Objectives of the Workshop and Challenges for Remedial Actions and Waste Management in Fukushima

Fukushima Environmental Safety Center
Japan Atomic Energy Agency (JAEA)
Mikazu Yui







Contents

- Background and status of off-site Fukushima contamination / remediation
- Overall goals of workshop
- Session 1-3 Questions; e.g.
  - How to decontaminate and how to reduce volume of wastes produced?
  - How will the contamination develop in the future?
  - How will public acceptance be gained?
  - What can scientists do to address these concerns?
- Approach and tools used in the workshop

Background and status of off-site Fukushima contamination / remediation

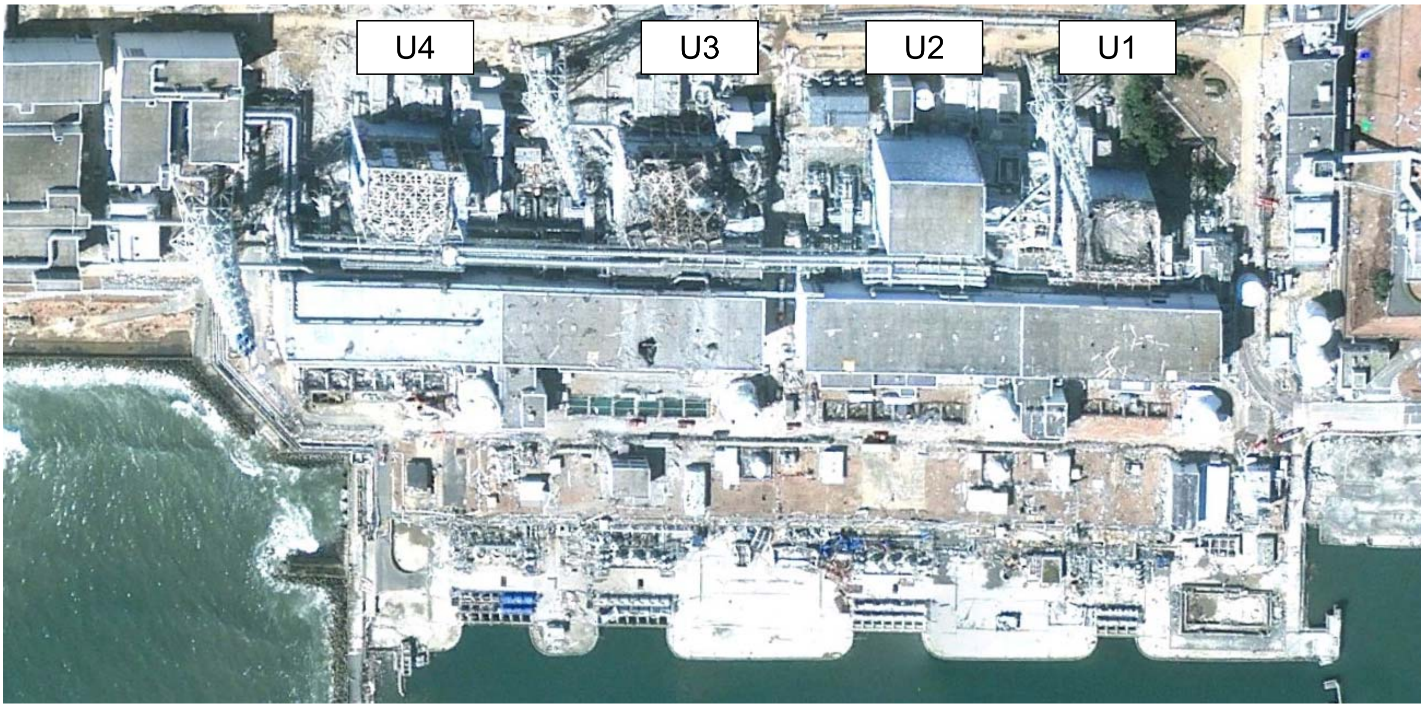
Status of
- Fukushima NPP accident
- Cs distribution
- R&D for implementation of decontamination
- Studies of Cs Behavior

Background to Fukushima NPP accident

11 March, 2011

Overview of the Fukushima NPP site

The disastrous earthquake and tsunami on March 11,2011 devastated Fukushima Daiichi Nuclear Power Station.

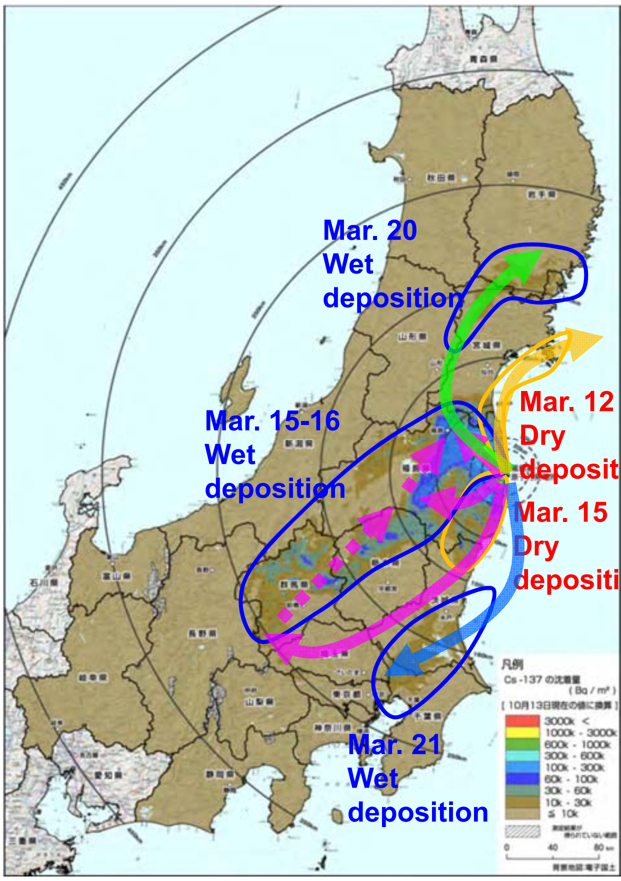


from Google maps HP

Estimated Deposition of Cs-137

- **Deposition of Cs-137 was estimated by WSPEEDI model, with input from measured surface soil concentration and meteorological data.**
- **Radioactive material deposited by wet and dry deposition processes depending on wind directions at the time of specific releases.**

H. Nagai *et al*., "Atmospheric dispersion simulations of radioactive materials discharged from the Fukushima Daiichi Nuclear Power Plant due to accident: Consideration of deposition process", The first NIRS symposium on reconstruction of early internal dose due to the TEPCO Fukushima Daiichi Nuclear Power Station accident, Chiba, Japan, 10-11 July, 2012

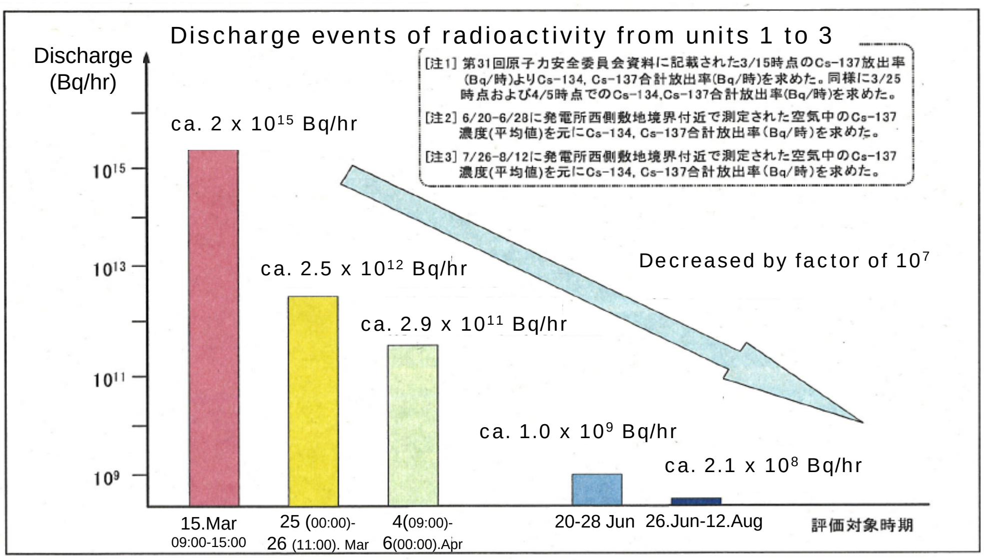


Discharge of radioactivity from units 1 to 3

	NSC(Aug.24)	Estimation By JNES	Estimation by NISA
Iodine-131	1.3×10^{17} Bq	1.3×10^{17} Bq	1.6×10^{17} Bq
Cs-137	1.1×10^{16} Bq	6.1×10^{15} Bq	1.5×10^{16} Bq

