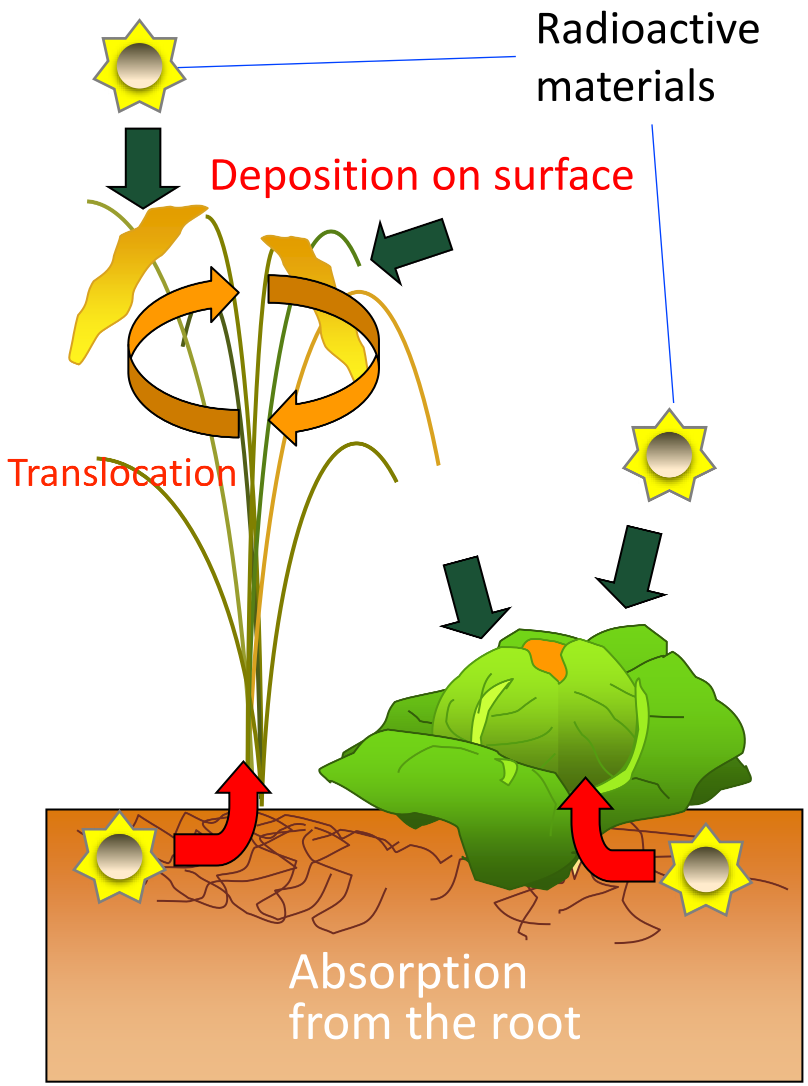
Long-term Effects

Transfer to Plants



Initial effects

Direct route (Deposition on leave surface directly from the air): Major route immediately after the release into the air

Route through translocation (Transfer within a plant): Radioactive materials absorbed into leaves and bark transfer to new leaves and fruits, etc.

Route of being absorbed from the root (Absorption of radioactive materials in soil from the root): Medium- to long-term transfer route after an accident

