Overview of the Results of Fukushima Decontamination Pilot Projects

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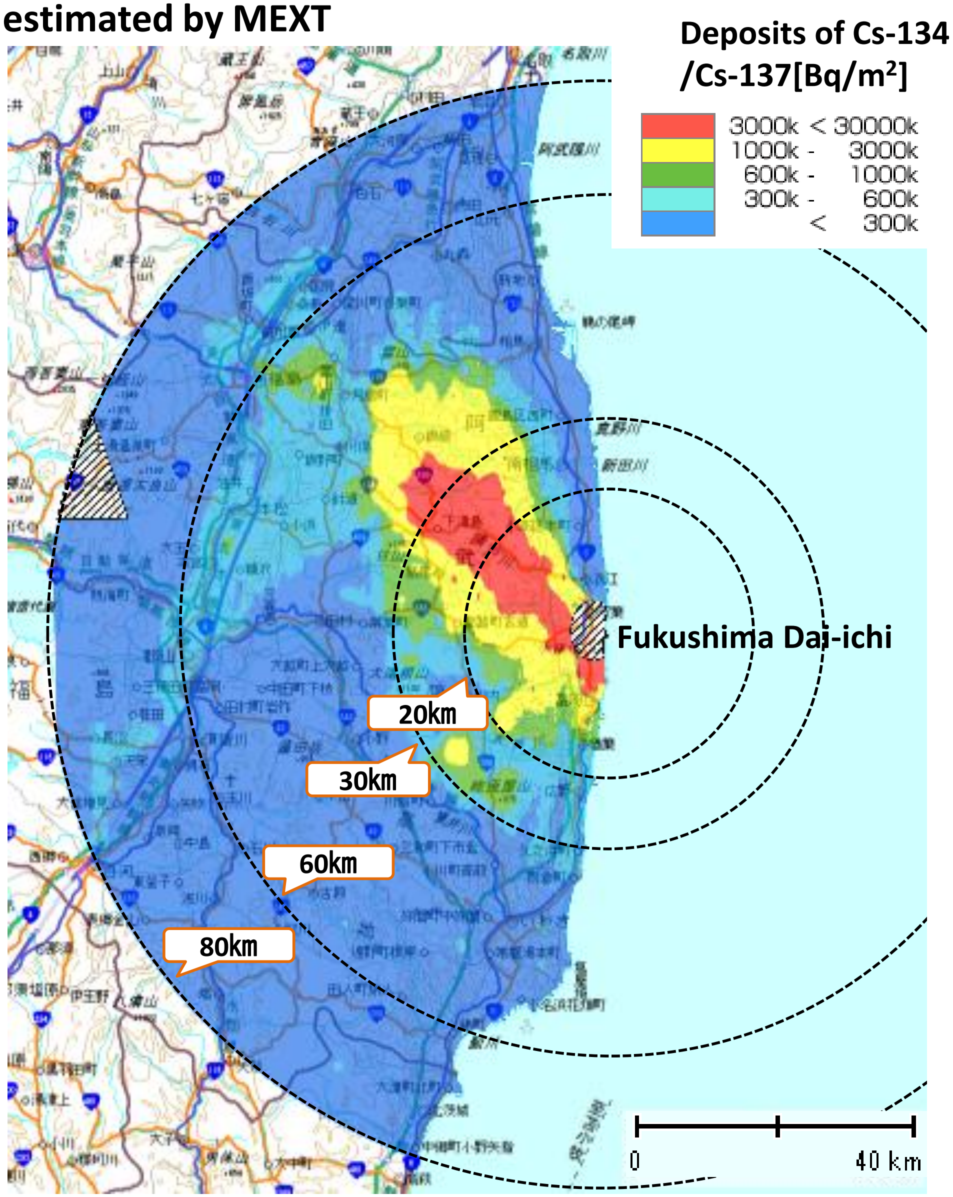
Fukushima Regional Contamination

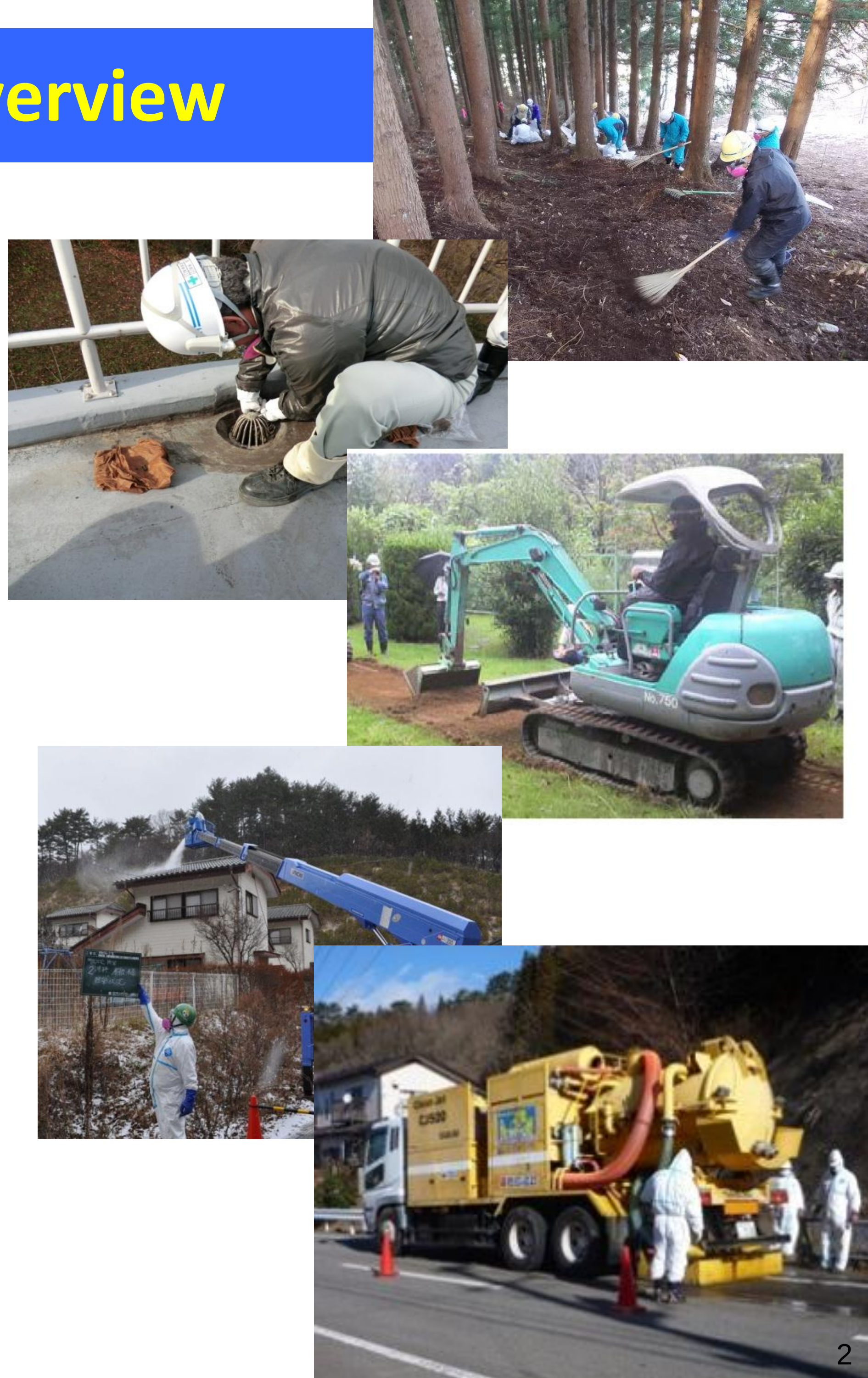
- **Off-site contamination mainly volatiles: initially concern focused on shorter-lived I isotopes ➔ evacuation and restriction of consumption of some foodstuffs**
- **After decay of shorter-lived isotopes, now dominated by Cs-134/-137 which is the focus for off-site clean-up actions**
- **Cs tends to bind strongly to surfaces, especially clays.**
- **Doses are generally low with a few exceptional locations and continually reduced by decay of radiocaesium, washoff / soil mixing.**