NSC: Nuclear Safety Commission of Japan (Aug.23, 2011)
JNES: Japan Nuclear Energy Safety Organization
NISA: Nuclear and Industrial Safety Agency

Estimates of integrated releases



From T.Inoue, presentation at GLOBAL 2011,Makuhari,Chiba,December 12-15,2011

Comparison of Discharged Radionuclides from Fukushima Dai-Ichi NPP and Chernobyl NPP Accidents

1. Discharge of radionuclides from the NPPS

Fukushima Dai-ichi NPP

- To atmosphere *1

^{131}I	: 1.3×10^{17} Bq
^{137}Cs	: 1.1×10^{16} Bq

- To ocean *2

^{131}I	: 2.8×10^{15} Bq
^{134}Cs	: 0.94×10^{15} Bq
^{137}Cs	: 0.94×10^{15} Bq

*1 2011/8/23 NSC (Nuclear Safety Commission oj Japan

*2 2011/4/21 TEPCO (Tokyo Electric Power Com.)

Chernobyl

Total	: 1.4×10^{19} Bq
^{131}I	: 1.8×10^{18} Bq
^{137}Cs	: 8.5×10^{16} Bq
^{90}Sr	: 1.0×10^{16} Bq
Total Pu	: 3×10^{15} Bq

*1 IAEA "STI/PUB/1239" (2006)

2. Land-use classification around the NPP site

Fukushima Dai-ichi NPP

- Urban area; <5%
- Paddy field; <10%
- Other field; <10%
- Forest; > 75%

Area contaminated by Cs-137 over 300kBq/m2

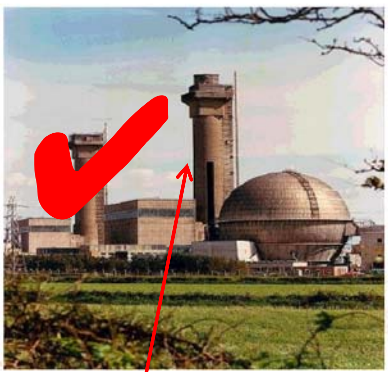
Chernobyl (Av. Belarus)

- Agriculture; 43%
- Forest; 39%
- River & Lake; 2%

"Belarus in Figures" (March, 2010)

From T.Inoue, presentation at GLOBAL 2011,Makuhari,Chiba,December 12-15,2011

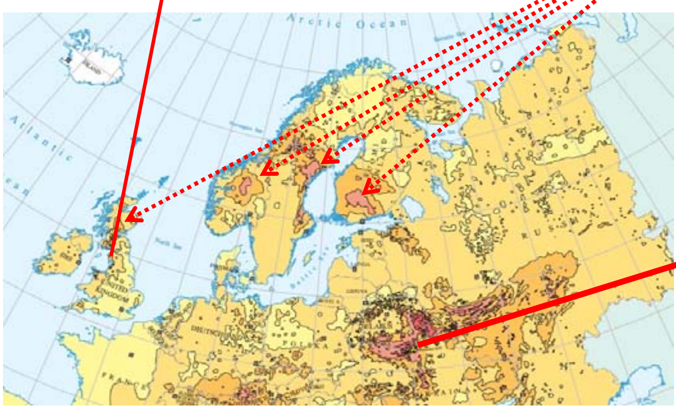
But Fukushima is NOT like Chernobyl!



Volatile, mainly short-lived fission products, e.g. Cs

Windscale,1957

Distant Fallout



Chernobyl,1986

- Explosively dispersed reactor core,
- Includes a full suite of long-lived actinides, U, Pu, •••
- CEZ remains hazardous indefinitely – (or until regional remediation)

Status of

Cs distribution

Ground monitoring

Soil sample collection and analysis

In situ measurement using a portable Ge gamma spectrometer

Measurement on ground (undisturbed flat fields) with a survey- meter

Mobile monitoring with the KURAMA system mounted in cars

Radionuclide deposition distribution

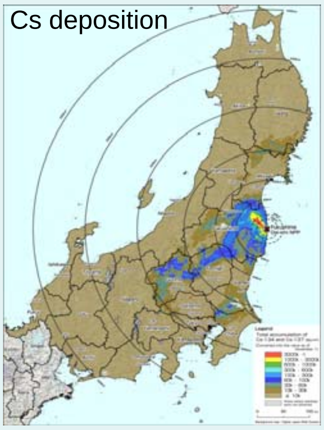
Air dose rate distribution

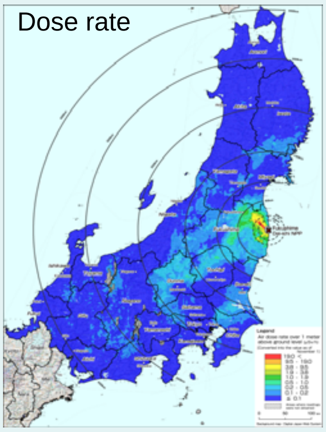
Airborne monitoring

Range	Large Area 100 km >	Semi Large 10 km >	Mid Area 1 km >	Small Area ~100m
Aircraft	Helicopter	UAV w/ FW	AUH	Micro UAV
Alt.	~ 300m	~ 150m	~ 50m	≲ 10m

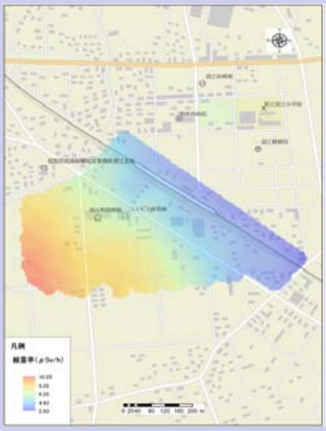
UAV – unmanned aerial vehicle
FW – fixed wing