Long-term effects

Long-term Effects

Distribution of Radioactive Cesium in Soil

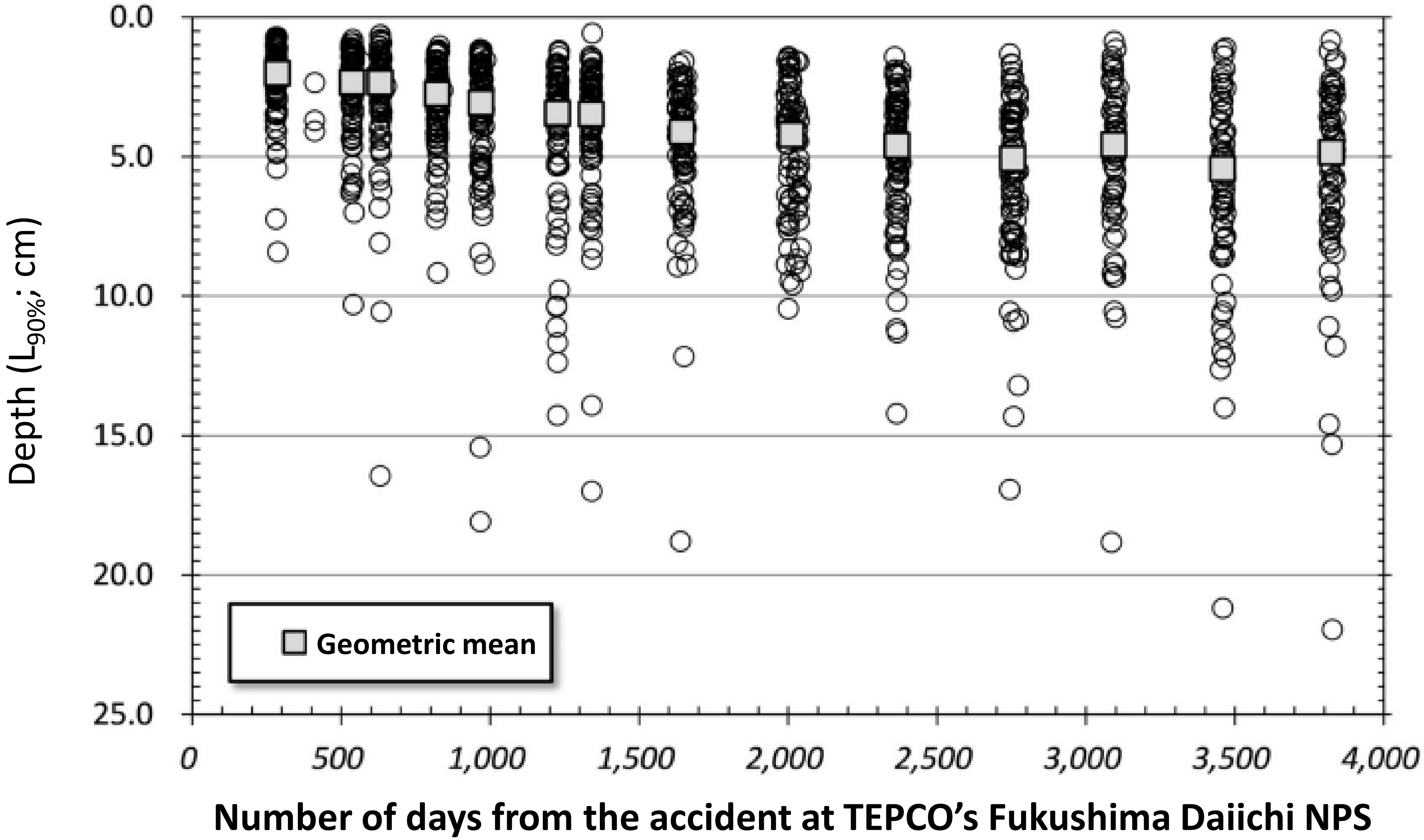


Figure: Data on changes over time in depth ($L_{90\%}$)* since December 2011 (85 locations at uncultivated land in Fukushima Prefecture, the southern part of Miyagi Prefecture and the northern part of Ibaraki Prefecture)

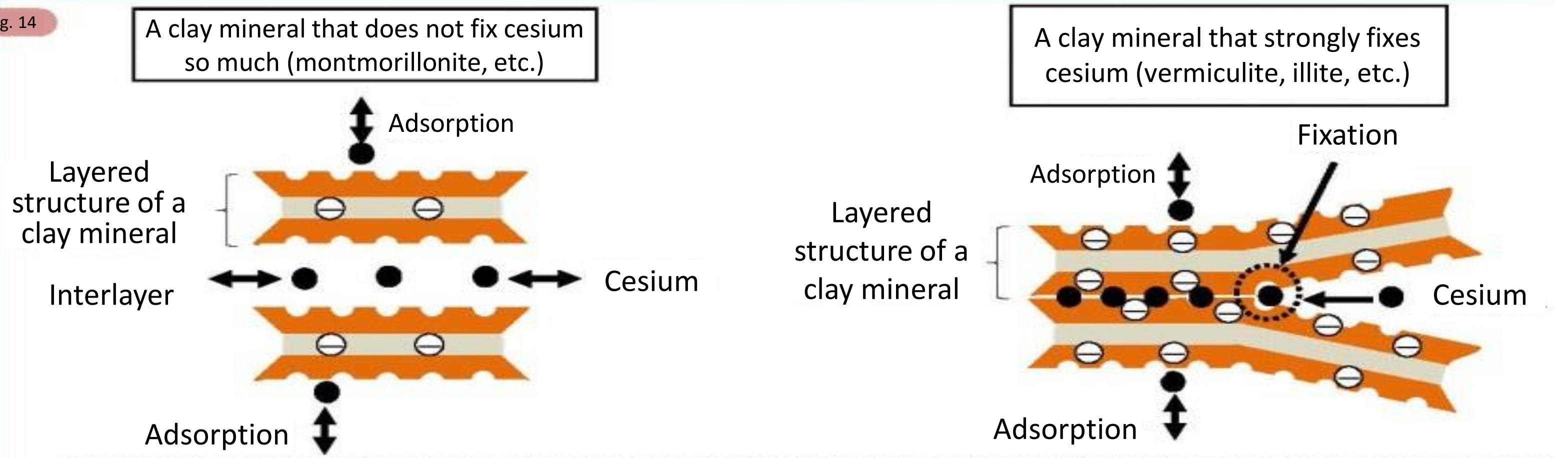
(Reference) Depth ($L_{90\%}$): The depth from the ground surface where 90% of all deposited radioactive cesium is contained

Source: Prepared based on the outcome report, "Survey of Depth Distribution of Radioactive Cesium in Soil," of the FY2021 project, "Compilation of Data on Distribution of Radioactive Materials Released due to the Accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS" commissioned by the Secretariat of the Nuclear Regulation Authority

Behavior of Radioactive Cesium in the Environment: Adsorption and Fixation by Clay Mineral

Adsorption and fixation of cesium

Fig. 14



[Explanation]

- A clay mineral on its surface has a negative charge and can adsorb cesium and part of the clay mineral can also incorporate and fix cesium in itself over time.
- Adsorbed cesium can be absorbed by plants, but once fixed, not so much is absorbed.