Cumulate deposits of Cesium (Cs-134 and Cs-137) estimated by MEXT



Fukushima Remediation Overview

- A wide range of focused clean-up projects were rapidly initiated by municipalities and local communities for sensitive areas (schools, playgrounds, …)
- 2 small test projects were initiated by JAEA in August: development and testing of technology (ended in March)
- Further technology demonstrations initiated in November in 11 municipalities, including those in the evacuation zone (ended in July)
- Parallel tests of novel decontamination technology (25 proposals funded) have been completed
- Regional decontamination is presently being initiated



Main Challenges for Implementation of Full-scale Decontamination

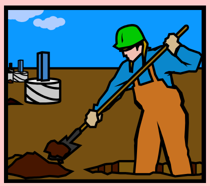
Which methods are appropriate?



What are the points to consider when preparing plans and ordering decontamination equipment/services?


What are the points to check when supervising decontamination work? What know-how should be used for decontamination work?





Is it possible to apply new technology?

- There was little organised quantitative information based on actual data (clean-up effectiveness, costs, volumes of wastes generated, etc.) that could be used when selecting between various alternatives for decontamination, waste transport and storage methods
- There was little documented guidance on decontamination for local governments, local residents and private sector companies on how to order decontamination equipment/services
- Possibilities of development and upgrading of new decontamination technologies had not been examined

Implementation Scheme for the Decontamination Pilot Projects

National government (Cabinet Office)

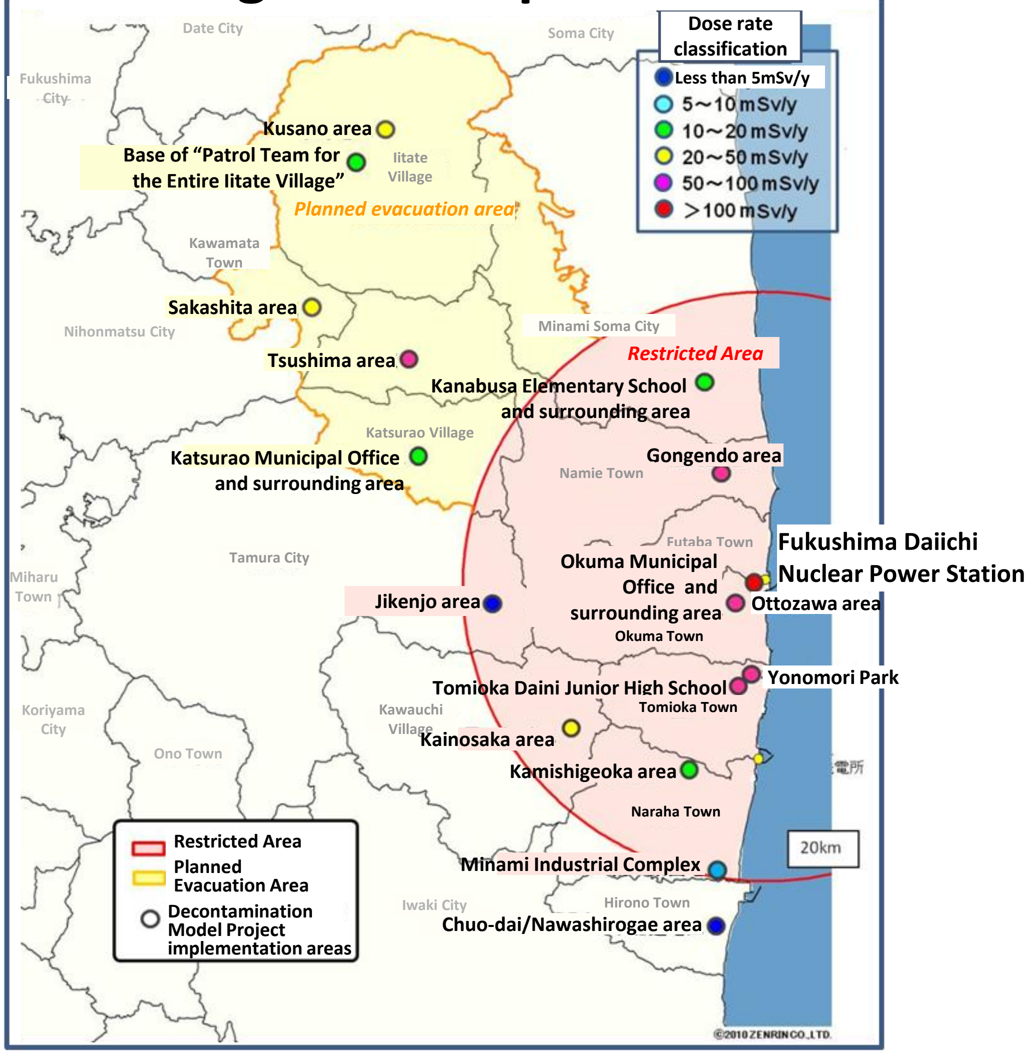
↓ Commissioning

Headquarters of Fukushima Partnership Operations, Japan Atomic Energy Agency

Public call for proposals

- **Municipality Group A: Taisei JV** (Minami Soma City, Kawamata Town, Namie Town, Iitate Village)
- **Municipality Group B: Kajima JV** (Tamura City, Futaba Town, Tomioka Town, Katsurao Village)
- **Municipality Group C: Obayashi JV** (Hirono Town, Okuma Town, Naraha Town, Kawauchi Village)

Target Municipalities



Futaba Town has advised us that they would not join the Decontamination Model Project as a target area.