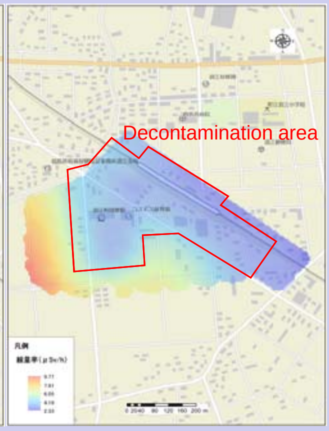
Aerial radiation monitoring



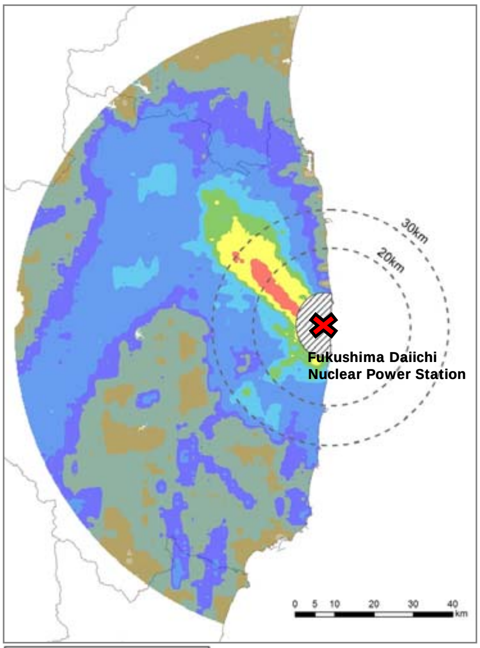


Autonomous Unmanned Helicopter

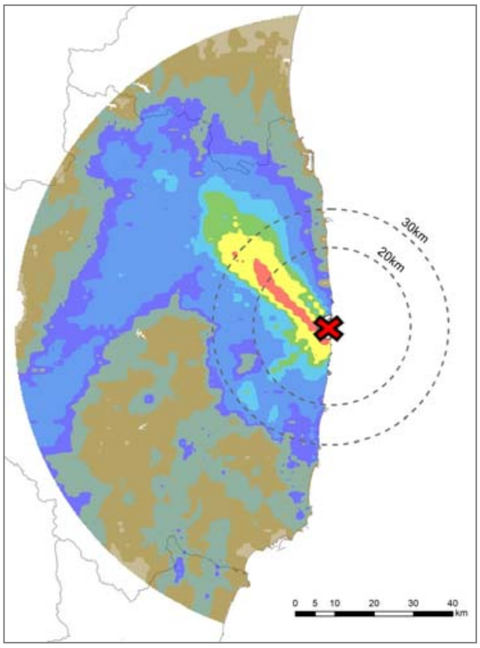




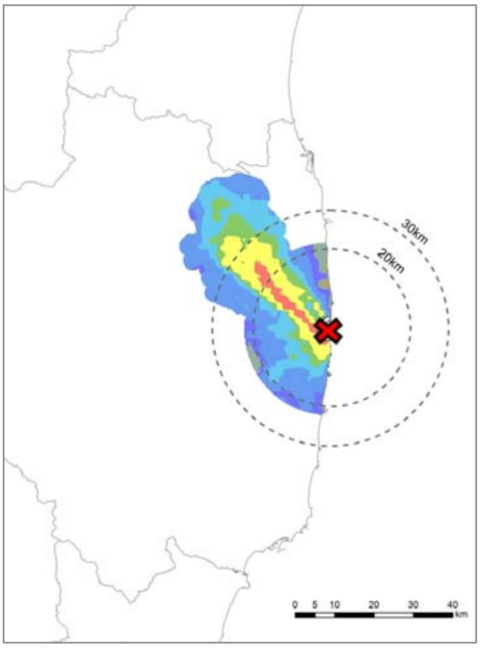
^{137}Cs distribution measured by aerial monitoring



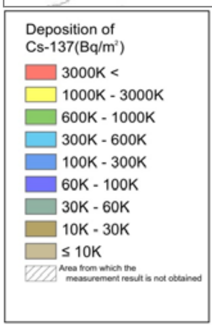
2 July 2011



28 June 2012



11 March 2013



Reference: Nuclear Regulation Authority
Monitoring information of environmental radioactivity level
WWW Document at http://radioactivity.nsr.go.jp/en/

Evaluation of additional accumulated effective doses over 50 years

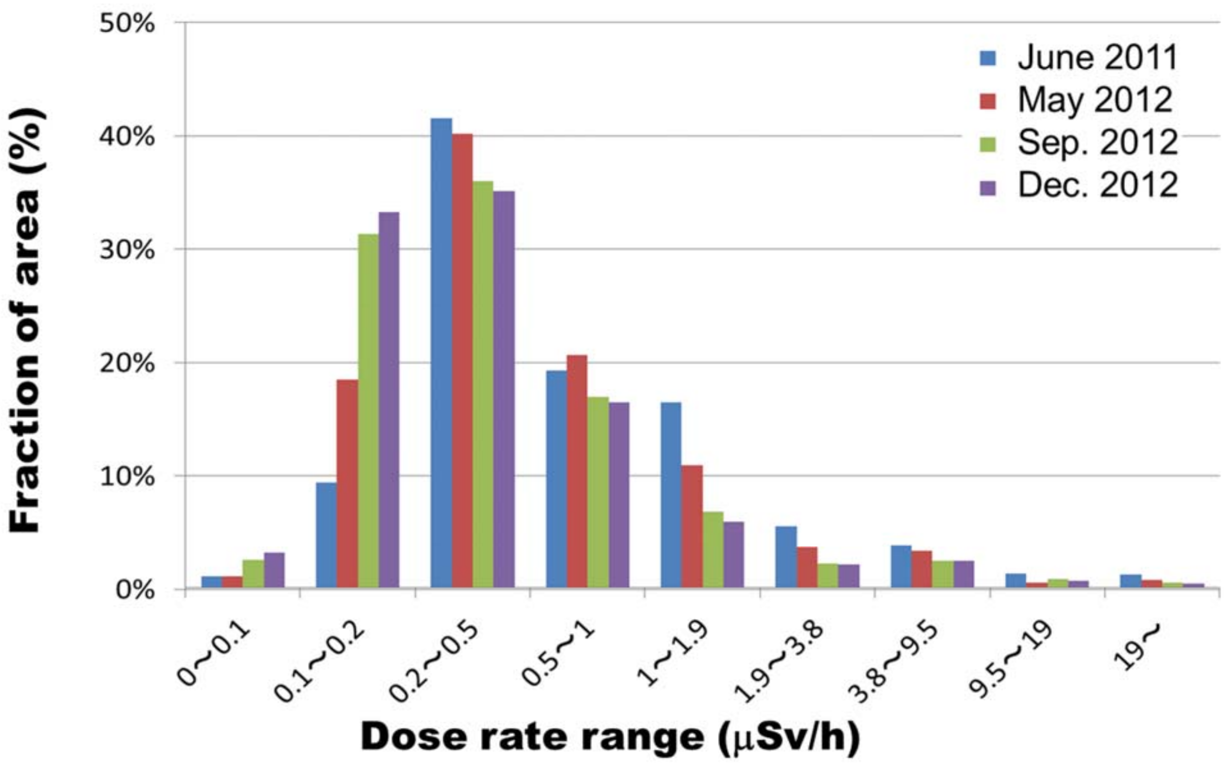
●**Maximum nuclide concentrations of soil (Bq/m²) were used.**
●**External exposures and inhalation due to re-suspension were evaluated.**

Nuclide	Half life	Maximum concentration (Bq/m2)	Effective dose for 50 years	
			Conversion coef. (μSv/(Bq/m²))	Dose (mSv)
Cs-134	2.065 y	1.4×10^{7}	5.1×10^{-2}	710
Cs-137	30.167 y	1.5×10^{7}	1.3×10^{-1}	2000(2.0Sv)
I-131	8.02 d	5.5×10^{4}	2.7×10^{-4}	0.015
Sr-89	50.53 d	2.2×10^{4}	2.8×10^{-5}	0.00061 (0.61 μSv)
Sr-90	28.79 y	5.7×10^{3}	2.1×10^{-2}	0.12
Pu-238	87.7 y	4	6.6	0.027
Pu-239+240	2.411×10^{4} y	15	8.5	0.12
Ag-110m	249.95 d	8.3×10^{4}	3.9×10^{-2}	3.2
Te-129m	33.6 d	2.7×10^{6}	2.2×10^{-4}	0.6

