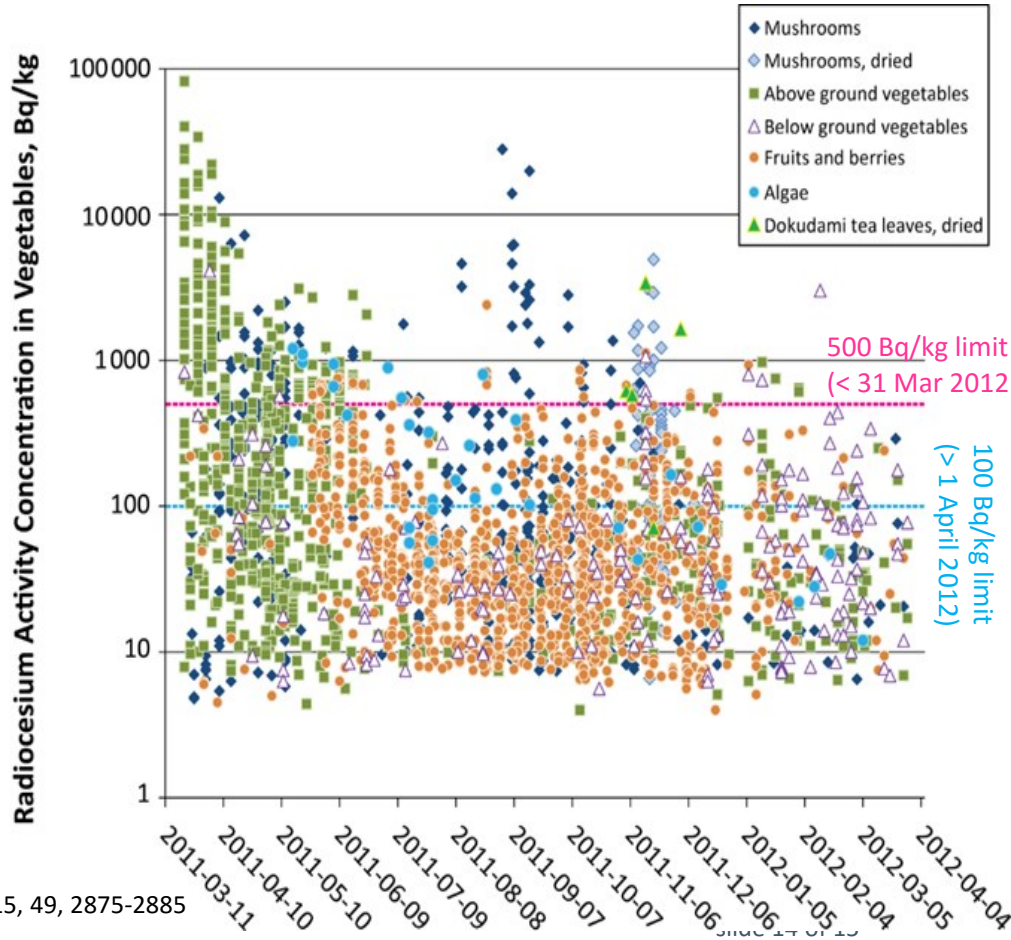
Koriyama City, drainage channel, winter 2011/2012
dose rate up ~1 µSv/h, high rCs conc.,
Fukushima-Pu detectable

Fukushima City, playground, winter 2011/2012
dose rate up to several µSv/h, high rCs conc.,
Fukushima-Pu detectable

Area and food monitoring

- Area monitoring: several recurring airborne and carborne dose rate and gamma spectrometric surveys, lab based monitoring → enormous amount of samples from different environmental compartments

- Unprecedented food monitoring program!
  - ~ 10^6 samples (rice: ~10^7 !),
  - started within days after the accident, despite heavily tsunami-impacted infrastructure along the eastern coast
  - treasure for future radio-ecological research!
- Foodstuff was largely safe, but…
  - High contamination levels in vegetables immediately after the accident
  - Monitoring of beef started too late



S. Merz et al. Environ. Sci. Technol. 2015, 49, 2875-2885

Conclusions

- **Fukushima - a disastrous event**, even if no detectable health consequences due to radiation (so far);
- **Enormous economic and socio-psychological cost**; estimated ~ 1400 additional fatalities due to stress during and after evacuation and resettlement;
- **For radio-ecological research:**
  - challenge: a number of new topics; essential for efficient mitigation and remediation
  - chance: new insights into environmental mechanisms (interaction tracer – environmental materials); training; development of new experimental methods and evaluation tools
  - problem: over many years decline of radio-ecological funds and humanpower

Fukushima – a prominent topic in radio-ecology conferences, latest e.g. ENVIRA (Thessaloniki, Sept 2015), ICOBTE (Fukuoka, July 2015)

Thank you for your attention!

"We shall come back"

(near the limit of the
"difficult to return zone",
7.5 km SW Fukushima-1 NPP)

Bundesamt für Strahlenschutz

Leibniz Universität Hannover