- **Public call for proposals: Proposals for complete clean-up: including planning, decontamination and evaluation stages were submitted by Joint Ventures (JVs). The 3 JVs shown above were selected after an examination* by JAEA.**
- **Implementation scheme: Each JV implemented its proposed technological activities and JAEA managed, supervised and evaluated the overall program.**
- **Target municipalities: Eleven municipalities in evacuated areas**
- **Sizes of the decontamination target areas: approx. 20ha per target municipality**
- **Total manpower effort for the model projects (excluding employees of JAEA): approx. 87,000 person-days**

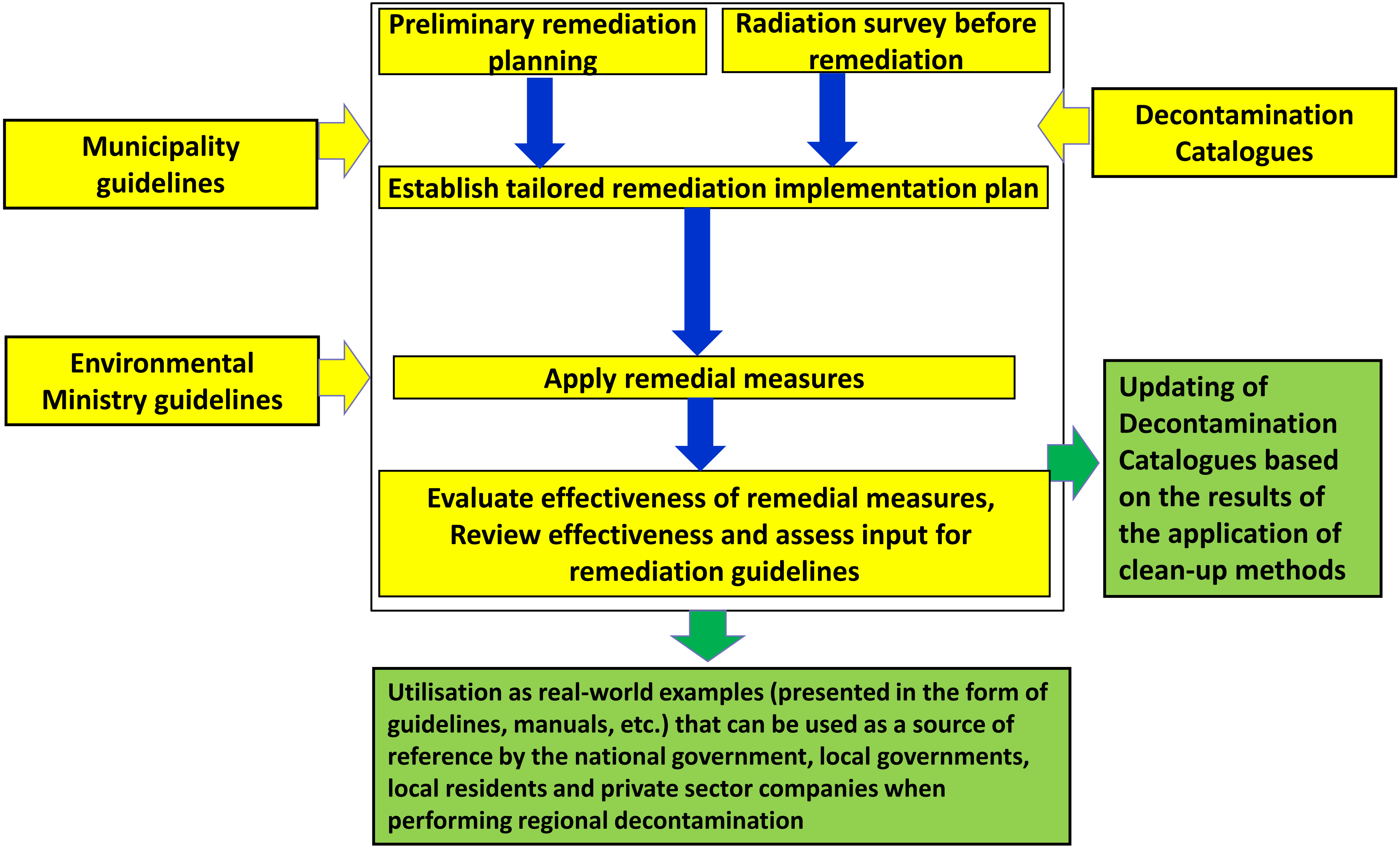
* An examination conducted by a committee appointed by JAEA

Features of Model Sites in Target Municipalities

Group/ Municipalities		Target areas	Decontaminated model sites (Total about 209 ha)		Annual dose before cleanup (mSv)
			Main constituents and features	Area (ha)	
Group A	Minami Soma City	Kanabusa Elementary School	Farmland, Building(Elementary School), Road, Forest, Residential area	13	5
	Kawamata Town	Sakashita area	Forest, Farmland, Road, Residential area	11	15
	Namie Town	Tsushima area	Building(Junior High School, etc.), Forest, Residential area, Road	5	48
		Gongendo area	Building(Station / Track, Library, etc.), Private house, Road, Farmland	13	26
	Iitate Village	Kusano area Base of "Patrol Team for the Entire Iitate Village"	Building(Iitate-home, etc.), Farmland, Private house, Residential area, Forest, Road	17	19
Group B	Tamura City	Jikenjo area	Farmland, Forest, Residential area, Road	15	4
	Katsurao Village	Katsurao Municipal Office and surrounding area	Forest, Building (Elementary School, Municipal office), Residential area, Road	6	8
	Tomioka Town	Yonomori Park	Building (Junior High School, Playing field, etc.), Residential area, Forest, Road (Road bordered with cherry-tree)	9	43
		Tomioka Daini Junior High School		3	32
	Futaba Town*	—	—	—	—
Group C	Hirono Town	Chuo-dai/Nawashirogae area	Building(Municipal office, Elementary School, Junior High School, Playing field), Residential area, Forest, Road	33	3
	Okuma Town	Okuma Municipal Office and surrounding area	Building(Municipal office, Public hall, Park), Residential area, Road	6	65
		Ottozawa area	Farmland, Forest, Residential area, Road	17	344
	Naraha Town	Kamishigeoka area	Farmland, Residential area, Forest, Road	4	11
		Minami Industrial Complex	Building(Factory, etc.), Road	37	4
	Kawauchi Village	Kainosaka area	Farmland, Forest, Private house, Road	23	20

*Futaba Town decided not to propose a target area for the decontamination pilot project.