Table 4

Soil components	Adsorption of Cs	Fixation of Cs
Soil organic matters	Strong	Weak
Clay minerals (non-micaceous)		
Kaolinite, Halloysite	Strong	Weak
Allophane, Imogolite	Strong	Weak to medium
Montmorillonite	Strong	Weak
Clay minerals (micaceous)		
Vermiculite	Strong	Strong
Illite	Strong	Medium to strong
Aluminum vermiculite	Strong	Medium to strong
Zeolite	Strong	Strong (Note)

(Note) Anchoring power of these components varies depending on production areas and qualities.

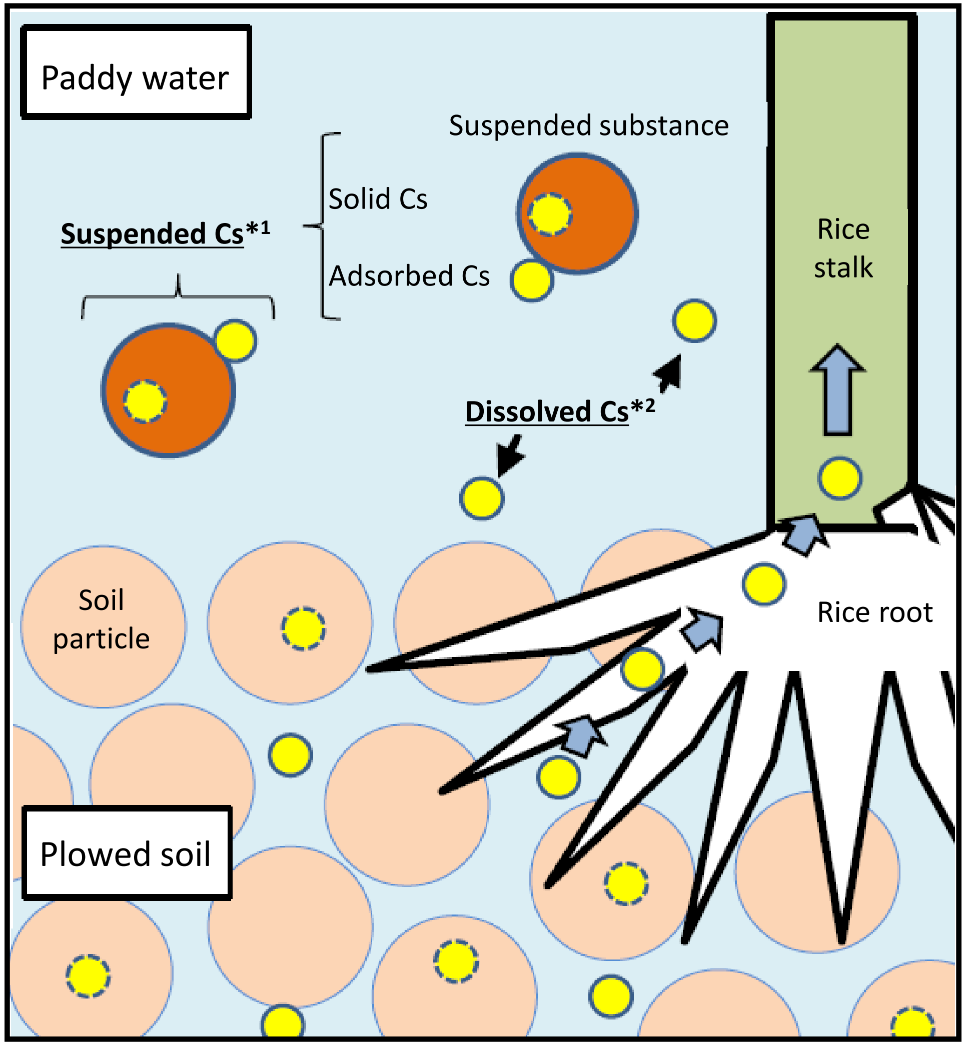
[Explanation]

- Soil organic matters and non-micaceous clay minerals, such as montmorillonite, have weak fixation power.
- Micaceous clay minerals, such as vermiculite and illite, strongly fix cesium.

