Subsidy Project of Decommissioning and Contaminated Water Management in the FY2016 and FY2017 Supplementary Budgets

R&D for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods)

Study of Waste Characterization, Storage and Management, Disposal, and Waste Stream

Accomplishment Report for FY2018

July 2019

International Research Institute for Nuclear Decommissioning (IRID)

Contents

1. Project Overview and Research Approach

Background and Purpose of the R&D

- The projects of decommissioning and contaminated water management for the Fukushima Daiichi Nuclear Power Station (NPS) of Tokyo Electric Power Company, Inc. (hereinafter, TEPCO) are ongoing according to *“The Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi NPS”* and *“The Progress Status and Future Challenges of the Mid-and-Long-Term Roadmap toward the Decommissioning of TEPCO's Fukushima Daiichi NPS"*[*1].

- Under such circumstances, research and development (R&D) of technologies for solid waste treatment and disposal was performed for nuclear decommissioning and contaminated water management according to the Mid-and-Long-Term Roadmap and the *"Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi NPS of TEPCO Holdings, Inc."*[*2].

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*1 The 39th Session of Team for Countermeasures for Decommissioning and Contaminated Water Treatment/Secretariat Meeting (2017).

*2 Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc., established by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) in 2017.

Mid-and-Long-Term Roadmap Policy

- The basic concept of waste management* (excerpts from description of research and development (R&D), partly reworded)
  - The characteristics of solid waste, such as nuclide composition and activity concentration, need to be understood to study solid waste treatment and disposal methods.
  - Generated solid waste shall be stored and managed by safe and rational methods and procedures based on their characteristics.
  - A method to select waste stabilization and solidification methods (preceding processing) on a rational basis shall be established, and preceding processing methods shall be selected by the established method before determining the technical requirements for disposal, in order to ensure the safety of solid waste storage and management.
  - To promote effective R&D on solid waste treatment and disposal, R&D projects related to the characterization, treatment, and disposal of solid waste work closely together. R&D is promoted by the sharing of research and issues among R&D teams, overviewing all activities of solid waste management, and identifying required R&D tasks.

The waste treatment and disposal measures, and their technical prospect of safety shall be proposed by around FY2021.

*Revised on September 26, 2017

Policy of Technical Strategic Plan 2017

- Strategic proposals for solid waste treatment and disposal* (partly reworded)
  - Focusing on waste characterization, storage, management, and preceding processing methods as predisposal management until the prospect of disposal can be obtained

Item	R&D task
Promotion of characterization	• Establishment of a solid waste characterization method that complementarily combines evaluation data based on analysis data and migration models • Optimization of analysis sample numbers, the simplification and speeding-up of analytical methods, etc.
Thorough storage and management	• Study on estimation methods and management of the volume of hydrogen gas produced from the secondary wastes generated from contaminated water treatment during the storage and management of solid waste • Study on methods to store and manage solid wastes generated by fuel debris retrieval
Establishment of a method for selecting the preceding processing method considering the possibility of disposal	• Establishment of a method for selecting waste treatment method based on safety evaluation results of in-process wastes for multiple disposal methods
Promotion of effective R&D by overviewing all activities of solid waste management	• R&D is promoted by sharing research progress and issues among projects, overviewing all activities of solid waste management, and identifying required R&D tasks

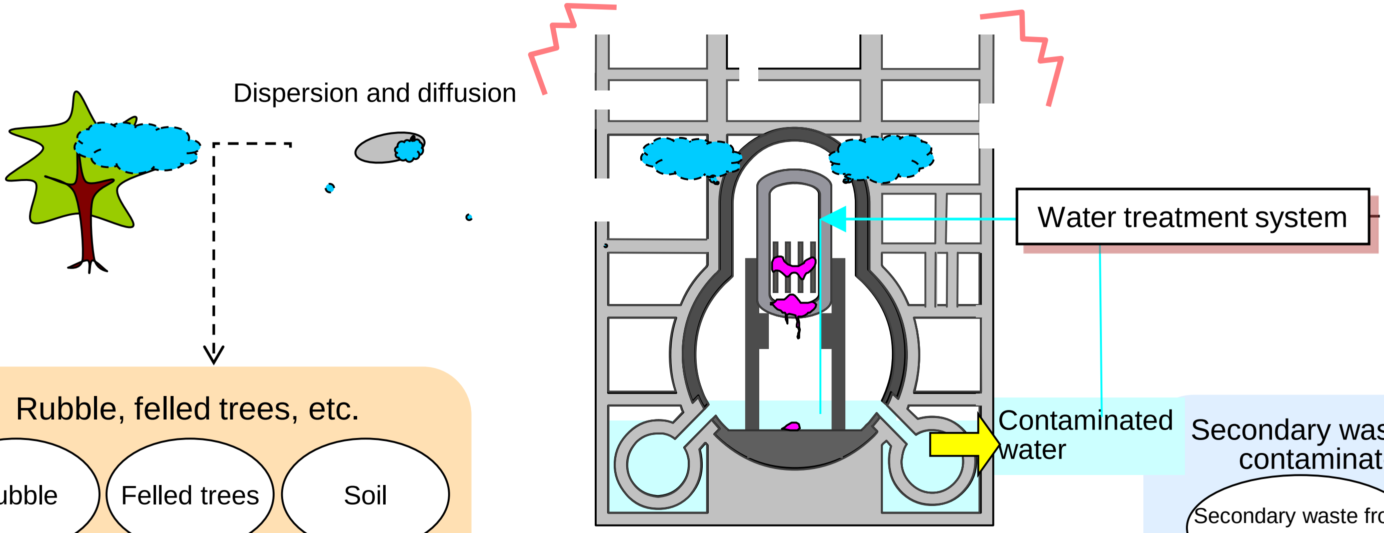
* Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc., by Nuclear Damage Compensation and Decommissioning Facilitation Corporation in 2017.

R&D Planning and Implementation

- Specific plans were established for each of the four main R&D items (characterization of solid waste, predisposal management of solid waste, study of disposal concept and safety evaluation methods for solid waste, and integration of R&D results) respectively.
  - The plans were developed based on the characteristics of waste.
  - The plans were created while referring to the process chart of the Technical Strategic Plan 2017 to ensure steady implementation of the Plan and to achieve the goals.
  - The plans were implemented under appropriate role assignments and with active information exchange to enable the concurrent progress of R&D activities.
- Assessment indexes for achieving goals were established and implemented.

Characteristics of Waste Generated by the Fukushima Daiichi Accident (Estimation)

- Waste generated out of control due to the accident
- Contamination originated from nuclear fuel in the reactor core of Unit 1 to Unit 3*
- Difficulty in estimating the amount of waste produced with the varying status of decommissioning work
- Extremely limited data due to an extensive contamination area and high-radiation locations (particularly for the composition of nuclides with long half-life)



Rubble, felled trees, etc.

Rubble | Felled trees | Soil

○ Very large volume, spreading into wide areas

○ Lack of previous experience in treatment and disposal of trees and soil

○ Mainly surface contamination by dispersion and diffusion with some penetrating contamination by way of accumulated water

Waste generated from debris retrieval

○ Very large amount with much volume of highly radioactive waste

○ Currently some waste is difficult to sample due to difficulty in accessing them

Secondary wastes generated from contaminated water treatment

Secondary waste from contaminated water treatment | Replaced pipes, storage tanks, etc.

○ Lack of performance record in treatment and disposal

○ Some waste at the site is difficult to sample.

○ The amount of produced waste and contained nuclides can be partially estimated based on the system features

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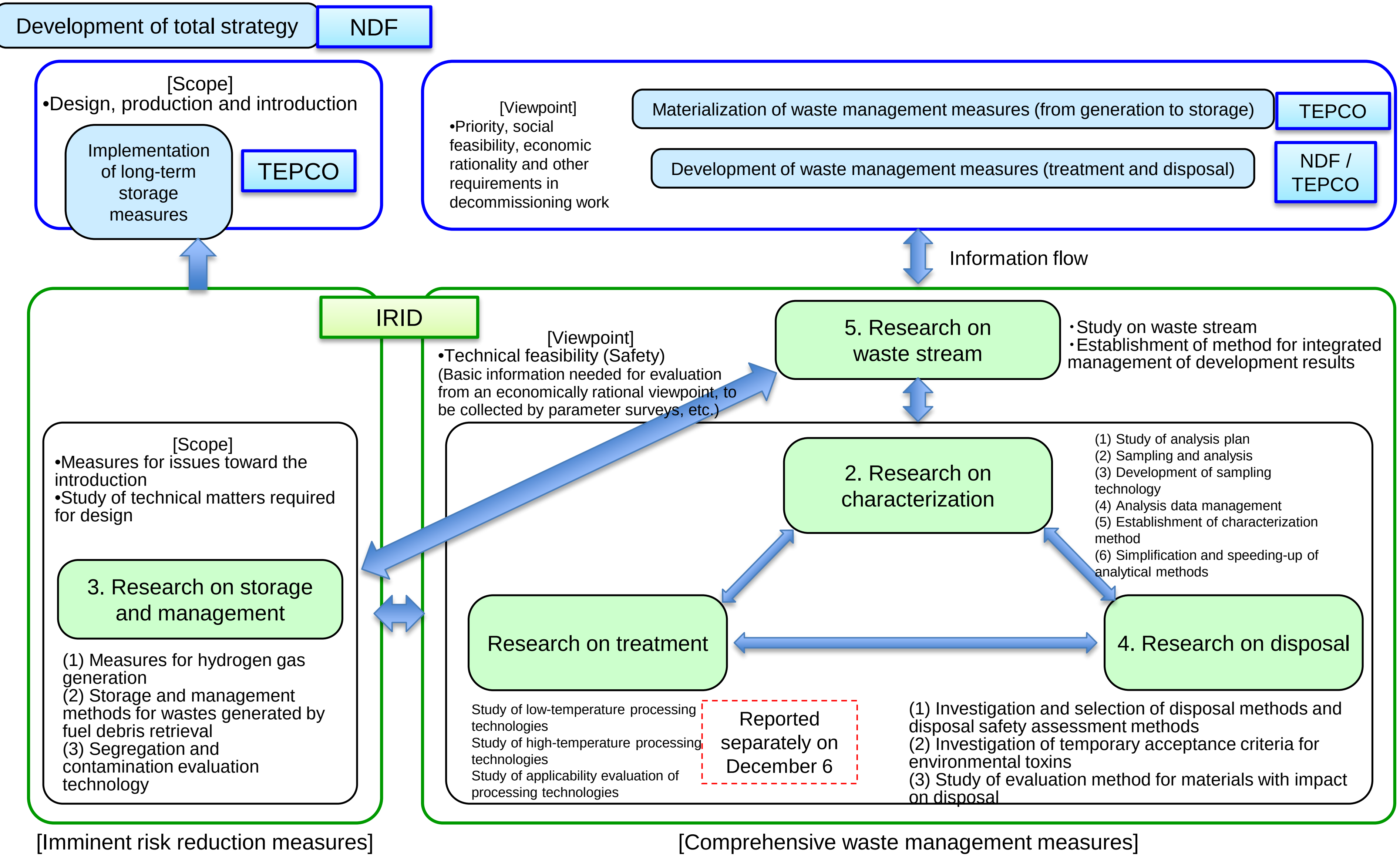
*Contamination originated from activated materials and reactor operation waste may be included.

