

(2) Report of the Results of the Decontamination Model Projects

Analysis and Evaluation of the Results of the Decontamination Model Projects - Decontamination Technologies -

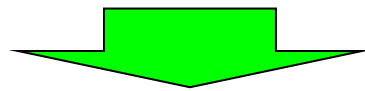
Masayuki Ito
Japan Atomic Energy Agency

Meeting for Reporting the Results of the Decontamination Demonstration Model Projects etc.
held on March 26, 2012 at Fukushima City Public Hall
under the auspices of the Cabinet Office's Team in Charge of Assisting the Lives of Disaster Victims,
the Ministry of the Environment and Japan Atomic Energy Agency

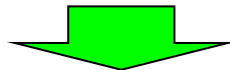
Evaluation Indicators Used in the Decontamination Demonstration Model Project

The 3 Major Quality Requirements for Decontamination

- **Speed** ... Area that each small group can decontaminate in one day
- **Efficiency** ... Stripping and removal effectiveness
(minimization of volume of decontamination waste generated)
... Reduce unnecessary work as far as possible
(secondary contamination)
- **Effectiveness** ... Reduction rates (surface count rate and air dose rate)



What are preferable decontamination technologies?



Decontamination methods that can satisfy the 3 major quality requirements
and the associated techniques employed

Basic Flow of Decontamination

Confirmation of the radiation contamination
through monitoring area status

Prediction of the decontamination effects:

- Available decontamination methods
- Prediction of the volume of the decontamination waste (removed soil, etc.) generated and the resultant dose reduction effects
- Constraints (such as the capacities of temporary storage sites and the need to obtain permission from land owners)

Selection of the decontamination method
(such as stripping, water washing etc)

3 major
quality
requirements

Execution of decontamination

Review of
the decontamination
method

Confirmation of the decontamination effects comparing
with pre- and post-decontamination monitoring

Were the predicted decontamination
effects achieved?

No

Yes

Completion of the decontamination

(1) Forests

Prediction of the decontamination effects:

- Available decontamination methods
- Prediction of the volume of the decontamination waste (removed soil etc.) generated and the dose reduction effect of the decontamination
- Constraints (such as the capacities of temporary storage sites and the need to obtain permission from land owners)

Consideration of decontamination methods based on type of forest

Deciduous forests

Removal of fallen leaves and humus, topsoil stripping, tree trunk washing

Evergreen forests

Removal of fallen leaves and humus, topsoil stripping, branch trimming, tree trunk washing, felling

Flat Ground

Slope ground

Is there a risk of slope ?

Yes

Consideration of protection of erosion (sediment discharge by rain)

No

Determination of the decontamination method to use

(1)-1 Retention of Radioactive Cesium in Forests

Difference in the air dose rate distribution trend with height between evergreen trees and deciduous trees

◆ Evergreen trees (Japanese cedar forest)

The trend was that the higher the measurement location on a tree, the higher the dose rate was or it was roughly the same. It is presumed that the evergreen trees (such as Japanese cedar trees), which have kept their leaves since before the accident, have a large amount of radioactive cesium adhering to their branches and leaves.

◆ Deciduous trees

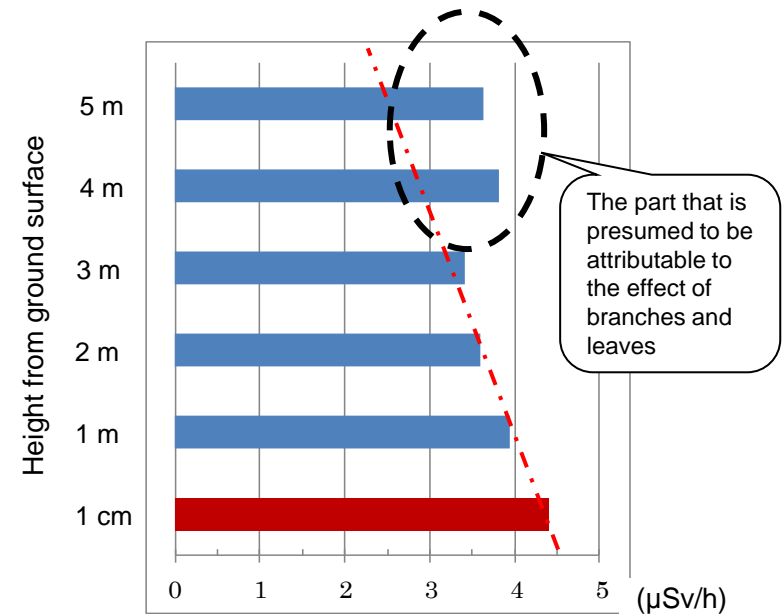
The trend was that the higher the measurement location on a tree, the lower the dose rate was. From this fact, it is presumed that most of the radioactive cesium that fell on the deciduous trees, which did not have leaves at the time of the accident, fell directly to the ground.

Air dose rate distribution on evergreen trees (Japanese cedar forest)
in the height direction

Height from ground surface	Air dose rate ($\mu\text{Sv/h}$)		
	North side	South side	East side
15 m	7.88	7.07	—
10 m	7.14	7.91	9.12
5 m	6.94	5.83	7.65

Air dose rate distribution in the height direction in a mixed forest of deciduous trees and bamboos

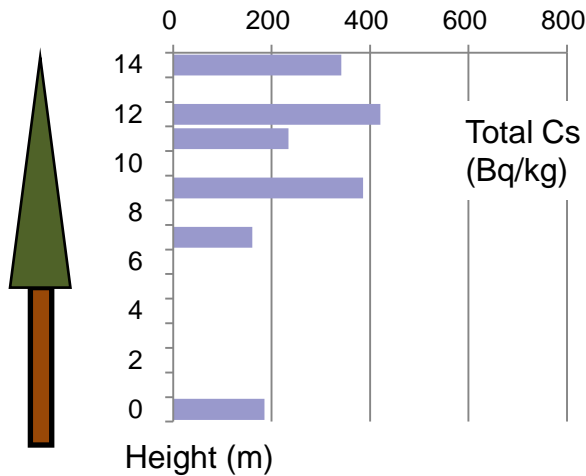
Height from ground surface	Air dose rate ($\mu\text{Sv/h}$)
432.0 cm	8.9
335.0 cm	9.49
216.5 cm	9.58
108.5 cm	11.64



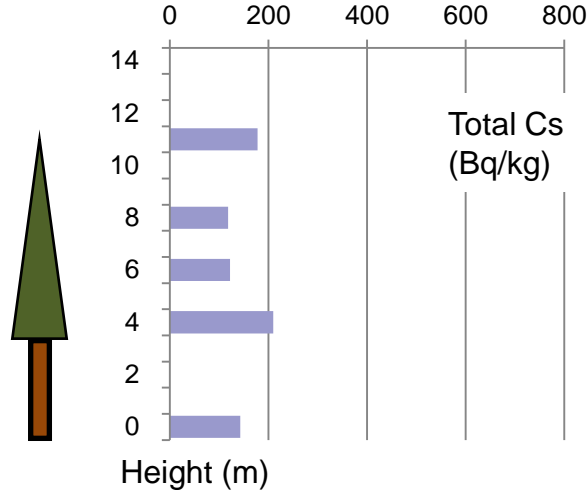
Air dose rate distribution on evergreen trees (Japanese red pine trees) in the height direction

(Reference Information) Sorption of Radioactive Cesium onto Trees

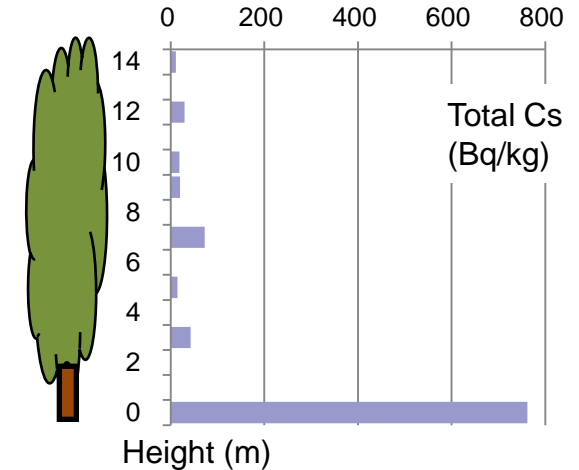
○ Mature Japanese cedar trees



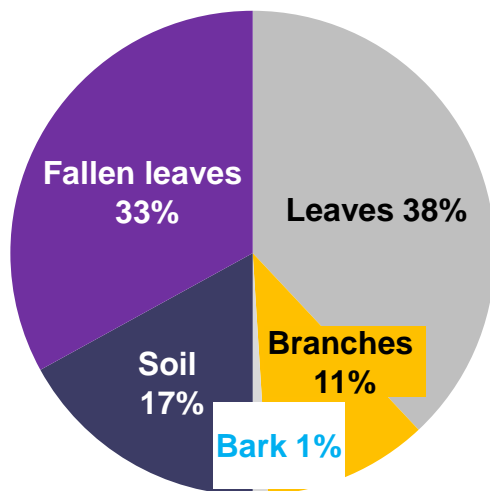
○ Young Japanese cedar trees



○ Deciduous trees



○ Distribution of radioactive cesium in a Japanese cedar forest



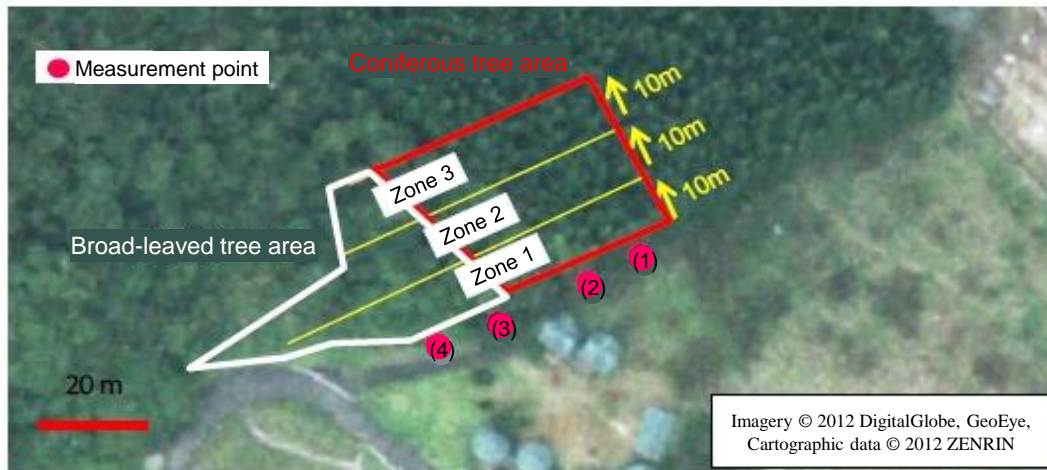
The concentration of cesium adhering to Japanese cedar trees (evergreen trees) was roughly the same at all heights. The total amount of radiocesium present on the trees was roughly the same as the amount of on and in the ground (as of September 2011).

With regard to deciduous trees, the radiocesium concentration on the fallen leaves on the ground was high, and it was presumed that most of the radioactive cesium was present on the ground.

Sources: "States of Distributions of Radioactive Substances in Forests and Analysis Results (interim report)," Forestry Agency, September 30, 2011; "Material No.8-1-1 for the Eighth Study Meeting for the Development of Maps of Distributions of Radiation Doses etc.," September 13, 2011

(1)-2 Decontamination of Forests

- Forest decontamination (through fallen leaves removal and litter layer removal) was performed from the forest edge adjacent to an inhabited area into the forest, and the change in the effect of radiation dose from the forest to the inhabited area with distance from the forest edge was observed. **Decontamination of the first 10m-wide zone (strip)**, which is the nearest zone to the inhabited area, brought about **an air dose rate reduction at the forest edge of approximately 40%**.
- On the other hand, **decontamination of the second and third zones** (the zones located deeper into the forest) brought about **almost no further air dose reduction** at the forest edge.
- Decontamination (through mowing, fallen leaves removal and litter layer removal) of the part of a forest that is adjacent to an inhabited area is **effective in reducing radiation doses in the inhabited area**.



Measured dose rates at the forest edge for different decontamination extents (distances from the forest edge) and different decontamination methods

Location	Measurement point	Before decontamination	After decontamination to a depth of 10 m from the forest edge (Zone 1)			After decontamination to a depth of 20 m from the forest edge (Zones 1 and 2)		After decontamination to a depth of 30 m from the forest edge (Zones 1, 2 and 3)	
			Mowing and fallen leaves collection*1	Litter layer removal	Branch trimming at the forest edge	Mowing and fallen leaves collection	Litter layer removal	Mowing and fallen leaves collection	Litter layer removal
Forest edge (coniferous tree area)	(1)	2.60	2.21	1.41	1.32	1.16	1.27	1.25	1.17
	(2)	2.45	2.30	1.63	1.36	1.45	1.35	1.20	1.29
Forest edge (broad-leaved tree area)	(3)	2.40	1.70	1.38	-*2	1.47	1.40	1.37	1.64
	(4)	2.70	2.26	2.02		2.15	2.18	1.45	1.87

*1: The dose rate values for Zone 1 after mowing and fallen leaves collection 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.

*2: For broad-leaved trees, no branch trimming was performed because all of their leaves had fallen.

(1)-2 Comparison of Forest Decontamination Methods

Decontamination method		Removal of fallen leaves, humus and topsoil	Trees		
			Trunk washing	Branch trimming in the lower part	Felling
Proportions of radioactivity on evergreen trees (as of September 2011)		50%	Trunks: 1%	Branches and leaves: 49%	Total: 50%
Removal rate		Approx. 80%	Approx. 30%	—	100%
Radiation dose rate reduction rate		40%	1% or less	10-20%	50%
Volume of decontamination waste generated		0.05–0.1 m ³ /m ² (non-flammable)	Small amount (bark and moss)	1-3 m ³ /tree (flammable)	Large amount (Bark, branches and leaves)
Secondary contamination		Does not occur.	Occurs.	Occurs.	Occurs.
Effects on trees and surrounding environments		On slopes, it is necessary to be careful not to cause erosion.	Tree species cannot withstand bark stripping.	Tree species cannot withstand bark stripping.	It is necessary to take erosion control and windbreak measures as appropriate.
Decontamination speed (flat areas)		300 m ² /day	4 trees/day	500 m ² /day	—
Applicability	Deciduous forests	◎	▲	—	—
	Evergreen forests	◎	▲	○	△

◎: highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(1)-3 Leaf Litter and Humus Layer Removal Methods (Flat Ground)

Flat ground: Humus and topsoil around tree bottoms (root bases) and in narrow areas are stripped manually (using rakes) to the required depth. In wide areas, stripping is performed using mechanical diggers.



