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IRID Annual Symposium 2014

Research and Development on Processing and Disposal of Radioactive Waste

July 18, 2014

International Research Institute for Nuclear Decommissioning

The contents of this presentation include the results of “Establishment of basic technology for decommissioning and safety of nuclear reactors for power generation in 2015 (technological study and research concerning forming an idea for processing and disposing of radioactive waste resulting from the accident)“, a project commissioned by the Ministry of Economy, Trade and Industry, and the 2014 subsidiary for decommissioning and contaminated water measures (development of technologies for processing and disposing of waste resulting from the accident).

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Table of Contents

1. Overview of radioactive waste management
2. Waste resulting from accident at Fukushima Daiichi nuclear power station
3. Outline of research into processing and disposal of radioactive waste
   3-1 Characterization
   3-2 Long-term storage
4. Issues and measures

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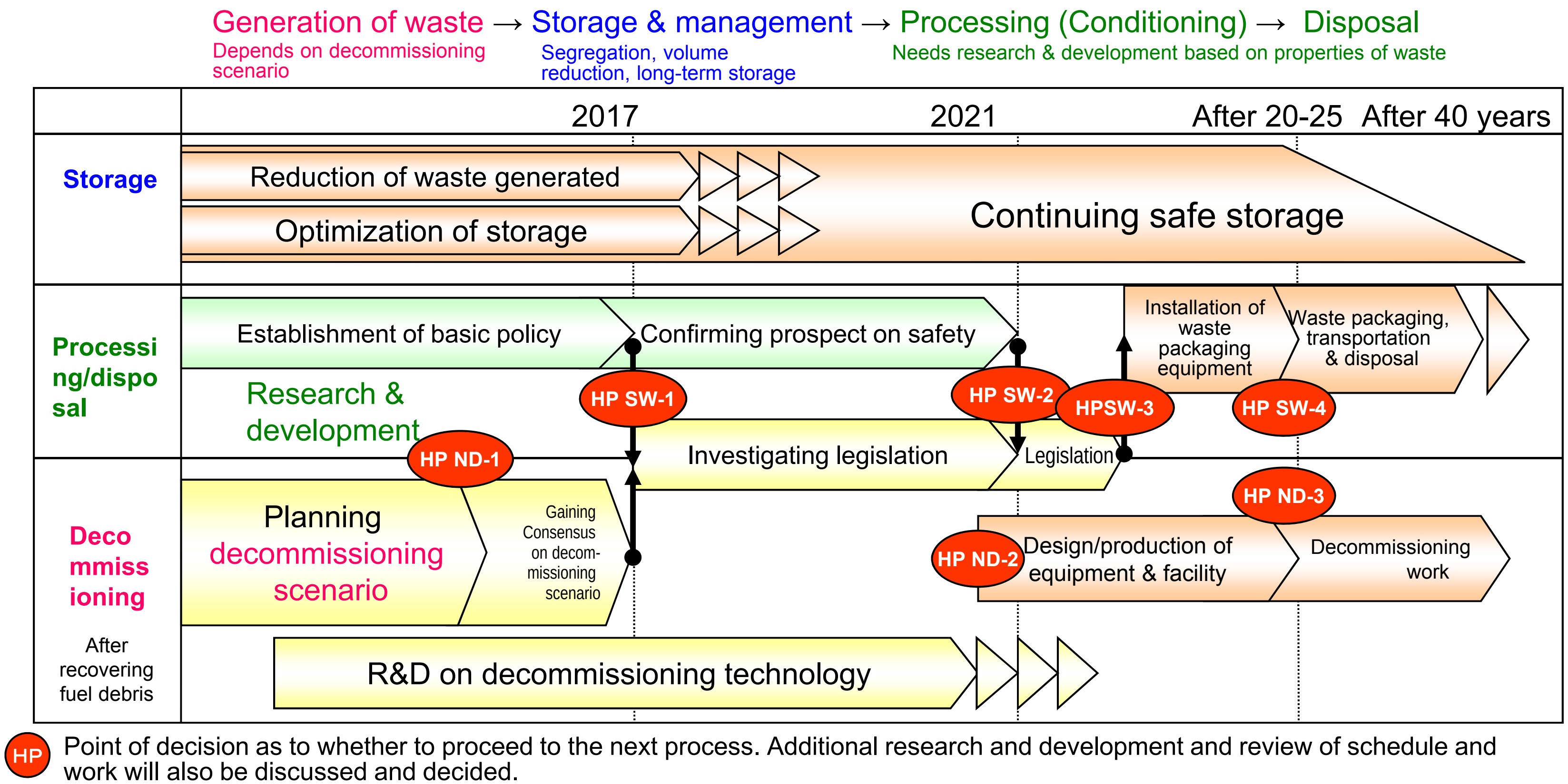
1. Overview of radioactive waste management

(1) Mid- and long-term roadmap for radioactive waste management



HP SW-1: Making basic policy for processing & disposing of solid waste (2017)
HP SW-2: Confirmation of prospect on safety for processing & disposing of solid waste (2021)
HP SW-3: Determination of specifications and production method of waste package (third term)
HP SW-4: Prospect of installing waste package production equipment and disposal of waste (third term)

HP ND-1: Planning decommissioning scenario (2015)
HP ND-2: Determination of techniques for decontamination and dismantling equipment (third term)
HP ND-3: Prospect of waste disposal and end of necessary research and development (third term)

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1. Overview of radioactive waste management

(2) System for implementing research and development

Agency of Natural Energy and Resources, Ministry of Trade, Economy and Industry

Fund management corporation

2013 subsidy for decommissioning & countermeasures against contaminated water (for development of technologies for processing and disposal of waste)

International Research Institute for Nuclear Decommissioning (IRID)

- Japan Atomic Energy Agency (JAEA)
- Tokyo Electric Power Co. (Tepco)

Establishment of cooperative relation

Collecting various information and opinions from home and abroad

- Universities, manufacturers, related organizations, etc., at home and abroad
  - Information sharing
  - Conducting joint research, etc.
- Academia, international organizations, etc., at home and abroad
  - Setting up task force in Atomic Energy Society of Japan
  - Setting up expert council at OECD/NEA

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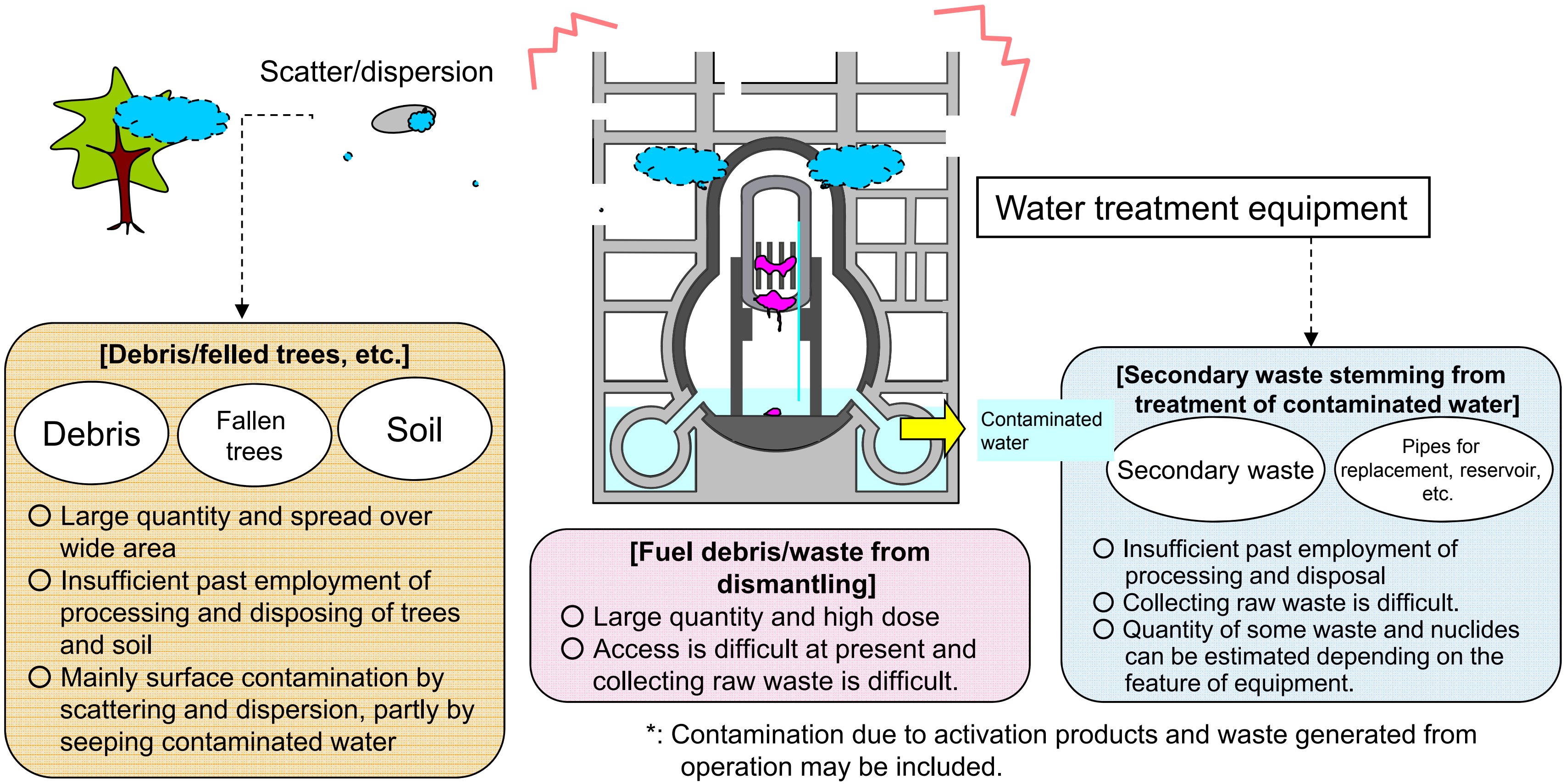
2. Waste resulting from accident at Fukushima Daiichi nuclear power station
(1) Features of waste

- Generated by accident in an uncontrollable state
- Contamination stemming from reactor fuel of units 1 to 3*
- Estimating the quantity is difficult because decommissioning work changes depending on the situation.
- Data (especially on composition of long-lived nuclides) is very limited because contamination stretches over a wide area and there are locations of high dose



*: Contamination due to activation products and waste generated from operation may be included.

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2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(2) Comparison between wastes from accident and operation

Item of uncertainty	Degree of countermeasure	
	Waste from operation	Waste from accident
Generation of waste [quantity, type, period]	◎	△
Handling (collecting/classifying) [difficulty]	◎	△
Characterization [sufficiency of information, difficulty of sampling, representativeness of sample]	○	△
Technologies for processing and packaging waste	○	? - △
Burial and disposal methods and safety assessment	△ - ○	?
Regulations, technical standards, guidelines, siting	△ - ○	?

◎: Fully understood or good prospect, ○: Fair prospect, △: Limited
?: Cannot be discussed

- Waste generated from operation has its own problem but is **fairly under control**.
  - Information on basic properties of waste, including quantity at present, future change, activity and chemical substances contained in individual waste is identified.
  - Both unprocessed and processed wastes are appropriately stored and managed in accordance with the current regulations.
  - Regulations and standards, as well as disposal method and safety assessment method, have been in place.
- Many uncertainties poses important technical problems to disposal of waste from the accident at Fukushima Daiichi. Solving these uncertainties and bringing the waste under control are the major goals of countermeasures and technology development.