1. Project Overview and Research Approach

- Role-sharing among Relevant Organizations, and Scope and Viewpoint of Study -



Development of total strategy

NDF

[Scope]
•Design, production and introduction

Implementation of long-term storage measures

TEPCO

[Viewpoint]
•Priority, social feasibility, economic rationality and other requirements in decommissioning work

Materialization of waste management measures (from generation to storage)

TEPCO

Development of waste management measures (treatment and disposal)

NDF / TEPCO

Information flow

IRID

[Viewpoint]
•Technical feasibility (Safety)
(Basic information needed for evaluation from an economically rational viewpoint, to be collected by parameter surveys, etc.)

5. Research on waste stream

- ･Study on waste stream
- ･Establishment of method for integrated management of development results

[Scope]
•Measures for issues toward the introduction
•Study of technical matters required for design

3. Research on storage and management

(1) Measures for hydrogen gas generation
(2) Storage and management methods for wastes generated by fuel debris retrieval
(3) Segregation and contamination evaluation technology

2. Research on characterization

(1) Study of analysis plan
(2) Sampling and analysis
(3) Development of sampling technology
(4) Analysis data management
(5) Establishment of characterization method
(6) Simplification and speeding-up of analytical methods

Research on treatment

4. Research on disposal

Study of low-temperature processing technologies
Study of high-temperature processing technologies
Study of applicability evaluation of processing technologies

Reported separately on December 6

(1) Investigation and selection of disposal methods and disposal safety assessment methods
(2) Investigation of temporary acceptance criteria for environmental toxins
(3) Study of evaluation method for materials with impact on disposal

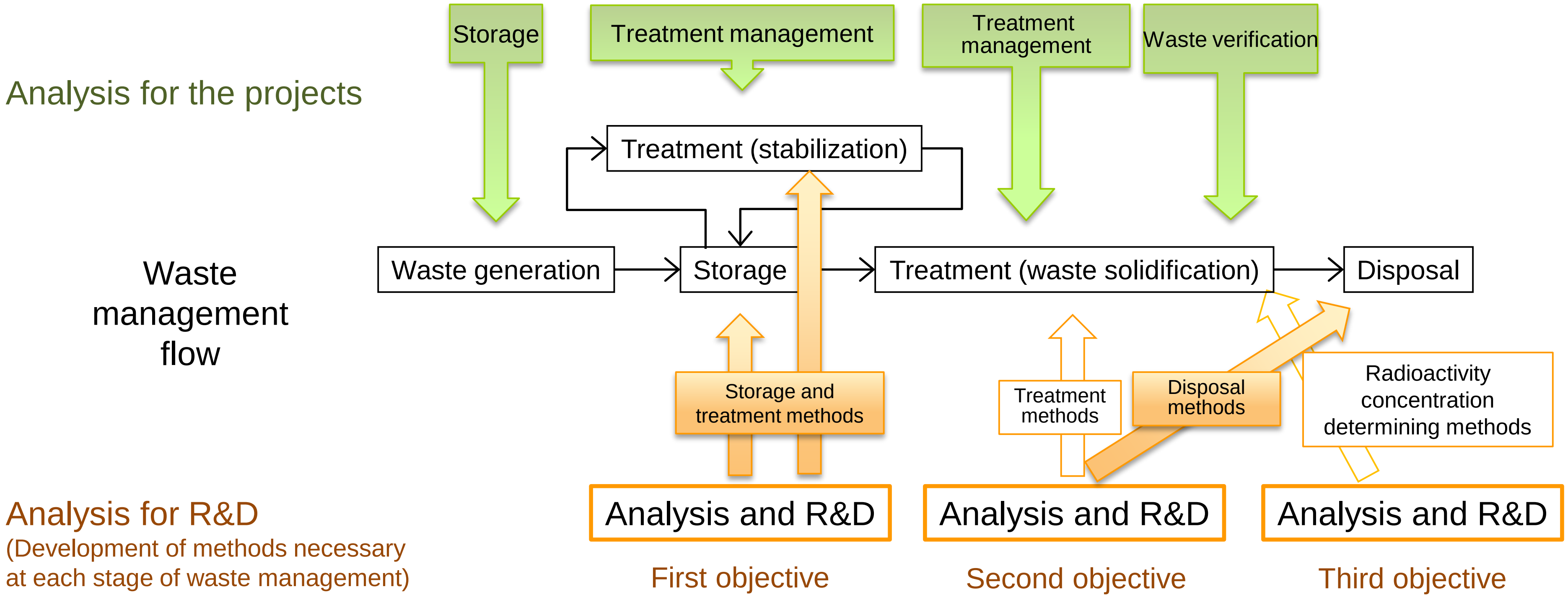
[Imminent risk reduction measures]

[Comprehensive waste management measures]

2. Research on Characterization

Objective of Analysis

- Analysis is essential for the implementation of the decommissioning projects, including waste management, and for their R&D.
- Waste management requires analysis with different objectives for each stage, broadly classified into storage, treatment, and disposal. The main objective is to establish storage and treatment methods, disposal methods, and activity concentration determining methods.
- In this project, analysis was conducted with the main objective of ensuring safety for the stabilization (preceding processing) and disposal of secondary waste generated from contaminated water treatment.



Contents of Report

(1) Study of Analysis Plan

(2) Sampling and analysis

① Sampling and transportation

② Conducting analyses

(3) Development of sampling technology

① Sampling of secondary wastes generated from contaminated water treatment, including sludge

② Study of sampling methods in the reactor building

(4) Analysis data management

(5) Establishment of characterization method

① Study on the migration behavior and the contamination mechanism of radionuclides

② Study of waste classification based on analysis data

③ Study on the representativeness of analysis data

④ Accuracy improvement of analytical evaluation methods

⑤ Summary of comprehensive inventory evaluation

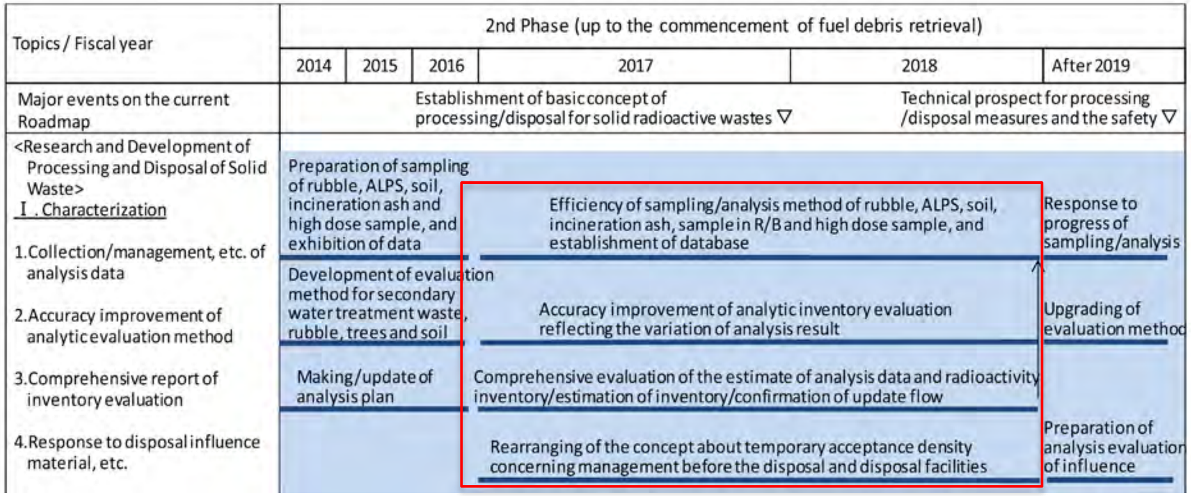
⑥ Data collection methods to improve accuracy

(6) Simplification and speeding-up of analytical methods

① Study on more efficient and reasonable analytical methods

② Study of simple and quick analytical methods

Correspondence of action plan with the Technical Strategic Plan 2017*



Topics / Fiscal year	2nd Phase (up to the commencement of fuel debris retrieval)					
	2014	2015	2016	2017	2018	After 2019
Major events on the current Roadmap			Establishment of basic concept of processing/disposal for solid radioactive wastes ▽		Technical prospect for processing /disposal measures and the safety ▽	
<Research and Development of Processing and Disposal of Solid Waste> I. Characterization						
1.Collection/management, etc. of analysis data	Preparation of sampling of rubble, ALPS, soil, incineration ash and high dose sample, and exhibition of data			Efficiency of sampling/analysis method of rubble, ALPS, soil, incineration ash, sample in R/B and high dose sample, and establishment of database		Response to progress of sampling/analysis
2.Accuracy improvement of analytic evaluation method	Development of evaluation method for secondary water treatment waste, rubble, trees and soil			Accuracy improvement of analytic inventory evaluation reflecting the variation of analysis result		Upgrading of evaluation method
3.Comprehensive report of inventory evaluation	Making/update of analysis plan			Comprehensive evaluation of the estimate of analysis data and radioactivity inventory/estimation of inventory/confirmation of update flow		
4.Response to disposal influence material, etc.				Rearranging of the concept about temporary acceptance density concerning management before the disposal and disposal facilities		Preparation of analysis evaluation of influence

* Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. (established by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (hereinafter referred to as NDF) in 2017).

(1) Study of Analysis Plan (1/2)

FY	Implementation plan	Goal achievement index
2017	• A mid-and-long-term analysis plan is developed based on the following information: the target schedule and the timings of judgment specified in the Mid-and-Long-Term Roadmap, analysis data accumulated to date and knowledge about various contamination behaviors, and the foreseeable availability of analysis samples. The following samples are collected for analysis: rubble, soil, incineration ash, secondary waste generated from contaminated water treatment, contaminated water stagnated at the basement of the building, etc. • An annual analysis plan is developed.	• Development of a mid-and-long-term analysis plan. • Development of an annual analysis plan.
2018	• An annual analysis plan is developed.	• Development of an annual analysis plan.

- The annual plan is to collect, transport, and analyze samples of rubble, contaminated water, secondary waste generated from contaminated water treatment, and soil. It is being implemented continuously since the last fiscal year (Table 1).
- The analysis data was reported at the Secretariat Meeting twice (at the 56th and 60th sessions). A report is being prepared for the analyzed data.

Items in red text are samples collected in this project

Table 1. Analysis plan for FY2018 (Status of transportation and analysis) (1/2)

Classification	Type	Sample	No. of samples	Analysis facility*1	Transport	Analysis status
Rubble	Floor and panels	Core samples obtained by the boring of concrete on the 1st to 5th floors of Unit 4 Reactor Building (R/B)	8	NDC	Dec 15, 2017	Reported at 60th session 17
	Samples associated with decontamination tests	Materials used for decontaminating floors and walls in R/Bs of Unit 1 to Unit 3 (flannel cloth, strippable paint, boring core, etc.)		JAEA, NSRI	Mar 29, 2018	Reported at 65th session
	Rubble	Blockages in Unit 2 TIP piping, PCV deposits in Unit 1		NFD	–*2	Reported at 65th session
		Rubble in and around R/Bs, rubble of stored cover soil (radioactivity distribution)	5	JAEA, Oarai	Feb 10, 2017	Reported at 56th session
		Rubble of R/Bs, rubble of stored cover soil, sand gravel of turbine buildings (radioactivity distribution)	5	JAEA, Oarai	Feb 27, 2018	Analysis in process
		Concrete of the No.4 cover soil tank (radioactivity distribution)	12	JAEA, Oarai	Feb 14, 2019	Analysis in process

*1 JAEA: Japan Atomic Energy Agency, NSRI: Nuclear Science Research Institute, Oarai: Oarai Research and Development Institute, NDC: Nuclear Development Corporation, NFD: Nippon Nuclear Fuel Development Co., Ltd. *2 Transported previously during other projects.