Source: From the following website: https://www.maff.go.jp/j/kanbo/joho/saigai/pdf/youin_kome2.pdf (in Japanese)

Behavior of Radioactive Cesium in the Environment: Transfer from Water to Plants

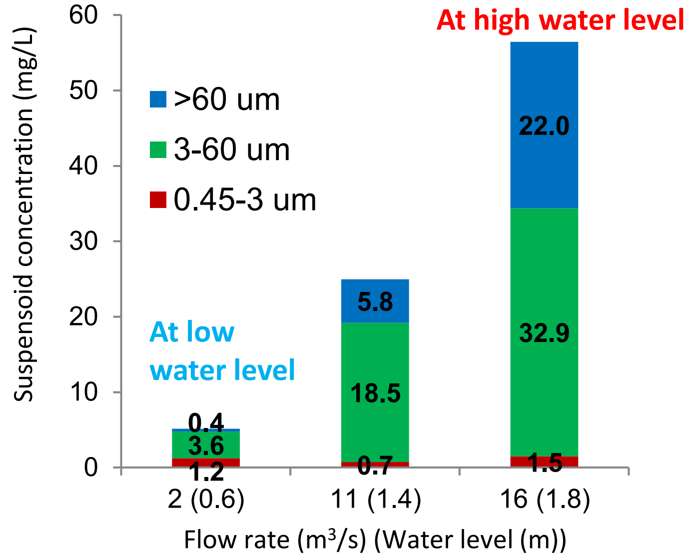
Forms of cesium in water



*1: Suspended form: Radioactive materials adsorbed and fixed in soil particles or organic matters; Suspended Cs is seldom absorbed directly from the root or stalk of rice.

*2: Dissolved form: Radioactive materials dissolved in water

Results of the survey conducted downstream of the Ukedo River (Ukedogawa Bridge) (2014)



Concentration and shape of suspensoid in river water at high water level

Concentration of dissolved and suspended Cs in river water

	At low water level	At high water level
River flow rate	2 m^3/s	16 m^3/s
Concentration of dissolved Cs-137	0.3 Bq/L	0.3 Bq/L
Concentration of suspended Cs-137	0.1 Bq/L	2.2 Bq/L
Percentage of dissolved Cs	75%	12%
Total concentration of Cs-134 and Cs-137	0.6 Bq/L	3.3 Bq/L

Source: From the following websites (in Japanese):
http://www.maff.go.jp/j/kanbo/joho/saigai/pdf/youin_kome2.pdf
https://fukushima.jaea.go.jp/report/document/pdf/pdf1702/hokokukai11.pdf

Long-term Effects

Behavior of Radioactive Cesium in the Environment: Outflow from Forest Soil

Surveys conducted so far revealed that the annual outflow rate of Cs-137 from forest soil is around 0.02% to 0.3% of the total amount of Cs-137 deposited on nearby watershed soil.

[Table 1] Outflow of radioactive Cs from watershed areas to rivers (Outflow rates)

Watershed area	Kawamata Town			Mt. Tsukuba	Marumori Town
	Around Mt. Iboishi*1	Around Mt. Ishihira*1	Around Mt. Kodaishi*1	Around Kasumigaura*2	Upstream of the Udagawa River*2
Survey period		44 to 45 days*3		21 months	15 months
Amount of Cs-137 deposited on soil (kBq/m^3)	544	298	916	13	170-230
Amount of outflow of Cs-137*4 (kBq/m^3)	0.087	0.026	0.021	0.06	0.22-0.34
Percentage of the amount of Cs-137 outflow against the total amount of Cs-137 deposited on soil	0.016%	0.009%	0.002%	0.5%	0.12-0.15%
Percentage of the annual amount of outflow of Cs-137*5	**0.13%**	**0.07%**	**0.02%**	**0.26%**	**0.10-0.12%**

*1: (Source) Outcome report of the FY2012 commissioned radiation measurement project, "Establishment of Methods to Ascertain Long-term Effects of Radioactive Materials Released due to the Accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS," JAEA

*2: (Source) National Institute for Environmental Studies, 2012 and 2013

*3: Extracted and totaled comparable data for these three watershed areas obtained from October 1 to 9 or 10, from October 22 to November 3, and from November 29 or 30 to December 18 or 19, 2012 (44 to 45 days)

*4: ◯ Watershed areas around Mt. Iboishi, Mt. Ishihira and Mt. Kodaishi: Total amount of Cs-137 in river water (dissolved Cs-137, suspended substances (SS) and large organic matters (leaves and branches flowing in the river))