Activities within the Decontamination Pilot Projects

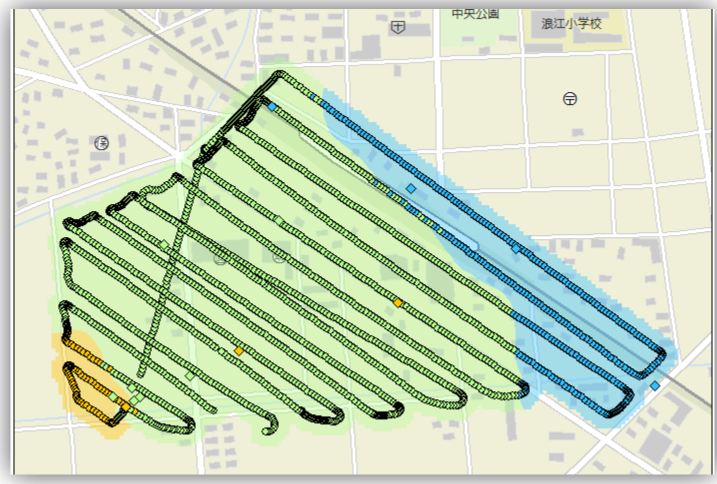


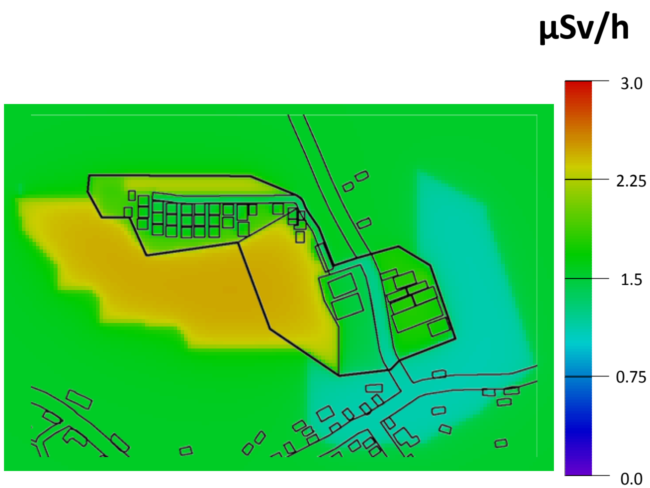
Site Characterisation

- Measurement approaches involved modification of existing technology
- The difficulty of site access led to some of the options illustrated, such as the detectors mounted in a remote-controlled helicopter, a buggy and a backpack
- When linked to appropriate data loggers, these provided rapid and user-friendly maps of radionuclide distributions

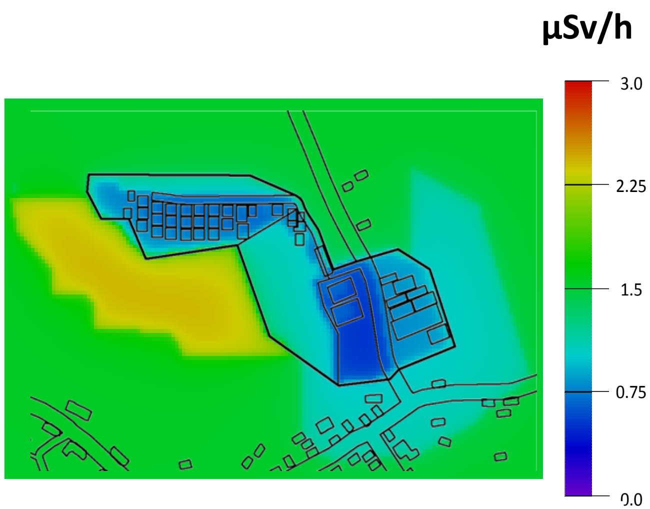
Data Interpretation & Synthesis

- Maps were essential to guide remediation planning, in particular identifying any "hotspots" needing special attention
- Depth profiles allowed assessment of benefits of different soil remediation approaches
- The impacts of different clean-up methods were assessed using a model to predict effective dose reduction, which can treat the effect of long-range gamma flux contribution

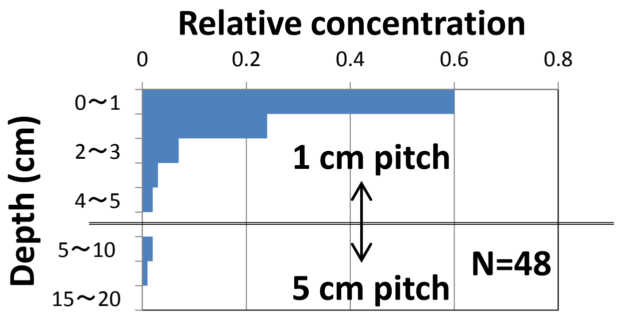




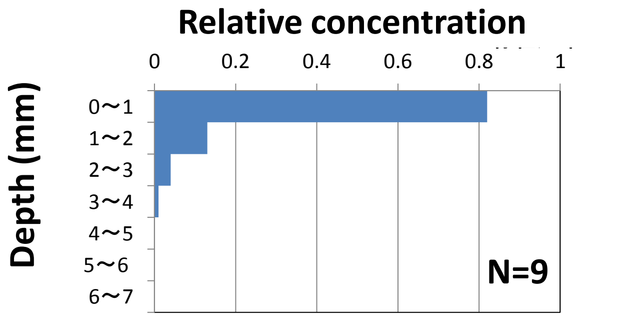
Dose rate before clean-up based on monitoring results



Dose rate after clean-up based on a model prediction



Schools and playing fields



Dense-graded pavements

Lessons Learned -Site Characterisation-

- Although the pilot projects were set up under extreme time pressure, which did not allow optimisation of procedures or standardisation of measurement protocols, manuals were developed to guide sampling and field measurement and independent quality assurance checks were introduced
- Unlike conventional civil engineering work, it was difficult to visually assess the progress of large-scale decontamination work. For example, when stripping topsoil manually, it was difficult to visually judge if the entire contaminated surface layer had been removed. Therefore, during clean-up, the surface dose rate was often monitored to check the effectiveness of procedures, particularly during removal of hotspots.
- Integration of electronic maps, geographical information (land use, etc.) and measured radiometric data has worked well, producing fast and efficient approaches to assessing the relative distribution of radioactivity (or dose rate) in any remediation area

Clean-up Technology

- In each of the demonstration sites, decontamination targets were identified and different technologies were applied to specific types of targets, such as forest, farmland, buildings and roads
- Although the majority of the effort involved manual washing and contaminated material removal using conventional technology, methods that might improve decontamination while decreasing volumes of waste were tested
- Radiation dose of clean-up workers was strictly controlled and always remained low (within the specified upper dose limit)