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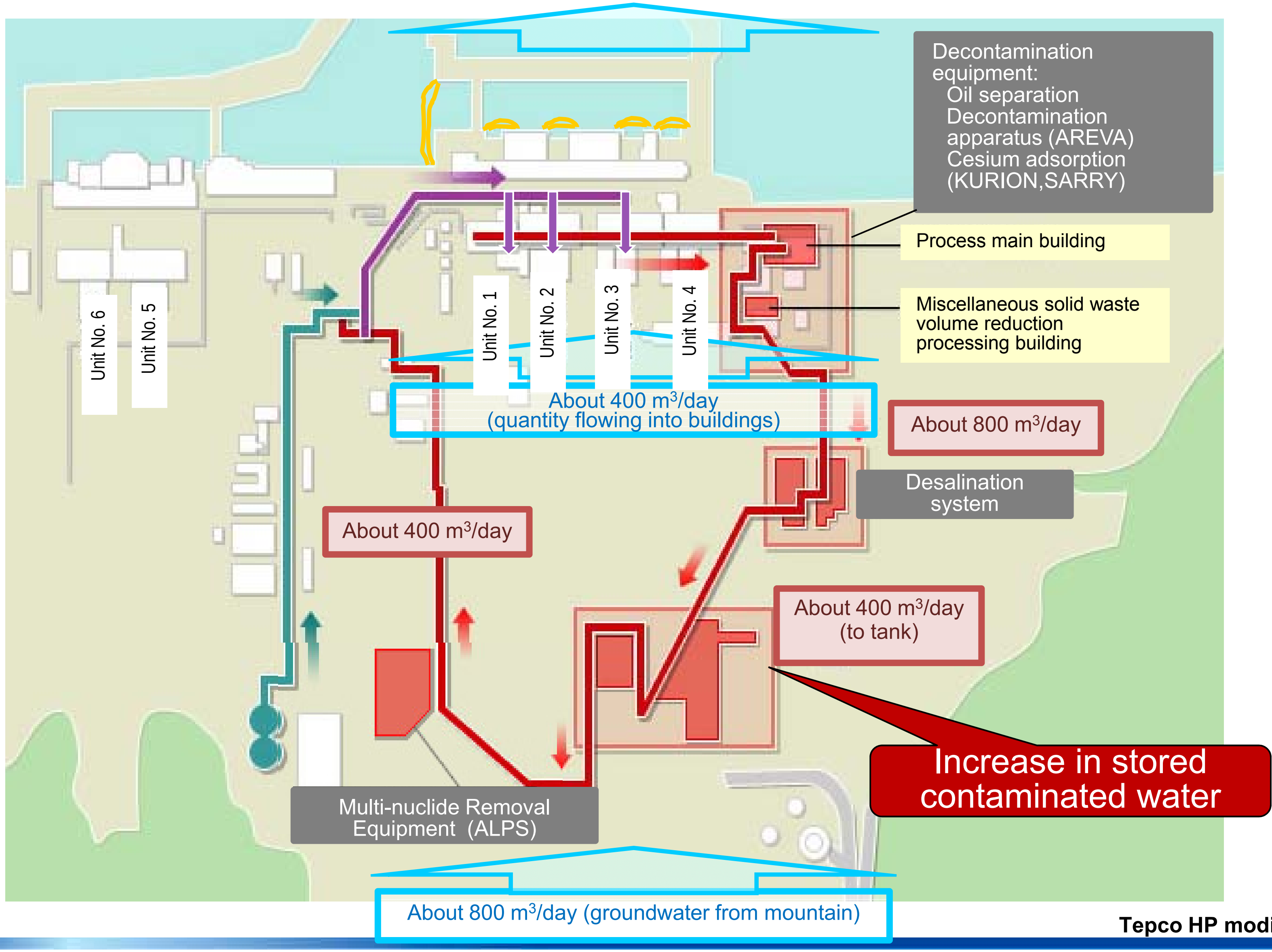
2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(3) Situation of contaminated water treatment at Fukushima Daiichi nuclear power station



Tepco HP modified

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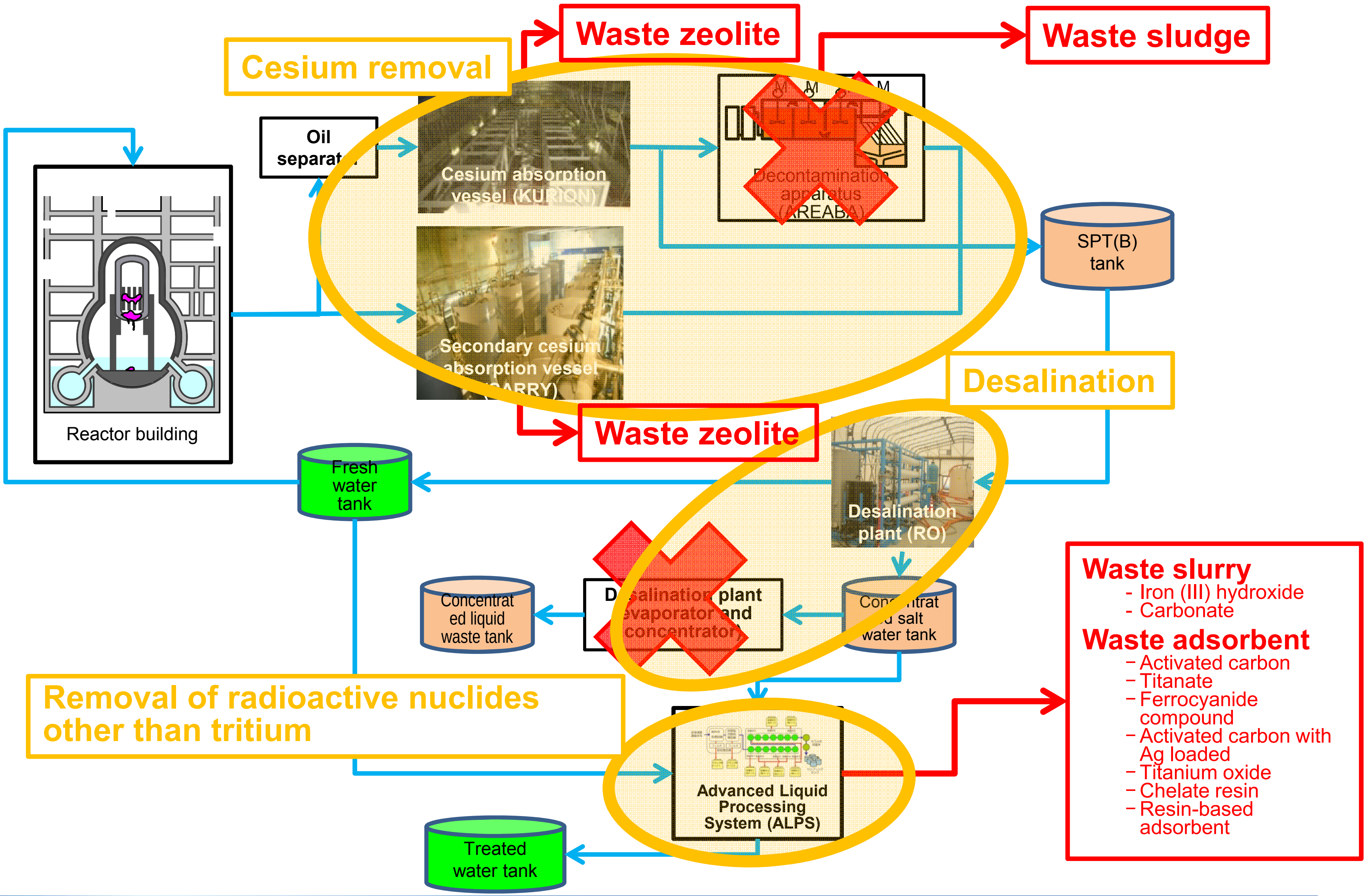
2. Waste resulting from accident at Fukushima Daiichi nuclear power station
(4) Outline of contaminated water treatment equipment and waste generated



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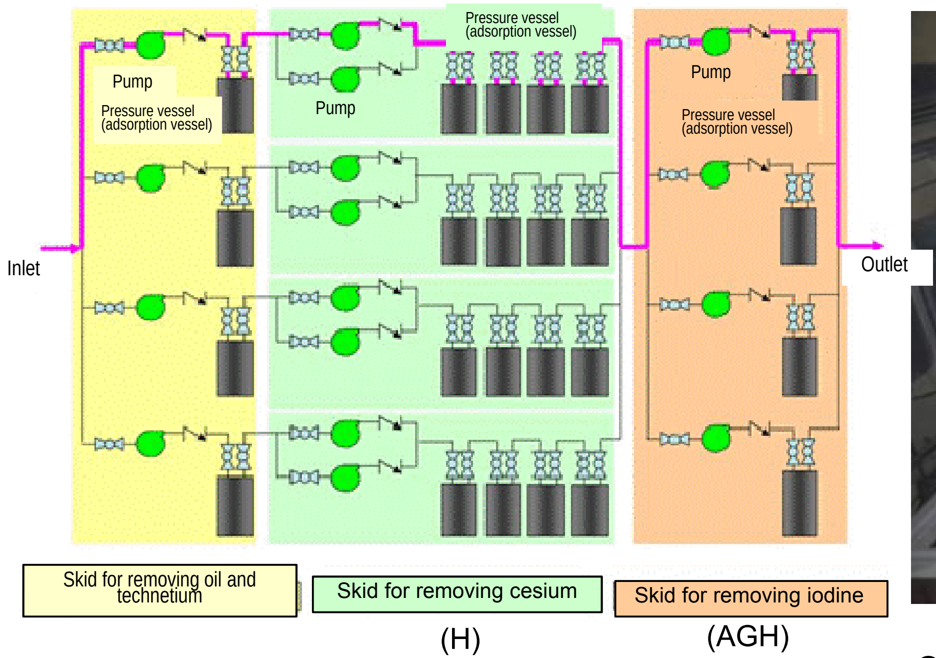
2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(5) Outline of cesium adsorption apparatus (KURION)

Outline of cesium adsorption apparatus (KURION)



- Dimensions: About 1.4 m (dia.) × 2.4 m (H)
- Weight: About 15 t
- Zeolite-filled stainless steel vessel within carbon steel container as shield

Appearance of cesium adsorption apparatus

- Adsorption vessel housed in adsorption skid
- To reduce exposure of workers, vessel is replaced when the dose equivalent rate on skid surface reaches about 4 mSv/h.
- Processing capacity: 1,200 m^3/day/4 systems = 12.5 m^3/h/system
- Adsorbent KURION-H
  KURION-AGH