Stripping of humus and topsoil around tree bottoms (manual work)



Stripping in a wide area (using mechanical diggers)

Important points:

- ◆ On flat ground, the humus layer should be removed in its entirety. Where a vacuum suction vehicle is used in a highly contaminated area, it is necessary to consider whether a bag filter needs to be installed between the vacuum suction vehicle and the suction inlet.
- ◆ It is important to determine the required stripping depth prior to performing the decontamination by setting up a test area and investigating the relationship between the stripping depth and the decontamination effect in the test area.
- ◆ For areas to be decontaminated manually, it is important to instruct all workers in advance to what extent they should remove the humus and topsoil, so that variations between the areas assigned to the individual workers in the extent of humus and topsoil removal and collection will be minimized.

(1)-3 Leaf Litter and Humus Layer Removal Methods (Slopes)

Overview of the removal work: Fallen leaves are collected manually (using bamboo brooms and blowers) and put into containers. In addition, humus of the litter layer is manually removed (using rakes) and collected, and the collected humus is transported to a vacuum suction vehicle through a suction hose and then transferred manually from the vacuum suction vehicle to containers.



Suction-based removal of humus



Vacuum suction vehicle (suction power: 120 m³/hour)

Important points:

- ◆ In the case of slopes, removing the humus layer in its entirety may lead to future erosion or slope failure after heavy rain. Therefore, it is necessary to determine the litter layer removal depth according to the state of contamination and consider whether slope protection measures need to be taken after removal.
- ◆ For highly contaminated areas, it is necessary to consider whether a bag filter needs to be installed between the vacuum suction vehicle and the suction inlet.
- ◆ In the case where the litter layer is removed in its entirety, it is important to remove it meticulously until the topsoil surface is completely exposed.

(1)-4 Important Points Regarding Forest Decontamination Methodology

○ Important points regarding the determination of the decontamination areas and methods

- (1) Decontaminating a forest adjacent to an inhabited area reduces radiation doses in the inhabited area (at the interface between the forest and inhabited area). However, this reduction effect is achieved by **decontaminating a strip of the forest with a width of approx. 10 m** as measured from the forest edge and almost no further reduction is brought about by performing decontamination further into the forest.
- (2) Because the litter layer under the layer of newly-fallen leaves is also contaminated with a large amount of radioactive cesium in many areas of **evergreen forests**, **removing the litter layer in addition to removing the undergrowth and the layer of newly-fallen leaves** brings about a better decontamination effect.
- (3) With regard to tree trunks, an excellent decontamination effect can be achieved by washing them using high-pressure water jet on the premise that it does not adversely affect the growth of the trees (bark peeling due to the washing is an acceptable cost) (example: a reduction rate of approx. 80% for zelkova trees in the Yonomori Park).
- (4) In the case of slopes such as those in mountain forests, removing the humus layer in its entirety may lead to future **erosion or slope failure** after heavy rain. Therefore, in the case where it is necessary to remove the humus layer in its entirety, it is necessary to consider whether **erosion prevention measures** (such as hurdle works and sandbagging) need to be taken.

○ Important points regarding the application of a selected decontamination method

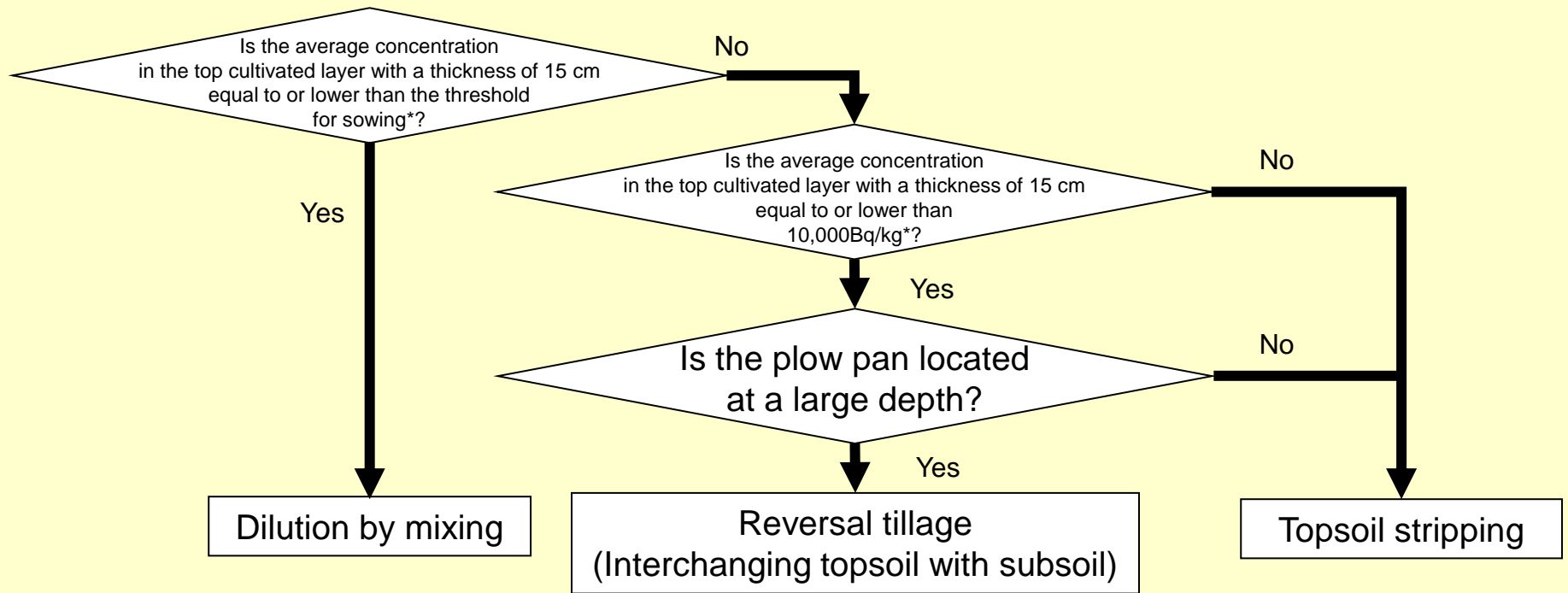
- (1) In both evergreen and deciduous forests, **removal of fallen leaves and the litter layer is the most effective means of decontamination**. In dense forests such as bamboo forests and slopes such as those in mountain forests, suction and transport using vacuum suction vehicles is effective.
- (2) It is important to **determine the required stripping depth** prior to removing the litter layer by setting up a test area and **investigating the relationship between the stripping depth and the decontamination effect** in the test area. For areas to be decontaminated manually, it is important to **instruct all workers in advance** to what extent they should remove the humus and topsoil, **so that variations between the areas assigned to the individual workers in the extent of humus and topsoil removal will be minimized**.

(2) Farmland

Prediction of the decontamination effects:

- Available decontamination methodology
- Prediction of the dose reduction effect of the decontamination procedures and prediction of the volume of decontamination waste likely to be generated (removed soil etc.)
- Constraints (capacities of temporary storage sites, the need to obtain permission from land owners, the guidelines of the Ministry of Agriculture, Forestry and Fisheries)

[An example work flow based on the “concept of the application of farmland soil decontamination technologies” (Ministry of Agriculture, Forestry and Fisheries)]

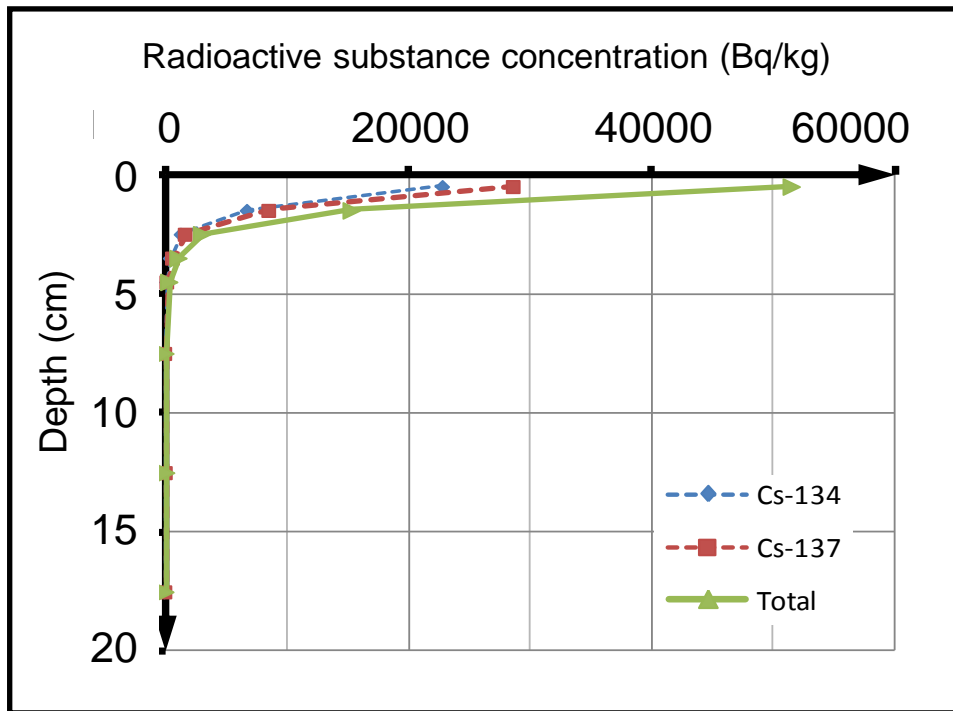


* The concentration criteria will be changed as necessary based on the guidelines of the Ministry of Agriculture, Forestry and Fisheries.

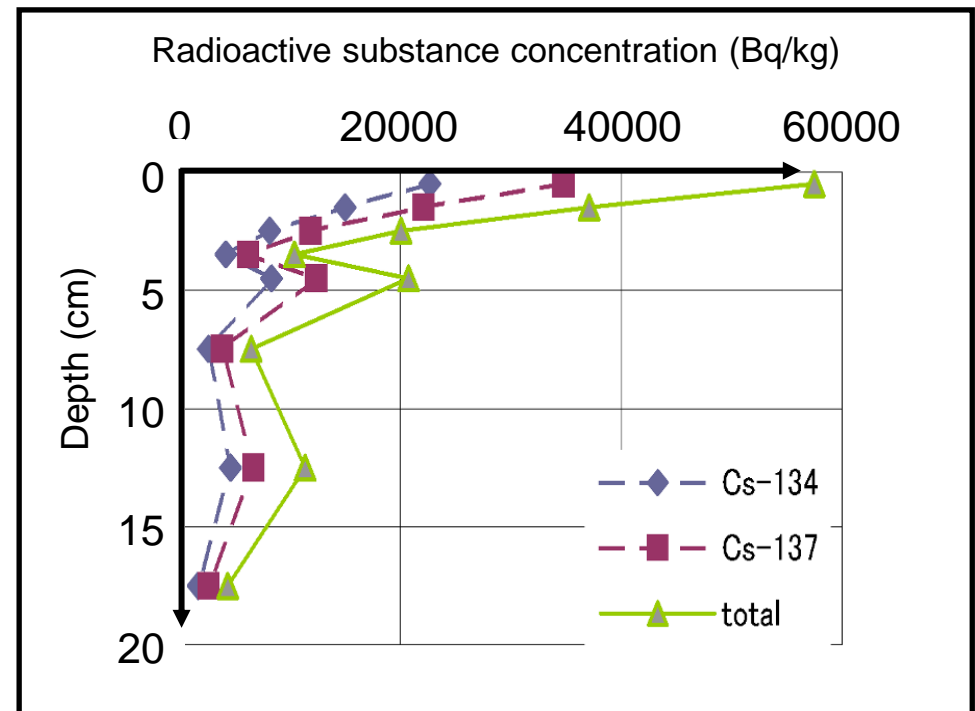
(2)-1 Retention of Radioactive Cesium in Farmland

Radioactive cesium profiles for paddy fields that had been cultivated immediately before the accident and fields that had not been cultivated

- ◆ In the paddy fields that had been cultivated immediately before the accident, radioactive cesium penetrated deeper into the ground than the paddy fields that had not been cultivated, and there were larger variations in concentration distribution, because of the irregularities made by tractor wheels.



Cesium concentration profiles in fields and paddy fields that were not cultivated immediately before the accident (around February 2011)



Cesium concentration profiles in fields and paddy fields that were cultivated immediately before the accident (around February 2011)

* The measured radioactivity concentration values in the graphs above are values that have not been corrected for the errors associated with the sampling and measurement methods used.

(2)-2 Comparison of Reversal Tillage Methods

Decontamination method	Reversal tillage (tractor + plow)	Interchanging topsoil with subsoil (mechanical digger)
Reduction rate	65 - 80%	Approx. 65%
Volume of removed soil	None	None
Secondary contamination	None	None
Effects on the surrounding environment	None	None
Tilling speed	1,000 m ² /day	300 m ² /day
Applicability	◎	○

◎: Highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(2)-3 Reversal Tillage

Tractor + plow

The soil is reversed using a cultivator with plow that is capable of reversing soil to the necessary reversal depth.



Interchanging topsoil with subsoil (mechanical digger)

Topsoil with a Cs content of approx. 90% is stripped off with a small stripping thickness and temporarily set aside. Subsoil is stripped off with a stripping thickness of approx. 30 cm and set aside. The removed topsoil is put in and spread, and then the removed subsoil is put over the topsoil and spread.