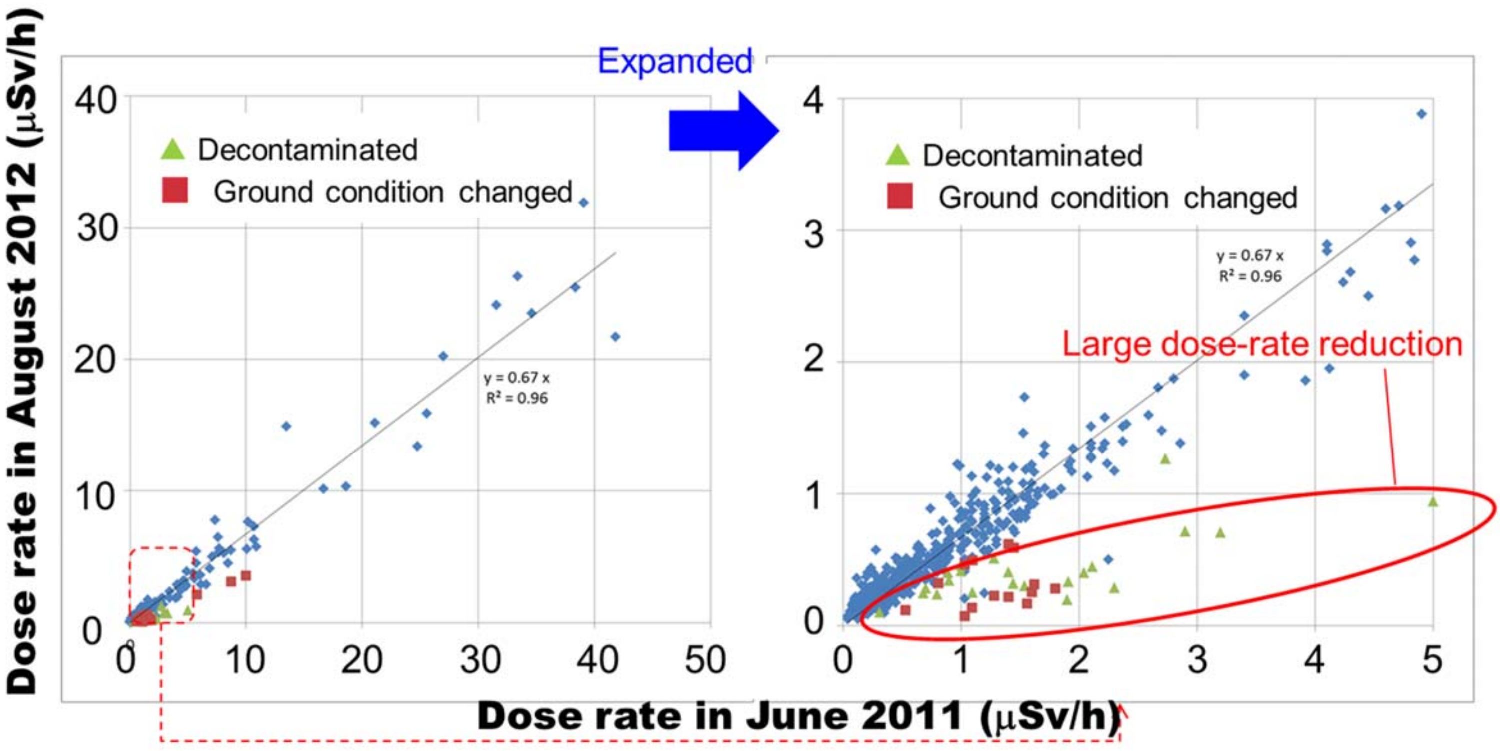
(Dose conversion coefficients from IAEA-TECDOC-1162)

Distribution of areas with different dose rates within the 80 km zone

● **Areas more than 0.2 μSv/h are decreasing, less than 0.2 μSv/h increasing.**
● **Nearly 70% of the total area has dose rates between 0.1-0.5 μSv/h.**



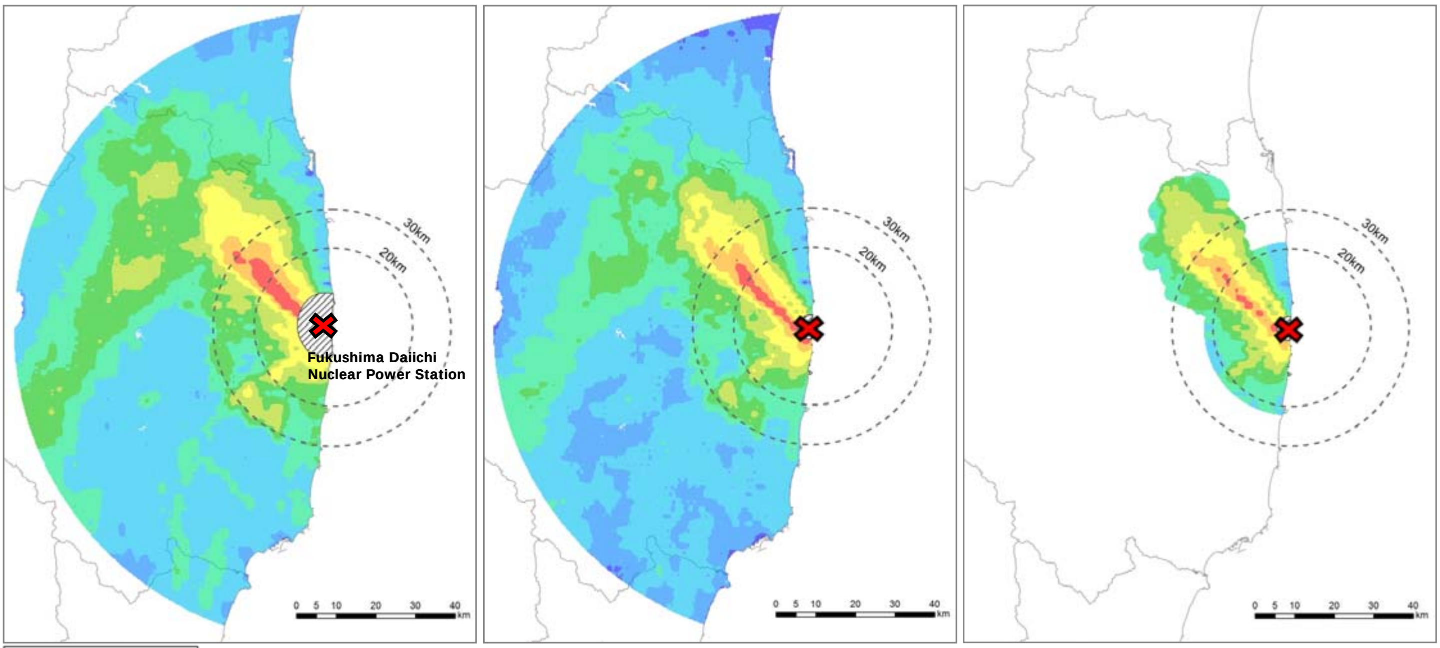
Comparison of dose rates in air at 1 m between June 2011 and Aug. 2012

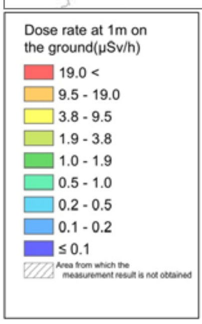


- **Dose rates in air decreased by more than 30%. (Physical decay : 25%)**
- **There exist locations showing large dose-rate reduction.**

1

Dose rate distribution in air at 1m measured by aerial monitoring





2 July 2011 | 28 June 2012 | 11 March 2013

Reference: Nuclear Regulation Authority
Monitoring information of environmental radioactivity level
WWW Document, http://radioactivity.nsr.go.jp/en/

1 What does this contribute further to information in slide 14?
mckinley mckinley, 2013/09/10

Status of

R&D for implementation of decontamination

"Decontamination Pilot Project" by JAEA

- **Prior to implementation of the national government's regional decontamination, the Cabinet Office commissioned a "Decontamination Pilot Project" from JAEA.**

- **The purpose of the project is to acquire technical data and knowledge to reduce the dose rates in living areas and provide integrated expertise for subsequent regional decontamination;**
  - **Check the availability and effectiveness of proven and new techniques**
  - **Determine associated costs, work duration, workforce requirements, waste generated and radiation exposure to workers**
  - **Establish waste management processes, including volume reduction of wastes and treatment of secondary wastes**
  - **Assess worker safety, including radiation protection**
  - **Establish optimal radiation monitoring procedures**
  - **Establish public communication approaches**