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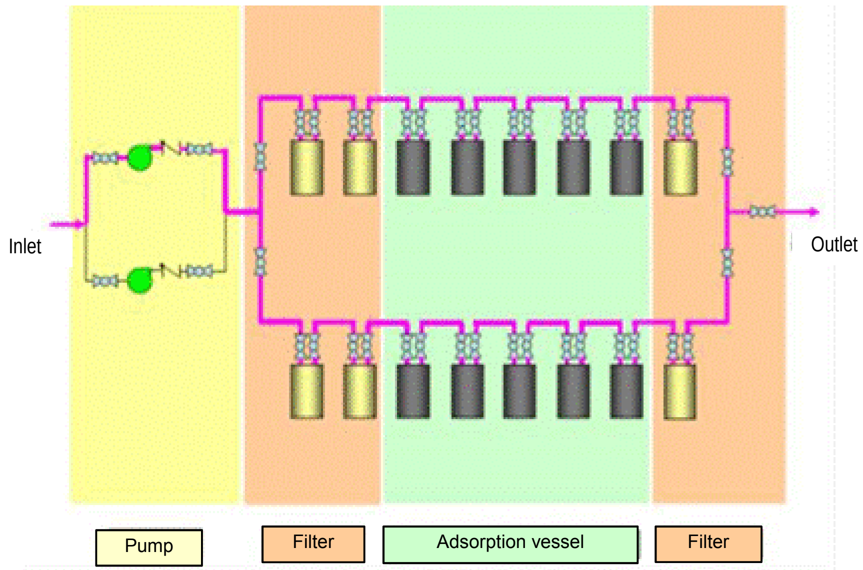
2. Waste resulting from accident at Fukushima Daiichi nuclear power station
(6) Outline of secondary cesium adsorption apparatus (SARRY)

Outline of secondary cesium adsorption apparatus (SARRY)



Appearance of secondary cesium adsorption vessel

- Started operation in August 2011
- Dimensions: 1.4 m (dia.) × 3.6 m (H)
- Weight: About 24 t
- Zeolite-filled stainless steel vessel within double-layered carbon steel container for shielding, with lead in its annulus
- To reduce exposure of workers, vessel is replaced when its dose equivalent rate on the surface of the adsorption vessel reaches about 4 mSv/h.
- Processing capacity: 20 to 25 m^3/h/system × 2 systems = 40 to 50 m^3/h
- Adsorption apparatus makeup
  - Preprocessing filter
  - Preceding stage: Synthesized zeolite for light decontamination
  - Succeeding stage: Titanium silicate* for thorough decontamination
  - Trailing dust filter

*Name: Crystalline titanium silicate, CST, titanosilicate

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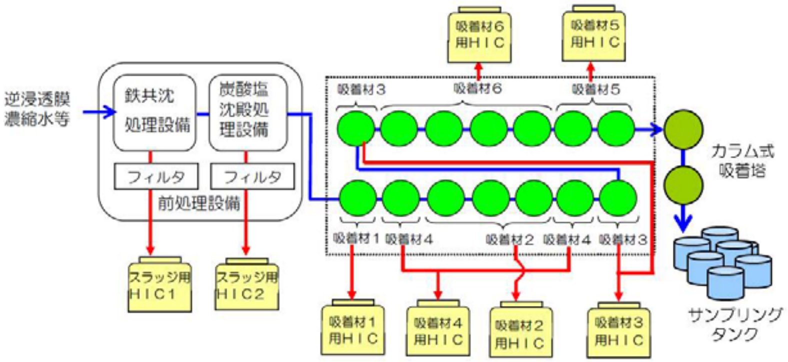
(7) Outline of Multi-nuclide Removal Equipment (ALPS※1)

◆ purpose

Existing water treatment facilities can mainly remove cesium. Besides, other nuclides are removed to reduce their concentration in the contaminated water aiming at the level of notification below ※2

※1 : Advanced Liquid Processing System
※2 : Notification for Dose Equivalent Limits on the Basis of the Ministerial Ordinance for Commercial Power Reactors

◆ Multi-nuclide removal equipment structure



- A, B, C line system
- 1 line (50% running flow) treatment amount : 250m^3 per day
- 3 lines are in operation (750m^3 per day)

◆ Characteristics and supposed generation of sludge and adsorption

		Major component	Component to be removed
Pre treatment	Iron coprecipitation	ferric hydroxide Ⅲ	organic substance, α nuclide, Co, Mn
	carbonate precipitation	carbonate	Sr, Mg, Ca
Adsorbent	Adsorbent 1	activated charcoal	colloid
	Adsorbent 2	titanate	Sr
	Adsorbent 3	Ferrocyanide compound	Cs
	Adsorbent 4	Ag impregnated carbon	I
	Adsorbent 5	titanium oxide	Sb
	Adsorbent 6	chelate resin	Co
Column	Adsorbent 7	resin adsorbent	Ru etc. Negatively charged colloid

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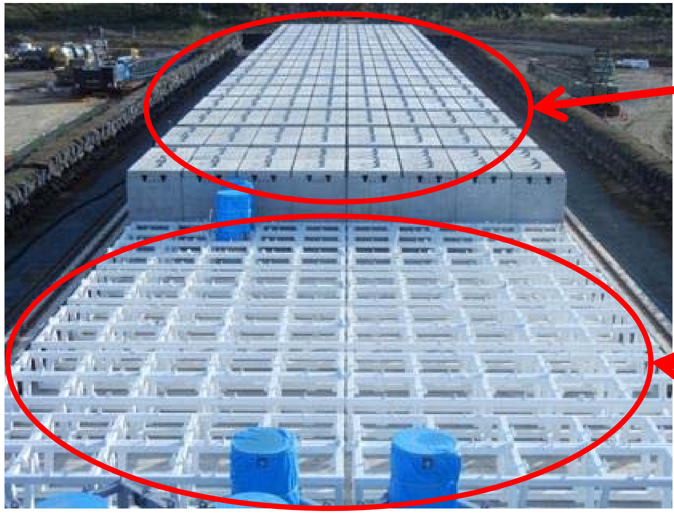
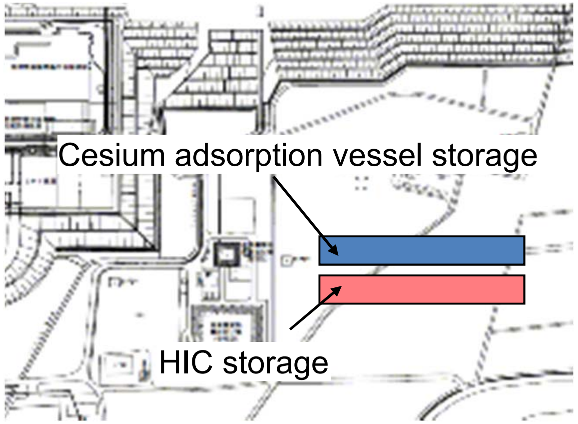
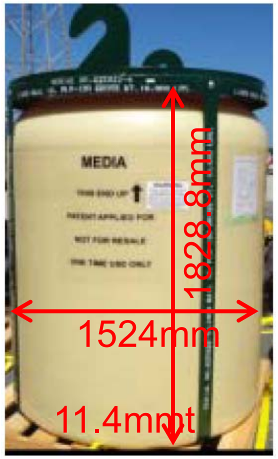
(8) Cesium adsorption vessel and HIC (High Integrity Container) temporary storage



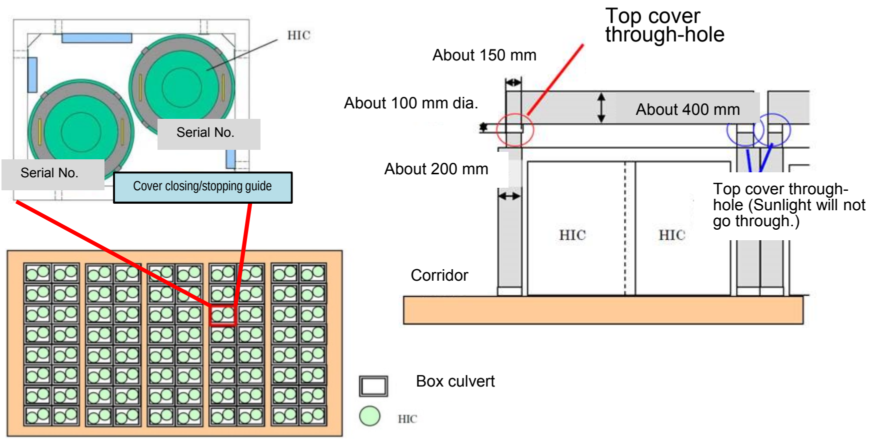
KURION (cesium adsorption apparatus) adsorption vessel storage (stored in concrete box culvert)

SARRY (secondary cesium adsorption apparatus) adsorption vessel storage





Appearance of HIC type 1 HIC



Temporary storage of HIC

(9) Features of debris and felled trees

Features of debris

- Reinforced concrete scattering around reactor building
- Reinforced concrete removed form remaining buildings
- Metallic objects scattering around reactor building and removed from remaining buildings
  - Contamination of low to high concentration mainly by radioactive material in gas form
  - In addition to the surface, the inside is also partially contaminated.
  - Salt and scattering inhibitor adhered.
  - SUS, carbon steel, aluminum alloy, led (shield)
  - PVC sheath (organic matter) such as of cables

Features of felled trees

- Organic (cellulose) waste
- Low dose on trunk
- Surface contamination and partially contaminated inside
- Mixed with salt and scattering inhibitor
- Volume of branches and leaves can be reduced by chipping.
- Humification has progressed, making it difficult to be separated from soil.

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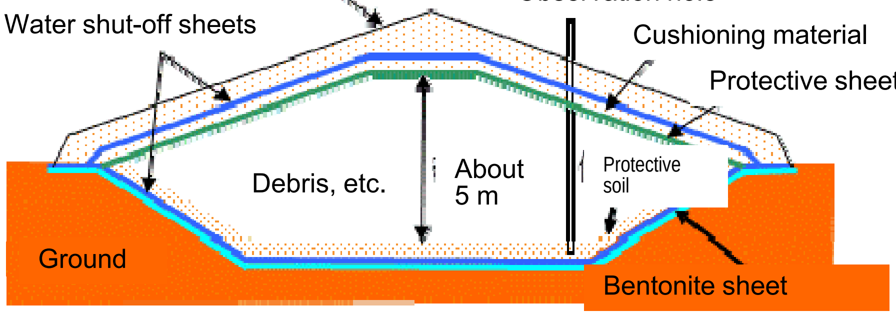
2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(10) Temporary storage conditions of debris and felled trees (1/3)

2. Waste resulting from accident at Fukushima Daiichi nuclear power station
(11) Temporary storage conditions of debris and felled trees (2/3)

◆ Conditions of soil-covered temporary storage facility



Structure of soil-covered temporary storage facility

Internal status

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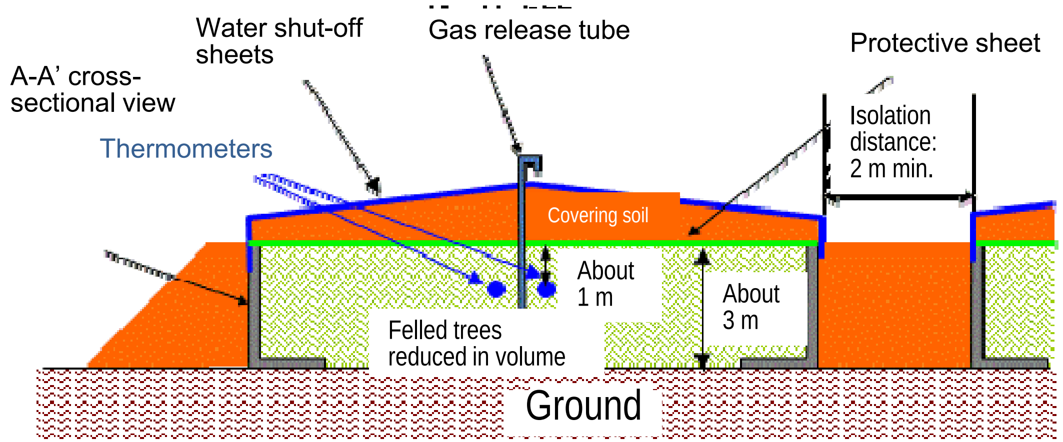
2. Waste resulting from accident at Fukushima Daiichi nuclear power station
(12) Temporary storage conditions of debris and felled trees (3/3)

◆ Temporary storage conditions of felled trees

Temporary storage of felled trees (trunks)

- Felled trees are separated into trunks, roots, and branches and leaves, and temporarily stored at fixed locations on Fukushima Daiichi site.
- Branches and leaves are stored in a soil-covered temporary storage tanks (whose temperature is regularly measured), to lower the dosage and risk of a fire.