Topsoil stripping
with a stripping thickness of 5 cm



Subsoil stripping
with a stripping thickness of 45 cm

Important point:

- ◆ It is important to determine the reversal depth after confirming the radioactivity concentration distribution in the depth direction and the depth of the plough pan.

Important points:

- ◆ It is important to determine the depths of the upper and lower layers to be interchanged after confirming the radioactivity concentration distribution in the depth direction and the depth of the plough pan.
- ◆ It is important to set aside the stripped upper and lower layer soil in such a way that the stripped upper layer soil is not mixed with the stripped lower layer soil.

(2)-4 Comparison of Topsoil Stripping Methods

Decontamination method	Thin-layer soil stripping equipment (hammer knife)	Mechanical Digger (stripping thickness = 5 cm)	Spraying of surface solidifying agent	
			Separate collection equipment	Collection by means of stripping by mechanical digger
Reduction rate	Approx. 70%	Approx. 65-95%	Approx. 80%	Approx. 80%
Volume of removed soil (overbreak ratio)	No overbreak	Thin-layer stripping with a thickness of less than 5 cm is difficult.	Overbreak is small	Overbreak is small
Secondary contamination	None	None	None	None
Stripping speed	700 m ² /day	700 m ² /day	300 m ² /day	300 m ² /day
Application conditions	<ul style="list-style-type: none"> It is not possible to strip off frozen soil 	<ul style="list-style-type: none"> Fields of compact soil with sufficient bearing capacity Furrows may be broken as a result of entry of heavy equipment 	<ul style="list-style-type: none"> Dry fields Solidifying agent does not solidify in pooled fields or when the temperature is below the freezing point 	<ul style="list-style-type: none"> Fields of compact soil with sufficient bearing capacity Solidifying agent does not solidify in pooled fields or when the temperature is below the freezing point
Applicability	◎	○	○	○

◎: Highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(2)-5 Topsoil Stripping (Thin-layer Topsoil Stripping Equipment)

Overview: Topsoil is stripped off in thin layers using thin-layer topsoil stripping equipment (hammer knife mowers or mowers). Runs will be repeated until the target stripping depth is reached.



Hammer knife mower

Advantage:

Mowing and thin-layer topsoil stripping can be done at the same time by using the hammer knife mower. Further, grass roots removal and soil loosening can be done at the same time, the collection work is easier.

Important points:

- ◆ Because the thickness of soil that can be stripped off in one go is 1cm or less, it is important to determine the stripping method after confirming the relationship between the number of runs and the stripping thickness and decontamination rate.
- ◆ It is important to neatly collect the stripped soil and roots manually using rakes, bamboo brooms, etc., and remove them.
- ◆ Because this is thin-layer stripping, the topsoil of depressions in unevenness surfaces is left without being stripped off. Therefore, it is important to check for areas where topsoil has not been stripped off and strip it off manually.

(2)-6 Topsoil Stripping (Topsoil Solidification and Separated Collection Equipment)

Overview: After mowing the grass and collecting it, solidifying agent is sprayed using solidifying agent spraying equipment. After a curing period of 3 days, topsoil is stripped off using separated collection equipment or a mechanical digger.



Spraying of solidifying agent

+



Equipment for separated collection of solidified soil

or



Mechanical Digger (sweeper mode)

Important points:

- ◆ Separation collection equipment cannot be used for soil with a high water content, because the piping of the transport section will clog with wet soil and sand. For soil with a high water content, stripping using a mechanical digger is effective.
- ◆ Because solidifying agents do not solidify when the temperature is below the freezing point, this method is not effective in winter.
- ◆ Solidifying agents do not solidify in fields that have standing water. Therefore, it is important to spray solidifying agents on dry fields.
- ◆ Because solidifying agents are grayish white, it is found out whether there is left to take, it eliminates the possibility of areas being missed and therefore all of the surface soil is removed.

(2)-7 Important Points about Farmland Decontamination Methods

○ Important points regarding the selection of a decontamination method

- (1) It is important to **select the decontamination method to use** (i.e. dilution by mixing, reversal tillage (interchanging topsoil with subsoil) or topsoil stripping) after conducting surveys to confirm the distribution and concentration of radioactive cesium with depth and the depth of the plough pan.
- (2) There was a tendency that 80% or more of the radioactive cesium was present within the top portion of the soil down to a depth of approx. 5 cm. The topsoil stripping thickness needs to be determined so that the radioactive cesium concentration down to the **cropping depth** (15 cm for paddy fields and 30 cm for other fields) **becomes lower than the cropping threshold**.
- (3) It is **difficult to strip topsoil off accurately with a stripping thickness of 5 cm or less with a mechanical digger (with a flat claw) only**, because mechanical diggers are civil engineering work equipment. When it is necessary to strip off topsoil with a stripping thickness of 5cm or less, it is necessary to use a thin-layer stripping method.
- (4) **When using equipment for separate collection of solidified topsoil on soil with a high water content**, it is important to select an appropriate collection method taking into consideration the fact that **wet soil adheres to the collection conveyor**.

○ Important points regarding the application of a selected decontamination method

- (1) Because the thickness of topsoil that can be stripped off at one time with thin-layer topsoil stripping equipment is 1cm or less, it is important to **confirm the relationship between the number of runs and the stripping thickness and decontamination rate**.
- (2) **Solidifying agents do not solidify in fields with standing water or when the temperature is low (e.g. in winter)**. Therefore, it is important to make sure that the application condition requirements for applying solidifying agents.

(3) Residential Houses and Large Buildings

Prediction of the decontamination effects:

- Available decontamination methods
- Prediction of the dose reduction effect of the decontamination method and prediction of the volume of the decontamination waste generated (removed soil etc.)
- Constraints (capacities of temporary storage sites, the need to obtain permission from land owners)

Consideration of decontamination methods

Material

Concrete, asphalt, metals, plastics, timber, earth, turf, gravel, roof tiles, etc.

Surface State

Large areas, small areas, corner sections, hard, soft, horizontal, vertical, etc.

Selection of
decontamination technique

Selecting a decontamination technique that is suitable for the environmental conditions regarding the material to be decontaminated, the state of surface, etc.

Consideration of work methods (pressure, number of times, etc.)

Selection of the decontamination method to use

(3)-1-1 Results of Decontamination of Large Buildings (roofs)

○ Results of decontamination of concrete roofs

- ◆ Concrete roofs (which had been waterproof-treated) and lightweight-concrete roofs;
 - high-pressure water jet-based washing was effective for decontamination.
- ◆ On concrete (mortar) roofs;
 - high-pressure water jet washing (approx. 10 MPa), • high-pressure water jet washing plus brushing, • high-pressure water jet washing plus nano-bubble washing, • high-pressure water jet washing plus nano-bubble washing, hydrogen peroxide water and special solutions, these methods were effect less than that achieved for waterproof-treated.

Roof material	Location	Decontamination method	Surface contamination density (cpm)		Surface contamination density reduction rate
			Before decontamination	After decontamination	
Mortar	Large Building C	High-pressure water jet washing + rotating wire brush	38,500	16,200	58
Mortar	Large Building C	High-pressure water jet-based washing using nano-bubble water with 3% hydrogen peroxide water and ozone water added	40,600	24,100	41
Mortar	Large Building C	High-pressure water jet-based washing	40,000	24,400	39
Mortar	Large Building C	High-pressure water jet-based washing using nano-bubble water	40,100	18,200	57
Mortar	Large Building C	Washing using water with 3% hydrogen peroxide water added	48,600	23,800	51
Waterproofing treatment	Large Building C	High-pressure water jet-based washing	65,000	4,300	93
Waterproofing treatment	Large Building A	Washing with water, polisher-based washing	21,229	4,006	81
Waterproofing treatment	Large Building D	High-pressure water jet-based washing	420	280	33
Lightweight concrete	Large Building E	High-pressure water jet-based washing	25,220	5,830	77

Large Building C



Waterproofing treatment

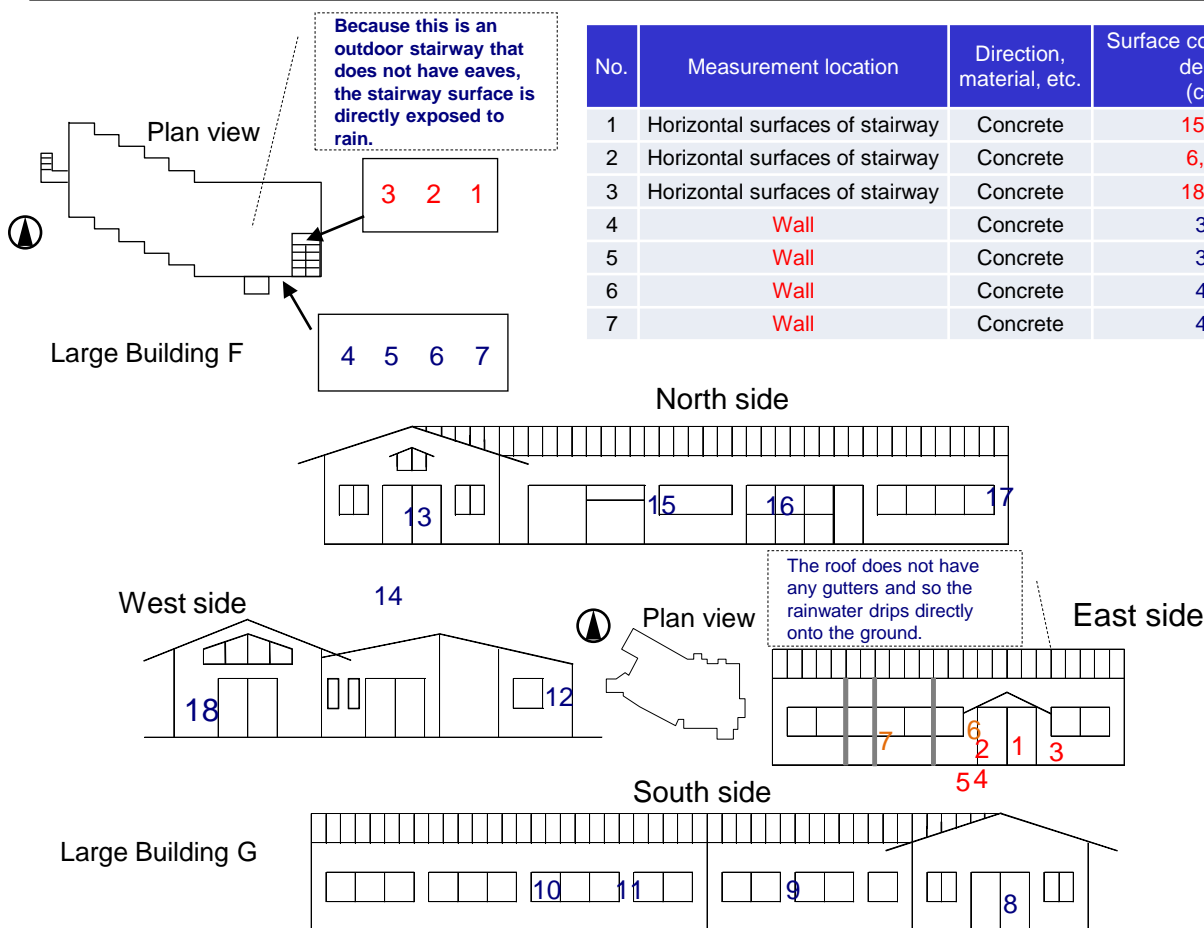


Mortar

(3)-1-2 Sorption of Contamination onto Each Parts of Large Buildings

○ Sorption of radioactive cesium

- ◆ Walls of large buildings (e.g. Large Building F) tend to have lower surface contamination densities than floors and concrete floors. On the other hand, there were walls that have been contaminated as a result of rain water dripping etc. (For example, the east side of Large Building G tended to have higher surface contamination densities than the other sides.)



No.	Measurement location	Direction, material, etc.	Surface contamination density (cpm)
1	Horizontal surfaces of stairway	Concrete	15,500
2	Horizontal surfaces of stairway	Concrete	6,750
3	Horizontal surfaces of stairway	Concrete	18,900
4	Wall	Concrete	340
5	Wall	Concrete	310
6	Wall	Concrete	430
7	Wall	Concrete	410

No.	Measurement location	Direction, material, etc.	Surface contamination density (cpm)
1	Entrance	Glass	3800
2	Entrance	Stainless steel frame	3150
3	Wall	Concrete	2750
4	Floor	Concrete	3190
5	Floor	Bricks	3110
6	Others	Wood	1190
7	Pillar	Concrete	1130
8	Door	Glass	710
9	Wall	Concrete	670
10	Window	Glass	530
11	Wall	Concrete	670
12	Wall	Wood	550
13	Door	Glass	380
14	Floor	Concrete	410
15	Wall	Concrete	640
16	Window	Glass	470
17	Wall	Concrete	670
18	Wall	Wood	450