(1) Study of Analysis Plan (2/2)

Table. Analysis Plan for FY2018 (Status of transportation and analysis, samples other than rubble)

Classification	Type	Sample	Number of samples	Analysis facility*1	Transport	Analysis status
Dismantling	Rubble	Unit 2 R/B (roof block, coping, sand layer)	9	NDC	Sept 14, 2018	In process
		Unit 2 R/B (Core samples obtained by the boring of outer wall)	12	JAEA, NSRI	Dec 12, 2018	In process
	Sludge	Sludge from Unit 2 to Unit 4 Turbine Buildings	10	NDC	Sept 14, 2018	In process
Contaminated water	Stagnant water	Stagnant water in Unit 1 to Unit 3 R/Bs and centralized radwaste building (centralized RW)	8	JAEA, NCL	Dec 12, 2018	In process
	Treated water	Treated water from existing ALPS	11	JAEA, NSRI	Oct 4, 2017, Feb 27, 2018	Reported at 56th session
		Treated water from expanded ALPS	12	NDC	Dec 15, 2017	Reported at 60th session
		Treated water from SARRY	3	JAEA, NSRI	Feb 14, 2019	
	Stagnant and contaminated water	Stagnant water in the R/Bs and the centralized RW building, treated water from KURION and SARRY, etc. (uranium analysis)	19	NFD	Nov 10, 2017	Reported at 56th session
		Stagnant water in the R/Bs and the centralized RW building, treated water from KURION and SARRY, etc. (Np analysis)*2	10	NFD	Same as above	Ended (Reporting planned)
Secondary wastes generated from contaminated water treatment	Sludge	Sludge from decontamination systems, clear supernatant liquid	2	JAEA, NCL	Nov 21, 2017	Reported at 56th session
	Adsorbent	Cerium oxide, activated carbon and chelate resin 2 used in the existing ALPS	3	JAEA, NCL	Oct 4, 2017	In process
		Titanium oxide used in the existing and expanded ALPS	2	JAEA, NCL	Dec 12, 2018	In process
Soil		Surface layer of areas F, H, J, and K, H4 tank area (measurement points A and B)	6	NDC	Dec 15, 2017	Reported at 60th session
		Areas K and P, H4 tank area (measurement point A) (particle size vs radioactivity concentration)	3	JAEA, NSRI	Oct 4, 2017	Reported at 56th session

Items in red text are samples collected in this project

*1 JAEA: Japan Atomic Energy Agency, NSRI: Nuclear Science Research Institute, NCL: Nuclear Fuel Cycle Engineering Laboratories, NDC: Nuclear Development Corporation, NFD: Nippon Nuclear Fuel Development Co., Ltd.. *2 Some of the stagnant water in the R/B and centralized RW building.

(2) Sampling and analysis ① Sampling and transportation – Collection of treated water samples –

FY	Implementation plan	Goal achievement index
2017 2018	• Sampling of slurries and adsorbents produced by the operation of existing and expanded multi-nuclide removal systems and treated water produced by the operation of cesium adsorption apparatus, secondary cesium adsorption apparatus (SARRY), and existing and expanded multi-nuclide removal systems, are performed in sequence according to the analysis plan and depending on the status of readiness for the sampling at target locations, which is determined by considering the reliability of the sampling method and the estimate of exposure dose associated with the sampling. In addition, available samples are collected in cooperation with on-site operations and transported to analysis facilities	• Samples are collected based on the annual analysis plan and transported to analysis facilities.

- Collection of samples of secondary waste generated from contaminated water treatment, is difficult due to the high dose rate, and hence for inventory estimation, water samples were collected from operating water treatment facilities. (Table 1)

Table 1. Results of water samples collected from contaminated water treatment facilities

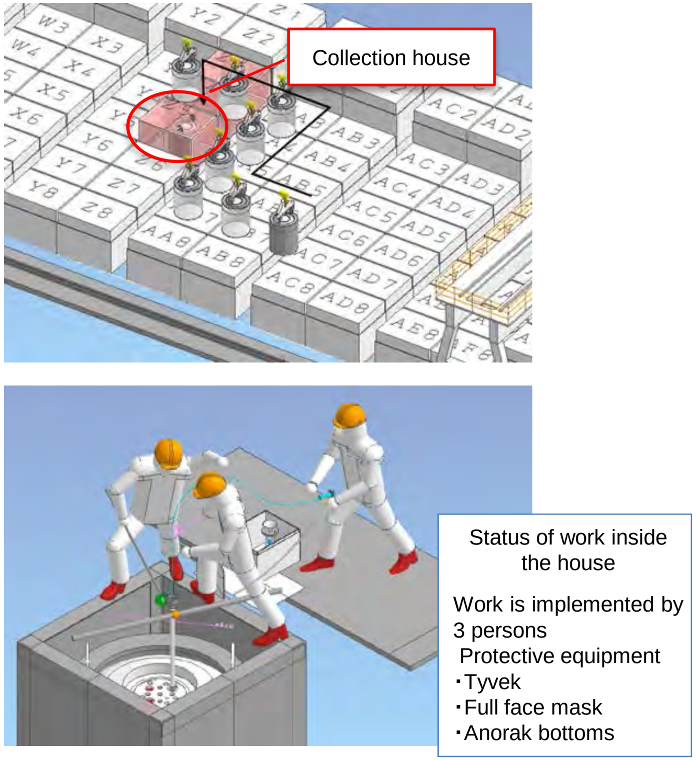
Sampling target		Sampling plan	Results (FY2017)		Results (FY2018)	
			Sampling date	Number of samples	Sampling date	Number of samples
KURION		Thrice a year	Sept 4, 2017	4	Aug 29, 2018	3
			Dec 12, 2017	3	-	-
			Feb 20, 2018	3	-	-
SARRY		Thrice a year	Jul 25, 2017	2	June 13, 2018	2
			Nov 15, 2017	2	Oct 10, 2018	2
			Mar 15, 2018	2	Jan 29, 2019	2
Existing ALPS	A system	Thrice a year from any one of A, B, or C systems	-	-	June 15, 2018	10
	B system		-	-	Nov 22, 2018	10
	C system		Aug 30, 2017	11	(Planned to be collected within 1 year)	-
Expanded ALPS	A system	Twice a year	Aug 30, 2017	10	June 15, 2018	10
			Dec 1, 2017	10	Jan 22, 2019	10
	B system	Once a year from any one of B or C systems	-	-	June 15, 2018	11
	C system		Aug 30, 2017	11	-	-

(2) Sampling and analysis ① Sampling and transportation
– Collection of ALPS slurry and adsorbent samples –

- Samples of secondary waste were collected from the Multi-nuclide Removal System (ALPS) (slurries and adsorbents). The slurries and adsorbents discharged from the operating processes were collected, along with the slurries and adsorbents stored in the No.2 and No.3 storage facilities which were collected from the high integrity containers (HIC). (Figure 1)
- Iron coprecipitation slurry (27 samples), carbonate slurry (9 samples), and adsorbents (24 samples) were collected. (Table 1, 2)
  - ✓ The exposure dose used for operation planning was calculated on the basis of the slurry analysis data (moisture content, etc.) collected in this project.

Table 2 .Results of secondary waste collected from water treatment facilities in operation

Sampling target			Results	
Contaminated water treatment facilities		**Type**	**Sampling date**	**Number of samples**
Existing ALPS A, B and C systems		Silver zeolite	Sept 05, 2017	3
		Titanium oxide	Aug 29, 2017	3
Expanded ALPS	**A system**	Carbonate slurry	May 28, 2018	9
	B and C systems	Titanium oxide	Nov 27, 2017	3



Status of work inside the house

Work is implemented by 3 persons
Protective equipment
・Tyvek
・Full face mask
・Anorak bottoms

Figure 1. Collection from storage container (HIC) in the No.2 storage facility

Table 3. Results of secondary waste collected from storage containers (HIC)

Sampling target			Results	
Contaminated water treatment facilities		**Type**	**Sampling date**	**Number of samples**
Existing ALPS A, B, and C systems		Iron coprecipitation slurry	Oct 12, 2018	3
			Oct 15, 2018	3
			Oct 16, 2018	1
			Oct 17, 2018	1
			Oct 18, 2018	1
			Oct 26, 2018	9
			Oct 29, 2018	9
		Titanium hydrochloride 1	Oct 25, 2018	3
		Titanium hydrochloride 2	Oct 19, 2018	3
		Titanium oxide	Oct 22, 2018	3
Expanded ALPS	**A system**	Titanium hydrochloride 1	Oct 24, 2018	3
	B and C systems	Cerium oxide	Oct 23, 2018	3

(2) Sampling and analysis ① Sampling and transportation – Collection of samples from Unit 4 –

- Samples of painted concrete from the building floor and samples of painted steel plates from distribution switchboards were collected from the 1st to 4th floors of Unit 4 R/B. (Table 1) (Figure 1)
- The feasibility of sampling by coring through the concrete floor inside the building and retrieving the cut core, using a dedicated coring tool that was developed in FY2017 considering remote operation, was verified. (Figure 2)

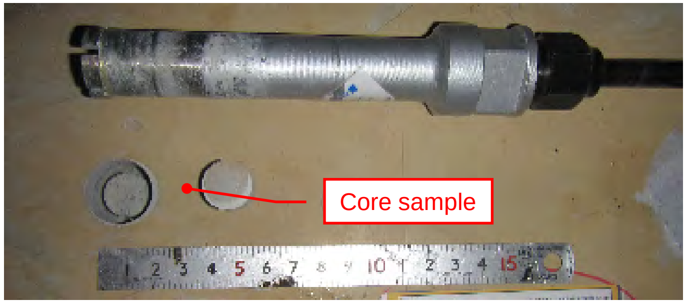


Figure 1. Drilling tool manufactured considering remote operation and the collected painted concrete floor sample