Scheduling of Decontamination

Forest decontamination

Farmland decontamination

↓

Decontamination of playing fields and large buildings

↓

Decontamination of residential houses

↓

Decontamination of roads

Clean-up of Trees and Forest

clipping

clipping

removing and replacing hotspot soil

removing humus layer

water jet

Clean-up of Farmland

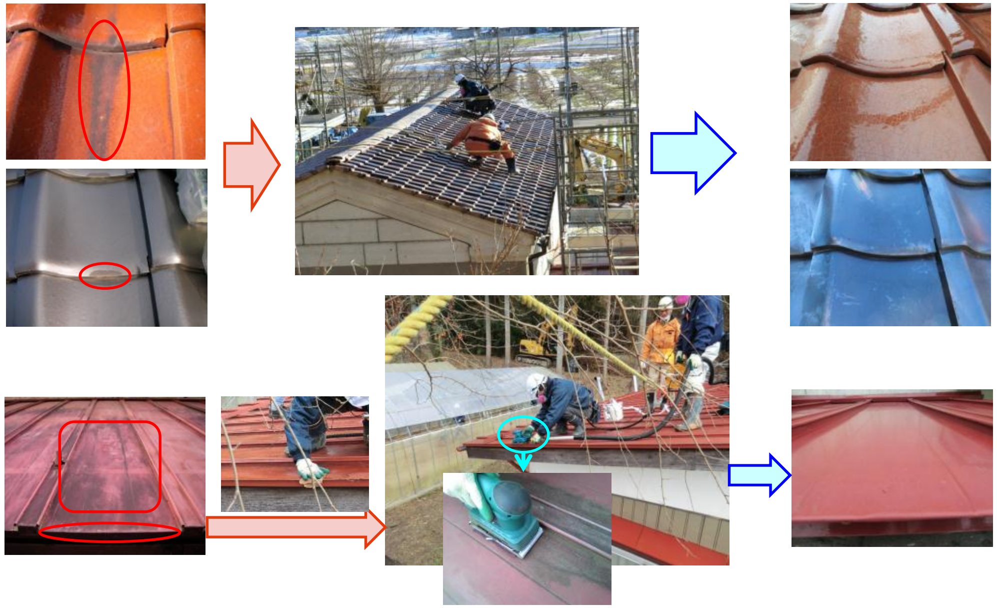
◆ ploughing

◆ turf stripping

◆ topsoil removal

Clean-up of Buildings

Pressure washing roofs



Wiping and grinding roofs

Cleaning gutters

Removing drainage hotspots

Stripping roof surfaces

Clean-up of Roads and Surfaces

- high pressure water

road cleaner

- ultra high pressure water

- surface stripping

- blasting

Iron shot blasting

Ice blasting

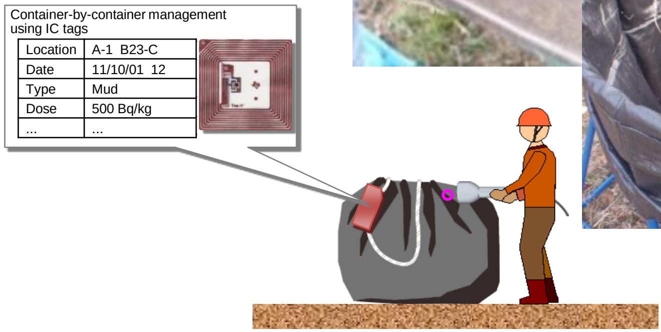
Lessons Learned -Clean-up-

- **Forest**
  - For both evergreen and deciduous forests, effective decontamination generally results from removal of leaf litter and humus layers
- **Farmland**
  - Many different techniques for either soil stripping (possibly with initial solidification or subsequent sorting) or soil profile inversion have been tested in different settings with pros and cons of each being identified
- **Buildings**
  - A special focus for buildings, especially houses, is cleaning roofs and, especially the hotspots found in gutters, drains and other locations where runoff is captured
  - Simple manual methods are generally sufficient and, although high pressure water jets can be used, these need to be carefully handled to prevent water penetration of tiled roofs
- **Roads and paved surfaces**
  - Depending on the required dose rate reduction for roads, potential techniques include high-pressure washing, brushing, ultra-high-pressure jet (up to about 200 MPa), blasting and surface stripping

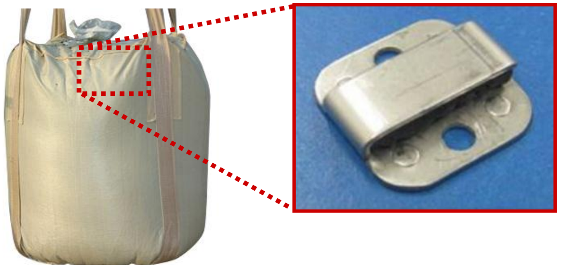
Waste Handling

- Solid waste was reduced in volume to the maximum extent possible – e.g. grinding / chipping of foliage
- Contaminated water or that used for cleaning was decontaminated by filtration or ion-exchange to a level that allow free release of fluids to open drainage
- In most cases, labelled heavy-duty flexible containers were used for solid waste transportation and storage

Measurement of surface dose rates of decontamination waste in the shielding zone



An example of IC tag



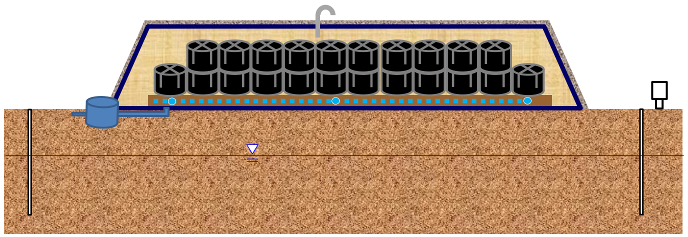
An example of metal tag

An example of paper tag

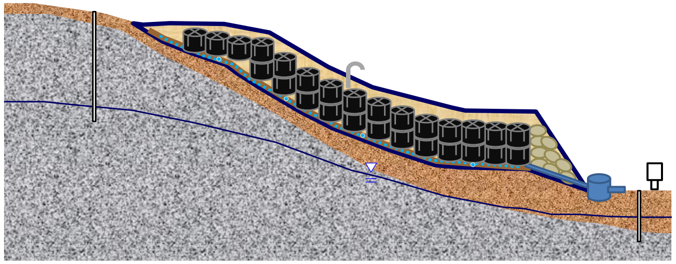
Management of decontamination waste information (tags)

Waste Storage

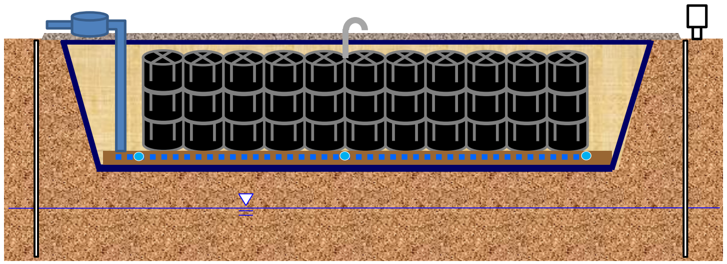
- Locations for temporary storage sites were selected taking into consideration topography, land use status, available areas of land, local government requests, etc., following checks that safety can be ensured
- A range of different approaches were used for temporary storage of waste on the surface or in shallow pits