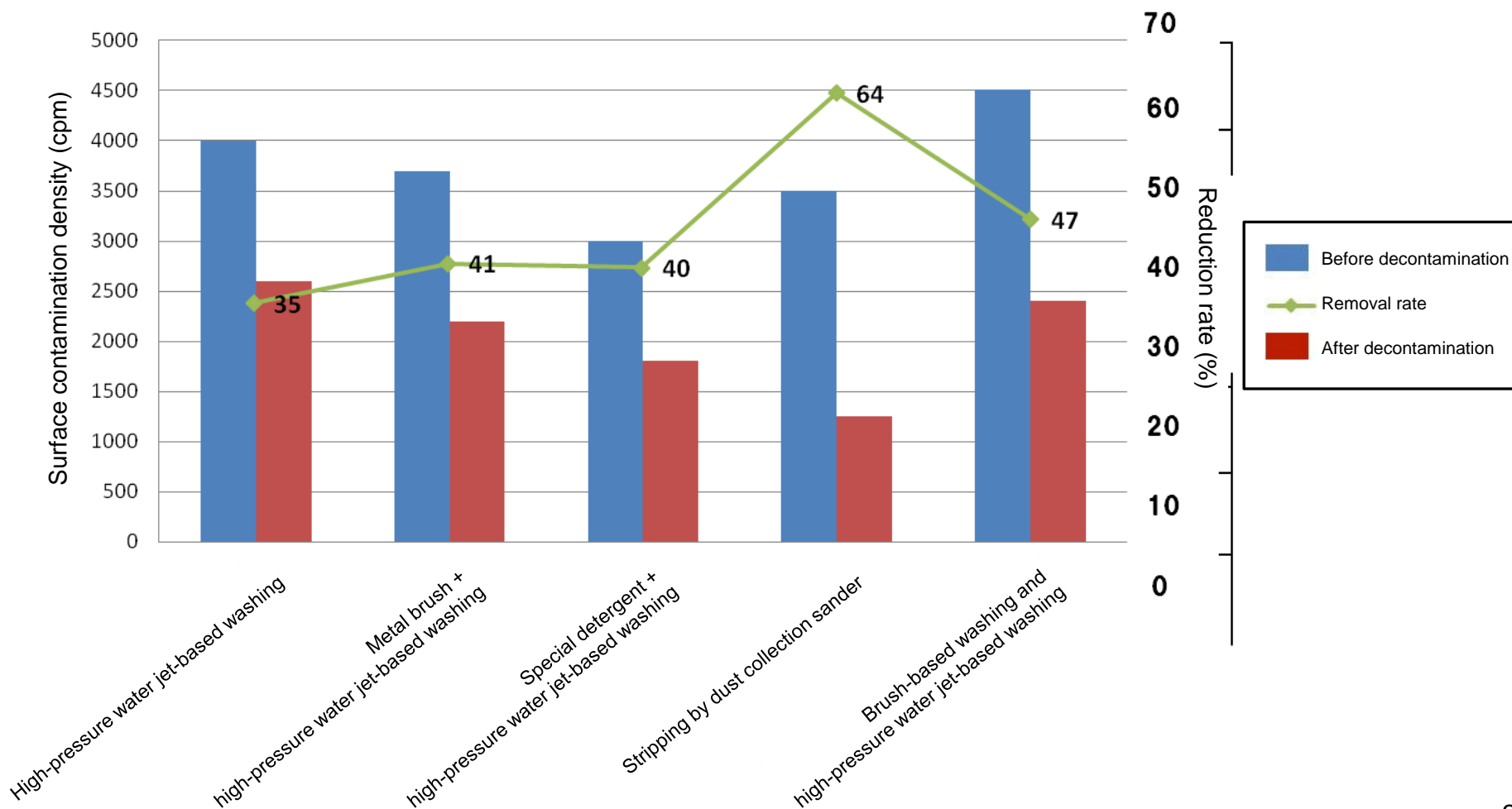
Red: parts whose surface contamination density is higher than 2,000 cpm.

Orange: parts whose surface contamination density is between 1,000 and 2,000 cpm.

(3)-1-3 Comparison of Concrete Floor Decontamination Methods (1)

○ Decontamination methods

- ◆ On concrete floors, the decontamination effect of high-pressure water jet-based washing is limited, while surface stripping using a dust collection sander is effective.
- ◆ Use of high-pressure water jet-based washing in combination with other techniques such as brushing using a steel brush did not enhance the decontamination effect of high-pressure water jet-based washing.



(3)-1-4 Comparison of Concrete Floor Decontamination Methods (2)

Concrete mortar (large buildings' roofs and walls, concrete floors, retaining walls, etc.)

Decontamination method	Dust collection sander (concrete planer)	Ultra-high-pressure water-based washing (150 Mpa or higher)	High-pressure water jet-based washing (10 to 50 Mpa)	Shot blasting
Reduction rate	60%-80% (depends on the number of times of application)	Approx. 70% (depends on the pressure and the number of times of washing)	30-70% (depends on the pressure and the number of times of washing)	Approx. 70% (blasting density and the number of times of blasting)
Volume of decontamination waste generated	Concrete debris, approx. 20 bags per hectar	Almost none	Almost none	Concrete debris, approx. 20 bags per hectare
Secondary contamination	It is necessary to collect a certain amount of dust by means of suction.	It is necessary to collect a very small amount of water that has been used for the washing by means of suction.	It is necessary to treat a certain amount of water at the downstream end.	It is necessary to collect a certain amount of dust by means of suction.
Decontamination speed	40 m ² /day	300 m ² /day	100-200 m ² /day	300 m ² /day
Application condition	<ul style="list-style-type: none"> • Inefficient for decontamination of a large area. • Cannot be used on rainy days. 	<ul style="list-style-type: none"> • Cannot be applied to corner sections. • Difficult to apply to vertical surfaces. 		<ul style="list-style-type: none"> • Cannot be applied to corner sections and narrow sections. • Difficult to apply to vertical surfaces. • Cannot be used on rainy days.
Applicability	△	○	○	○

◎: Highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(3)-1-5 Dust Collection Sander (Concrete Planer)

Overview: Concrete surface is stripped using a dust collection sander (a concrete planer equipped with a dust collection function). In high-dose areas, spread of dust is prevented by installing a HEPA filter on the dust collector to capture dust.



Concrete stairway



Concrete floor



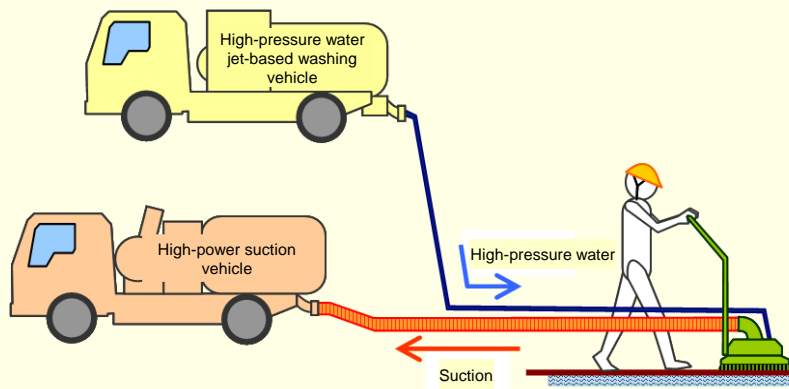
Concrete floor

Important points:

- ◆ It is important to remove all of the concrete debris left on the surface.
- ◆ It is important to determine the specifications after investigating the relationship between the number of times of stripping (depth) and the decontamination effect.
- ◆ In high-dose areas, it is necessary to prevent spreading of dust by installing a HEPA filter on the dust collector to capture dust.

(3)-1-6 Ultra-high-pressure water jet-based washing (150 MPa or higher)

Overview: Concrete surface is stripped with a small stripping thickness using ultra-high-pressure water jet-based washing equipment (150 MPa or higher). The water that has been used for the stripping is collected using a vacuum vehicle and transported to a water treatment facility.



Medium size ultra-high-pressure water jet-based washing equipment



Handy type ultra-high-pressure water jet-based washing equipment

Important points:

- ◆ In the case where radioactive substances have penetrated deep into the concrete, it is necessary to strip the surface portion using a very high water pressure or perform high-pressure water jet-based washing twice or more. Therefore, it is important to determine the specifications after confirming the relationship between the pressure and the number of times of stripping and the decontamination effect. When measuring the reduction effect, it is important to perform the measurement after the measurement target surface has dried so that the shielding effect of the decontamination water is eliminated.
- ◆ Overlaying (mortar) may become necessary depending on the stripping thickness.

(3)-1-7 High-pressure water jet-based washing (+ wire brush)

Overview: Washing using high-pressure water jet washer (10 Mpa - 50 Mpa) is performed. Brushing using a wire brush prior to the washing improves the reduction rate. The water that has been used for the washing is collected at the downstream end and treated.



Washing of a roof (wire brush)



Washing of a concrete floor



Washing of a retaining wall

Important points:

- ◆ It is important to instruct the workers to keep the distance between the injection nozzle and the decontamination target surface within 20 cm and supervise the washing work to ensure that the workers follow the instruction.
- ◆ It is important to take measures to prevent the water that has been used for the washing from spattering and filtrating into soil.
- ◆ To achieve a high reduction rate, it is necessary to strip the concrete surface and to consider using high-pressure water jet-based washing and a wire brush in combination.

(3)-1-8 Shot Blasting

Overview: Concrete surface is stripped by means of grinding by shot blasting and the generated concrete debris is collected by vacuum suction. The grinding material (steel balls) is collected using magnets.



Medium-scale shot blasting



Closeup of medium-scale shot blasting work

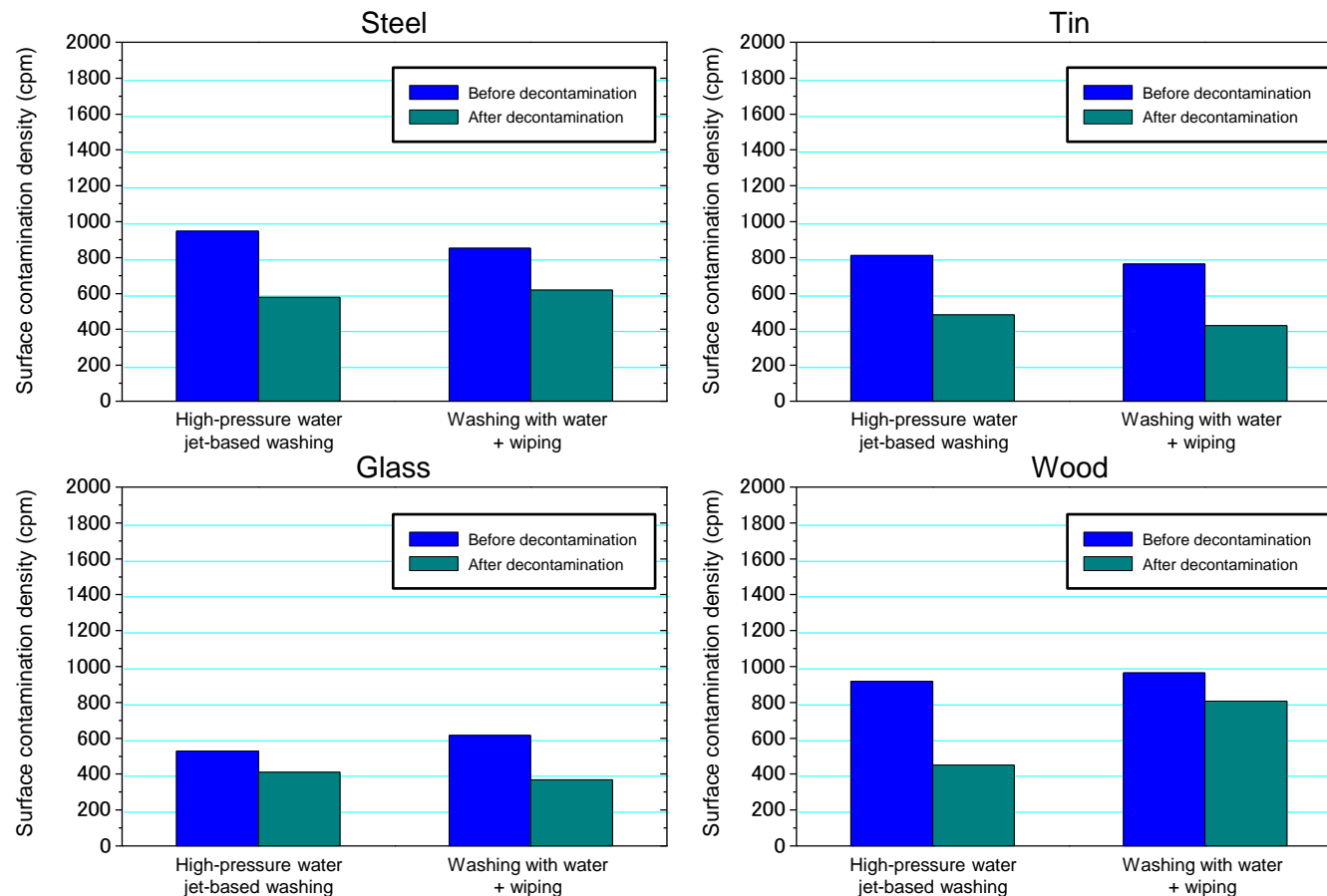
Important points:

- ◆ The concrete debris left on the ground is usually removed by collecting them using bamboo brooms, but it is desirable to use manned mobile cleaning equipment in addition to bamboo brooms, because fine debris can become airborne. In addition, it is important to collect all of the grinding material (steel balls) used.
- ◆ Because the stripping depth differs between the central and edge parts of the target surface, it is necessary to perform shot blasting with an overlap of about edge part that striped before run. In addition, it is necessary to confirm the relationship between the blasting density and the decontamination effect in advance, because the stripping depth varies with the blasting density (In the Model Project, a blasting density of 200 kg/m² was adopted).

(3)-1-9 Comparison of Building Decontamination Methods (Walls)

○ Decontamination methods for buildings (walls)

- ◆ With regard to decontamination of walls by wiping and high-pressure water jet-based washing, there was no major difference in the decontamination effect between walls of different materials (steel, tin, glass and wood) or between the decontamination methods.
- ◆ From the viewpoint of workability, it is considered that decontamination by wiping, which does not involve the risk of spattering to the surrounding environment with the wash water, is effective.