(a) Painted concrete floor

(b) Painted steel plates from distribution switchboards

Figure 2. Collected samples

Table 1. Results of samples collected from inside Unit 4 R/B

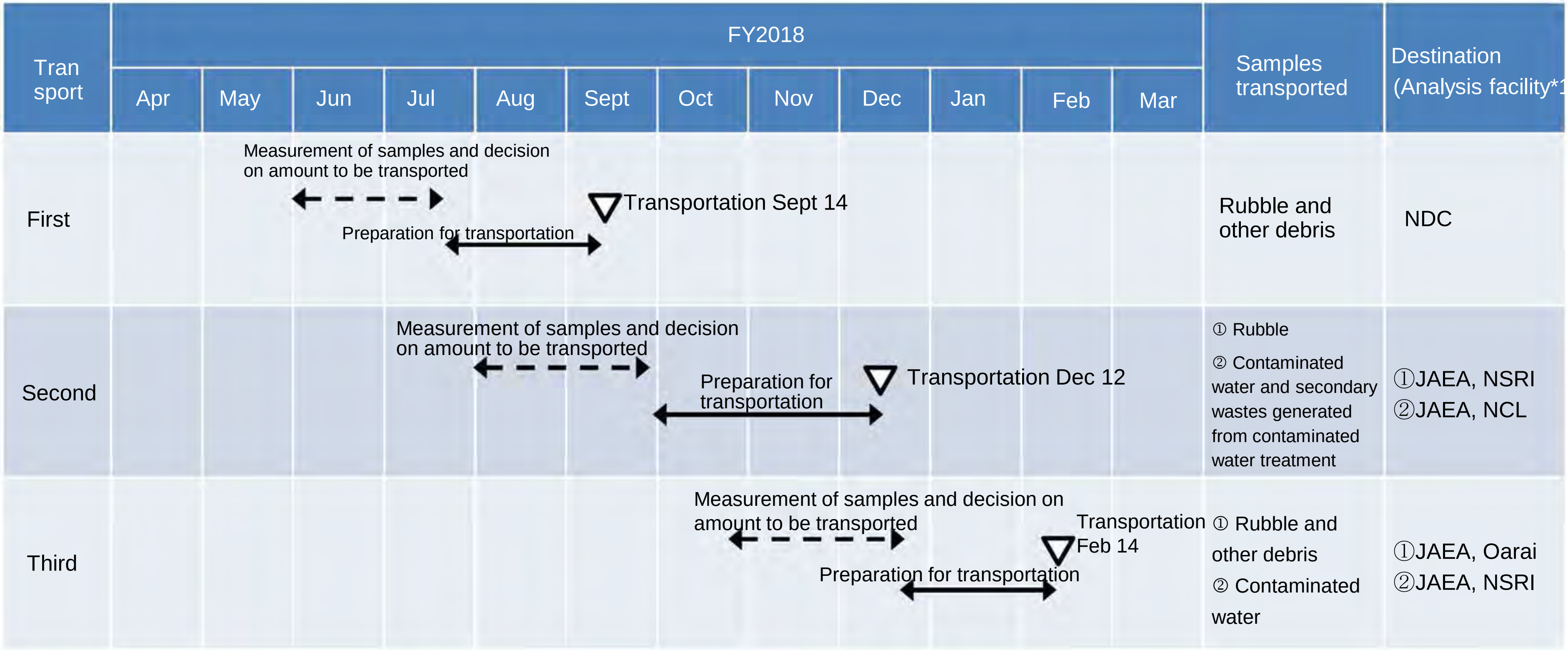
Sampling locations	Type	Results	
		Sampling date	Quantity
First floor	Painted concrete floor	Jul 05, 2017 Jul 06, 2017	5 locations x 2 samples
	Painted steel plates from distribution switchboards	Jul 05, 2017	1 location x 2 samples
Second floor	Painted concrete floor	Jul 04, 2017 Jul 05, 2017	5 locations x 2 samples
	Painted steel plates from distribution switchboards	Jul 05, 2017	1 location x 2 samples
Third floor	Painted concrete floor	Jul 07, 2017	2 locations x 2 samples
	Painted steel plates from distribution switchboards	Jul 07, 2017	1 location x 2 samples
Fourth floor	Painted concrete floor	Jul 10, 2017	2 locations x 2 samples
	Painted steel plates from distribution switchboards	Jul 10, 2017	1 location x 2 samples

(2) Sampling and analysis ① Sampling and transportation

– Results of transportation –

- Analysis samples were transported to an analysis facility located in the Ibaraki area in three separate batches (Table 1).
- The samples remaining after the analysis were to be transported back from the Ibaraki analysis facility to Fukushima Daiichi Nuclear Power Station (1F), but the plan was not implemented.

Table 1. Transportation of analysis samples outside the 1F plant



Transport	FY2018												Samples transported	Destination (Analysis facility*1
	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar		
First		Measurement of samples and decision on amount to be transported	← - - -	- - → Preparation for transportation ←——	——→	▽ Transportation Sept 14							Rubble and other debris	NDC
Second				Measurement of samples and decision on amount to be transported	← - - -	- - →	Preparation for transportation ←——	————	——→ ▽ Transportation Dec 12				① Rubble ② Contaminated water and secondary wastes generated from contaminated water treatment	①JAEA, NSRI ②JAEA, NCL
Third							Measurement of samples and decision on amount to be transported	← - - -	- - →	Preparation for transportation ←——	——→ ▽ Transportation Feb 14		① Rubble and other debris ② Contaminated water	①JAEA, Oarai ②JAEA, NSRI

*1 JAEA: Japan Atomic Energy Agency, NSRI: Nuclear Science Research Institute, NCL: Nuclear Fuel Cycle Engineering Laboratories, Oarai: Oarai Research and Development Institute, NDC: Nuclear Development Corporation

(2) Sampling and analysis ② Conducting analyses

FY	Implementation plan	Goal achievement index
2017 2018	• Sample analysis is performed according to the analysis plan. • Besides activity concentration, other characteristics necessary for the storage and management of waste are be analyzed.	• Implementation of analysis and the reporting of analysis data in line with the annual analysis plan.

- Rubble, contaminated water, secondary waste generated from contaminated water treatment, and soil were analyzed mainly from the viewpoint of treatment (stabilization) and disposal (contamination behavior of nuclides). (Table 1)

Table 1. Overview of analysis (Results presented on the following slides)

Classification	**Sample**	**Treatment (stabilization)**	**Disposal (contamination behavior of nuclides)**
Rubble and waste from dismantlement	Unit 4 boring core		• Location dependence of nuclide composition
	Sludge (contained in stagnant water)		• Nuclide composition
Contaminated water	ALPS		• Nuclide composition of adsorbents
	Stagnant water		• Behavior of uranium and Np
Secondary wastes generated from contaminated water treatment	Sludge from decontamination systems	• Elemental composition, particle size, etc.	• Nuclide composition
	ALPS adsorbents		• Nuclide composition
Soil			• Particle size and location dependence of nuclide composition

(2) Sampling and analysis ② Conducting analyses

– Boring core in Unit 4 R/B (1/2) –

- The core samples obtained by the boring of the floor on 1st to 4th floors of Unit 4 R/B were analyzed*(Figure 1).
- ^{137}Cs was detected in all the samples, while ^{3}H and ^{238}Pu were detected in the samples from the 1st floor through to the 4th floor. The contamination level is below the controlled area standards (Figure 2).
- The contamination source is Unit 3, and the contamination on the 1st to 4th floors seems to be the same.

Figure 1
Appearance of concrete core
(4RB-1F-C-E2)

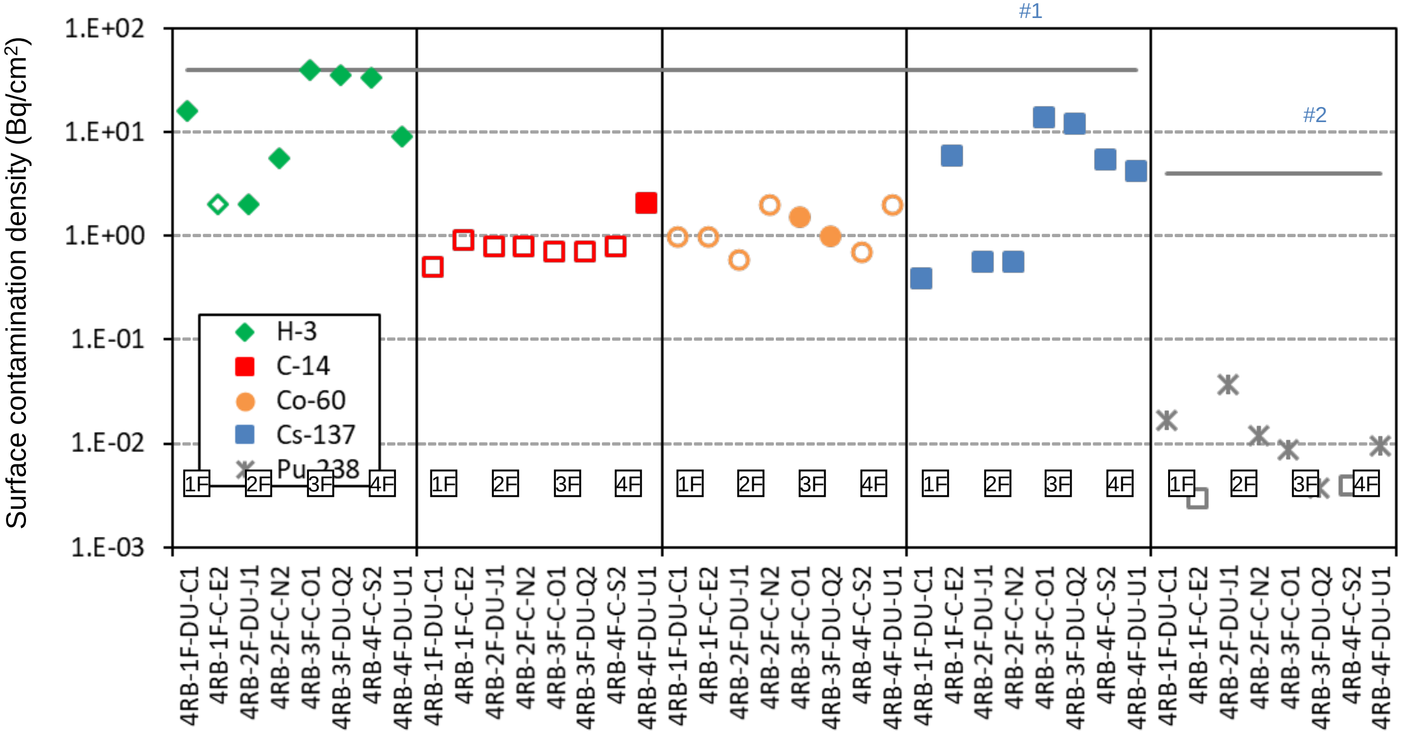


Figure 2. Concentration of detected nuclides

Note) Value corrected for attenuation on March 11, 2011. The white-fill plot points indicate values less than the lower detectable limit. Straight lines #1 and #2 indicate the surface concentration limits (40 Bq/cm² for radioisotopes that do not discharge alpha rays and 4 Bq/cm² for radioisotopes that discharge alpha rays) of objects that may be touched by people, such as walls in controlled areas, as stipulated by law.