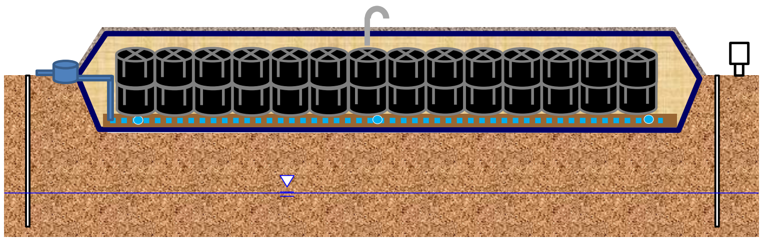
Above ground storage type (on flat ground)



Above ground storage type (on slopes)

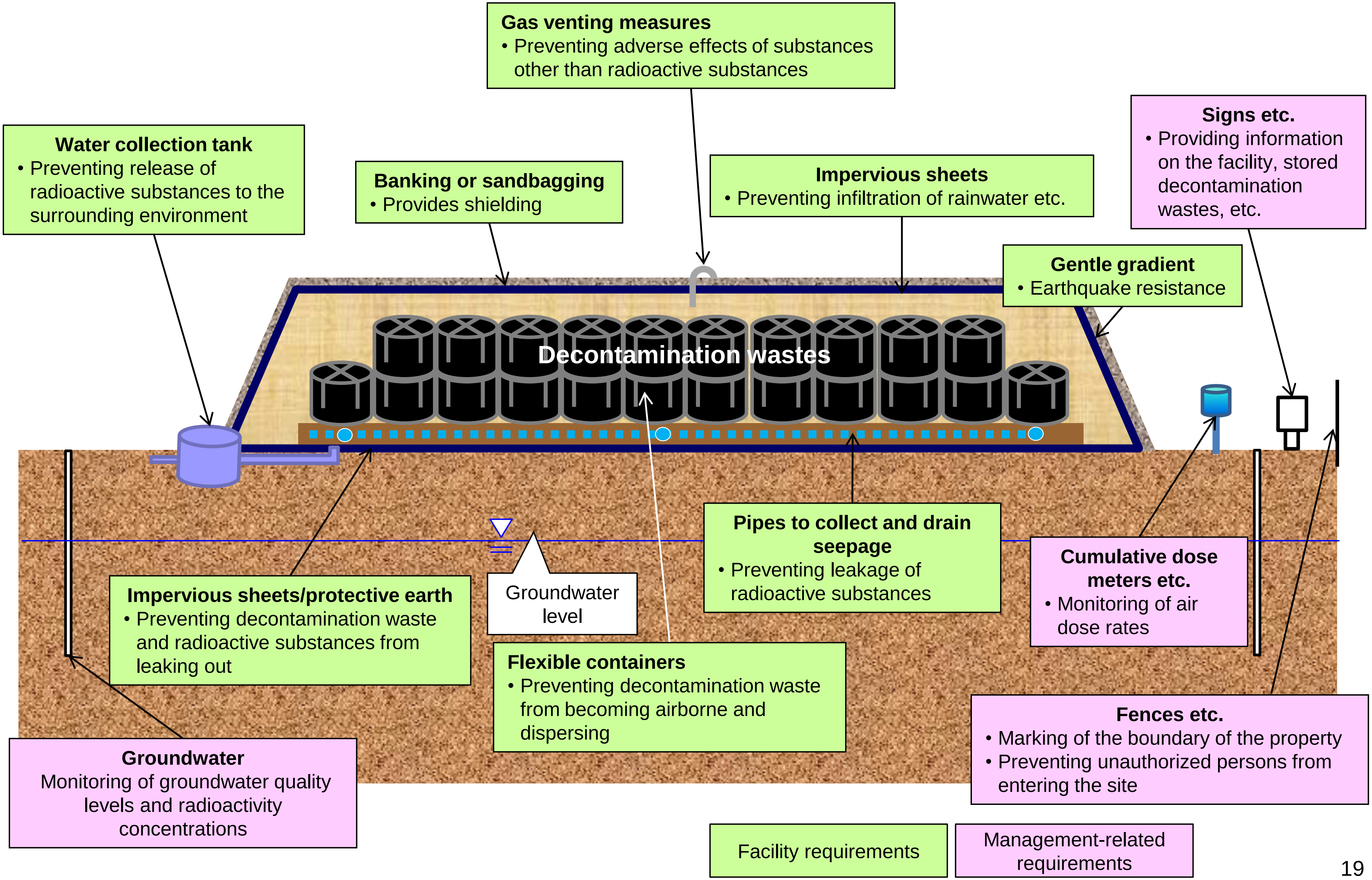


Underground storage type



Semi-underground storage type

Requirements on Temporary Storage

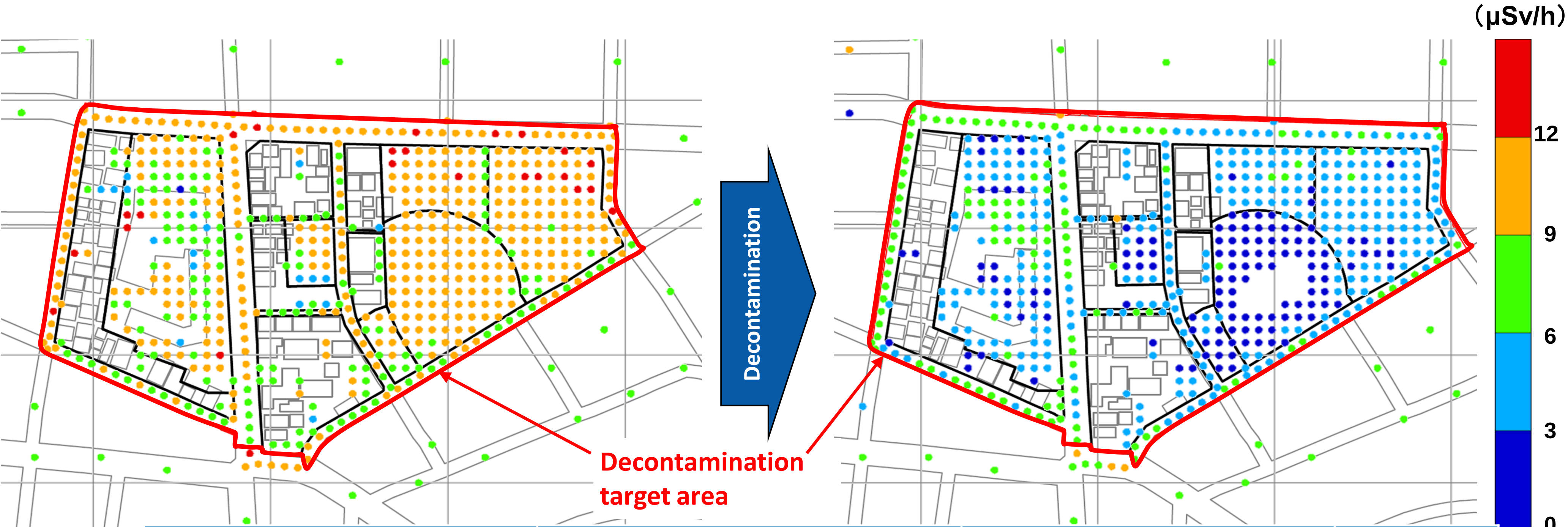


Lessons Learned -Waste Management-

- A range of options were investigated to reduce the volumes of waste produced and ensure that water can be cleaned to the extent that it can be discharged to normal drainage
- Resultant solid wastes were packaged in standard flexible plastic containers, labelled and stored at the temporary storage sites (until centralised interim storage is available)
- The designs of such temporary stores were tailored to available sites, but all included measures to assure mechanical stability (*e.g.* graded cover with soil) and prevent releases to groundwater (impermeable base and cap, gravity flow drainage including catch tanks and radiation monitors)
- The facilities at the demonstration sites had been carefully monitored to check performance is maintained and, in case of any problems, appropriate actions were taken