(3)-1-9 Important Points about Decontamination of Large Buildings

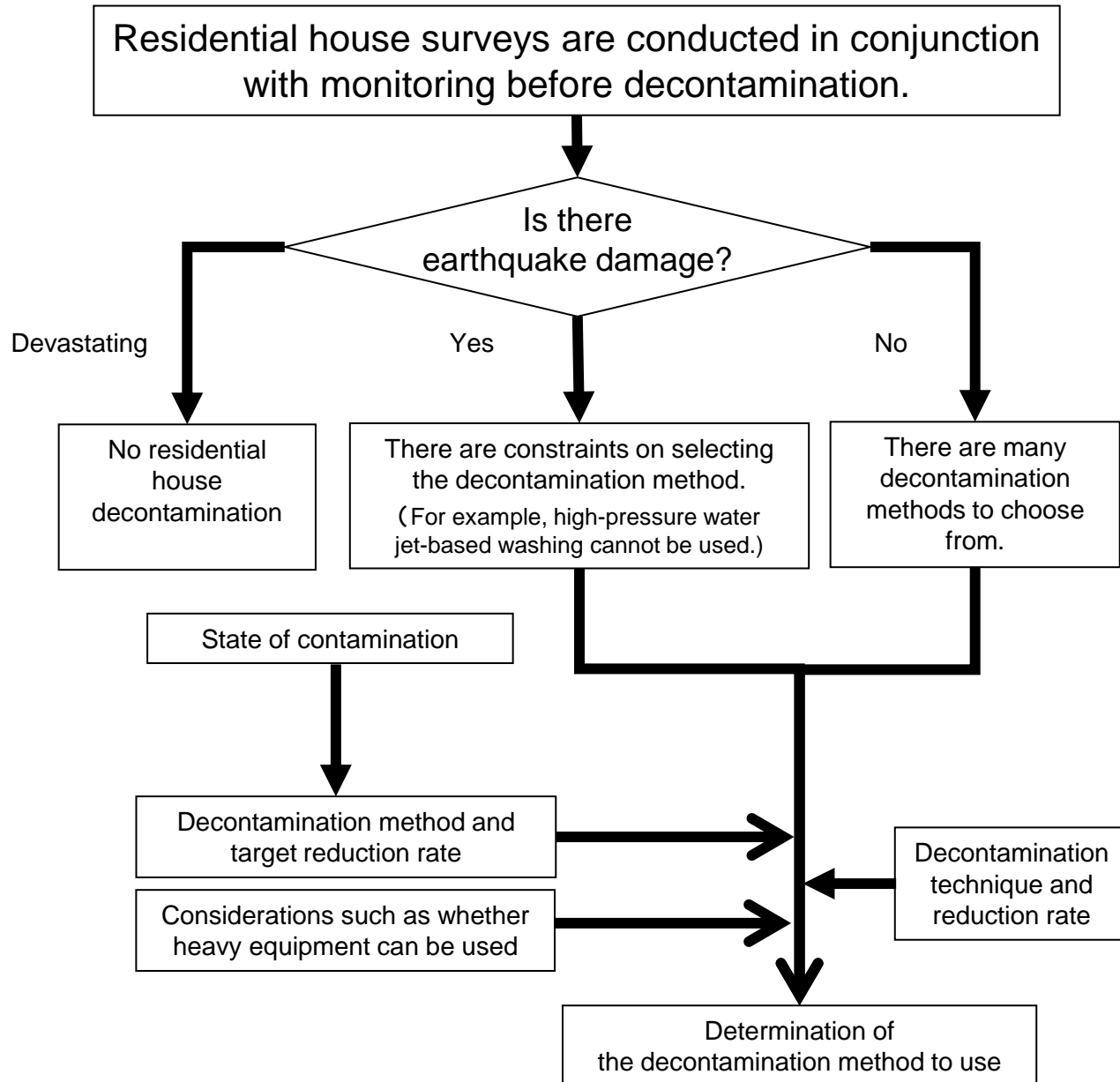
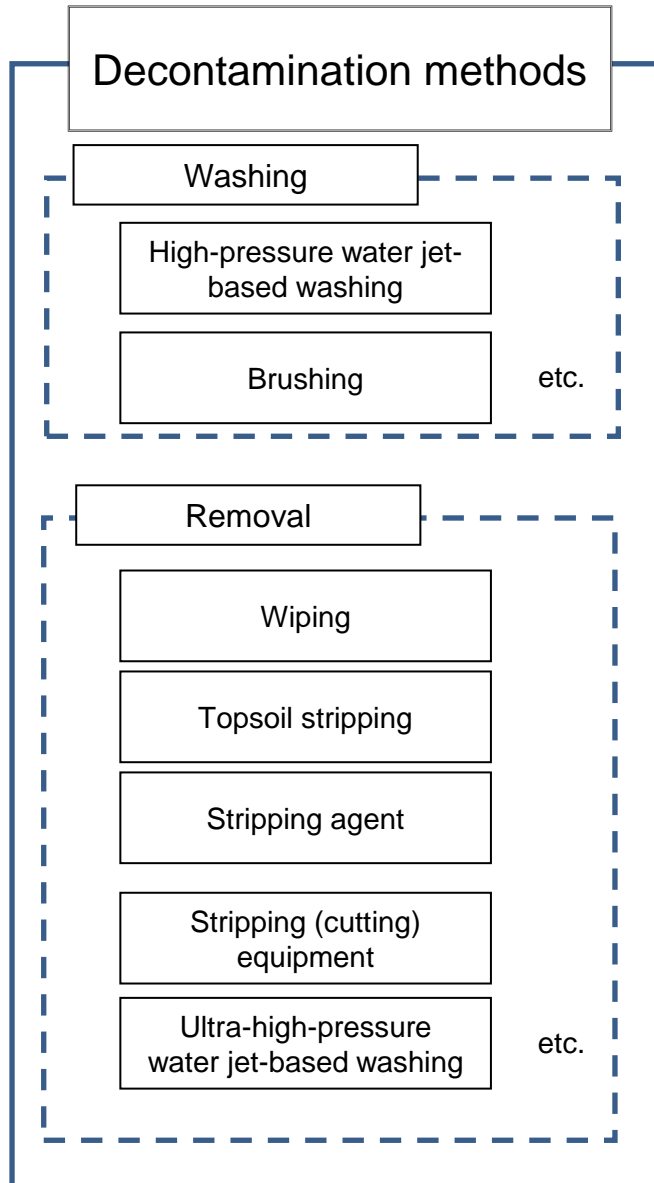
○ Important points regarding selection of a decontamination method

- (1) Large amounts of radioactive cesium remain in earth dust etc. that is present in parts of large buildings where earth dust etc. that once adhered to surfaces of the buildings collects as a result of rainwater flows (such as gutters and parts onto which rainwater drips).
- (2) For decontamination of concrete roofs (that have been waterproof-treated), high-pressure water jet-based washing is effective.
- (3) On concrete (mortar) roofs, a reduction rate of approximately 50% can be achieved by using high-pressure water jet-based washing (at a pressure of 10 to 20 Mpa) and wire brush-based brushing in combination.
- (4) With regard to decontamination of walls by wiping and high-pressure water jet-based washing, there is no major difference in the decontamination effect between walls of different materials (steel, tin, glass and wood).
- (5) From the viewpoint of workability, it is considered that decontamination by wiping, which does not involve the risk of spattering of the wash water to the surrounding environment, is effective.

○ Important points regarding the application of a selected decontamination method

- (1) When using high-pressure water jet-based washing, it is important to instruct the workers to **keep the distance between the injection nozzle and the concrete surface within 20 cm** and supervise the washing work to ensure that the workers follow the instruction.
- (2) When using high-pressure water jet-based washing, it is important to take measures to **prevent the water that has been used for the washing from spattering and filtrating into soil.**
- (3) For both ultra-high-pressure water jet-based washing and shot blasting, **it is important to determine the specifications after confirming the effect**, because the reduction effect of ultra-high-pressure water jet-based washing varies with **the water pressure and the number of times of washing** and the reduction effect of shot blasting varies with **the blasting density and the number of times of blasting.**

(3)-2 Flow of Residential House Decontamination Method Selection



(3)-2-1 State of Contamination of Individual Components of Residential Houses

○ Components of residential houses



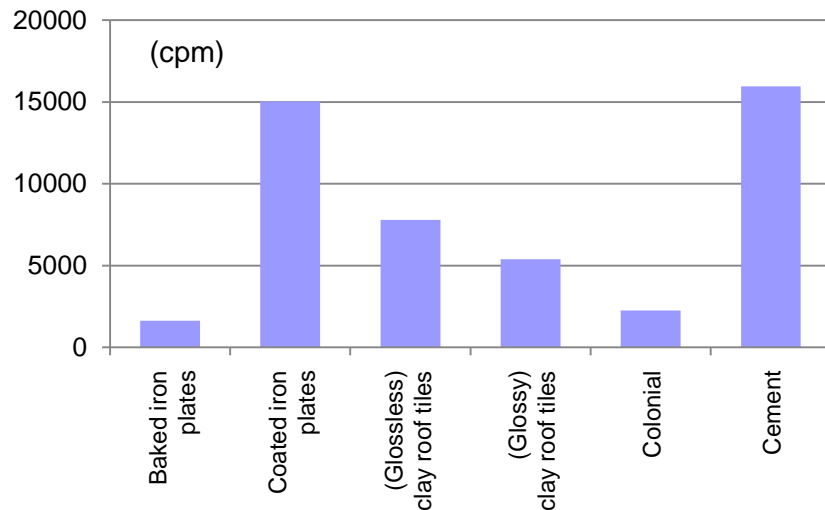
○ State of contamination of each component

		Municipality A (approx. 2 μ Sv/h)	Municipality B (approx. 9 μ Sv/h)
Buildings	Roofs	5,000 cpm	7,800 cpm
	Walls	700 cpm	2,300 cpm
	Gutters	3,700 cpm	11,000 cpm
Outdoor	Garden soil	3,900 cpm	9,100 cpm
	Pavements	4,400 cpm	12,000 cpm

(Note) The value for roofs is the average value for (glossless) clay roof tiles.

○ Roofs

(measurements taken in the same municipality)



(3)-2-2 Comparison of Residential House Decontamination Methods (Roofs)

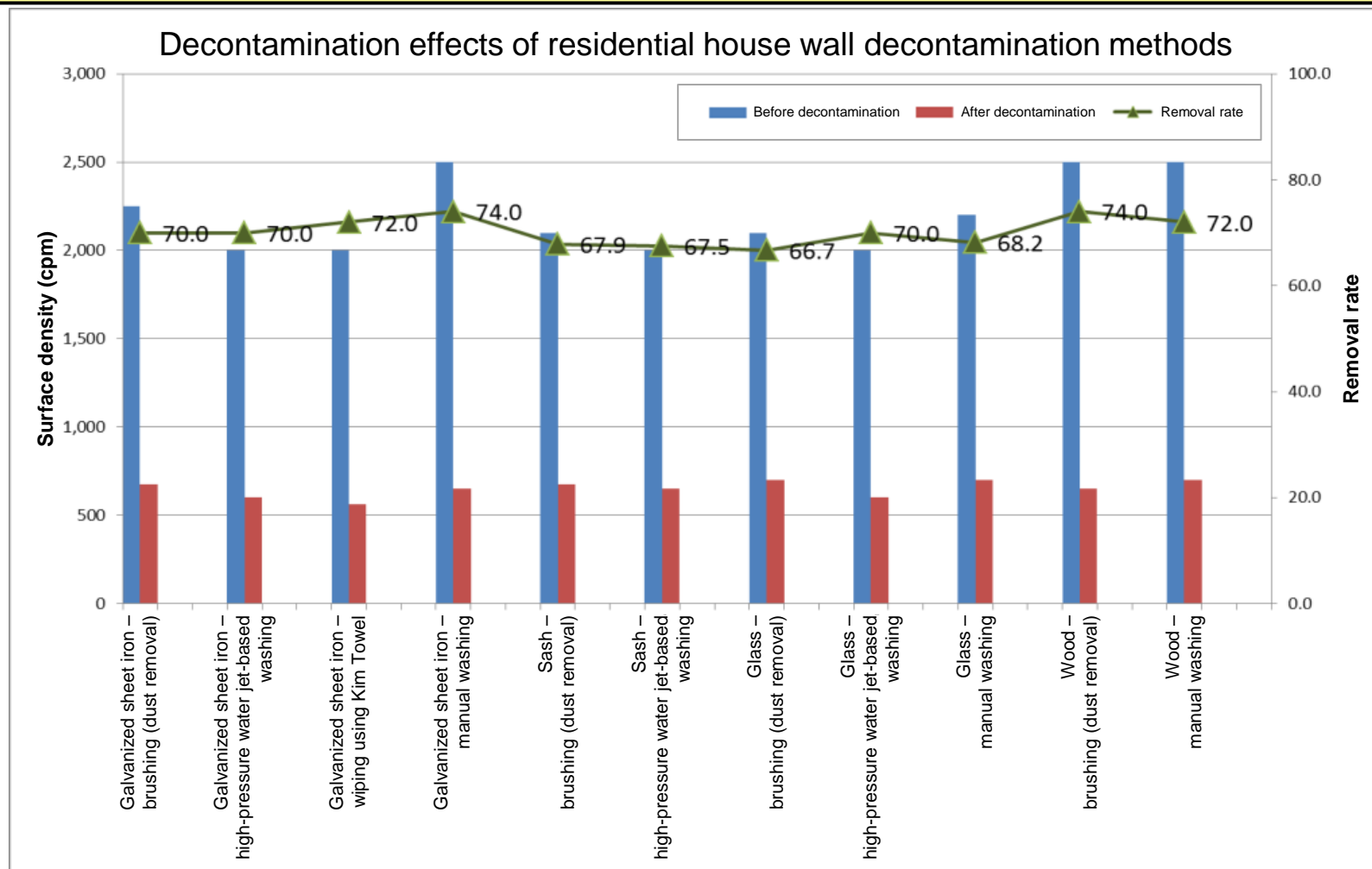
Residential houses (roofs)

Decontamination method		High-pressure water jet-based washing	Brushing	Wiping	Application of stripping agent
Reduction rate	Bake coating iron plate	—	Approx. 10%	Approx. 10%	Approx. 10%
	Spray coating iron plate	—	Approx. 30%	Approx. 5%	Approx. 15%
	Clay roof tile	—	Approx. 50%	Approx. 70%	Approx. 30%
	Cement roof tile	Approx. 30%	Approx. 5%	Approx. 0%	Approx. 30%
	Slate	Approx. 10%	Approx. 0%	Approx. 25%	Approx. 35%
Amount of decontamination waste		Almost none	Almost none	Small amount (waste cloth)	Small amount (stripping agent)
Secondary contamination		Splashed water infiltrates into soil	Almost no secondary contamination occurs because the water is collected at the downstream end.	None	None
Decontamination speed			120 m ² /day	120 m ² /day	10 m ² /day
Application conditions		<ul style="list-style-type: none"> It is necessary to perform topsoil stripping in the surrounding area. There is a risk that water may infiltrate through gaps between roof tiles. 	<ul style="list-style-type: none"> Collection of the water that has been used for the washing Treatment is necessary. 	<ul style="list-style-type: none"> It is necessary to treat the water that has been used to wash the waste cloth. 	
Applicability		▲	○	○	▲

◎: Highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(3)-2-3 Comparison of Residential House Decontamination Methods (Walls)

- ◆ Decontamination of galvanized sheet iron, sash, glass and wood walls was performed by “manual washing,” “wiping,” “high-pressure water jet-based washing” and “brushing,” and it was confirmed that there was no major difference in the surface contamination density between the decontamination methods, after decontamination.
- ◆ It can be said that, among the decontamination methods, “wiping” is an especially effective method in terms of workability because it does not involve the risk that the water that has been used for washing may spatter to surrounding environments.