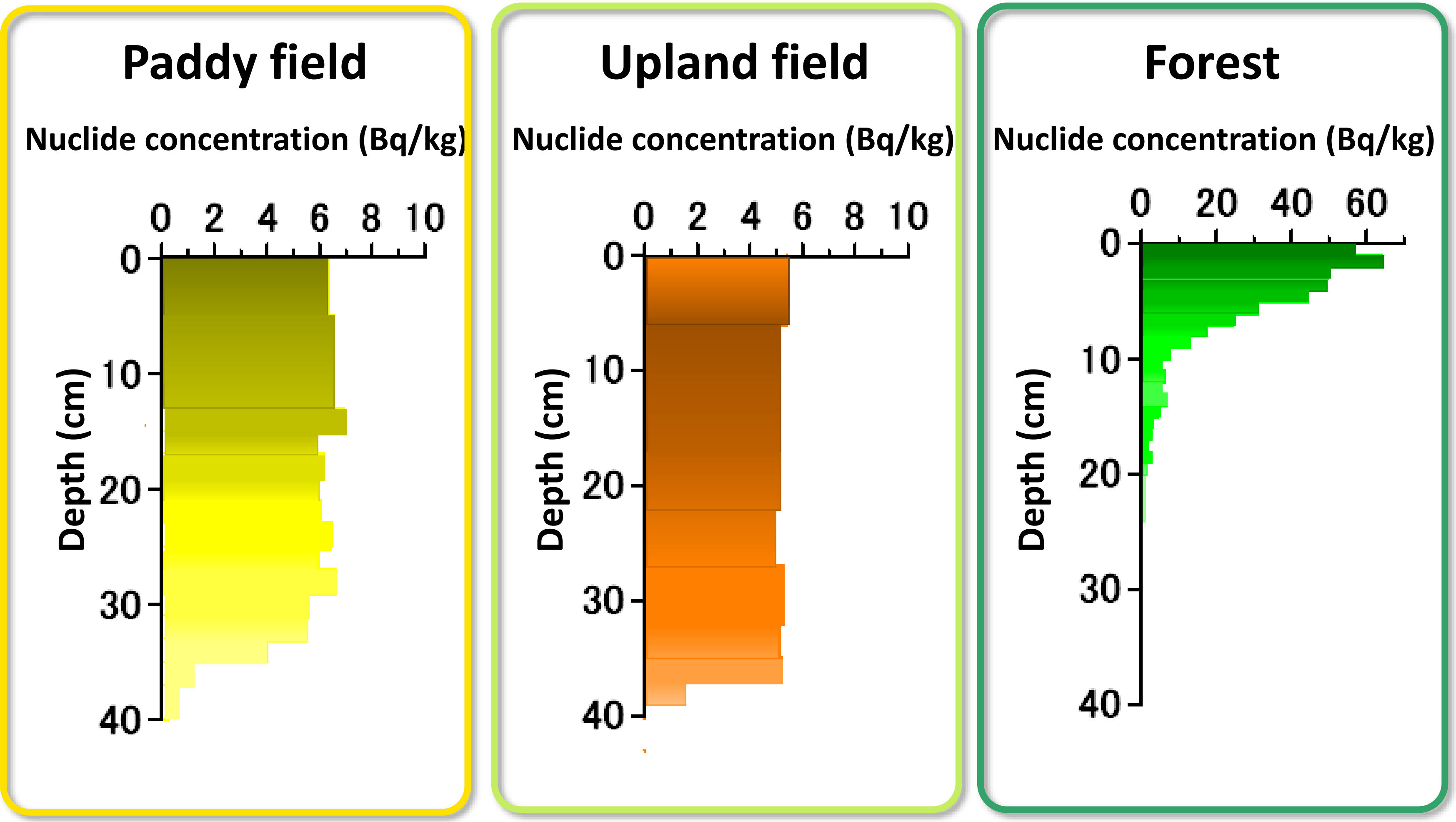
- Dissolved Cs-137: The concentration of dissolved Cs in normal times (August and October 2012) multiplied by the river flow rate
- SS: The radioactive Cs concentration in SS samplers multiplied by the SS flow rate, which was obtained based on contiguous data from a turbidity meter and the river flow rate
- Large organic matters: The radioactive Cs concentration in organic matters multiplied by the total amount trapped

◯ Watershed areas around Kasumigaura and the upstream of the Udagawa River: Cs-137 derived from SS

*5: The data indicated in the above table is converted into the annual outflow rate based on the outflow rate against the amount of Cs-137 deposited on soil and the survey period (calculated by the Ministry of the Environment).
Natural decay of radioactive cesium and precipitation during the survey period are not taken into consideration in the calculation.

Effects of Nuclear Test Fallout (Japan)

Depth distribution of Cs-137 concentrations in soil samples collected in Hokkaido in October 2009



Bq/kg: becquerels per kilogram

Source: Prepared based on the Compilation of the Outcomes of the 52nd Environmental Radioactivity Survey (2010), Kikata, et al.