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* The 60th Session of Team for Countermeasures for Decommissioning and Contaminated Water Treatment / Secretariat Meeting, Nov 29, 2018

(2) Sampling and analysis ② Conducting analyses

– Boring core in Unit 4 R/B (2/2) –

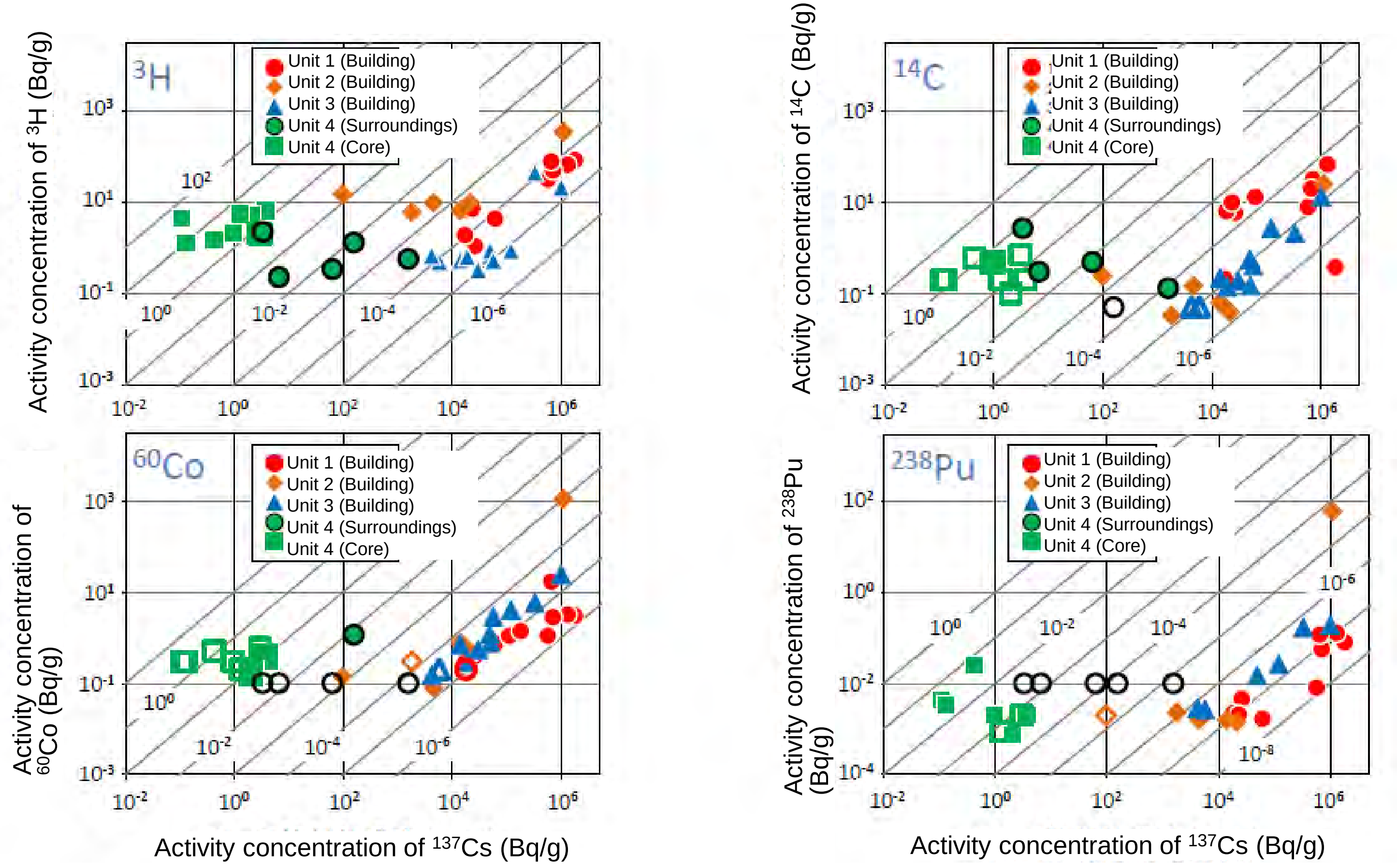

Figure 1 Concentration of nuclides detected from the rubble (boring core) samples collected from inside and around the R/B (Graph plotted for 137Cs*)

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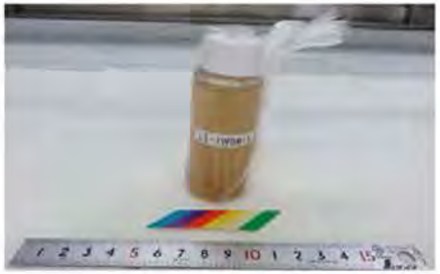
* White-fill plot points indicate that the values of nuclides shown on the vertical axis are lower than the detectable limit. The diagonal lines represent the concentration ratio of two nuclides.

(2) Sampling and analysis ② Conducting analyses

– Sludge contained in stagnant water –

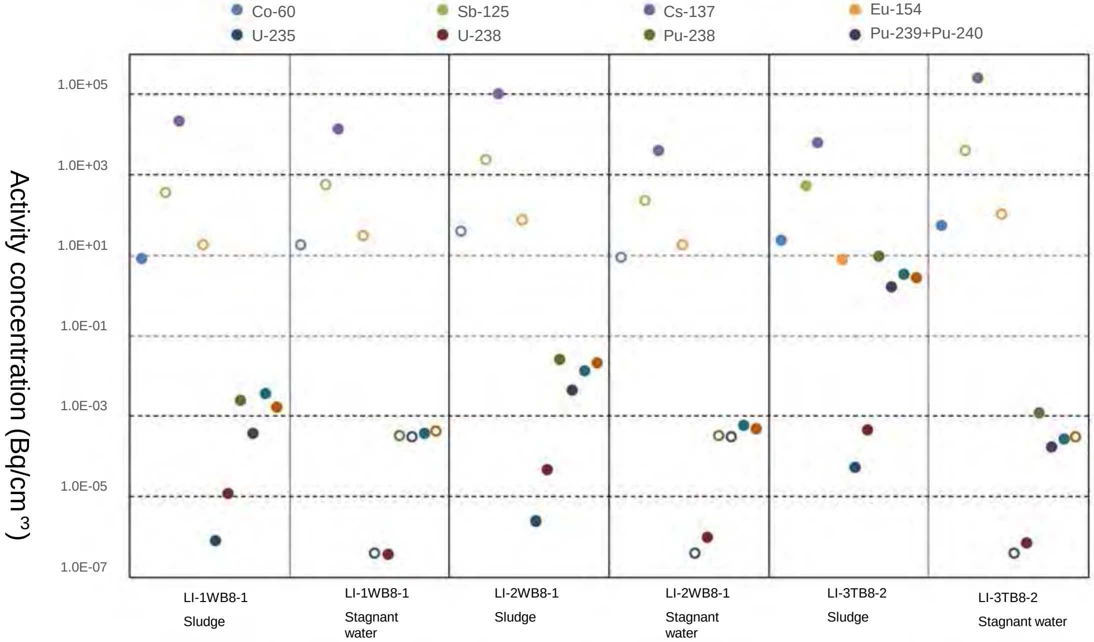
- The sludge contained in stagnant water was analyzed to understand the contamination caused by contact with contaminated water (Figure 1).
- The α nuclides were detected in more sludge samples than in stagnant water. 154Eu was also detected in the sludge from Unit 3 Turbine Building, but the α nuclide concentration tended to be higher than other sludge (Figure 2).
- The elemental composition of sludge has a high ratio of iron, aluminum, and silicon, and there is a possibility that α nuclides are incorporated in ferric hydroxide or in the clayey components.



Stagnant water samples

Sludge separated from water

Figure 1. Appearance of stagnant water and sludge samples (LI-1WB8-1)



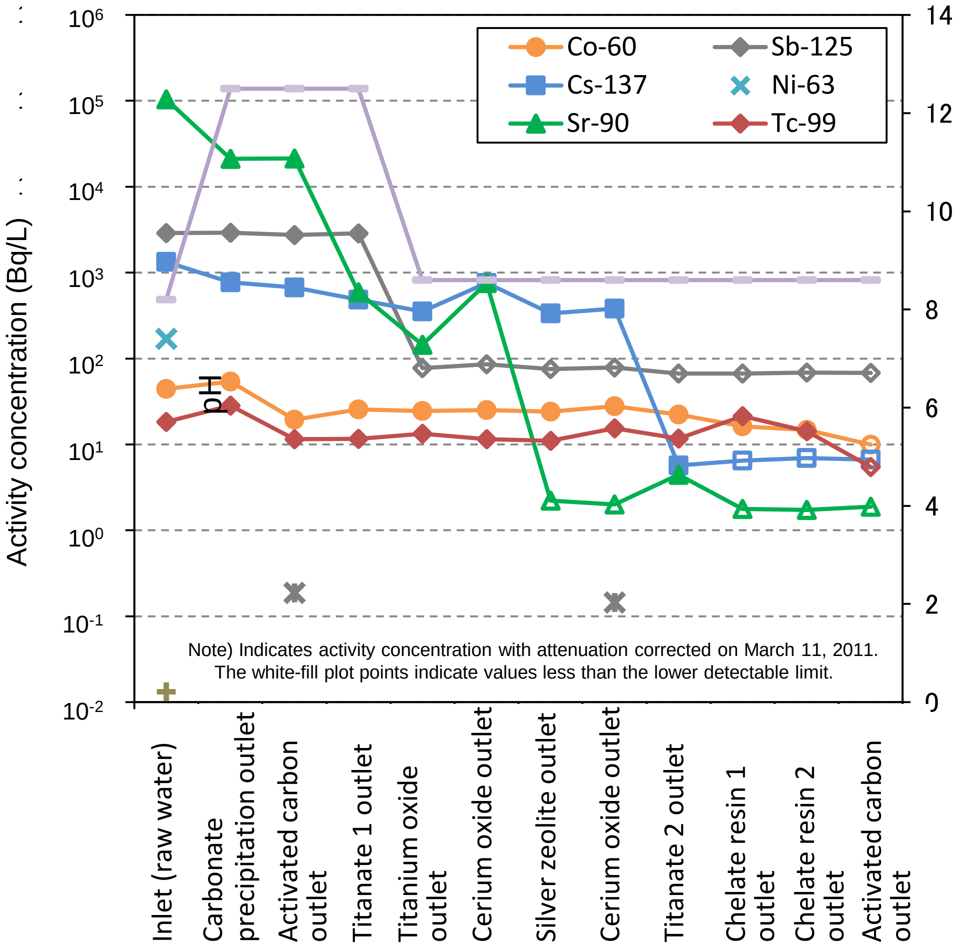
Note 1) Shows detected nuclides only Note 2) Attenuation-corrected concentration for Mar 11, 2011 Note 3) White-fill plot points indicate values less than the lower detectable limit

Figure 2. Concentration of nuclides detected from the stagnant water and sludge collected from the basement of each building

(2) Sampling and analysis ② Conducting analyses

– Treated water from the Multi-nuclide Removal System (ALPS) –

- The water collected from the ALPS process was analyzed to estimate the radioactivity of secondary waste produced by APLS*.
- The main nuclides that are removed and adsorbed by each process and adsorbent are as follows:
  - Carbonate precipitates: ^{63}Ni, ^{90}Sr
  - Activated carbon (first half): ^{60}Co
  - Titanate 1: ^{90}Sr
  - Titanium oxide: ^{90}Sr, ^{125}Sb
  - Silver zeolite: ^{90}Sr
  - Titanate 2: ^{137}Cs
  - Activated carbon (latter half): ^{60}Co, ^{99}Tc
- The concentration at the outlet of the adsorption vessel may be higher than the concentration at the inlet. Verification requires further collection of data.
- ^{106}Ru, ^{129}I, ^{154}Eu, ^{235}U and $^{239+240}$Pu were not detected in any of the samples.



Note) Indicates activity concentration with attenuation corrected on March 11, 2011.
The white-fill plot points indicate values less than the lower detectable limit.