(3)-2-4 Comparison of Residential House Decontamination Methodologies (Gutters)

- ◆ With regard to decontamination of gutters, there was no major difference in the decontamination effect between wiping and high-pressure water jet-based washing. Wiping is a better option in terms of workability because it does not involve the risk of spattering of the water that has been used for washing.

Difference in the effect of decontamination of gutters between the decontamination methods

Decontamination method	Description of the decontamination work	Surface contamination density reduction rate
Wiping	In the case where there are deposits (such as mud and moss) in gutters, wiping of the gutter using a waste cloth or paper towel is performed after removing the deposits.	30 to 90%
High-pressure water jet-based washing	In the case where there are deposits (such as mud and moss) in the gutters, the gutters are washed by high-pressure water jet-based washing after first removing the deposits.	Approx. 60%



(3)-2-4 Important Points about Decontamination Methodologies for Residential Houses

○ Important points regarding the selection of a decontamination method

- (1) For rainwater gutters, a high decontamination effect can be achieved by wiping the gutters after removing any deposits.
- (2) With regard to roofs, the decontamination effect varied depending on the roof material.
 - ☐ For clay roof tile roofs and coated iron roofs, brushing using a deck brush is effective.
 - ☐ For clay roof tile roofs, wiping is also effective.
 - ☐ Stripping agent is more effective for slate and cement roof tiles than the other methods.
 - ☐ For cement roof tiles, the effects of all of the decontamination methods were limited.
- (3) Decontamination of tin, sash, glass and wood walls was performed by “manual washing,” “wiping,” “high-pressure water jet-based washing” and “brushing,” and it was confirmed that there was no major difference in the reduction rate between the decontamination methods.

○ Important points regarding the application of a selected decontamination method

- (1) With regard to high-pressure water jet-based washing, applying the water jet horizontally can result in infiltration of water into the house through gaps between roof tiles. When decontaminating slate and metal walls by high-pressure water jet-based washing, it is necessary to perform topsoil stripping in the surrounding areas after decontamination.
- (2) With regard to wiping and brushing, it is important to determine the number of times of wiping/brushing after conducting a test to confirm the relationship between the number of times and the decontamination effect (The number of times was 3 in the Model Project). It is important to make sure that the measurement of the surface contamination density after decontamination is performed after the target surface has dried, because the target surface is shielded by the moisture from the wiping/brushing immediately after decontamination.

(3)-3 Playing Fields

Prediction of the decontamination effects:

- Available decontamination methods
- Prediction of the dose reduction effect of the decontamination and prediction of the volumes of the decontamination wastes to be generated (removed soil etc.)
- Constraints (capacities of temporary storage sites, the need to obtain permission from land owners)

Consideration of decontamination methods:

Material

Tennis courts, weed fields, playing fields, etc.

Surface State

Large areas, small areas, corner section, presence of irregularities, presence of spots at which contaminants accumulate, etc.

Selection of the decontamination technique

Selecting a decontamination technique that is suitable for the environmental conditions regarding the material, the characteristics of the area to be decontaminated, etc.

Consideration of work methods (stripping thickness, number of times, etc.)

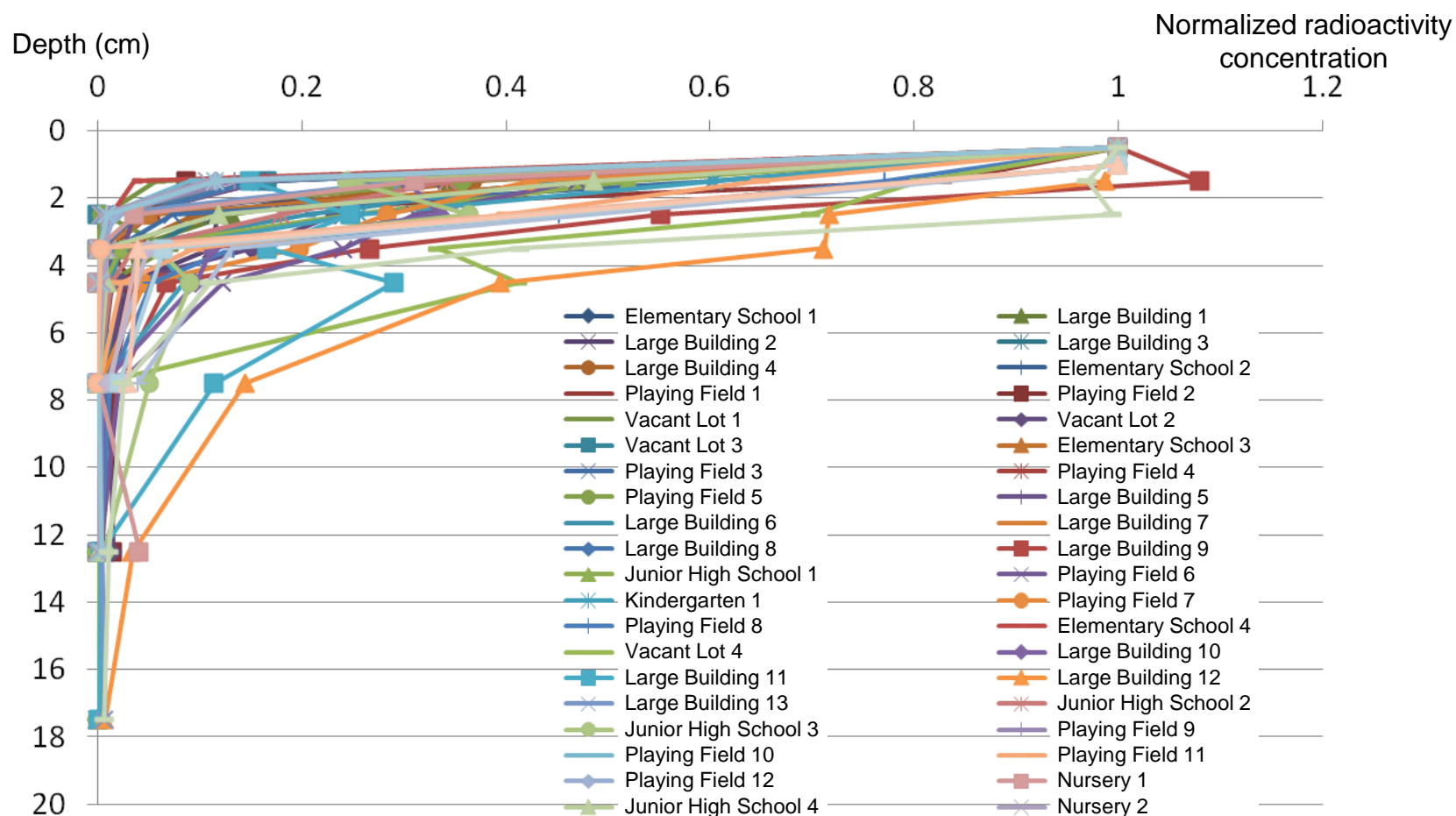
Selection of the decontamination method to use

(3)-3-1 Retention of Radioactive Cesium in Playing Fields

Differences in the trends of retention and remaining of radioactive cesium

- ◆ In the soil of the parks and playing fields, 90% or more of the radioactive cesium was present within approx. 3 to 5 cm from the ground surface at most of the measurement points (37 out of 40 points).
- ◆ In the soil of the other 3 points, 90% of the radioactive cesium was present within 8 cm from the ground surface.

Schools and playing grounds (all contaminated areas)(normalized)



(3)-3-2 Comparison of Playing Field Decontamination Methodologies

Decontamination method	Thin-layer topsoil stripping			Interchanging topsoil with subsoil
	Hammer knife mower + sweeper	Road surface stripping equipment	Motor grader	
Reduction rate	Approx. 90%	80% (low-dose area) 90% (medium- and high-dose area)	80% (low-dose area) 90% (medium- and high-dose area)	Approx. 85%
Volumes of removed soil etc. (overbreak)	200 m ³ /ha (target depth: 2 cm) No overbreak	300 m ³ /ha (target depth: 2 cm) Control below 3 cm is difficult.	200 m ³ /ha (target depth: 2 cm) Control below 2cm is difficult.	None
Secondary contamination	Almost none	Almost none	Certain secondary contamination occurs.	Almost none
Decontamination speed	300 m ² /day	1,500 m ² /day	1,000 m ² /day	300 m ² /day
Application conditions	<ul style="list-style-type: none"> • Flats surface • Cannot be used on frozen soil. • Topsoil must be compact. 	<ul style="list-style-type: none"> • Flats surface • Topsoil must be compact. 	<ul style="list-style-type: none"> • Flat surface • Cannot be used on frozen soil. • Topsoil must be compact. 	<ul style="list-style-type: none"> • Difficult to apply when there is a drain layer etc.
Applicability	○	○	○	◎

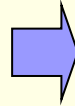
◎: Highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(3)-3-3 Hammer Knife Mower + Sweeper

Overview: Topsoil is loosened using a modified hammer knife mower and collected using a modified sweeper. The collected topsoil is transferred to flexible containers using a mechanical digger and transported.



Hammer knife mower



Topsoil collection by sweeper

Important points:

- ◆ This method is not suitable for decontaminating a large area because the work speed is low.
- ◆ In this method, it is important to loosen the top portion of the playing field soil down to several millimeters using a modified hammer knife to improve the efficiency of modified sweeper-based topsoil collection.
- ◆ It is important to determine the number of runs (it was 3 times in the Model Project) after confirming the contamination distribution in the depth direction and confirming the stripping thickness per run (measured stripping thickness per run was approx. 6mm) with the target depth set to a depth that allows 90% or more of the cesium to be removed.

(3)-3-4 Road Surface Stripping Equipment

Overview: In the case where the surface on which topsoil stripping is to be performed is soft, the ground surface is compacted using a vibration roller to reduce the sinking of the road surface stripping equipment before performing topsoil stripping along the lanes set up in advance. The removed soil is put onto trucks using the stripping equipment's belt conveyor.



Road surface stripping equipment



Blade tip part (bit)

Important points:

- ◆ It is important to measure the distribution of radioactive substances in the vertical direction and determine the stripping depth by setting up a test area and investigating the relationship between the stripping depth and the decontamination effect in the test area prior to performing the topsoil stripping.
- ◆ Because road surface stripping equipment is a piece of very wide heavy equipment, it is not possible to perform topsoil stripping with road surface stripping equipment at the edges of a playing field. Therefore, at the edges of the playing field and near the playground equipment, it is necessary to perform topsoil stripping manually or using a mechanical digger.
- ◆ In the case where the ground is soft, it is necessary to be careful to prevent the stripping of topsoil to a stripping depth that is larger than the target depth due to the sinking of the road surface stripping equipment.

(3)-3-5 Motor Grader

Overview: After performing rolling with a compound roller to make the ground surface flat, topsoil stripping using a motor grader is performed. The removed topsoil is collected using a mechanical digger and put into containers.



Motor grader



Topsoil stripping



Packing of removed soil

Important points:

- ◆ It is important to investigate the distribution of radioactive cesium in the vertical direction and determine the stripping depth by setting up a test area and investigating the relationship between the stripping depth and the reduction rate in the test area prior to performing topsoil stripping.
- ◆ It is important to remove all of the topsoil that has been stripped off, without allowing it to scatter.
- ◆ It is important to perform planar measurement to check for parts in which topsoil has not been stripped off due to the presence of irregularities.

(3)-3-6 Interchanging Topsoil with Subsoil

Overview: The portion of topsoil in which 90% or more of the radioactive cesium is present is stripped off with a small stripping thickness and set aside. Then, subsoil is stripped off with a stripping thickness of approx. 20 cm and set aside. The removed topsoil is put in and spread, and the removed subsoil is placed over it and spread.

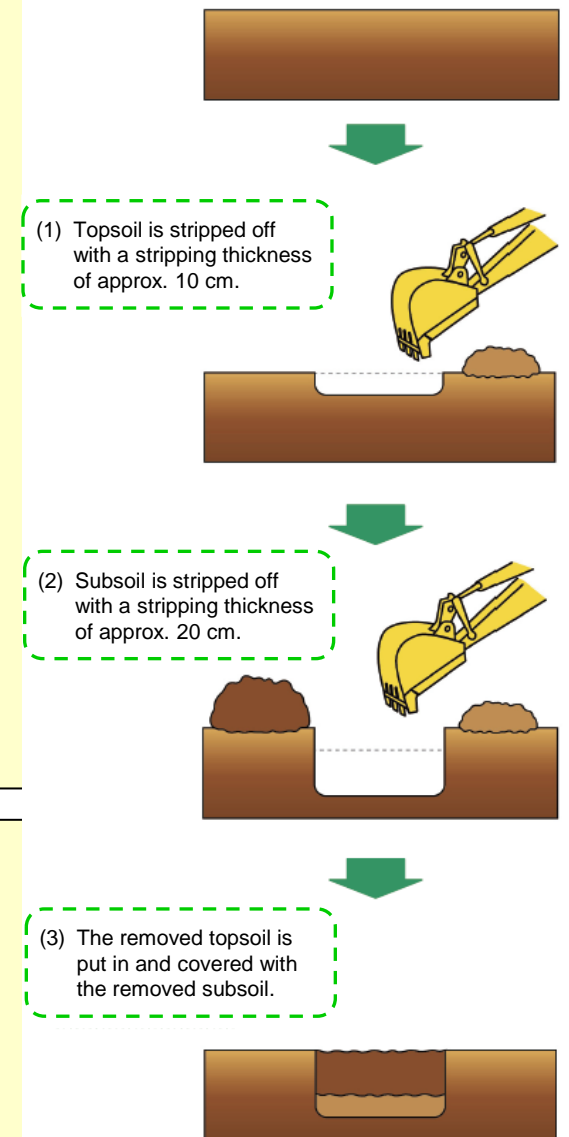


Topsoil stripping (10 cm)

Subsoil stripping (20 cm)

Important points:

- ◆ It is important to determine the depths of the topsoil layer and subsoil layer to be interchanged after confirming the radioactivity distribution in the vertical direction.
- ◆ In high-dose areas, it is important to take into account the shielding effect (98% shielding with an earth covering of 30 cm) when determining the depth of the subsoil layer.