Temporary storage of felled trees (branches and leaves)



Structure of felled tree temporary storage tank

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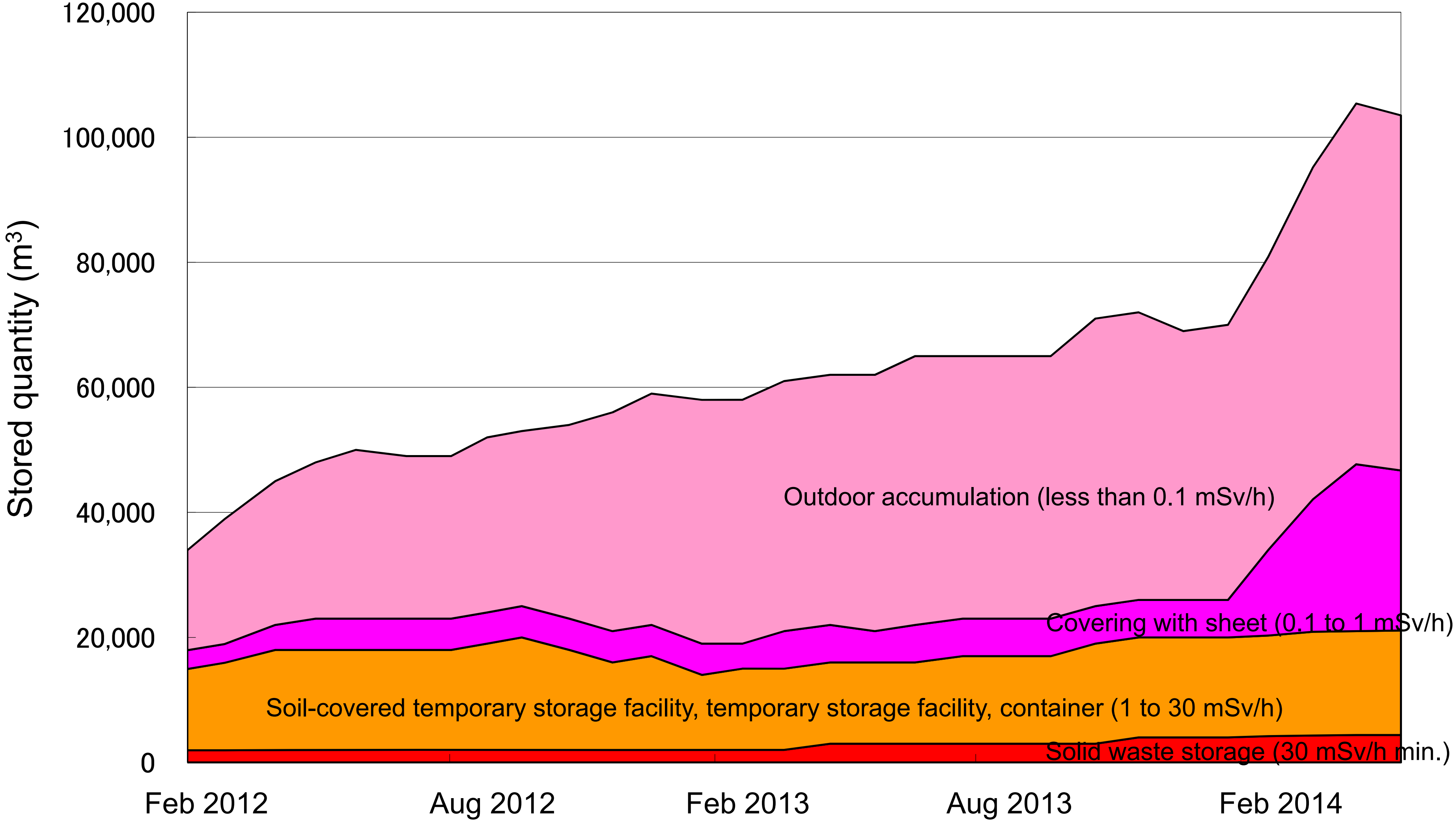
(13) Change in quantity of stored debris



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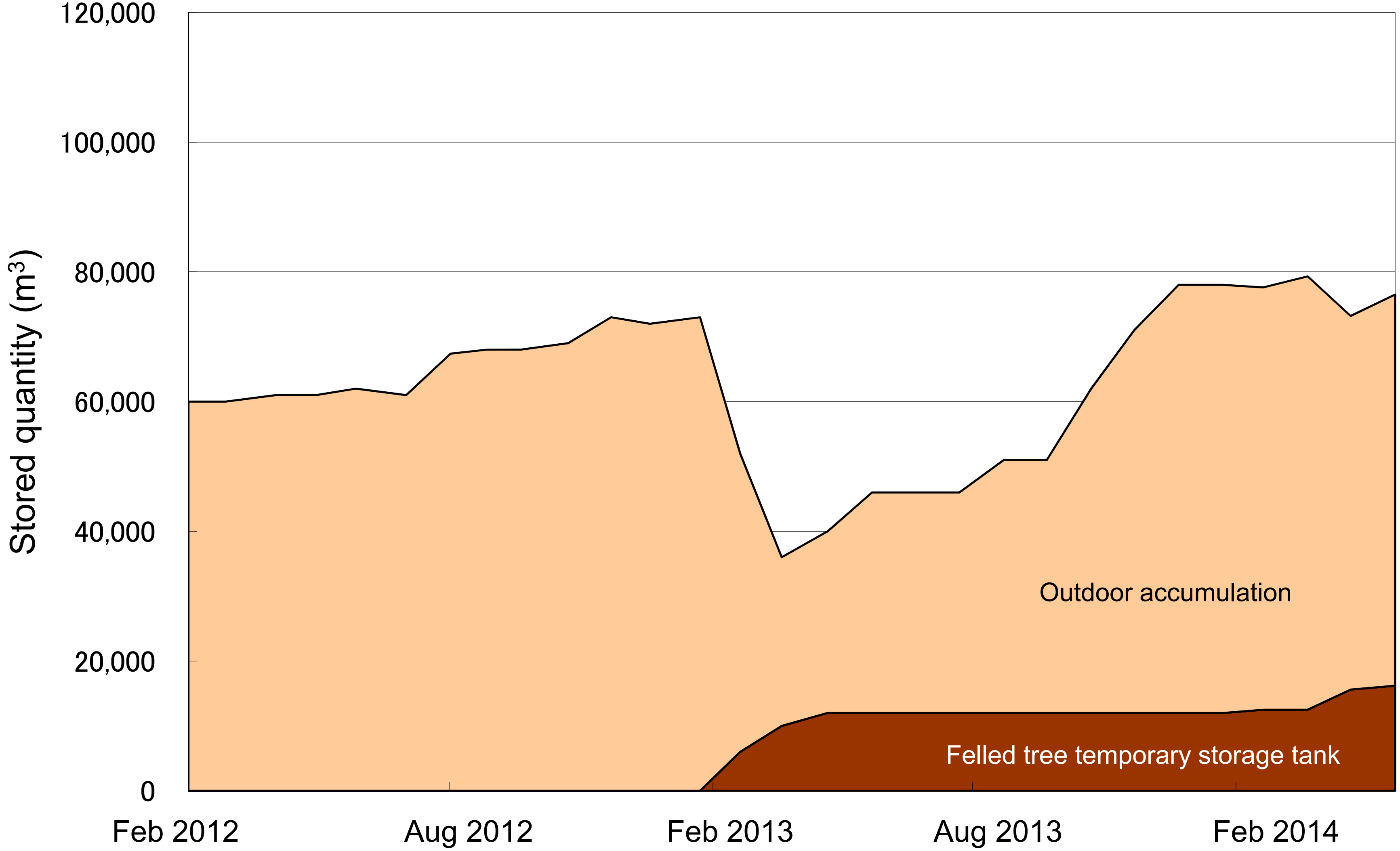
2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(14) Changes in quantity of felled trees stored



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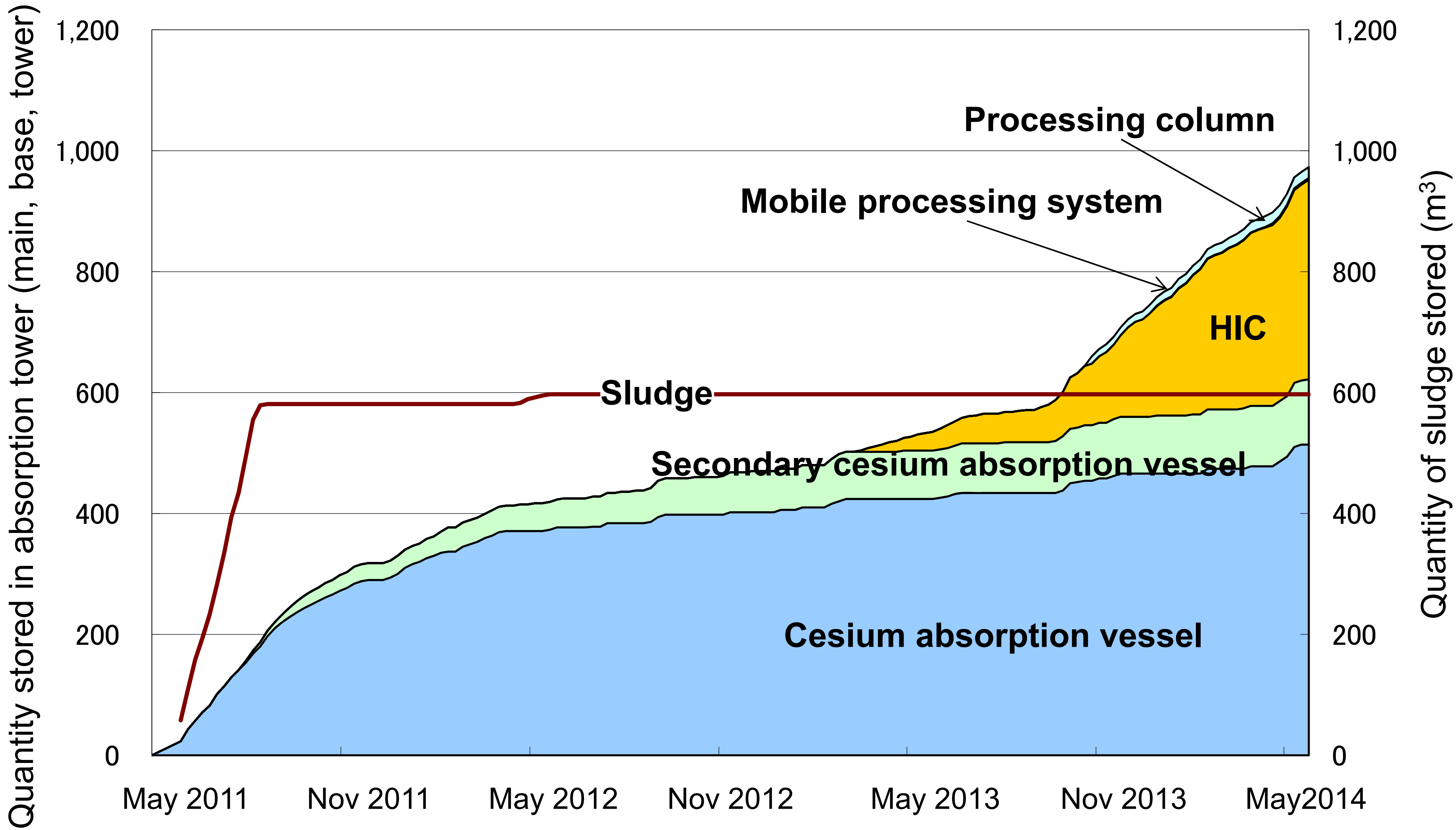
2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(15) Changes in quantity of water-treated secondary waste stored