Figure. Activity concentration at the main equipment outlets of ALPS (expanded B system)

* The 60th Session of Team for Countermeasures for Decommissioning and Contaminated Water Treatment / Secretariat Meeting, Nov 29, 2018.

(2) Sampling and analysis ② Conducting analyses – Analysis of uranium in contaminated water –

- The U isotopic composition was analyzed for a variety of contaminated water samples in order to understand the contamination behavior of uranium*.
- The ^{235}U/ ^{137}Cs ratio in the stagnant water in Unit 2 and Unit 3 PCVs is about a digit larger than that in the stagnant water in R/B, T/B, and centralized RW building. (Figure 1)
- The ratio of ^{235}U/ ^{238}U is often closer to the value of damaged fuel than to the natural uranium ratio. The ratio is small for Unit 1 R/B and T/B and Unit 2 T/B, and the contribution of natural uranium is relatively large. (Figure 2)
- The ^{235}U/ ^{238}U ratio varies depending on the sampling location and falls between the damaged fuel to natural uranium ratio. The source of uranium in the stagnant water is believed to be the damaged fuel and the contribution of natural components contained in various materials.

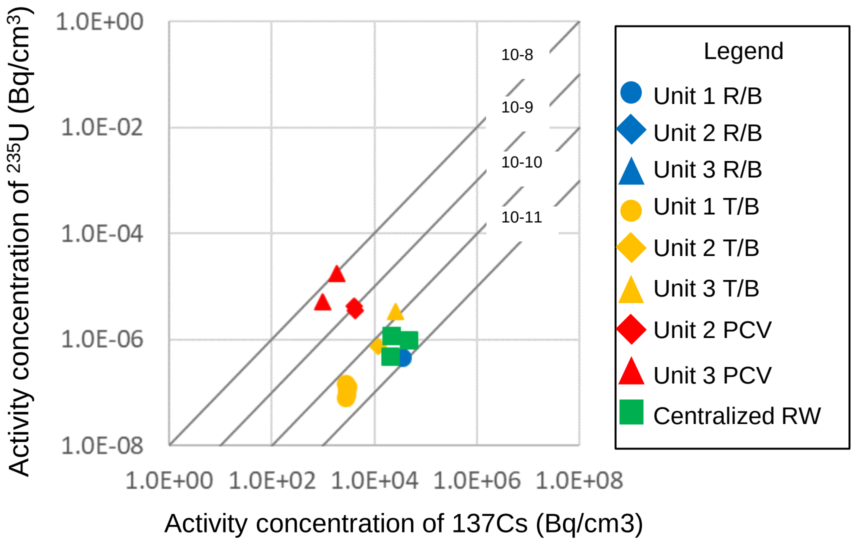


Figure 1. Activity concentration ratio of ^{235}U and ^{137}Cs in a variety of contaminated water samples

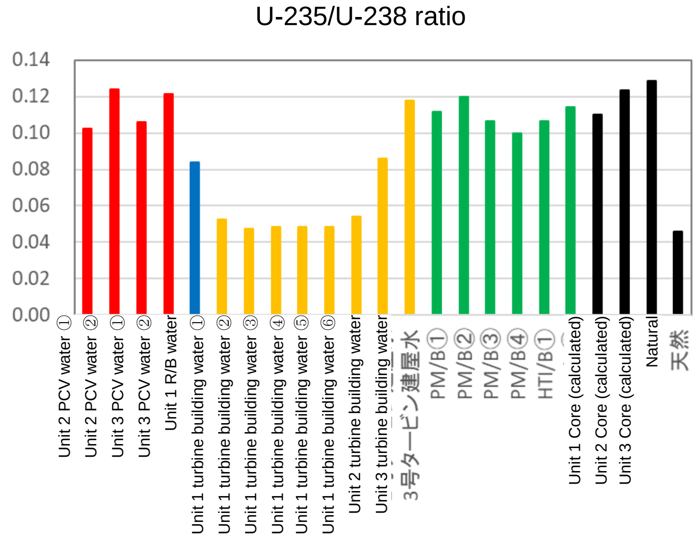


Figure 2. Activity concentration ratio ^{235}U and ^{238}U in a variety of contaminated water samples

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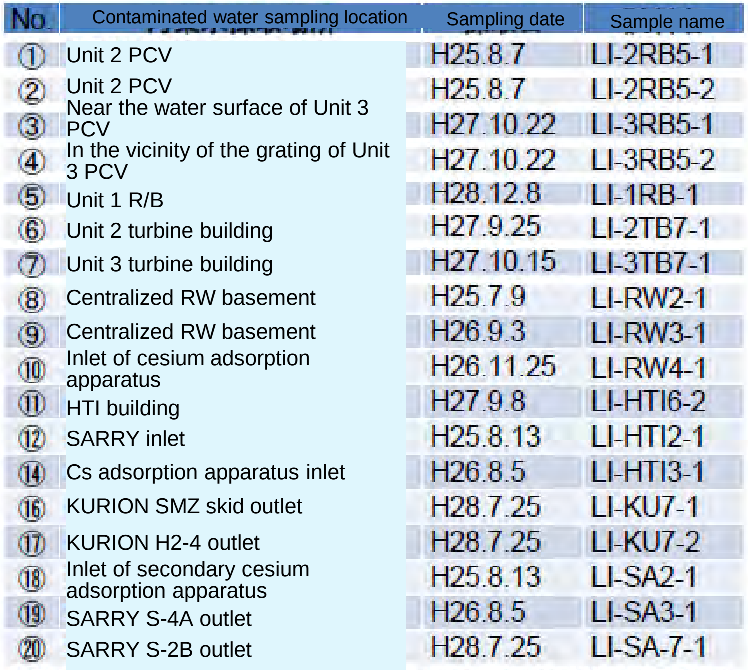
* The 56th Session of Team for Countermeasures for Decommissioning and Contaminated Water Treatment / Secretariat Meeting, Jul 26, 2018.

(2) Sampling and analysis ② Conducting analyses

– Analysis of Np in contaminated water –

- The Np concentration in a variety of contaminated water samples was analyzed in order to understand the contamination behavior of Np, and the difference with U and Pu was studied (Table 1).
- U, Pu, and Cm have almost the same transport rate in the stagnant water inside Unit 2 and Unit 3 PCVs. Meanwhile, Np in Unit 2 and Unit 3 shows about a digit higher transport rate than the other α nuclides, which suggests that Np has higher solubility than other α nuclides (Figure 1).
- The transport rate of Pu is reduced to about 1/100 in the stagnant water after passing through the Turbine Building. It is presumed that Pu in the turbine building has been removed by sedimentation or adsorption (Figure 1).

Table 1. Contaminated water samples analyzed for ^{237}Np



No.	Contaminated water sampling location	Sampling date	Sample name
①	Unit 2 PCV	H25.8.7	LI-2RB5-1
②	Unit 2 PCV	H25.8.7	LI-2RB5-2
③	Near the water surface of Unit 3 PCV	H27.10.22	LI-3RB5-1
④	In the vicinity of the grating of Unit 3 PCV	H27.10.22	LI-3RB5-2
⑤	Unit 1 R/B	H28.12.8	LI-1RB-1
⑥	Unit 2 turbine building	H27.9.25	LI-2TB7-1
⑦	Unit 3 turbine building	H27.10.15	LI-3TB7-1
⑧	Centralized RW basement	H25.7.9	LI-RW2-1
⑨	Centralized RW basement	H26.9.3	LI-RW3-1
⑩	Inlet of cesium adsorption apparatus	H26.11.25	LI-RW4-1
⑪	HTI building	H27.9.8	LI-HTI6-2
⑫	SARRY inlet	H25.8.13	LI-HTI2-1
⑭	Cs adsorption apparatus inlet	H26.8.5	LI-HTI3-1
⑯	KURION SMZ skid outlet	H28.7.25	LI-KU7-1
⑰	KURION H2-4 outlet	H28.7.25	LI-KU7-2
⑱	Inlet of secondary cesium adsorption apparatus	H25.8.13	LI-SA2-1
⑲	SARRY S-4A outlet	H26.8.5	LI-SA3-1
⑳	SARRY S-2B outlet	H28.7.25	LI-SA-7-1

Samples ⑬ and ⑮ are contaminated water samples collected from the HTI building on Nov 25, 2014 and from KURION outlet on Mar 9, 2015 respectively. 237Np analysis was not carried out for these samples.

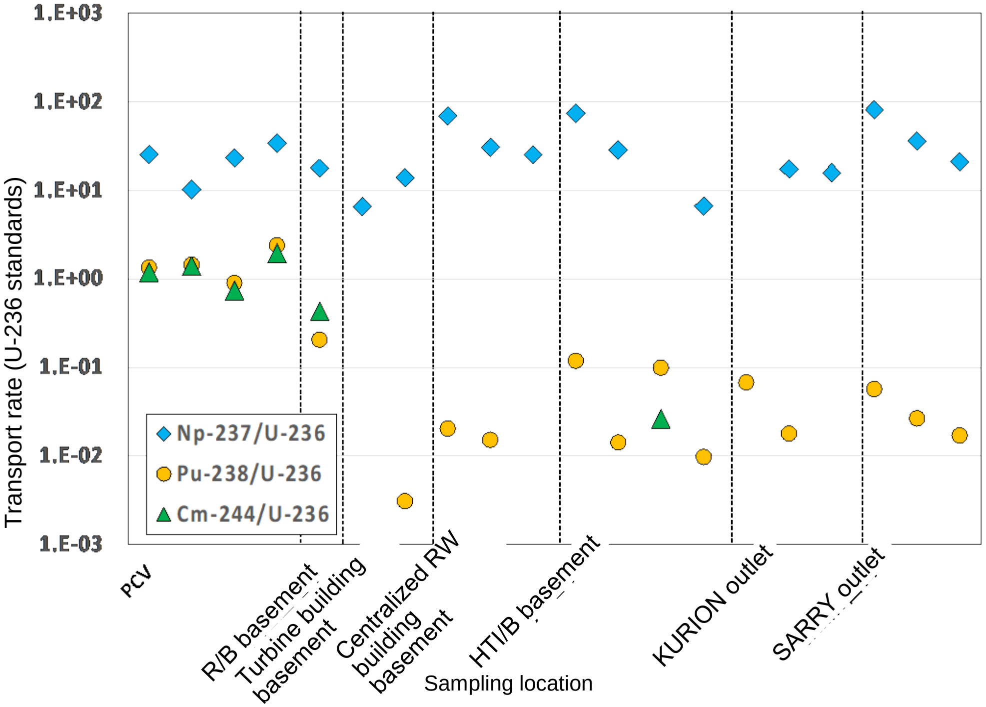
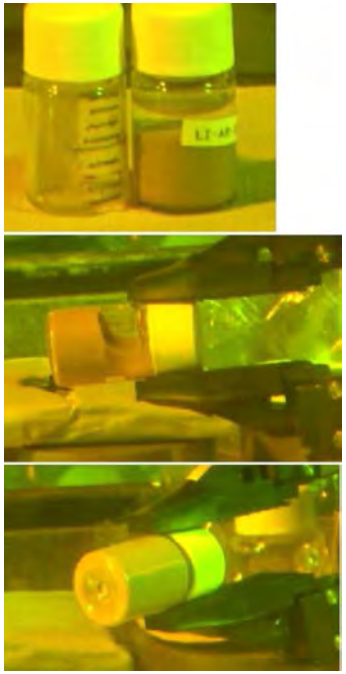


Figure 1. Activity concentration ratio of ^{237}Np and ^{236}U in a variety of contaminated water samples
(Transport rate standardized in fuel composition)

(2) Sampling and analysis ② Conducting analyses

– Analysis of sludge from decontamination systems (1/3) –

- The fluidity (Figure 1) and radioactivity of the sludge from decontamination systems, which is one of the secondary wastes generated from contaminated water treatment*, was analyzed for the study of predisposal management (dehydration and transfer methods) (Table 1 on page 28).
- One mL of solid-liquid mixed sludge sample and 10 mL of supernatant liquid was put into a stoppered measuring cylinder (10 mL, inner diameter about 11 mm Φ, height about 11 cm). The measuring cylinder was repeatedly turned over to stir the contents and left standing to observe the sedimentation. The temporal change in the height of the phase boundary was measured. (Figure 2)



① When left standing, the sludge settled and a supernatant layer appeared.