Decontamination Pilot Project

Clean-up of Roads and Pavement

◆ high pressure water

road cleaner

◆ surface stripping

◆ blasting

Iron shot blasting

Ice blasting

Clean-up of Houses

Clean-up of Farmland

- plow

- turf stripping

- topsoil removal

hardening

Clean-up of Trees and Forest

- weeding
- removal of leaf mold
- clipping
- water horsing

clipping

clipping

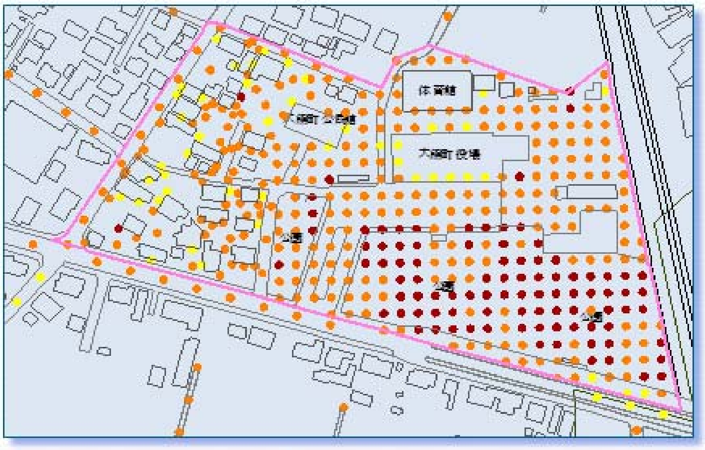
curing

removal of leaf mold

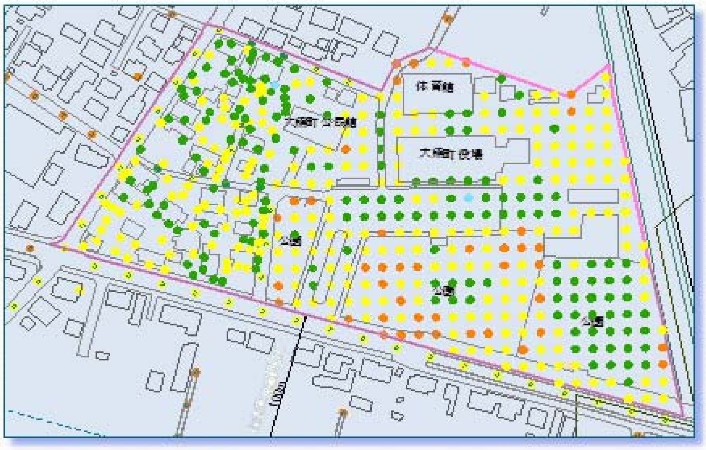
water jet

Before and After Clean-up

Dose rate before clean-up



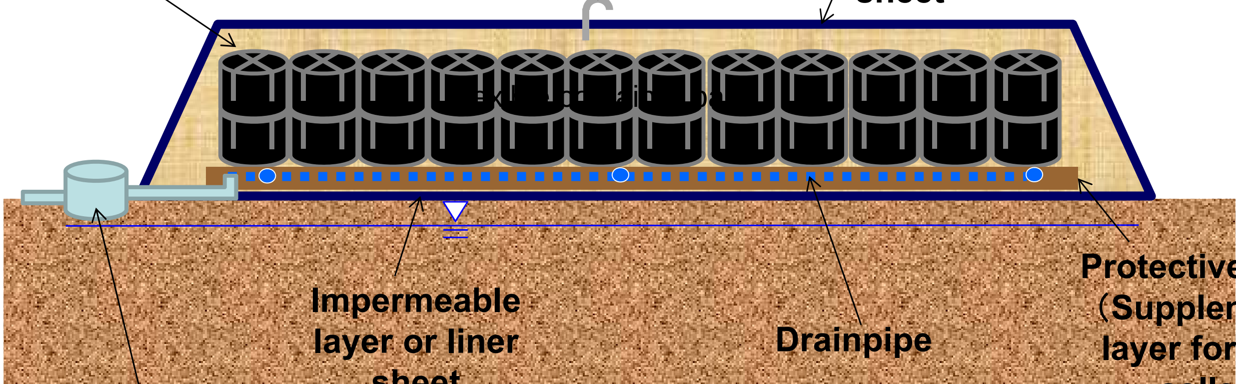
Dose rate after clean-up



	BEFORE, μSv/h	AFTER, μSv/h
playground	8.4 - 33.1 (19.2 ave.)	2.0 - 14.5 (7.2 ave.)
residential area	2.5 - 26.7 (11.5 ave.)	1.8 - 8.7 (3.9 ave.)
road, parking lot	5.2 - 43.6 (13.8 ave.)	2.0 - 15.7 (5.3 ave.)
outside the area	7.2 - 18.8 (11.3 ave.)	6.7 - 13.8 (9.7 ave.)

- 0 μSv/h≦測定値＜1.0 μSv/h
- 1.0 μSv/h≦測定値＜1.9 μSv/h
- 1.9 μSv/h≦測定値＜3.8 μSv/h
- 3.8 μSv/h≦測定値＜9.5 μSv/h
- 9.5 μSv/h≦測定値＜19.0 μSv/h
- 19.0 μSv/h≦測定値

Temporary Storage of Waste



Temporary storage under construction

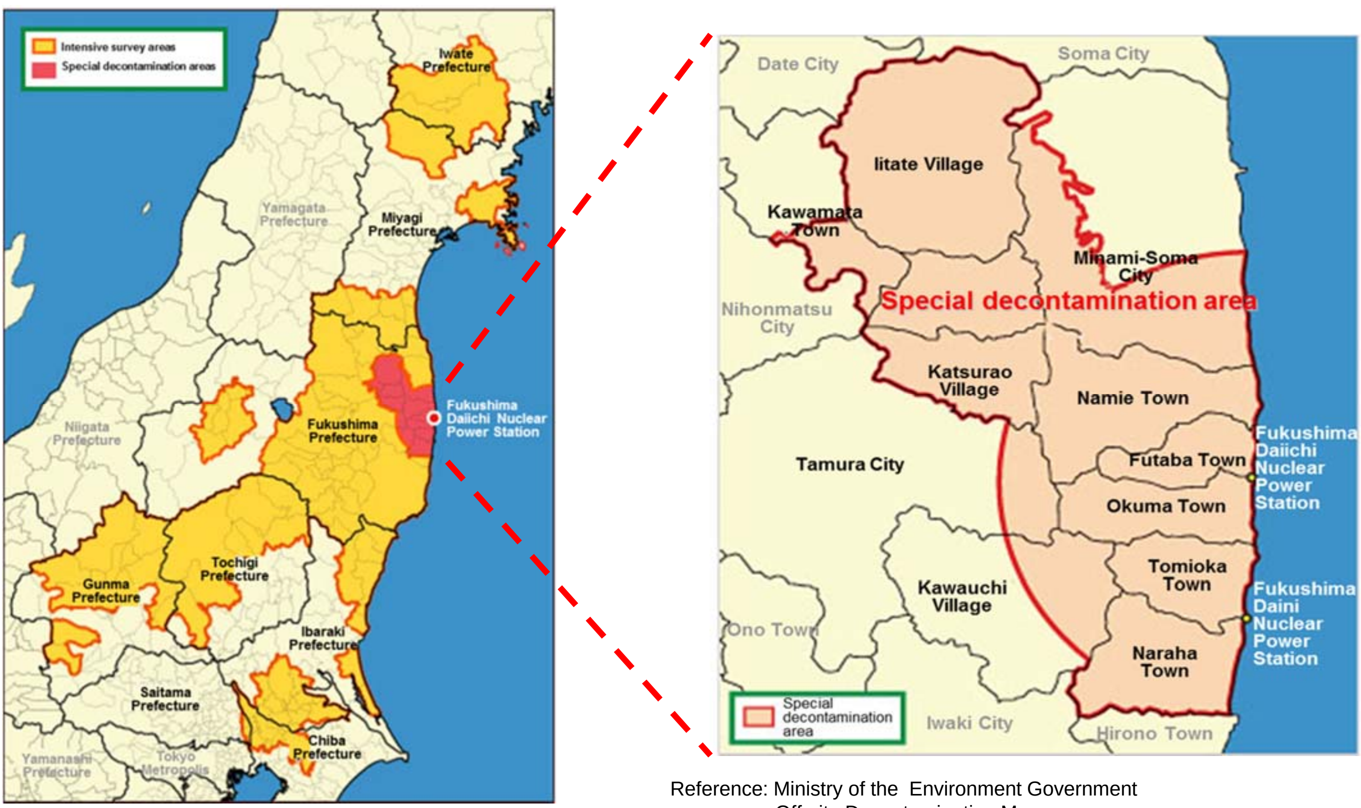
Decontamination Implementation

➢**Special Decontamination Area(＞20 mSv/y)**
:11 Municipalities **by National Government**

➢**Intensive Contamination Survey Area (1 to 20mSv/y)**
by Each Municipality Funded by Government
:104 Municipalities, 8Prefecturs

➢**Based on the Guidelines for Decontamination Works**
Issued by Ministry of the Environment

Special Decontamination Area and Intensive Contamination Survey Area



Reference: Ministry of the Environment Government
Off-site Decontamination Measures
WWW Document,http://josen.env.go.jp/en/documents/pdf/documents_02.pdf

STATUS OF

STUDIES ON Cs BEHAVIOR

Cs sorption behavior

Cs sorption can be significantly affected by:

- ➢Characteristics of solid phases present
- ➢Ionic strength of aqueous phase
- ➢Organic matter present

Critical factor is:

- ➢Degree of reversibility of Cs sorption on natural materials

Cs dissolved concentrations in water are now very low, thus

- ➢Cs sorption / uptake generally irreversible (or very poorly reversible)
- ➢Cs transport associated with solid particles (suspensions, colloids), especially in fresh waters

Further Studies Needed for Decontamination work

- ➢**Decontamination for Forest**
- ➢**Decrease in Waste Generation**
- ➢**Waste Storage and Disposal**
- ➢**Possible Recontamination processes**

Based on Understanding of Cs Behavior in the Environment: In many cases may be dominated by sorption on clay minerals in the soil zone

The most difficult decontamination work is for forest

➢Forest covers about 70% of Fukushima Prefecture

➢Limited forest decontamination is reasonable, considering effective dose reduction, ecosystem conservation and prevention of risks like landslides

➢After decontamination, long-term investigation of the potential Cs source term from non-decontaminated forest is important.