(3)-3-7 Important Points about Playing Field Decontamination Methodologies

○ Important points regarding the selection of a decontamination method

- (1) The result of the measurement to confirm the distribution of radioactive cesium concentration in the playing field soil in the vertical direction showed that 90% or more of the radioactive cesium was present within approx. 3 to 5 cm from the ground surface at most of the measurement points (37 out of 40 points).
- (2) Because the width of road surface stripping equipment and motor graders is 2m, topsoil in hollow parts of irregular surface playing fields will be left without being stripped off. Therefore, irregular playing fields need to be leveled in advance.
- (3) “Hammer knife mower + sweeper” is not suitable for decontaminating large areas, because the work speed is low.
- (4) In all of the methods, manual topsoil stripping or topsoil stripping using a back hoe is required in narrow areas.

○ Important points regarding the application of a selected decontamination method

- (1) In the case of the “hammer knife mower + sweeper” option, it is important to determine the number of runs after confirming the stripping depth per run (it was approx. 6mm in the Model Project) and the contamination distribution in the depth direction.
- (2) In all of the methods, topsoil in hollow parts of irregular playing fields will be left without being stripped off because of the width of the equipment. Therefore, it is important, regardless of the method employed, to perform planar radiation measurements and perform manual topsoil stripping in the areas in which topsoil has not been stripped off to the required degree.
- (3) It is important, regardless of the method employed, to determine the stripping depth after setting up a test area and investigating the relationship between the stripping depth and the reduction rate in the test area.

(3)-4-1 Main Decontamination Methods for Gardens of Residential Houses

Garden soil

Decontamination method	Stripping of moss, weeds and topsoil (manual)	Soil stripping (manual + mechanical digger)
Reduction rate	Approx. 60% or higher (depends on the stripping depth)	Approx. 60 to 90%
Volumes of decontamination wastes	Moss, grass, soil Approx. 300 bags/ha (In the case where soil is stripped off with a stripping thickness of 2 cm.)	Soil Approx. 600 bags/ha (In the case where soil is stripped off with a stripping thickness of 5 cm.)
Secondary contamination	Almost none	Almost none
Work speed	350 m ² /day (5 to 7 persons/day/group)	700 m ² /day (5 to 7 persons/day/group)

Gravel and pebbles

Decontamination method	Stripping of gravel	Washing of pebbles by high-pressure water jet
Reduction rate	Approx. 50 to 60%	Approx. 90%
Volumes of decontamination wastes	Gravel and soil 900 bags/ha	Small amount of soil and sand
Secondary contamination	None	Certain secondary contamination occurs.
Work speed	160 m ² /day (stripping) (In the case where the stripping thickness is 3 cm.)	200 m ² /day

(3)-4-2 Main Decontamination Methods for Outdoor Spaces around Residential Houses

Turf

Decontamination method	Large turf stripping equipment	Shoulder mowing equipment, sod cutter
Reduction rate	Approx. 50 to 80%	Approx. 80%
Volumes of decontamination wastes	Turf and soil 0.02 to 0.05 m ³ /m ²	Turf and soil Approx. 0.02 m ³ /m ²
Secondary contamination	Almost none	Almost none
Work speed	3,000 m ² /day	500 m ² /day
Notes	There must not be small stones. Residue must be stripped off manually.	There must not be planted trees and plants. Residue must be stripped off manually.
Applicability	○	○



Large turf stripping equipment



Sod cutter

(3)-4-3 Main Decontamination Methods for Outdoor Spaces around Residential Houses

Trees and plants

Decontamination method	Pruning, trimming of low branches and removal of soil under vegetation
Reduction rate	Approx. 60% (depends on the topsoil stripping thickness)
Volumes of decontamination waste	260 to 600 bags/ha (in the case where garden soil is stripped off with a stripping thickness of 2.5 to 5 cm)
Secondary contamination	Certain secondary contamination occurs
Work speed	300 m ² /day
Notes	<ul style="list-style-type: none">• Pruning and low-branch trimming themselves only bring about a small decontamination effect. They should be considered as a preparation for topsoil removal.• Over-pruning should be avoided.

(3)-4-4 Important Points about Decontamination Methodologies for Gardens of Residential Houses

○ Important points regarding the selection of a decontamination method

- (1) It is important to **apply** the same decontamination methods selected for forests, playing fields, unpaved roads, etc. **to the corresponding decontamination targets** in the gardens.
- (2) **With regard to turf**, it is desirable to use sod cutters etc. **capable of stripping off the thatch layer or root mat as well**.

○ Important points regarding the application of a selected decontamination method

- (1) The important points regarding decontamination are the same as the important points regarding the decontamination methods selected for forests, playing fields, unpaved roads, etc.
- (2) In particular, it is desirable to **remove the accumulated fallen leaves and humus in the areas surrounding the planted trees and plants**, because the dose rates in the accumulated fallen leaves and humus in the areas surrounding the planted trees and plants are high as in the case of forests. To do this, it is **necessary to perform low-branch trimming up to 30 cm from the ground surface** so that the accumulated fallen leaves and humus can be removed manually.
- (3) **For turf**, it is important to **totally remove the turf grass residue and topsoil residue manually or using a sweeper** after performing stripping down to the thatch layer (root mat).

(4) Paved Roads (Parking Lots)

Prediction of the decontamination effects:

- Available decontamination methods
- Prediction of the dose reduction effect of the decontamination and prediction of the volumes of the decontamination wastes to be generated (removed soil etc.)
- Constraints (capacities of temporary storage sites, the need to obtain permission from land owners)

Consideration of decontamination methods:

Material

Dense-graded asphalts,
draining-type pavements

Surface State

Large areas, small areas, corner
sections, presence of distortions
and/or damages

Selection of decontamination techniques

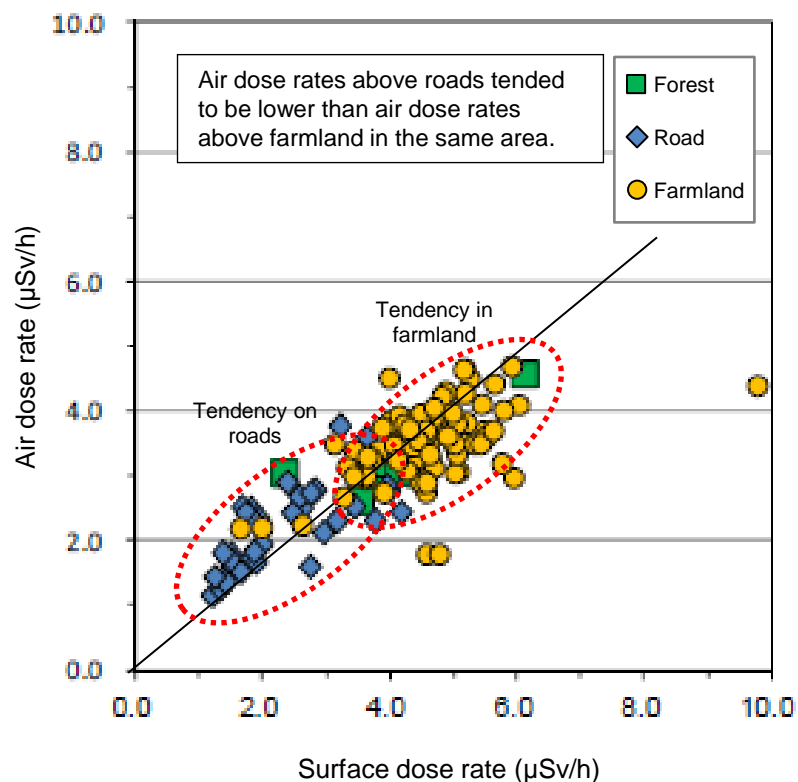
Selecting the decontamination techniques suitable
for the environmental conditions regarding the material,
surface state, etc.

Consideration of work methods (jet pressure, number of applications, etc.)

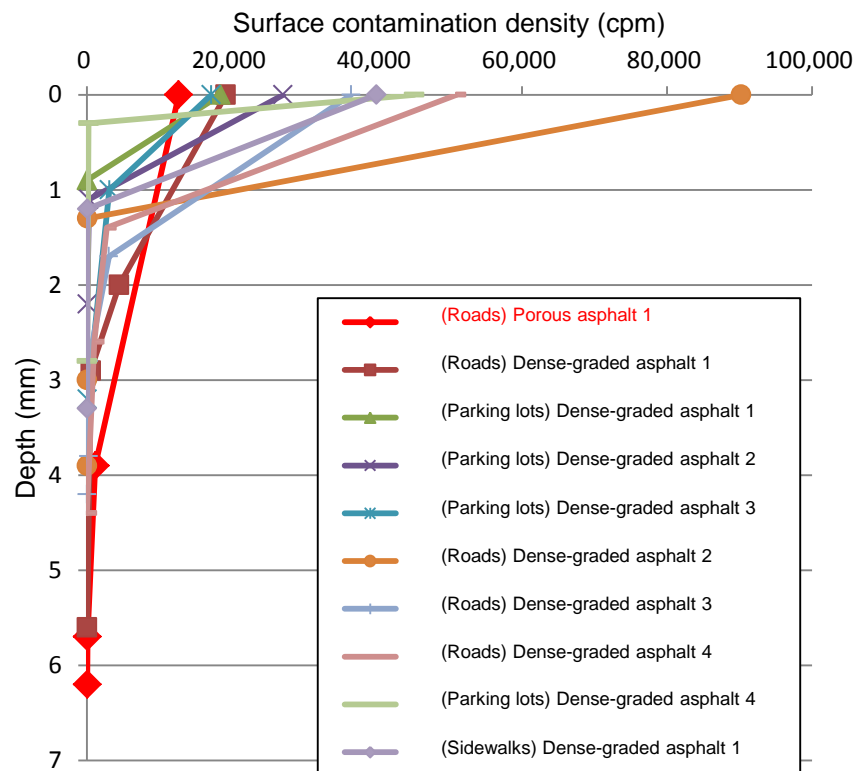
Selection of the decontamination method to use

(4)-1 Sorption of Radioactive Cesium to Paved Road Surfaces

- ◆ Dose rates above paved road surfaces tend to be lower than dose rates above earth surfaces of farmland, forest, etc. in the surrounding area. It is considered that this is because radioactive substances that had adhered to paved road surfaces were washed away by rain etc. after the accident.
- ◆ The measurement results of the surface contamination density distribution in asphalt pavements in the vertical direction within the high-dose areas showed that most of the radioactivity was present within approx. 2 to 3 mm of the pavement surface for dense-graded asphalt pavements and within approx. 5 mm of the pavement surface for porous asphalt pavements (permeable asphalt pavements etc.).

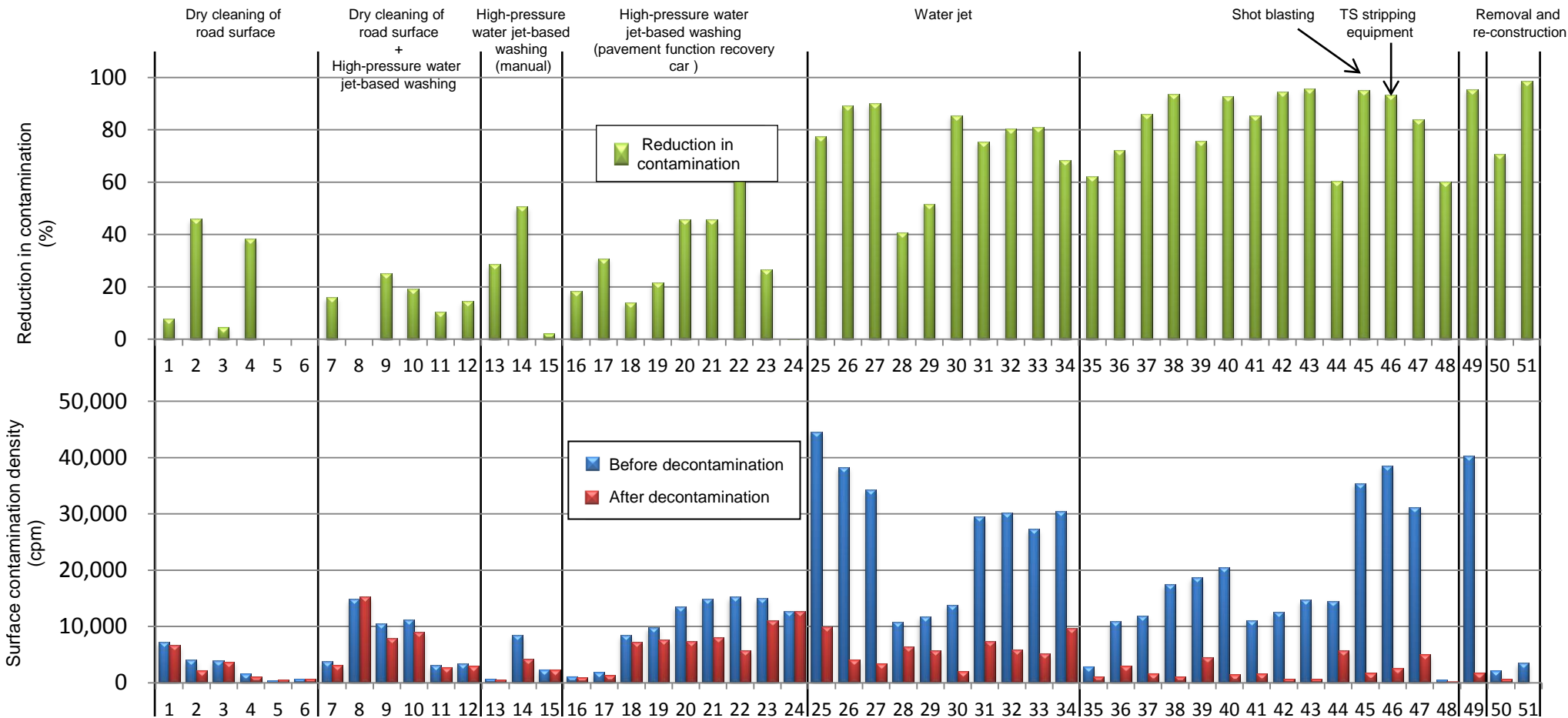


Relationship between surface dose rate and air dose rate by land use category



(4)-2 Decontamination Methods and contamination reduction for Paved Road Surfaces

- ◆ For asphalt pavements, better reduction effects can be achieved by decontaminating the surface by stripping/cutting, water jet, shot blasting, TS stripping equipment, etc. than by decontaminating the pavement through cleaning (e.g. dry cleaning of road surface) or washing (high-pressure water jet-based washing, pavement sweep washing vehicle, etc.)
- ◆ In the case where a stripping/cutting technique is used, it may be difficult to apply the method in the proximity of buildings, walls, etc. because all stripping/cutting techniques are machine-based. In addition, there may be variation in the decontamination effect on distorted or worn road surfaces.