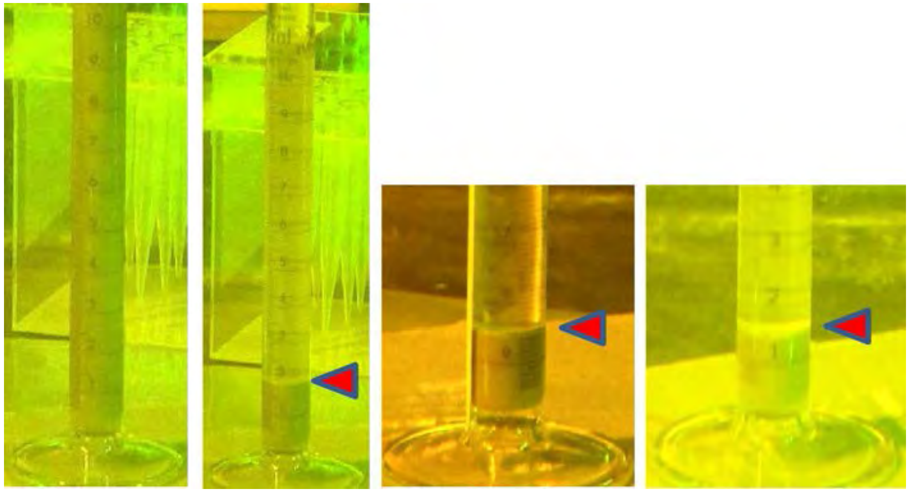
② Sludge did not flow even when

the vial was turned sideways.

③ As the vial was stirred, the solids

and supernatant liquid mixed gradually.

Figure 1. Flow in the vial



Immediately after stirring	One hour later	About one day later	About two days later

◀ : Position considered as sludge phase boundary

Figure 2. Sedimentation of the sludge

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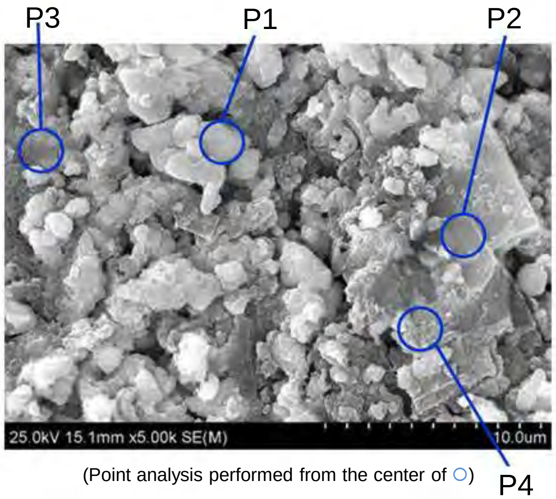
* The 52nd Session of Team for Countermeasures for Decommissioning and Contaminated Water Treatment / Secretariat Meeting, Mar 29, 2018

(2) Sampling and analysis ② Conducting analyses

– Analysis of sludge from decontamination systems (2/3) –

- The shape of the particles in the sludge from decontamination systems was observed by means of SEM-EDX and the elemental composition was measured to study predisposal management (dehydration and transfer methods)*.
- One mL of pure water was added to the vial containing the sludge, the contents were stirred and dispersed. Some of this was taken and dropped on a filter, dried, and then platinum was evaporated to obtain a sample for SEM-EDX, which was measured. The particles constituting the sludge showed multiple shapes and were confirmed to be a mixture of components with different compositions (Figure 1).
- From the results of the EDX surface analysis, it was believed that Ba and S were present in large amounts, and $BaSO_4$ accounted for 60-70%. The amount of ferrocyanide was estimated to be second largest. Besides this, Zn was detected (Figure 2).



(Point analysis performed from the center of ○)

Figure 1. SEM image of sludge from decontamination systems (Magnified 5000 times)

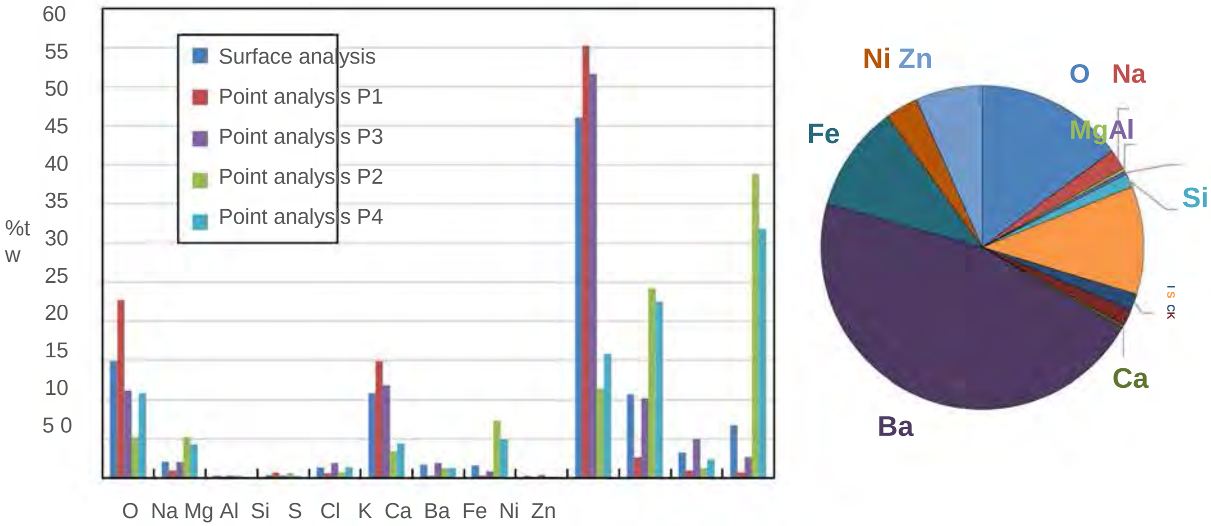


Figure 2. Results of elemental analysis of sludge from decontamination systems (Surface analysis and point analysis by EDX)

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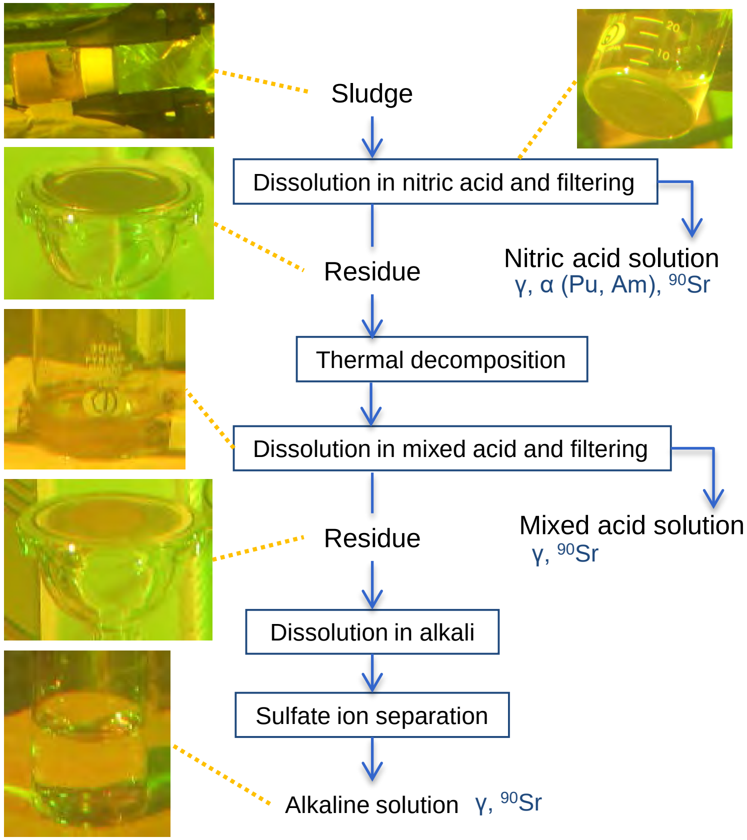
* The 56th Session of Team for Countermeasures for Decommissioning and Contaminated Water Treatment / Secretariat Meeting, Jul 26, 2018

(2) Sampling and analysis ② Conducting analyses

– Analysis of sludge from decontamination systems (3/3) –

- The radionuclide concentration of the sludge from decontamination systems was analyzed to study disposal methods. Since sludge is insoluble, it was dissolved in a phased manner and then analyzed (Figure 1).
- The analysis revealed that the main nuclide was the β-rays emitting ^{90}Sr, while the sludge also contained ^{137}Cs (daughter product ^{137m}Ba), ^{134}Cs, and ^{125}Sb as the main γ-rays emitting nuclides, and ^{238}Pu as the α-rays emitting nuclide (Table 1) . TEPCO is using the data to study the sludge transport and treatment methods.



Sludge

Dissolution in nitric acid and filtering

Residue

Nitric acid solution
γ, α (Pu, Am), ^{90}Sr

Thermal decomposition

Dissolution in mixed acid and filtering

Residue

Mixed acid solution
γ, ^{90}Sr

Dissolution in alkali

Sulfate ion separation

Alkaline solution γ, ^{90}Sr

Figure 1. Pretreatment method of the sludge from decontamination systems and the appearance of the sample

Table 1. Results of activity concentration analysis of sludge from decontamination systems

Sample name	Activity concentration [Bq/cm^3]#1		
	^{54}Mn (About 312 days)	^{60}Co (About 5.3 years)	^{125}Sb (About 2.8 years)
LI-AR-SL1 #2 (Nitric acid solution)	$(4.1\pm0.3)x10^4$	$(4.1\pm0.1)x10^3$	$(2.6\pm0.1)x10^4$
Same as above (Mixed acid solution)	< $1x10^4$	$(1.8\pm0.2)x10^3$	< $4x10^4$ $(1.1x10^3)$#3
Same as above (Alkaline solution)	< $4x10^4$	< $2x10^2$	< $5x10^3$
LI-AR-SL1	$(4.1\pm0.3)x10^4$	$(5.9\pm0.2)x10^3$	$(2.6\pm0.1)x10^4$

Sample name	Activity concentration [Bq/cm^3]#1		
	^{137}Cs (About 30 years)	^{90}Sr (About 29 years)	^{238}Pu#4 (About 88 years)
LI-AR-SL1 (Nitric acid solution)	$(2.7\pm0.1)x10^4$	$(3.6\pm0.1)x10^6$	$(1.4\pm0.4)x10^{-2}$
Same as above (Mixed acid solution)	$(6.5\pm0.1)x10^6$	$(4.3\pm0.1)x10^6$	-
Same as above (Alkaline solution)	$(6.3\pm0.1)x10^5$	$(5.8\pm0.1)x10^7$	-
LI-AR-SL1	$(7.1\pm0.1)x10^6$	$(6.6\pm0.1)x10^7$	$(1.4\pm0.4)x10^{-2}$

#1 Activity concentration was corrected on Mar 11, 2011. The numerical value after ± in the analysis value is the calculation error. The sum total is the addition of the quantitative values. The activity concentration is the value per 1 cm^3 of the sludge. #2 LI-AR-SL1-3 was analyzed. #3 Reference value because yield in Cs removal treatment is not corrected. #4 LI-AR-SL1-2 was analyzed.