Results of Dose Reduction by Wide Area Decontamination
[Example Tomioka Town (Yonomori Park area, 9 ha)]

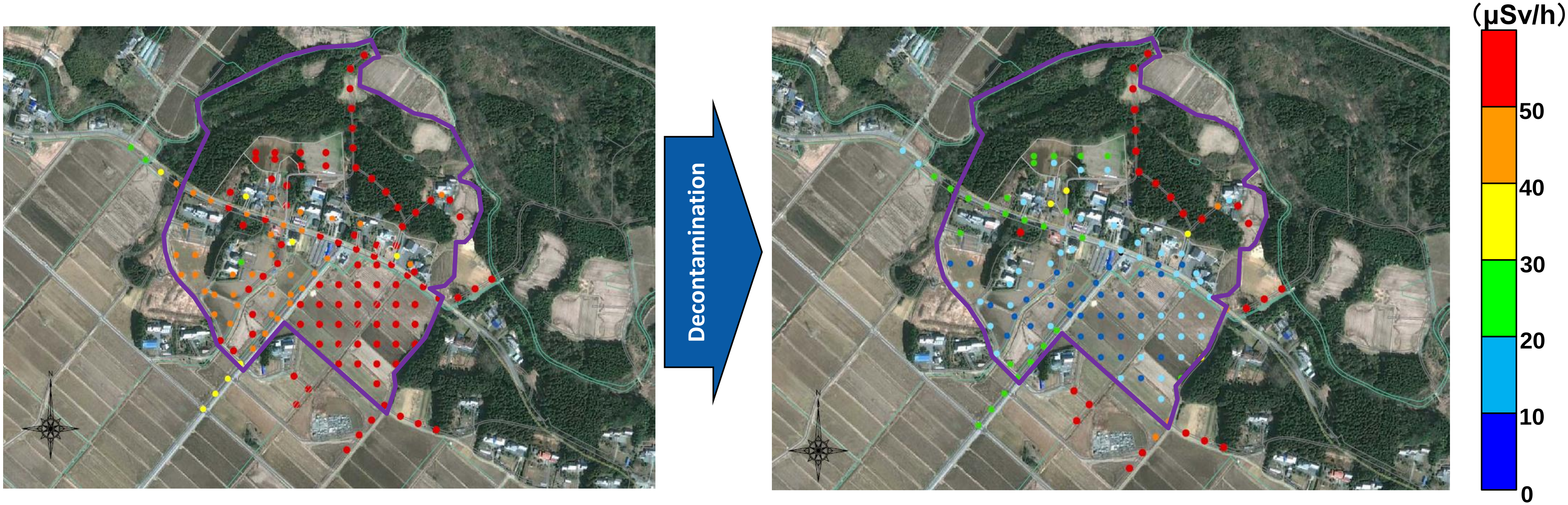
Dose rate before clean-up | **Dose rate after clean-up**



Land use status	Dose rate before clean-up (mean μSv/h)	Dose rate after clean-up (mean μSv/h)	Dose reduction (%)
Residential area	8	4	50
Large buildings	9	5	50
Playing field	11	2	80
Roads	9	5	40
Forests	10	4	60
Outside the decontamination target area	8	7	10

Results of Dose Reduction by Wide Area Decontamination
[Example Ohkuma Town (Ottozawa area, 17 ha)]

Dose rate before clean-up | **Dose rate after clean-up**



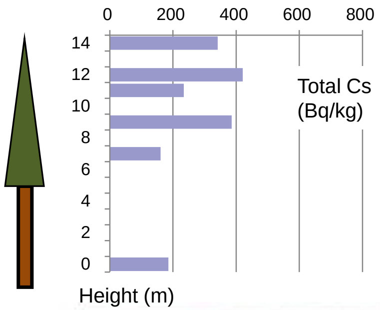
Land use status	Dose rate before clean-up (mean μSv/h)	Dose rate after clean-up (mean μSv/h)	Dose reduction (%)
Forests	137	63	50
Farmland	62	12	80
Residential areas	55	15	70
Roads (paved)	55	17	70
Roads (unpaved)	113	76	30
Outside the decontamination target area	65	52	20*

***The data for outside the decontamination target area may reflect reduction in the long-range gamma flux contribution from within the clean-up area**

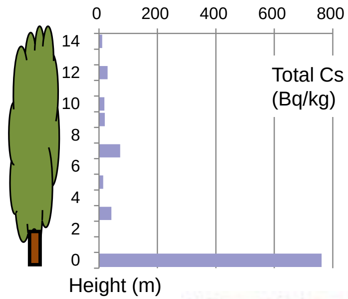
Results of Dose Reduction by Wide Area Decontamination

- **Estimated annual dose reduced to less than 20 mSv/y, for areas with 20 – 30 mSv/y before decontamination**
- **Estimated annual dose could not be reduced below 20 mSv/y, for areas exceeding 40 mSv/y before decontamination**
- **In case of agricultural and residential area of Ottozawa, Ohkuma, the dose rate reduced by 70 %. However, estimated annual dose could not be reduced below 50 mSv/y**
- **The fractional dose rate reduction was smaller in areas of relatively low dose rate, compared with high dose rate areas**

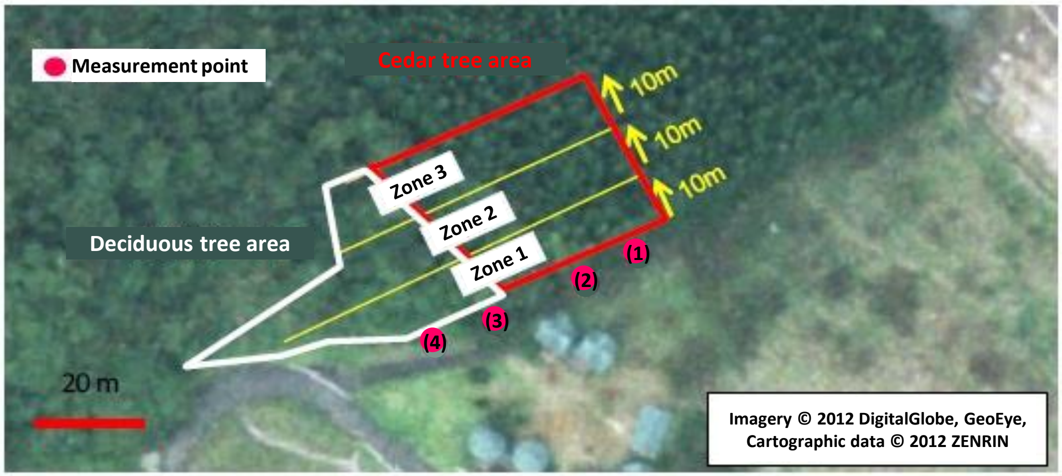
Recommended Clean-up Technologies (forest)