Long-term Effects

Distribution of Radioactive Materials in Forests

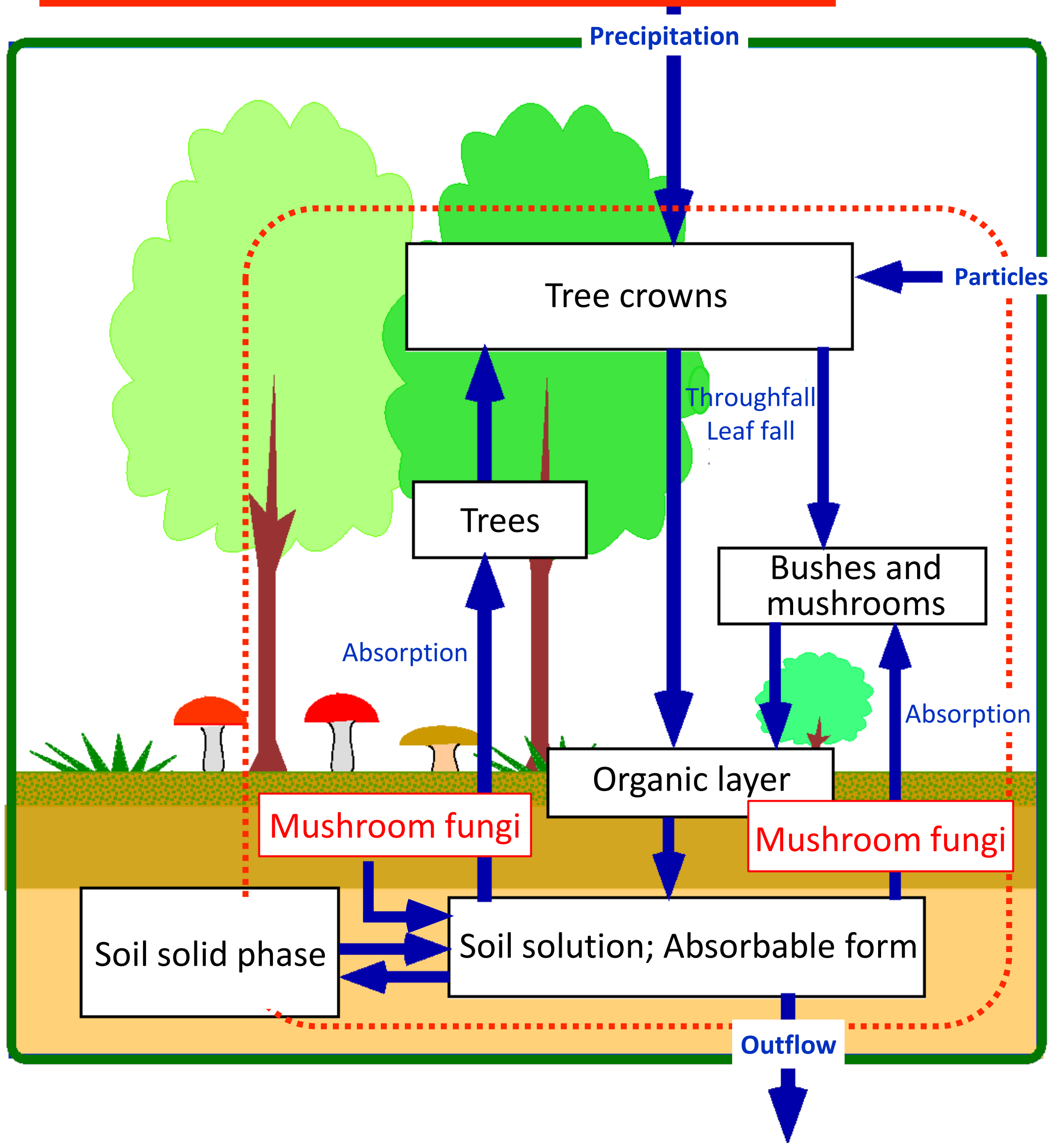
Distribution changes over time (years).

Immediately after deposition from the air:
- Leaves and branches on tree crowns (partially absorbed from their surface and translocated to other parts)
- Around the surface of the soil organic layer (mulch layer)

Thereafter:
- From tree crowns to the soil organic layer
- From the organic layer to subsoil
- Absorption into plants from the root