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2. Waste resulting from accident at Fukushima Daiichi nuclear power station

(16) Draft of policy for reducing volume and recycling waste

Type of waste	Temporary processing	Future plan
Concrete debris	• Reducing volume by pulverizing • Encouraged recycling as sub-base materials	Recycling as reproduced concrete to be considered
Metal debris	• Reducing volume by cutting	Volume reduction by melting and creating ingots and recycling into casting products to be considered
Felled trees	• Reducing volume of trunks with a low surface dose rate by burning, while continued storage in the original form outdoors • Reducing volume of branches and leaves with a high surface dose rate, while continuing soil-covered storage for the purpose of shielding	Recycling to be considered if there are needs

* The level of contamination that will serve as a criterion for recycling should be decided by assessing in detail the radiation workers and users have been exposed to, and radiation released to the environment.

* A large amount of metal waste will be generated in the future because it is planned to replace 377 steel cylindrical tanks (flange-joined) with welded tanks.

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3．1 Outline of research into processing and disposal of radioactive waste

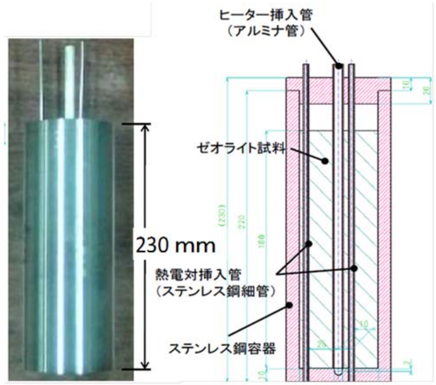
(1) flow chart and research items on disposal of radioactive waste

Analysis on radioactive nuclide in waste

JAEA staff collecting rubble near 4th reactor

Analytical work on ^{3}H, ^{14}C

Measurement of thermal conductivity of waste



Measurement of effective thermal conductivity of zeolite layer

Characterization

- Analysis on concentrations of radioactive nuclide
- Physical properties and chemical composition

Long term storage

- Assessment of safety on long term storage
  - Safety of hydrogen gas
  - Corrosion of container
  - Stability of waste

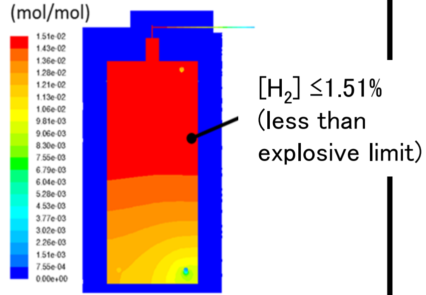
Conditioning (processing for disposal package)

- Technical research on conditioning
- Basic test for technical assessment
  - Vitrification
  - Geopolymer solidification

Disposal

- Investigating disposal concept
- Disposal safety assessment
- Domestic and international research on disposal concept and safety assessment techniques, and their applicability

Hydrogen generation from the waste



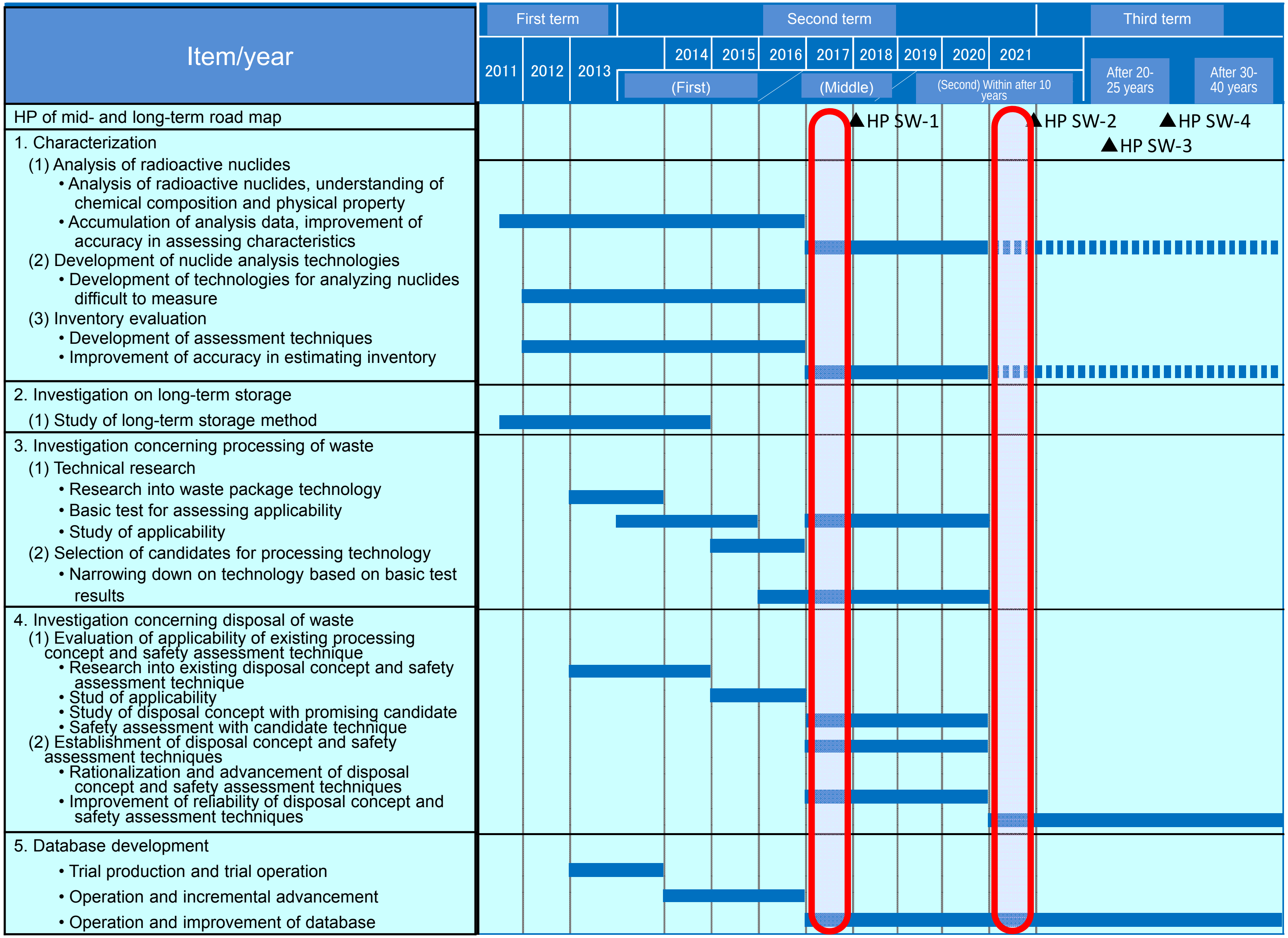
Calculated result on hydrogen concentration

Basic test for technical assessment on conditioning

Vitrification

Geopolymer solidification

3. Outline of research into processing and disposal of radioactive waste
(2) Schedule



(3) R&Ds on waste management strategy

Objective of HP SW-1
Lining up the candidate operations from generation, storage and to disposal (waste management stream) with their argument

R&D Items

1) Making plans to investigate waste management stream
Drawing up plans to create and improve the waste management stream including subsequent processing and disposal, considering its origin and its pathway concerning contamination with respect to each waste

2) Listing relevant items in investigation on characterization, long term storage, processing and disposal

3) Investigating candidates of waste management streams that can be applicable for processing and disposal for each waste

- Investigating a proper candidate among waste management streams that can be applied to processing and disposal by studying and understanding the effect of relevant items

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3. Outline of research into processing disposal of radioactive waste
(4) R&Ds on characterization

Objective of HP SW-1

Presenting collected information on characteristics of major waste

R&D Items

1) Analysis of waste sample

- Collection and analysis of rubbles including sample inside a reactor building, soils, secondary waste after water treatment, aiming to 50 samples per year .

2) Inventory evaluation

- Amount and inventory evaluation based on information of analytical value and origin of waste
- Establishment of analytical inventory estimation method through creation of nuclide transfer model based on nuclide discharge behavior from a reactor, dissolution behavior to contaminated water, nuclide sorption behavior into construction material, and adsorbing materials.
- Making inventory data set of each separate waste based on evaluation with analytical results and modeling

3) Data collection on secondary waste

- Data collection for investigating long term storage methods and processing technologies
- Data collection on physical and chemical characteristics of secondary waste generated from secondary cesium adsorption equipment or multi-nuclear removal equipment

4) Investigation of nuclide analysis which has difficulty in measurement

- Establishing chemical procedure for unanalyzed nuclides
- Analytical method of high dose waste

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3. Outline of research about processing and disposal of radioactive waste

(5) R&Ds on long term storage

Objective of HP SW-1

Presenting the way of long term storage for secondary waste from water treatment for optimization and rationalization of processing and disposal.

R&D Items

1) Stabilization of multi-nuclide removal equipment slurry

- As for slurry from pretreatment of multi-nuclide removal equipment, presenting the way to remove water and to stabilize.
- Other countermeasures are taken according to the situation on the site.

2) Evaluation of vessel from Cs adsorption

- As for the safety of storage for Cs adsorption vessel (KURION), presenting an outlook for hydrogen generation and corrosion of materials. For the corrosion, countermeasures are to be investigated.

3) Evaluation of vessel from second Cs adsorption

- As for the safety of storage for Cs adsorption vessel (SARRY), presenting an outlook for hydrogen generation and corrosion of materials.

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3. Outline of research about processing and disposal of radioactive waste

(6) R&Ds on processing

Objective of HP SW-1

Assembling information on treatment and conditioning technologies for existing waste, presenting candidate conditioning technique which could be applicable for wastes (secondary waste from water treatment, rubbles, trees or other) which characteristics are understood to some extent, and conducting initial selection.

R&D Items

1) Basic test of treatment and conditioning

- To get data needed for evaluation of treatment and conditioning technique for each waste based on the waste research result, characteristics of waste and the study for disposal method.

2) Research for technique of treatment and conditioning

- After the research of existing technique of treatment and conditioning, making a technique catalog including their outline, status of technical development, past employment, throughput, performance of waste package, etc.
- Evaluating techniques with consideration on waste properties and latest result on waste disposal method, and extracting data required for future selection.