○Distribution of radioactive cesium in Japanese cedar trees (Forestry Agency, September, 2011)



○ Deciduous trees (Forestry Agency, September,2011)



Cleaning a forest perimeter about 10 m wide at boundaries with living areas gave a significant dose rate reduction (40 to 50%)

Location	Measurement point	Before clean-up	After clean-up to a distance of 10 m from the forest edge (Zone 1)			After clean-up to a distance of 20 m from the forest edge (Zones 1 and 2)		After clean-up to a distance of 30 m from the forest edge (Zones 1, 2 and 3)	
			Mowing and leaf litter removal*1	Humus layer removal	Branch trimming at the forest edge	Mowing and leaf litter removal	Humus layer removal	Mowing and leaf litter removal	Humus layer removal
Forest edge (cedar tree area)	(1)	2.6	2.2	1.4	1.3	1.2	1.3	1.3	1.2
	(2)	2.5	2.3	1.6	1.4	1.5	1.4	1.2	1.3
Forest edge (Deciduous tree area)	(3)	2.4	1.7	1.4	ND	1.5	1.4	1.4	1.6
	(4)	2.7	2.3	2.0		2.2	2.2	1.5	1.9

*1: The dose rate values for Zone 1 after mowing and leaf litter removal are measurements taken at a height of 1cm from the ground surface. The values at a height of 1m would be approx. 80% of these values.

Recommended Clean-up Technologies (forest)

Decontamination method		Removal of leaf litter and humus layers (on flat ground)	Removal of leaf litter and humus layers (on slopes)	Removal of leaf litter, humus layers and topsoil (on flat ground)	Trees	
					Trunk washing	Branch trimming in the lower part
Proportions of radioactivity on evergreen trees (as of August - September 2011)		44-84 %			Trunks: 1-3%	Branches and leaves: 14-53%
Percentage dose reduction*		5-90 %	5-90%	20-80%	30-85 %	5-40 %
Volume of decontamination waste generated		0.2-0.9m^3/m^2	0.2-0.9m^3/m^2	1-2m^3/m^2	Small amount	2.7m^3/m^2 (non-reducing waste volume)
Secondary contamination		Does not occur.	Does not occur.	Does not occur.	Occurs. (Soil infiltration of droplets)	Occurs. (Drop branches to forest floor)
Effects on surrounding environments		On slopes, it is necessary to be careful not to cause erosion.				
Cost (JPY)		530/m^2	760/m^2	890/m^2	3,390/tree	580/m^2
Decontamination speed		510 m^2/day (11 persons)	340 m^2/day (11 persons)	220 m^2/day (5 persons)	32 trees/day (4 persons)	150 m^2/day (4 persons)
Applicability	Deciduous forests	◎	◎	○	▲**	–
	Evergreen forests	◎	◎	○	▲**	○

◎: highly effective; ○: effective; △: moderately effective; ▲: limited effect

* Percentage dose reduction is calculated using the values of surface contamination density measured before and after decontamination. In the case of the branch trimming, the values of air dose rate are used.

** Since the trees like being in park are touched by people, trunk washing is effective.

Recommended Clean-up Technologies

Land use classification			Comprehensive evaluation
Forest			◎Removal of leaf litter and humus layers (on flat ground and slopes), ○Removal of leaf litter, humus layers and topsoil (on flat ground), ▲Trunk washing, ○Branch trimming in the lower part (evergreen tree)
Farmland			◎Machine that strips off surface of soils, ○Backhoe (stripping off depth of 5 cm of the soil), ◎Reversal tillage (by tractor and plough), ○Ploughing to replace surface soil with subsoil (by backhoe)
Residential area	Roof		▲High pressure water, ○Brushing, ○Wiping, ▲Apply a remover
	Gutter		△High pressure water, ○Wiping
	Wall		○Brushing
	Topsoil		○Removal of topsoil
	Rubble		○Washing of the rubble, ○Removal of the rubble
	Turf		○Removal of the Turf
	Garden tree		▲Clipping a garden tree
	Interlocking block		△High pressure water
Large structure	Concrete and Mortar surface		△Sanding machine with the dust-collection (Plane which scrapes concrete), ○Ultrahigh pressure water (Over 150MPa), ○High pressure water (10-20MPa), ○Iron shot blasting
	Roof floor	Concrete surface	○High pressure water (including brushing)
		Waterproof coating surface	○High pressure water (including brushing)
		Downpipe	○High pressure water(Maximum 50MPa)
Playing field			○Strips off surface of soils (Large mower+Sweeper), ○Strips off surface of soils (Road planers), ○Strips off surface of soils(Motor grader), ○Ploughing to replace surface soil with subsoil
Swimming pool			○High pressure water
Turf			○Turf stripper
Paved road			▲Road cleaners + Riding style road sweepers, △High pressure water (About 15MPa)+Brushing, △Car of a functional recovery drainage pavement, ○Ultrahigh pressure water (120～240MPa),○Iron shot blasting, ○TS Road planers

◎:highly effective, ○:effective, △:moderately effective, ▲:limited effect

Video of clean-up Technologies

Lessons Learned -Informed Consent-

- To obtain the consent from local residents, which is necessary to allow such work to progress, the support from mayors of local municipalities and heads of administrative districts was indispensable

- Briefing sessions with communities and use of a clear and simple consent form also helped to facilitate this process

- Materials for explaining remediation to stakeholders and providing the basis for establishing dialogue with them have been developed, including plans of remediation and temporary storage and rapid communications on evaluating effectiveness of remedial measures

Conclusions and Future Perspective

- **The decontamination pilot projects have provided:**
  - **Experience and tools for planning and coordinating efficient, safe and cost-effective remediation programmes**
  - **Evaluation of the applicability of remediation technology with an assessment of the pros and cons of different approaches**
  - **Guidelines for tailoring of projects to the conditions found in different sites**
- **Practical experience has shown that stakeholder involvement in implementation of clean-up activities is essential**
- **All such explicit and tacit knowledge is being captured in a user-friendly web-based communication platform, which should be operational in both Japanese and English**
- **The regional work will allow displaced populations to return home to normal lifestyles as quickly as possible**