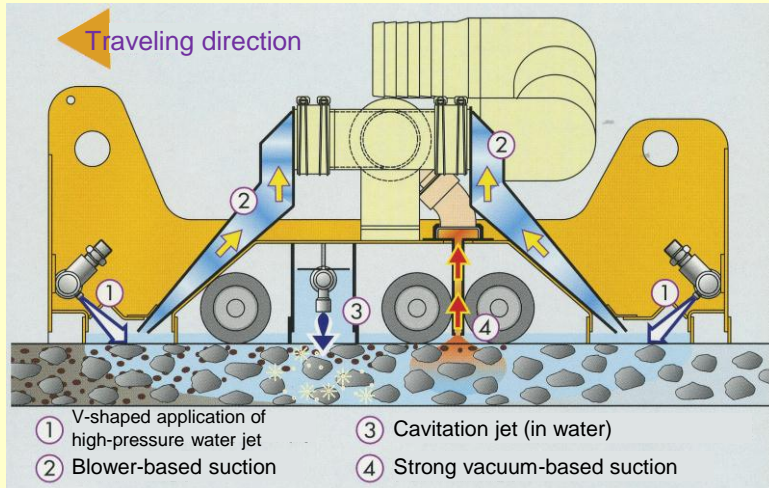
(4)-3 Comparison of Asphalt Pavement Decontamination Methods

Decontamination method	Pavemen sweep washing vehicle	High-pressure water jet-based washing (10-20 Mpa)	Ultra-high-pressure water jet-based washing (240 Mpa)	Shot blasting	TS stripping equipment
Reduction rate	0-60%	2 – 50%	40-90% (pressure, number of times of washing)	60-95% (depends on the blasting density and the number of times of blasting)	95% or higher
Volumes of decontamination wastes (overbreak)	Almost none	Almost none	Straight asphalt sludge	Asphalt debris (approx. 30 bags/ha)	Thin stripping below 5 mm is difficult. Approx. 60 bags/ha
Secondary contamination	Water that has been used for the washing is collected. Almost no secondary contamination occurs.	Downstream end treatment is performed. Certain secondary contamination occurs.	Water that has been used for the washing is collected. Almost no secondary contamination occurs.	Certain secondary contamination occurs.	Certain secondary contamination occurs.
Work speed	2500 m ² /day	300 m ² /day	300 m ² /day	300-800 m ² /day	1000 m ² /day
Application conditions	<ul style="list-style-type: none"> Roads whose surface is smooth and not distorted or damaged 	<ul style="list-style-type: none"> Roads whose surface is not damaged Roadside gutter lids can also be washed. 	<ul style="list-style-type: none"> Roads whose surface is not damaged Roadside drain lids can also be washed. 	<ul style="list-style-type: none"> Dry roads Roads whose surface is not distorted or damaged 	<ul style="list-style-type: none"> Dry roads Roads whose surface is not distorted or damaged
Applicability	△	△	◎	○	○

◎: Highly recommended; ○: recommended; △: recommended depending on the target decontamination rate; ▲: not recommended

(4)-4 Draining Type Pavement Washing Vehicle

Overview: Radioactive substances-containing earth, sand, etc. adhering to road surfaces are removed and collected using draining type pavement washing vehicles. The collected earth, sand, etc. are transported out of the site as sludge.



Schematic diagram of the washing section



Closeup of the washing section



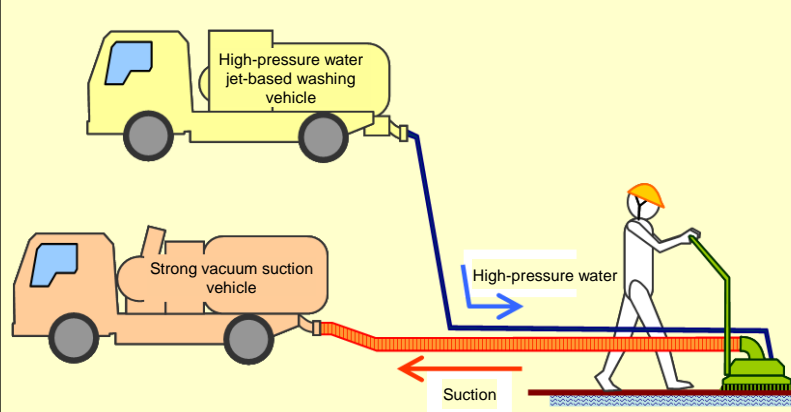
Function restoration vehicle

Important points:

- On roads that have large furrows and roads whose surface has been distorted or damaged by the earthquake etc., good decontamination effect cannot be achieved because there will be gaps between the high-pressure washing section and the road surface. The water collection rate will also be low.
- It is expected that the above-mentioned problems can be alleviated if a washing attachment is developed that allows a high collection rate to be achieved and prevents lateral leakages during work.

(4)-5 Ultra-high-pressure Water Jet-based Washing (150 Mpa or higher)

Overview: Asphalt pavements (straight asphalt pavements etc.) are stripped off with a small stripping thickness using ultra-high-pressure water jet-based washing equipment (150 Mpa or higher). The water that has been used for the stripping is collected using a vacuum suction vehicle and transported to a water treatment facility.



Medium size ultra-high-pressure water jet-based washing equipment



Handy type ultra-high-pressure water jet-based washing equipment

Important points:

- In the case where radioactive substances have penetrated deep into the pavement, it is necessary to strip the surface portion using a very high water pressure or perform high-pressure water jet-based washing twice or more. Therefore, it is important to determine the specifications after confirming the relationship between the pressure and the number of times of stripping and the decontamination effect. When measuring the reduction effect, it is important to perform the measurement after the measurement target surface has dried so that the shielding effect of the decontamination water is eliminated.
- If the function of pavement is reduced by the stripping, stripping surface may be covered by asphalt again.

(4)-6 Shot Blasting (Thin Layer Stripping)

Overview: Asphalt pavement surface is stripped by means of grinding by shot blasting and the generated asphalt debris is collected by vacuum suction. The grinding material (steel balls) are collected using magnets.



Medium-scale shot blasting



Large-scale shot blasting



Closeup of a blasted surface

Important points:

- ◆ The asphalt debris left on the road is usually removed by collecting them using bamboo brooms, but it is desirable to use manned mobile cleaning equipment in addition to bamboo brooms, because fine debris can become airborne. In addition, it is important to collect all of the grinding material (steel balls) used.
- ◆ Because the stripping depth differs between the central and edge parts of the target surface, it is necessary to perform shot blasting with an overlap width of about half the width of the stripping machine. In addition, it is necessary to confirm the relationship between the blasting density and the decontamination effect in advance, because the stripping depth varies with the blasting density (In the Model Project, a blasting density of 200 kg/m² was adopted for large-scale shot blasting).
- ◆ If the function of pavement is reduced by the stripping, stripping surface may be covered by asphalt again.

(4)-7 TS Road Surface Stripping Equipment (Thin Layer Stripping)

Overview: Asphalt pavement is stripped to the desired stripping thickness (5 mm or more) using road surface stripping equipment and the generated asphalt debris is transported to trucks using the stripping equipment's belt conveyor. The stripping residue is collected manually.



The asphalt debris generated is transported to trucks using the belt conveyor.



Main body of TS(Thin Silent) road surface stripping equipment

Important points:

- ◆ The asphalt debris left on the road is usually sweeping using bamboo brooms, but it is desirable to use manned mobile cleaning equipment in addition to bamboo brooms, because fine debris can become airborne.
- ◆ In the case where the target road surface has hollows that have been made by the earthquake etc., it is necessary to use other methods (such as ultra-high-pressure water jet-based washing and shot blasting) to supplement the surface stripping by the TS stripping equipment, or the asphalt pavement in the hollow parts of the road will be left without being stripped.
- ◆ If the function of pavement is reduced by the stripping, stripping surface may be covered by asphalt again.

(4)-8 Important Points about Road Decontamination Methods

○ Important points regarding the selection of a decontamination method

- (1) The measurement results of the surface contamination density distribution in asphalt pavements in the vertical direction in the high-dose areas showed that most of the radioactivity was present **within approx. 2 to 3 mm of the pavement surface for dense-graded asphalt pavements and within approx. 5 mm of the pavement surface for porous asphalt pavements (permeable asphalt pavements).**
- (2) **“Pavement stripping”** excels the other paved road decontamination methods in terms of decontamination effect, but **generates larger amounts of decontamination wastes** than the other methods. Because most of the radioactivity that fell on asphalt-paved roads is present within several millimeters of the asphalt pavement surface, it is important to **select a method that achieves a good decontamination effect while minimizing the amount of decontamination waste.** This can be achieved by minimizing the stripping thickness.
- (3) **The maximum reduction rate** that can be achieved with **draining type pavement function restoration vehicles** is about 50%, but they can be an efficient means of decontamination when the target reduction rate is low, because **the work speed is about 3 to 8 times as high as** the work speeds of the other methods.
- (4) Among the thin layer stripping-based methods, stripping using **TS stripping equipment** is the method that achieves the highest reduction rate. The work speed is also high. However, because it is **difficult to accurately strip off pavement with a stripping thickness of 5 mm or less, overbreak will be made and** larger amounts of decontamination wastes will be generated than in the case of the other methods.

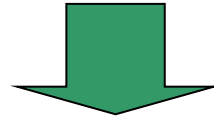
○ Important points regarding the application of a selected decontamination method

- (1) Because the **pavement stripping thickness** depends on the dose reduction target for the decontamination target area, it is important to select the most appropriate method after **confirming the distribution of the radioactive substances in the pavement in the vertical direction.**
- (2) The reduction rate that is achieved by ultra-high-pressure water jet-based washing varies with the water pressure and the number of times of washing, and the reduction rate that is achieved by shot blasting varies with the blasting density and the number of applications. Therefore, for these methods, it is important to **determine the specifications after confirming the effect.**

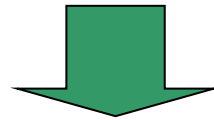
Combinations and Procedures with Surface (Planar) Decontamination in Mind

Forest decontamination

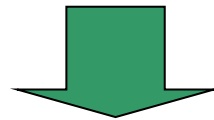
Farmland decontamination



Decontamination of playing fields and large buildings



Decontamination of residential houses



Decontamination of roads

Combinations and Procedures with Surface (Planar) Decontamination in Mind

Residential house



From top to bottom

Roof
Rainwater cullis
Wall
Concrete floor
Interlocking
Trees and soil of the garden

Ground surface

Decontamination is performed from top to bottom.

Large building

STEP 1

Roofs

STEP 2

Gutters

STEP 3

Walls, windows and doors

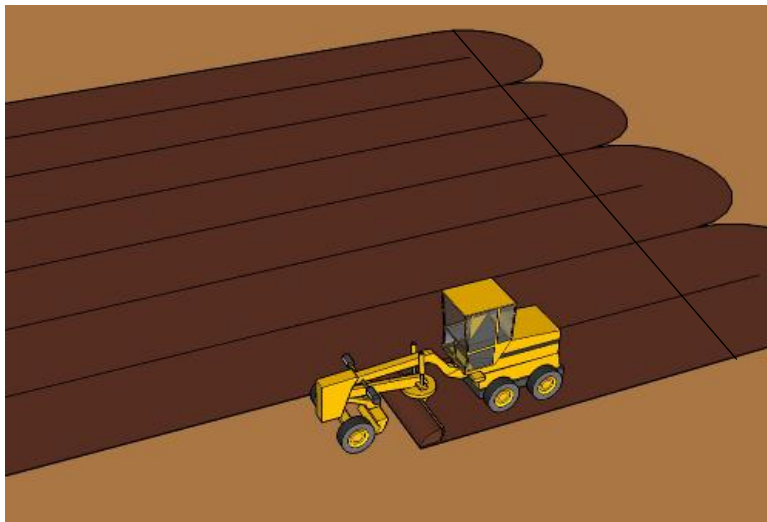
STEP 0

Trees taller than roofs are decontaminated before the roofs.

STEP 4

Ground surface is decontaminated last.

Large areas should be decontaminated without interruptions.





Thank You for Your Attention.



Japan Atomic Energy Agency