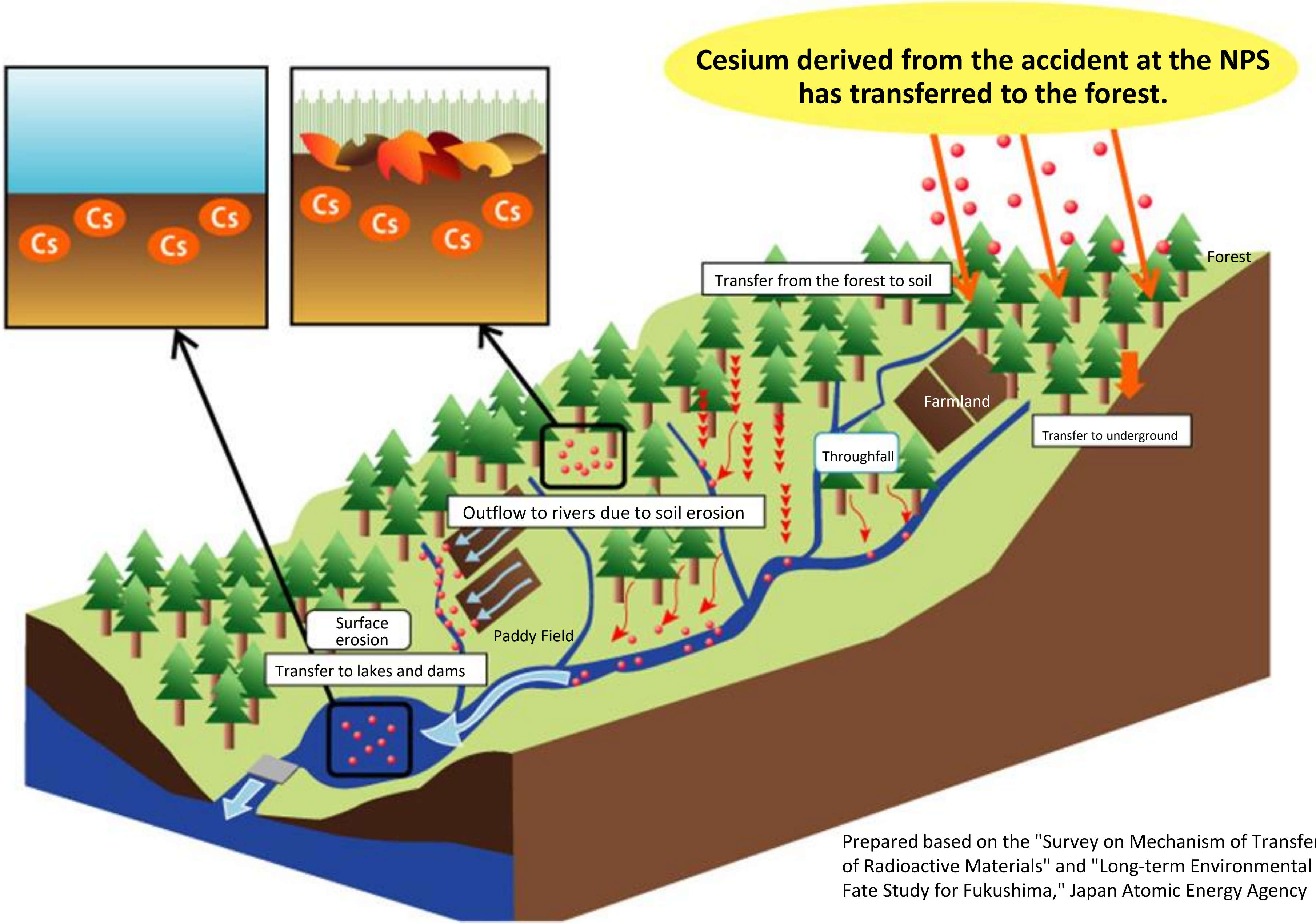
In the end:
- Mostly deposited in the soil surface layer including the organic layer