Based on this study, countermeasures to reduce Cs transport in relevant areas may also be considered.

Fukushima-TRACE Project

Long-term assessment of Transport of RAdioactive Contaminant in the Environment of Fukushima

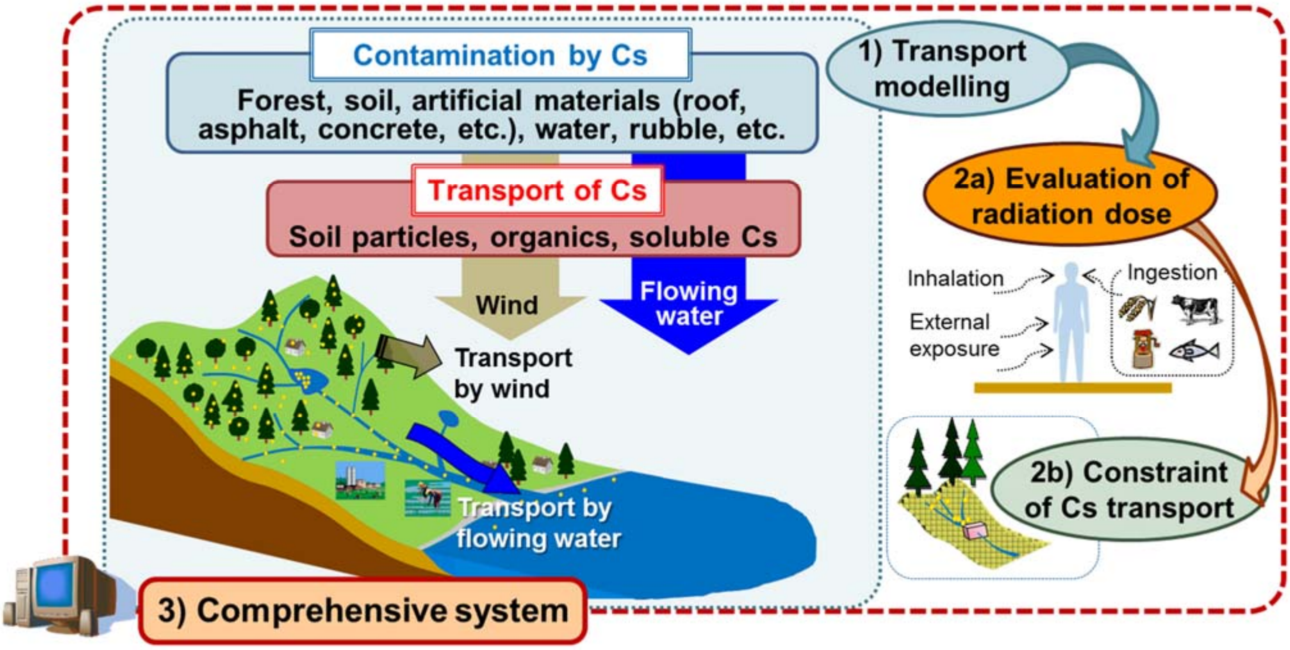
⇨Studies on Cs Transport in the Forest ~ River ~ Reservoir(Dam, Lake) ~Estuary System.

F-TRACE PROJECT

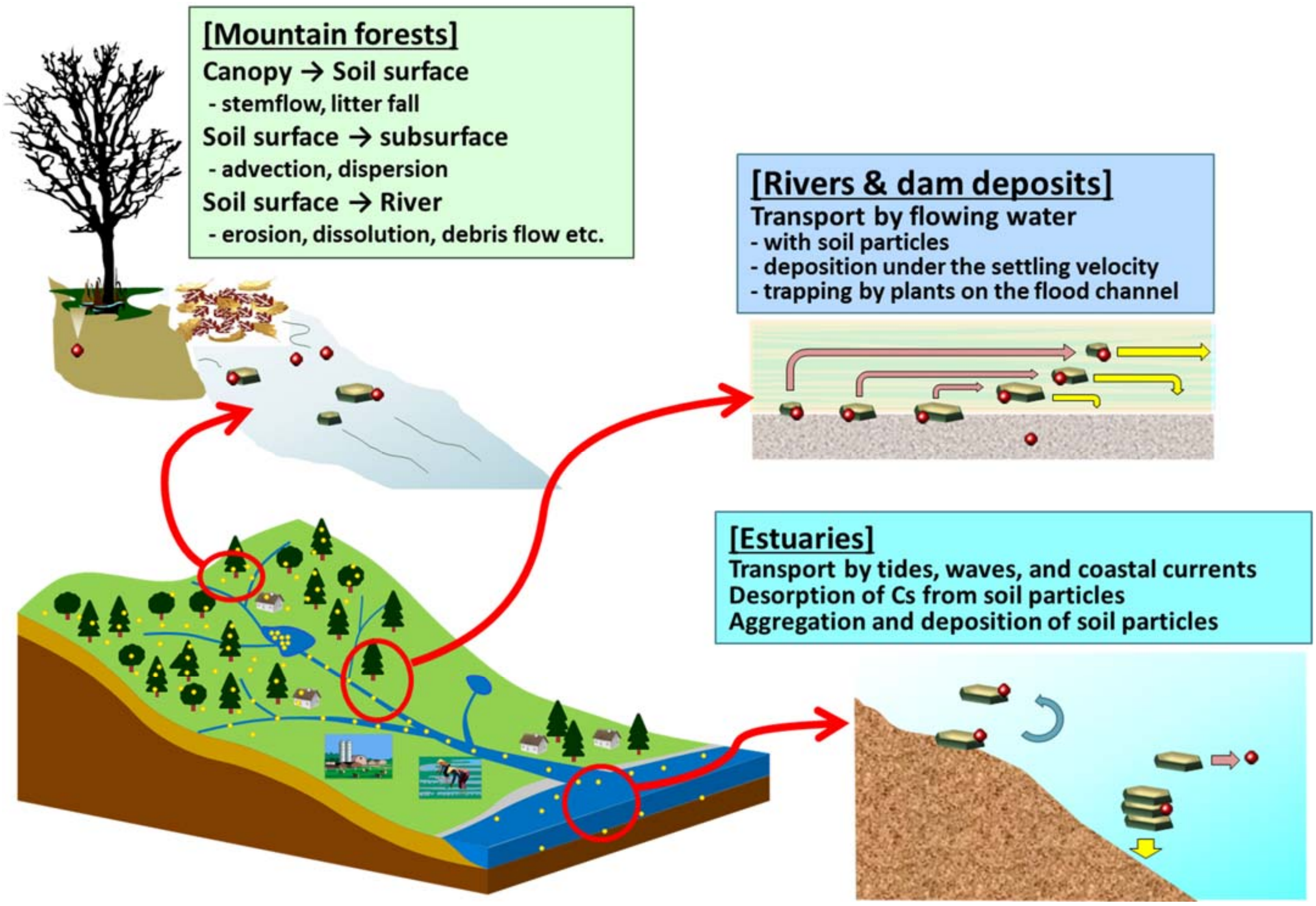
Overview of the Fukushima-TRACE project

❑ Objectives

1) Elucidation of transport behavior of radionuclides (esp. radiocaesium; Cs) from contaminated forest to biosphere and sea.
2) Development of dose evaluation system and methodology to constrain Cs transport.
3) Construction comprehensive system for prediction and constraint of radionuclide transport.