3) Initial selection of candidate technique

- Selecting technique of treatment and conditioning for R&Ds aiming at HP SW-2 considering the result of 1) and 2) and the R&D result from characterization and disposal method.

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3. Outline of research about processing and disposal of radioactive waste

(7) R&Ds on waste disposal

Objective of HP SW-1

Presenting candidate of disposal concept which considered to be applicable for each accident waste and their assessment method.

R&D Items

1) Research and sorting out of properties for disposal concept

2) Extracting important isotopes (investigating disposal concept suited for accident waste based on existing disposal concept)

- To understand disposal classification of waste occurred by the accident
- To understand influencing characteristic of waste occurred by the accident
- To understand the response characteristic of disposal system
- Selection of candidate for proper disposal concept and safety assessment method

3) Investigation on new disposal concept and other

- As for dismantling wastes which are to be produced in bulk and practically difficult to apply existing disposal concept as it is, new disposal concept and its applicability are to be examined.

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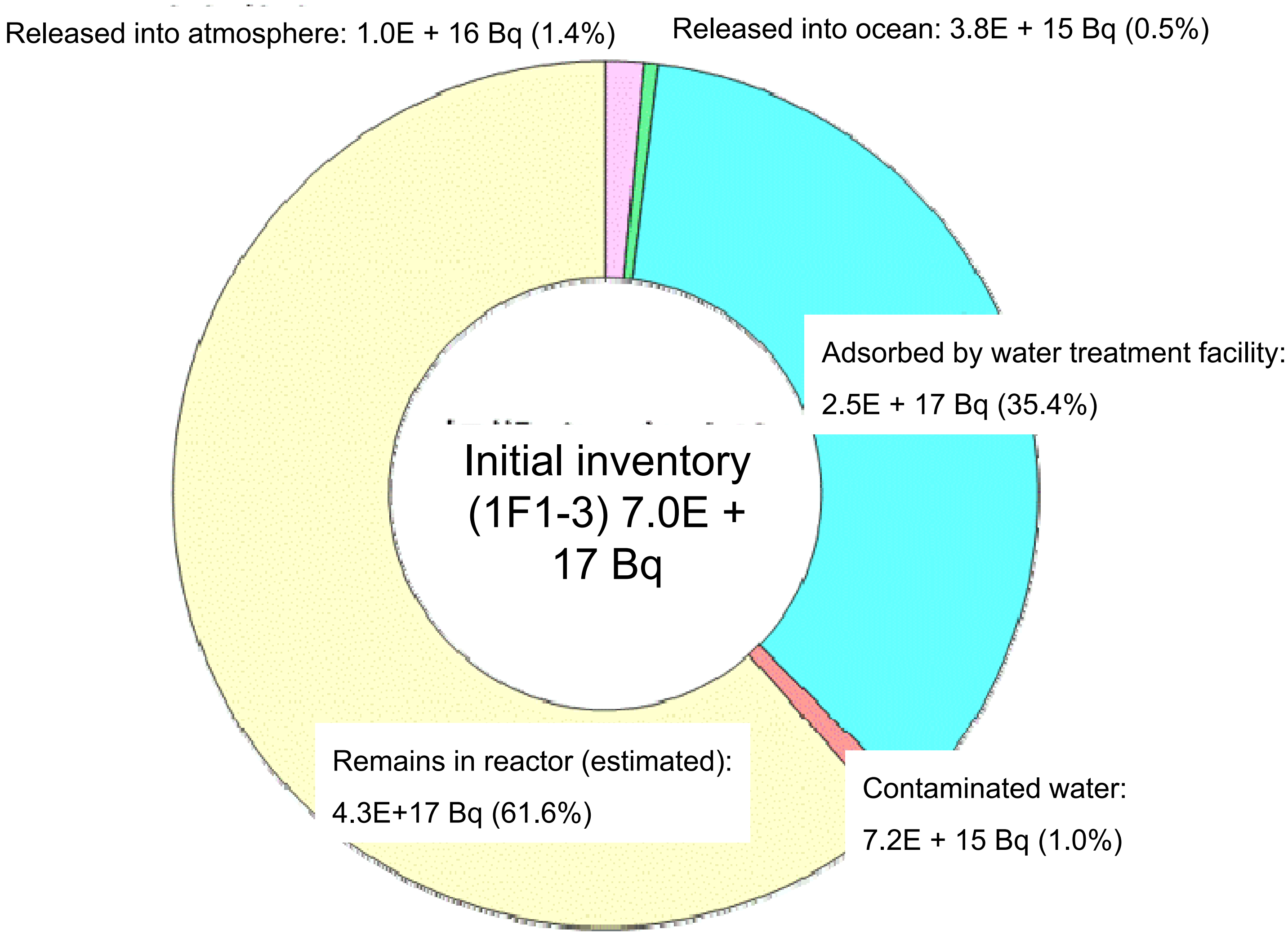
3.1 Characterization

(1) Result of estimating distribution of Cs-137



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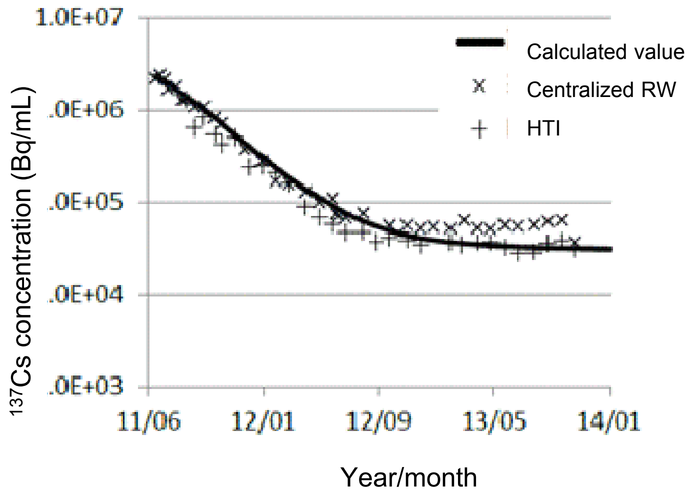
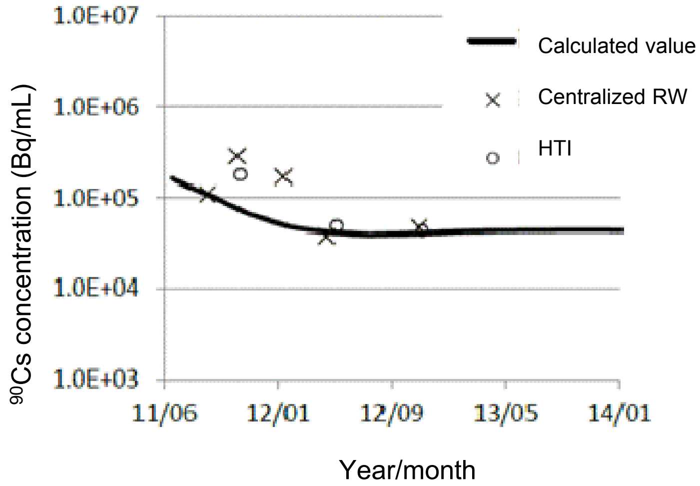
3.1 Characterization

(2) Model assessment of mass transfer of major nuclides to contaminated water

Changes in concentration of ^{137}Cs in contaminated water



Changes in concentration of ^{90}Sr in contaminated water



	^{137}Cs	^{134}Cs	^{90}Sr	^{125}Sb	^{106}Ru	^{60}Co	^{54}Mn
Initial reactor core inventory (Bq)	7.0E+17	7.2E+17	5.2E+17	4.2E+16	2.2E+18	9.4E+12	2.8E+14
Initial concentration (Bq/ml)	2.4E+06	2.2E+06	1.6E+05	1.7E+02	2.3E+01	1.4E+02	5.2E+02
Continuous transfer rate (Bq/d)	2.5E+13	2.6E+13	3.6E+13	1.3E+10	8.8E+09	1.4E+09	1.3E+09
Half-life	30.04y	2.065y	28.74y	2.758Y	373.6Y	5.271y	312.1y

- More than 99% of Cs-137 and Cs-134, which moved to contaminated water in the initial stage has been decontaminated.
- Estimated that the main fraction at present are those continuously transferred from fuel and others (equivalent to about 2.1% of those remaining in the reactor/year).
- Other than Cs, more than 99% of FPs which transferred to contaminated water in the initial stage, has already been diluted and transported. At present, the components that are continuously transferring from the fuel and others are estimated to be the main fraction.
- The analysis value of Co-60 varies much more than that of other nuclides and thus Co-60 may have flown from more than one sources (waste that had been stored before the accident). (At present, the main fraction is estimated to be those which are continuously transferring.)

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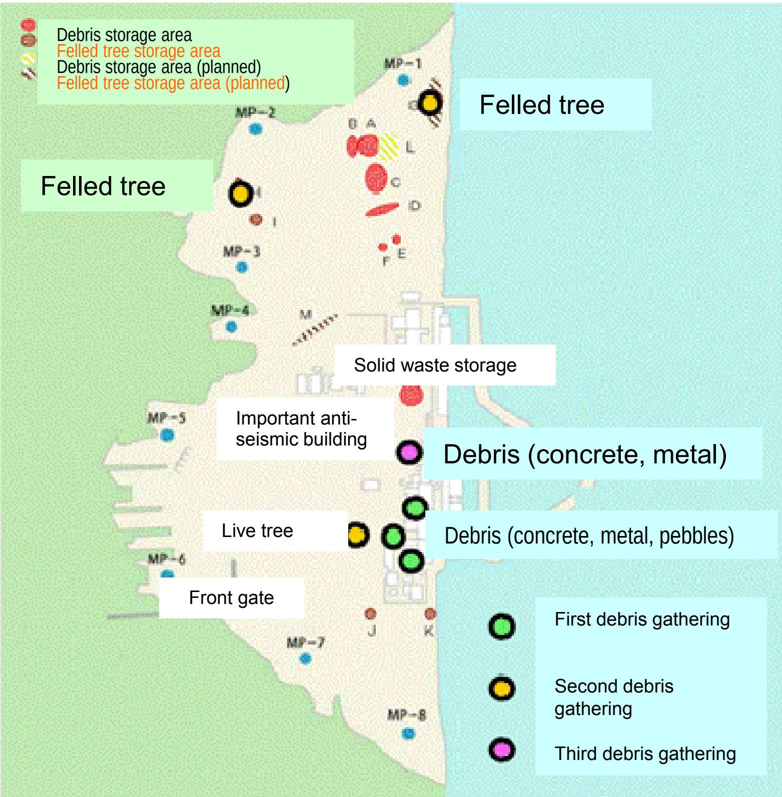
3.1 Characterization

(3) Method of assessing radioactive concentration

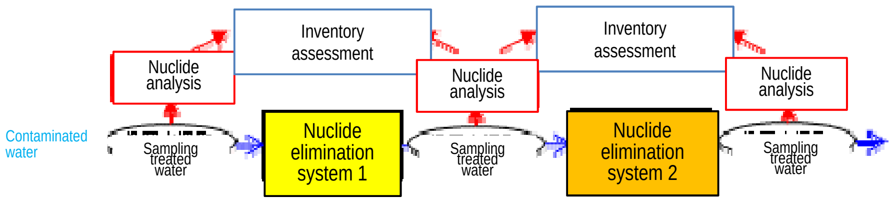
Assessment of radioactive concentration on debris and felled trees

- Concrete and debris from areas around units 1, 3, and 4, where debris was scattering were sampled and their radioactivity was analyzed.
- Felled trees in two storage areas and by collecting pine tree leaves around unit 3 were sampled and their radioactivity was analyzed.