Dynamic transfer within the forest



Long-term Effects

Transfer of Fallen and Deposited Cesium in the Environment

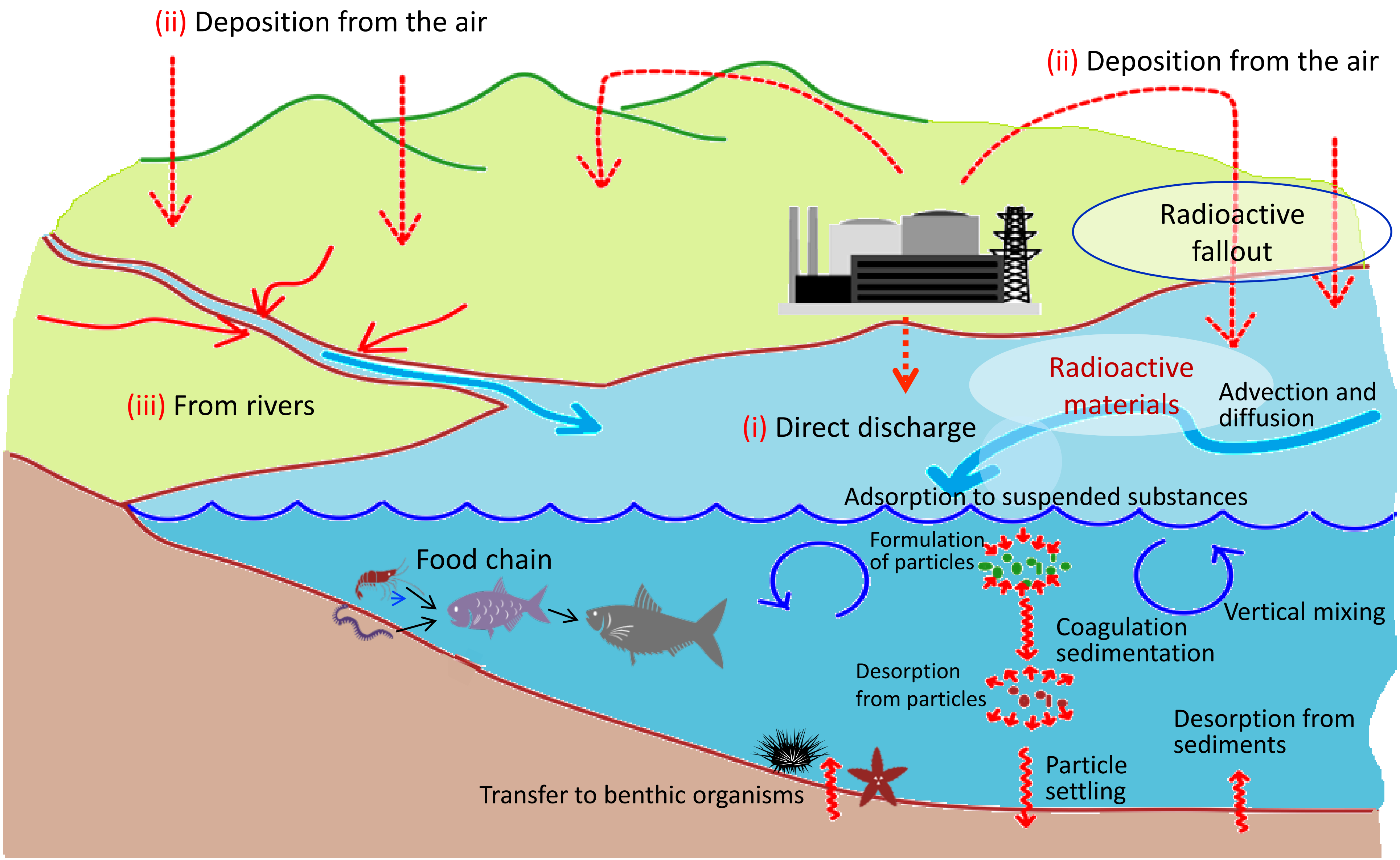


Prepared based on the "Survey on Mechanism of Transfer of Radioactive Materials" and "Long-term Environmental Fate Study for Fukushima," Japan Atomic Energy Agency

Long-term Effects

Distribution of Radioactive Cesium in the Ocean

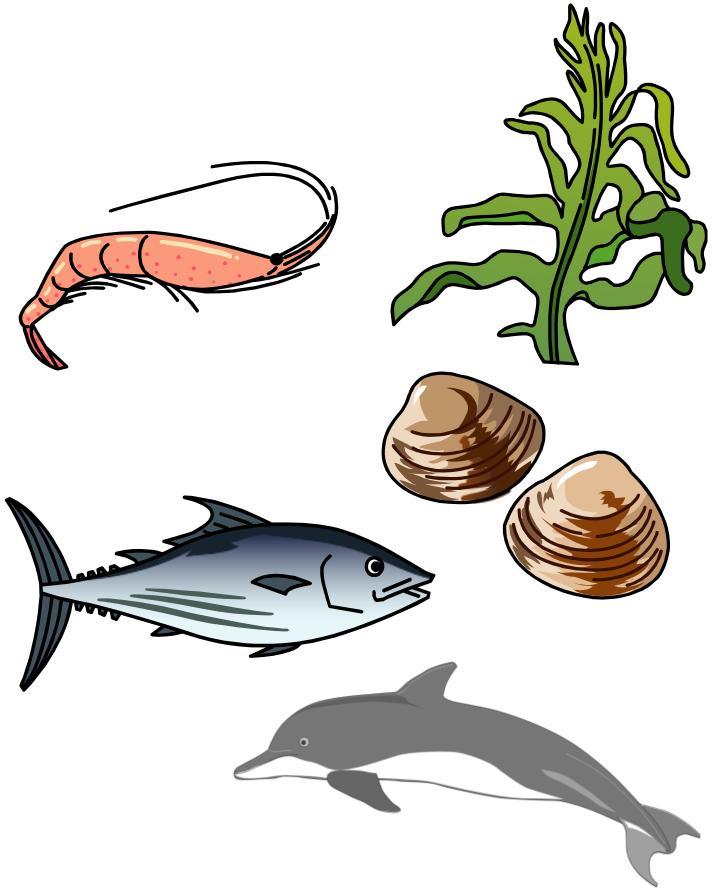
"Direct discharge (into the ocean)" and "Deposition from the air" show the situation immediately after the accident.



Concentration Factors for Marine Organisms

Concentration factor = (Radioactivity concentration in a marine organism) / (Radioactivity concentration in seawater)

Types of organisms	Concentration factor* (cesium)
Squids and octopuses	9
Phytoplankton	20
Zooplankton	40
Algae	50
Shrimps and crabs	50
Shellfish	60
Fish	100
Dolphin	300
Sea lion	400



The current radioactive cesium concentrations in seawater are at the same level as that before the accident (0.001 - 0.01 Bq/L).

* Concentration factors are recommended values in the following document by the IAEA.

Source: "Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment, 2004," International Atomic Energy Agency (IAEA)