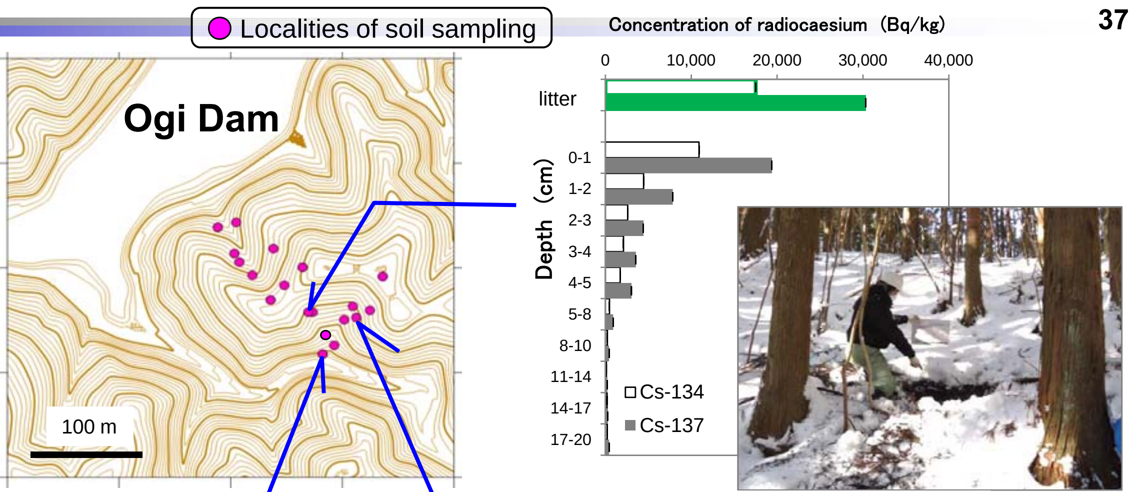
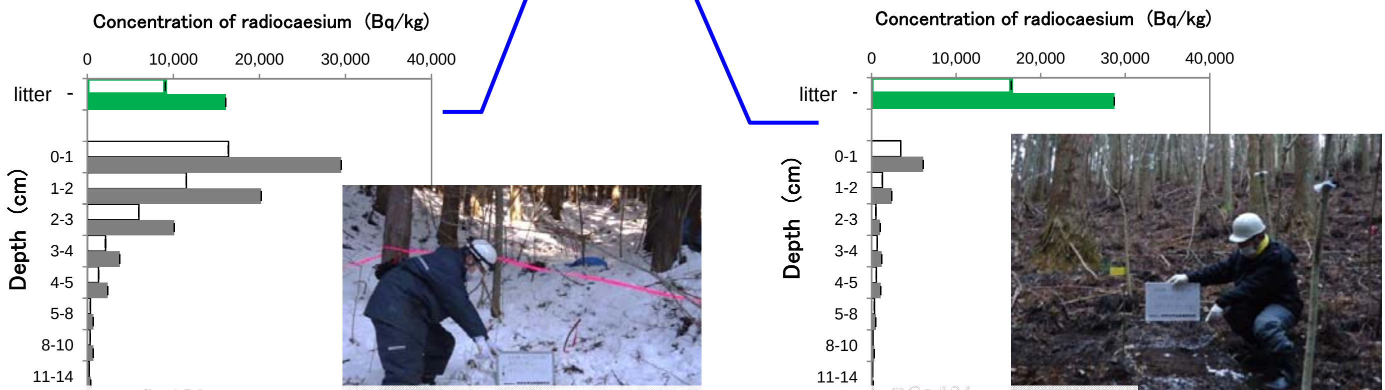


Key phenomena influencing Cs transport



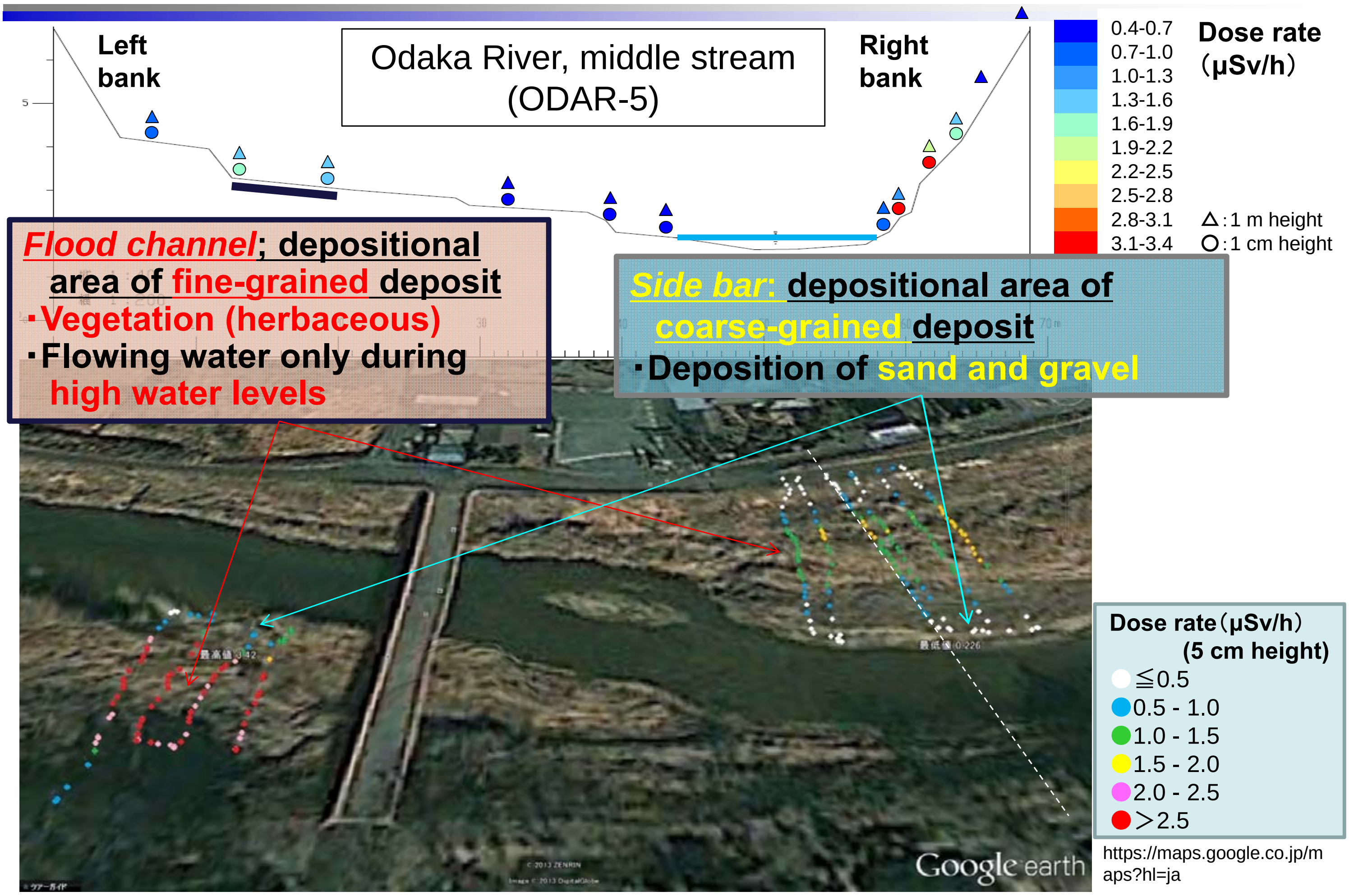
Depth profiles of Cs in forest topsoil

- **Soil sampling by scraper plate**
  - Up to 20 cm depth
  - 1 cm intervals until 10 cm depth, then 2 cm intervals

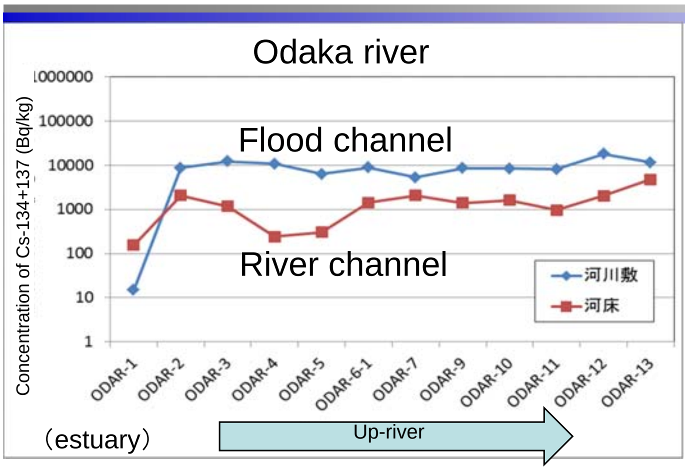
- More than 90% of Cs remains within 5 cm topsoil depth including the litter layer (~2 y after the accident).