Assessment of radioactive concentration of secondary waste for contaminated water treatment

- Dose of waste zeolite and sludge stemming from contaminated water treatment is high and direct analysis of radioactivity is difficult.
  → Indirect assessment using result of analyzing radioactivity of contaminated water and treated water is under way.
- Basic concept of inventory assessment



Nuclides to be analyzed

- Referring to nuclides for assessment of existing disposal systems, the following nuclides have been selected to be analyzed:

γ-ray nuclides: ^{60}Co, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu

β-ray nuclides: ^{3}H, ^{14}C, ^{36}Cl, ^{41}Ca, ^{59}Ni, ^{63}Ni, ^{79}Se, ^{90}Sr, ^{99}Tc, ^{129}I, ^{241}Pu

α-ray nuclides: $^{233, 234, 235, 236, 238}U$, ^{237}Np, $^{238,239,240,242}Pu$, $^{241,242m,243}Am$, $^{244,245,246}Cm$

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3.1 Characterization

(4) Result of nuclide analysis

Result of analyzing nuclides on debris and felled trees
(debris and felled trees: 57 samples)

Nuclide		Radioactive concentration (Bq/g)		
		Debris & felled trees	Recommended upper-limit value of concentration*1	
			Trench disposal	Pit disposal
γ nuclide	^{60}Co	ND(<7E-02) - 5.6E+00	1E+04	1E+09
γ nuclide	^{137}Cs	2.0E+00 - 1.9E+05	1E+02	1E+08
β nuclide	^{14}C	ND(<5E-02) - 2.7E+00	-	1E+05
β nuclide	^{63}Ni	ND(<5E-02)	-	1E+07
β nuclide	^{79}Se	ND(<5E-02) - 2.1E-01	-	-
β nuclide	^{90}Sr	ND(<5E-02) - 1.0E+02	1E+01	1E+07
β nuclide	^{99}Tc	ND(<5E-02) - 8.9E-02	-	1E+03
α nuclide	^{238}Pu	ND(<5E-03)	-	1E+04 @Am-241
α nuclide	$^{239}Pu+^{240}Pu$	ND(<5E-03)	-	
α nuclide	^{241}Am	ND(<5E-03)	-	
α nuclide	^{244}Cm	ND(<5E-03)	-	

*1: "About upper-limit value of radioactivity concentration for burial disposal of low-level radioactive solid waste" (Nuclear Safety Commission: May 21, 2007)

Result of estimating inventory of cesium adsorption vessel

	KURION	SARRY
Total adsorbed (Bq)	1.7E+17	8.0E+16
Average adsorbed (Bq/unit)	4.0E+14	1.0E+15

The concentration exceeds the upper-limit value for pit disposal and it should be taken into consideration when processing and disposal methods are studied.

Result of analyzing contaminated water

- Contaminated water analyzed: 25 samples
- 2.4E-03 Bq/g of ^{238}Pu and 8.3E-04 Bq/g of $^{239Pu+240}Pu$ were detected from the contaminated water (centralized RW・HTI/B).
- From the isotopic composition, Pu is considered to stem from the accident at Fukushima Daiichi nuclear power station and equivalent to that found in the environment which is attributed to fallout.

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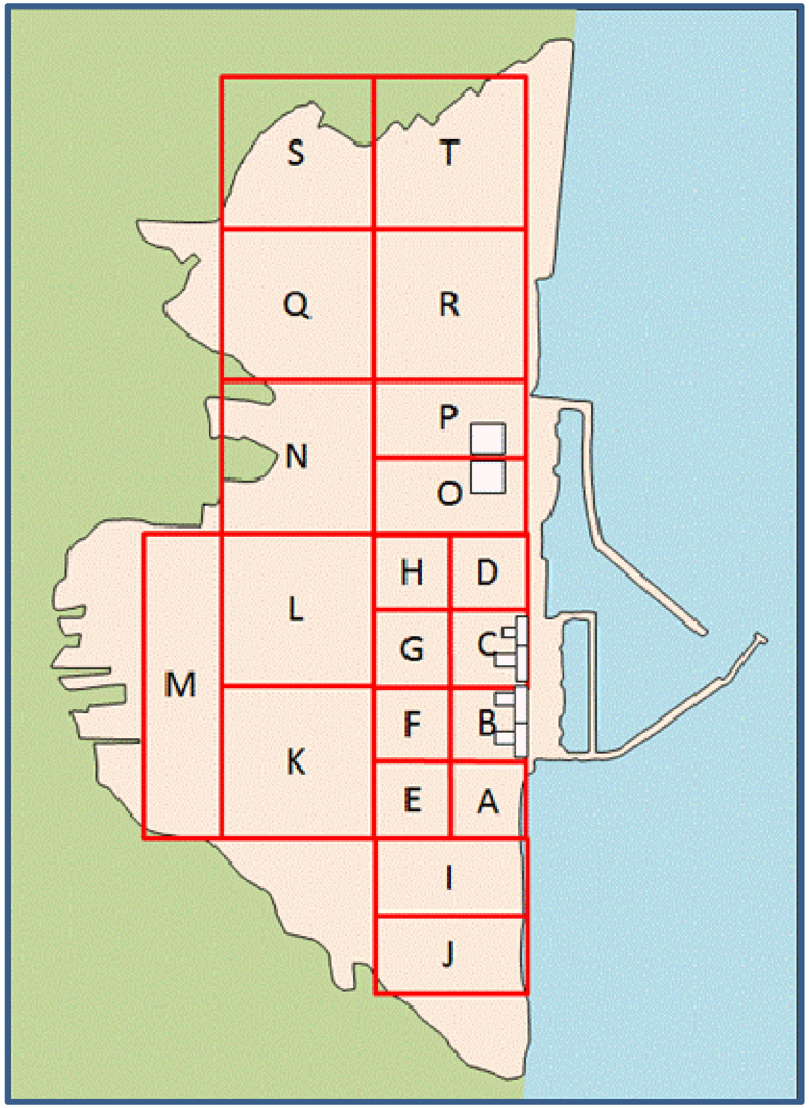
3.1 Characterization

(5) Distribution of radioactivity on standing trees in 1F site (1)

- Areas from which standing trees were sampled were decided based on the distribution of the air dose rate in the site of the power station. Areas around the reactor buildings where the air dose rate was high were divided into small segments (see the figure on the right).
- Pine trees, representative trees in the site, were sampled. Branches and leaves at a height of 4 m above ground were collected from three trees in each area.
  (Note that the type of the tree and height were changed depending on the situation of the location.)
- The surface dose rate of the samples was measured and branches and leaves (or grass) with a high dose rate (1 to 3 samples/area) in all the areas were selected as samples for analysis.



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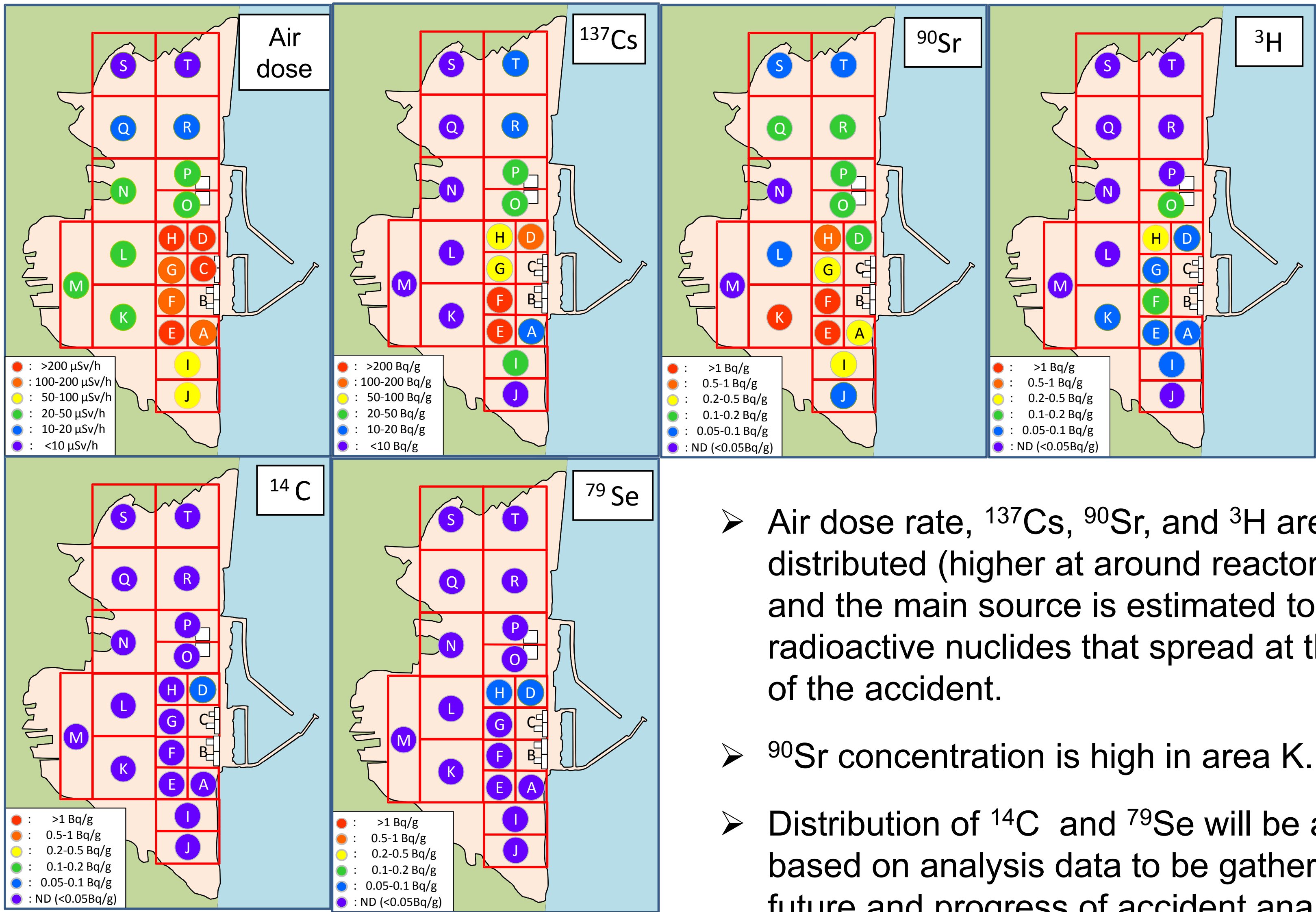
3.1 Characterization

(5) Distribution of radioactivity on standing trees in 1F site (2)



- Air dose rate, ^{137}Cs, ^{90}Sr, and ^{3}H are similarly distributed (higher at around reactor building) and the main source is estimated to be the radioactive nuclides that spread at the time of the accident.
- ^{90}Sr concentration is high in area K.
- Distribution of ^{14}C and ^{79}Se will be assessed based on analysis data to be gathered in the future and progress of accident analysis.