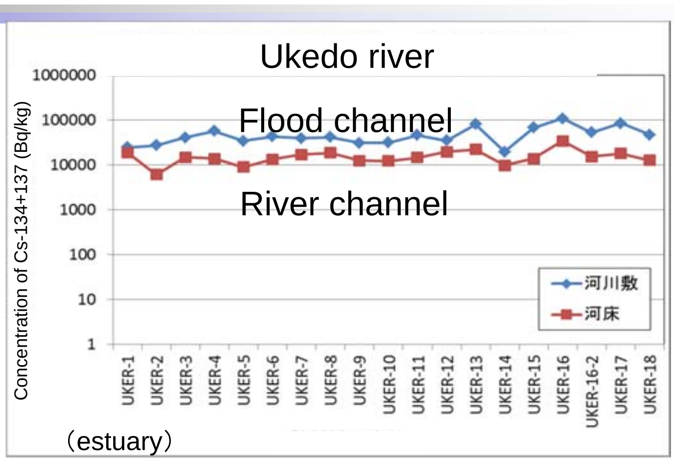
Dose rate distributions in river sediment

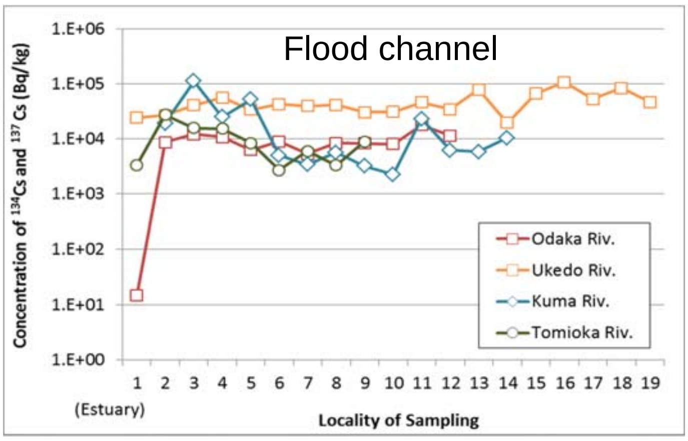


https://maps.google.co.jp/maps?hl=ja

Cs concentrations in river sediments







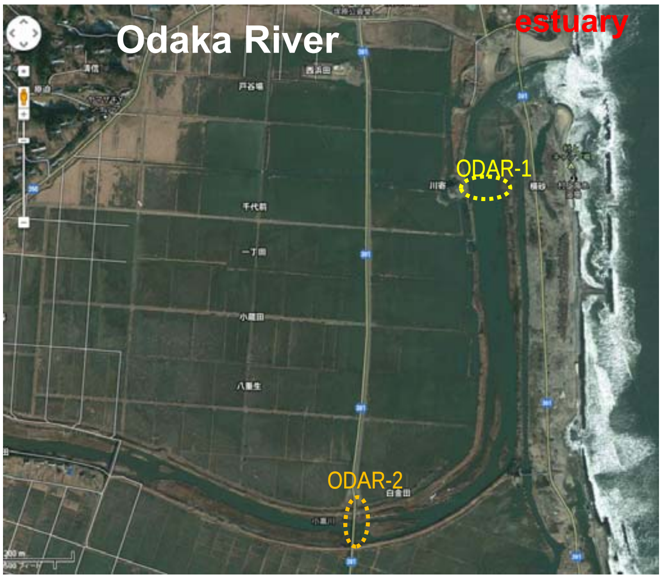
- Cs concentration of sediment in flood channel is higher than that of river channel, but the difference is within one order of magnitude.

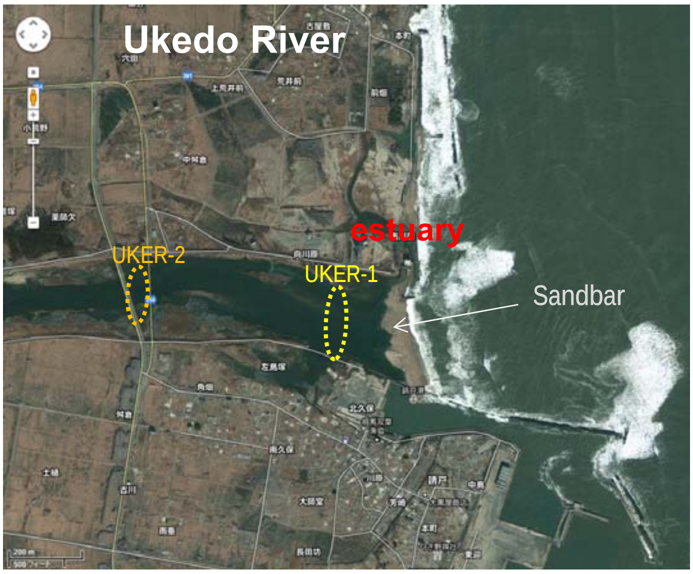
⇒Cs is strongly adsorbed onto sediments.

- Cs concentration drastically decreases at the closest point to estuary in Odaka River, where;
  - ✓ no coastal sandbar was formed at estuary,
  - ✓ salinity near estuary was similar to seawater.

⇒Cs was possibly desorbed from soil particles near estuary due to high salinity (possibly also dilution – mixing with lower contaminated sediments from coast)

Salinity of river water





➢Observation:
No coastal sandbar was formed at estuary.

➢Sample analyses of ODAR-1 and 2 show:
Salinity near estuary was similar to seawater.

➢Observation:
Coastal sandbar was formed at estuary.

➢Sample analyses of OKER-1and 2 show:
Salinity near estuary was similar to freshwater.

Summary of Status

- ➢ Clear importance of understanding Cs behavior that will support development of practical ways for…
  - Decreasing waste generation during cleanup
  - Long-term assessment of the impact of Cs in untreated forest
- ➢ Continuous / focused R&D (F-TRACE project) is needed to decrease uncertainties and allow optimal treatment to assure a safe future for Fukushima.

Overall Goals of Workshop

- International expert review of current plans for F-TRACE / R&D supporting regional decontamination and waste management (technical QA)
- Summary of relevant international experience and assessment of relevance to Fukushima (mining of international Knowledge Base)
- Brainstorming to gain input for key identified challenges (capture of national / international tacit knowledge)
- Establishing contacts between experts in this field (network building)

Session 1 - Questions

- How can we predict future radiocaesium migration?
- How can we reduce waste volume from decontamination activities?
- How to rationalise forest decontamination (covers ~70% of the Fukushima prefecture)
- How can international experience help deal with these difficulties?
- How do we gain public acceptance/confidence

Session 2 - Questions

- How do we provide a mechanistic understanding of Cs behaviour on RELEVANT environmental materials
- Relate this understanding to practical application in waste volume reduction and further decontamination work
- What international experience is available contribute to these difficulties

Session 3 - Questions

- How can we predict radiocaesium migration from forests
- What models are available?
- How do we test them?
- How do we validate them (much trickier)?
- What will Cs migration prediction contribute to e.g.
  - Rationalisation of forest decontamination?
  - Rationalisation of river, lake, reservoir decontamination?
  - Development of measures to prevent radiocaesium getting into agricultural irrigation water?
  - Future dose rate evaluation to predict return of residents from evacuated areas

Approach and tools

- 3 technical sessions with focused presentations by national / international experts
- Discussion / brainstorming to capture undocumented expertise, focused by use of an argumentation model (very intuitive, requires no preparation by participants)
- Field trip to allow foreign participants to gain insight into the research areas and encourage contacts between foreign experts and JAEA team
- Summarisation of output in a report produced quickly after the workshop