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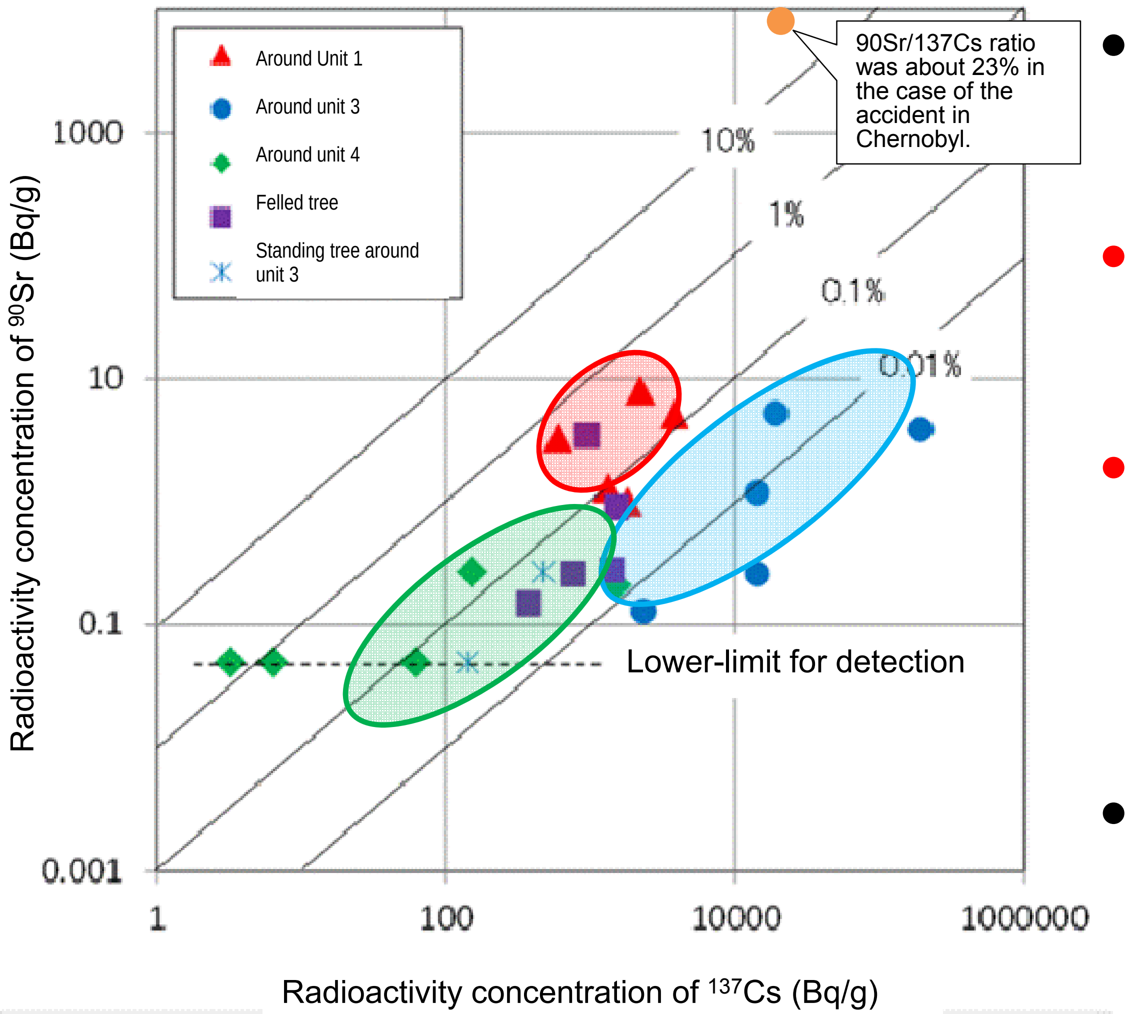
3.1 Characterization

(6) Relation of radioactivity concentration of ^{137}Cs and ^{90}Sr on debris, etc.



- <u>$^{90}Sr/^{137}Cs$ ratio</u> showed rather small difference between debris and felled trees and was <u>in the range of 0.002 to 0.62%.</u>
- **<u>Trend of proportional relation can be seen between ^{137}Cs and ^{90}Sr concentration on debris and felled trees.</u>**
- **<u>The trend of debris differs depending on the location where the sample was collected and the sample.</u>** Although at present the number of data is limited, collecting data will be continued to improve the precision of the correlation between the two.
- $^{90}Sr/^{137}Cs$ ratio (about 23%) for waste generated from the Chernobyl accident is close to the composition in fuel and it is considered that the difference in development between the two accidents reflects on the ratio of ^{137}Cs and ^{90}Sr in waste.

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3.2 Long-term storage

(1) Assessment of generation of hydrogen and hydrogen cyanide, and analysis of temperature in storage tank during temporary storage of waste sludge

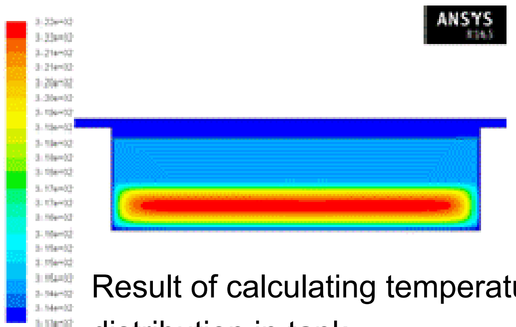
Waste sludge temporary storage tank

Mitsubishi Heavy Industry News, No. 5131, November 14, 2011

Assessment of generation of hydrogen and hydrogen cyanide

- Assessed by conducting irradiation test under condition where seawater components and sludge coexist
  - (1) Radiation chemical yield of hydrogen (G value)
    - The G value, to which ferrocyanides and seawater contribute, was **within 2 times that of pure water at maximum**.
    - Hydrogen concentration in the storage tank is not considered to reach the explosive limit (4%) because the tank is ventilated.
  - (2) Generation of hydrogen cyanide (HCN)
    - **Hydrogen cyanide in gas phase was less than detection limit (less than 5 ppm)** at irradiation equivalent to storage for 10 years (6MGy).

Analysis of temperature in storage tank



Result of calculating temperature distribution in tank

- Temperature initially rises at a rate of about 0.03°C/h and then gradually reaches steady state. It is assessed that **it levels out at outdoor temperature +20°C after about 50 days**.
- When the outdoor temperature is 40°C, the center temperature is about 60°C, **which is sufficiently lower than the decomposition temperature of ferrocyanide (250°C to 280°C). It is thus considered that hydrogen cyanide is not generated by thermal decomposition.**

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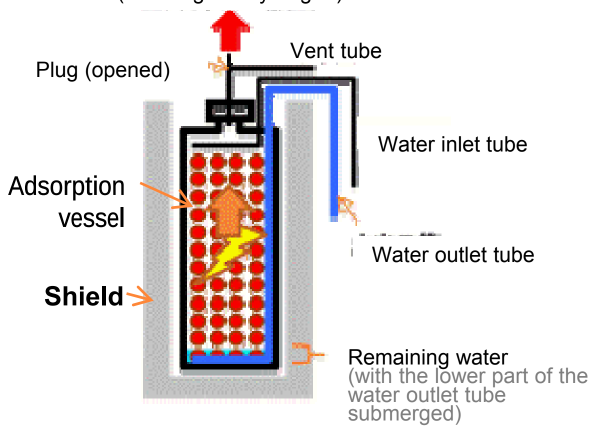
3.2 Long-term storage

(2) Analysis of temperature and hydrogen distributions in zeolite adsorption vessel

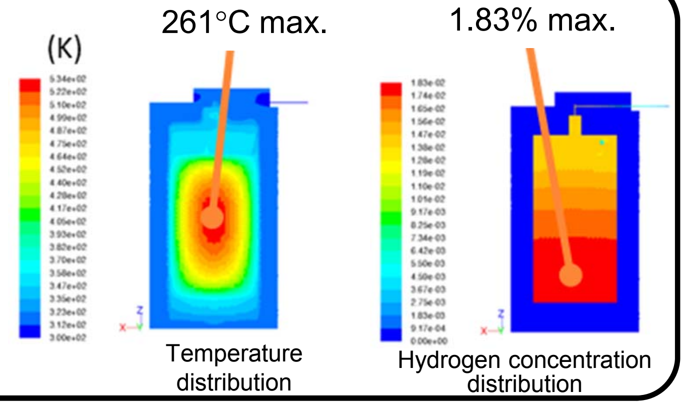
- Distribution of temperature and hydrogen in the waste zeolite adsorption vessel was assessed, assuming that **the lower part of the water outlet tube is occluded by remaining water, cutting off inflow of air**, in the initial stage of storage.
- It was considered that **cesium concentration was not uniform but distributed in the vertical direction** in the adsorption vessel.



Schematic diagram of adsorption vessel (when water remains)

Analysis result (example)

- Decay heat: 618 W
- Hydrogen generation (25°C, 1 atm)
  Zeolite layer: 24.3L/d
  Submerged layer surface: 0.76L/d
- Thermal conductivity of submerged layer is 1.1 times that of water



Hydrogen (H_2) concentration calculated through analysis

Cs adsorption	Water level	Maximum temperature	H_2 concentration
618W unequal adsorption	24 cm (lower part of water outlet submerged)	261°C	≦1.8%
504W uniform adsorption	Ditto	211°C	≦1.6%
Ditto	0cm	210°C	≦1.1%

- Cs amount adsorbed and distribution in vessel (axial direction) were calculated from operation data and adsorption analysis code (ZAC) in the case of 618 W.
- In the 504 W case , Cs adsorption was calculated from analysis data of contaminated water and treated water and adsorption equilibrium, on the assumption that Cs was uniformly adsorbed.

- If water remains in the adsorption vessel, air is discharged through the upper plug. Hydrogen (H_2) concentration is kept below the explosive limit (4%) even when Cs amount adsorbed is maximum. Zeolite layer temperature is assessed to be lower than the self-ignition temperature of hydrogen (about 560°C).
- Without water in the adsorption vessel, air flows in from the water outlet tube and is discharged from the upper vent plug. Consequently, the hydrogen concentration is relatively low.

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4. Issues and measures

Issue	Possible measures		
	Characterization	Processing and conditioning waste	Disposal
Large quantity of waste generated	• Selection of option of decommissioning scenario	• Volume reduction (such as incinerating organic materials and high-temperature melting) technologies	• Securing volume at disposal site • Improvement of installation density by optimizing waste package installation method, layout, etc.
Insufficient inventory assessment	• Increase of actually measured data (existing technique) • Development of innovative nuclide analysis technique • Simplifying and automating existing nuclide analysis technologies	• Homogenization (including blending) technology • High-temperature melting technology	• Confirmation of safety through assessment conservatively taking dispersion of inventory for safety assessment into consideration
Possibility that types and nuclide composition of raw waste differ from those of conventional waste	• Ditto	• Development of high-performance solidifier • Establishment of method and technology for processing specific substances (such as ferrocyanides)	• Ditto
Existence of substances that have not considered for conventional waste, such as impurities and mixture	• Development of chemical component analysis technique	• Decontamination technology • Segregation technology	• Confirmation of safety based on study of scenario, model, and impact to parameters (including changes) for safety assessment and on fluctuation of assessment result • Development of disposal system that suppresses influences of impurities and mixtures • Improvement and development of scenarios, models, and parameters through phenomenological understanding of influencing processes, etc.
No regulations for classifying waste and disposal	—	—	• Applicability assessment of disposal concept for each division of waste and waste packages targeted (disposal site feasibility and safety)

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Thank you for your attention.

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