(2) Sampling and analysis ② Conducting analyses

– Analysis of the adsorbents from the Multi-nuclide Removal System (ALPS) –

- The γ-rays emitting nuclides in cerium oxide and activated carbon were analyzed from among the adsorbents from expanded ALPS to study the disposal methods. (Table 1, Figure 1)
- ^{60}Co, ^{106}Ru (daughter product ^{106}Rh), ^{125}Sb, ^{134}Cs and ^{137}Cs (daughter product ^{137m}Ba) were detected as the main γ-rays emitting nuclides#. (Figure 2)
- Dissolution of samples is underway to analyze α-rays and β-rays emitting nuclides. Dissolution generates residues, so the method to be used for dissolving the samples was studied.

Table 1. Analysis samples for ALPS adsorbents

Sample name	Sample number	Sampling locations	Mass (g)
Cerium oxide	ADCe-AAL8-1	Expanded ALPS BC system	23
Activated carbon	ADC-AAL8-2	Expanded ALPS BC system	16

Left: Cerium oxide
Right: Activated carbon

Figure 1. Appearance of the analysis samples

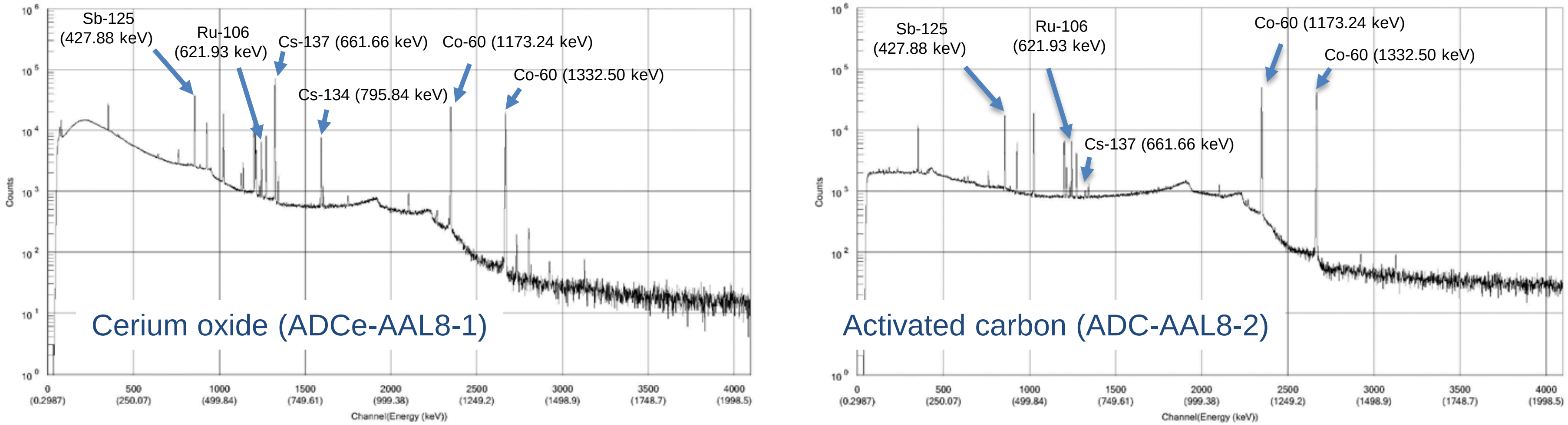
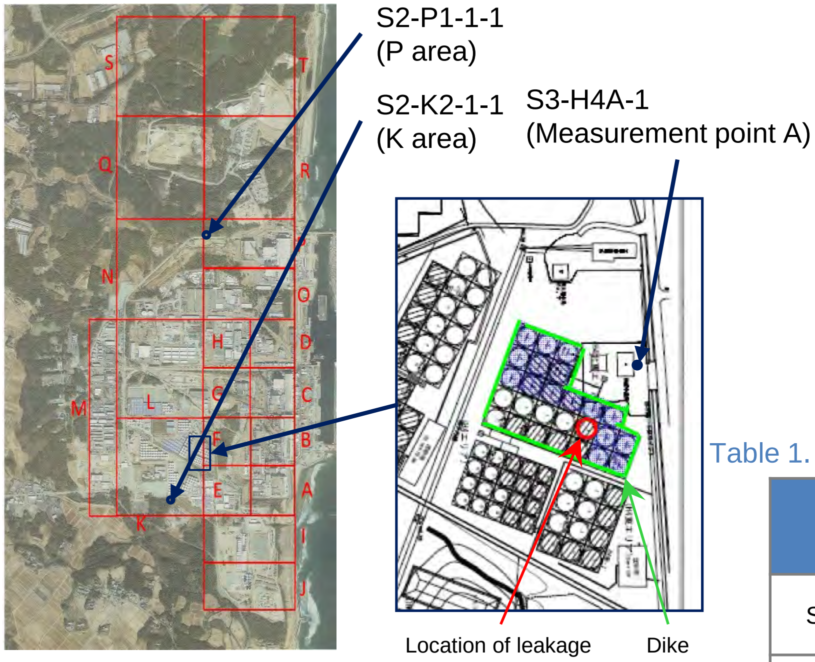


Figure 2. γ-Ray spectrum of adsorbents

Samples in 50 mL vials were measured. Since this is a solid sample, quantification based on this data is difficult.

(2) Sampling and analysis ② Conducting analyses
– Analysis of soil –

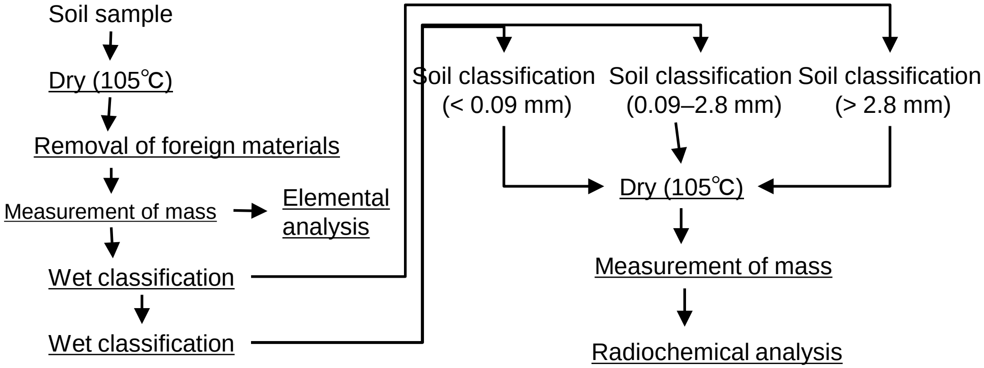
- The relationship between the concentration of major nuclides and the particle size of soil was examined to study the treatment methods.
- The soil samples collected on the site (Figure 1) were classified by the wet method, and the dry mass was measured (Figure 2).
  - ✓ JIS standard nominal size sieves of 2.8 mm and 90 μm were used. Particles with a particle size of 2.8 mm or more were not included.
- The gross α, ^{90}Sr, and ^{137}Cs concentration in the classified soil was analyzed. ^{137}Cs and ^{90}Sr migrate in the same way, regardless of particle size, and are concentrated in soils with small particle size. (Table 1)



Note) The mesh on the map was installed in this PJ.

H4 tank area

Figure 1. Soil sampling locations



Soil sample

Dry (105℃)

Removal of foreign materials

Measurement of mass

Elemental analysis

Wet classification

Wet classification

Soil classification (< 0.09 mm)

Soil classification (0.09–2.8 mm)

Soil classification (> 2.8 mm)

Dry (105℃)

Measurement of mass

Radiochemical analysis

Figure 2 Procedure of soil analysis

Table 1. Particle size distribution and radioactive mass balance of wet-classified soil samples

Sample number	Weight [g]	Particle size [mm]	Dry weight [wt%]	Radioactive mass balance [%]	
				^{90}Sr	^{137}Cs
S2-K2-1-1	50	<0.09	79	89	90
		0.09 to 2.8	21	11	10
S2-P1-1-1	50	<0.09	57	94	95
		0.09 to 2.8	43	6	5
S3-H4A-1	35	<0.09	45	88	93
		0.09 to 2.8	55	12	7

(3) Development of sampling technology

– ① Sampling of secondary wastes generated from contaminated water treatment, including sludge (1/2)–

FY	Implementation plan	Goal achievement index
(Collection of cesium adsorbent, etc)		
2017	• The issues that were clarified by the conceptual study (such as the adhesion of adsorbent) are studied to substantiate a collection method.	• Show proposed collection method of cesium adsorbent and absorbent sampling methods.
2018	• Based on the results of detailed discussions in FY2017, plan of sampling device is developed to start designing a mock-up device.	• Development of a development plan, and the design of a mock-up.

- For the collection of cesium adsorbent, an element testing apparatus was manufactured and a confirmation test of the sampling performance of the adsorbent (zeolite) was conducted. (Figure 1)
- Since the sampling performance is not stable due to the sampling depth, a structure and shape of the sampling head for collecting samples in a stable manner was determined in which a movable vane protrudes when the rotation direction is switched and gathers the sample inside the sampling head. (Figure 2)
- The sampling head and rod, which are the main elements of the sampling device and a part of the mock-up device, were designed. (Figure 3)

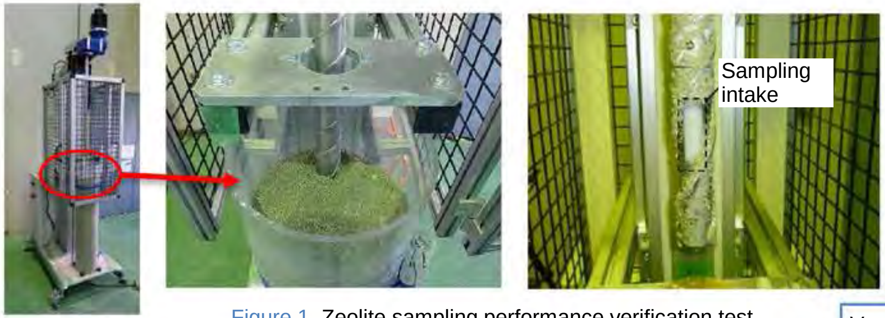
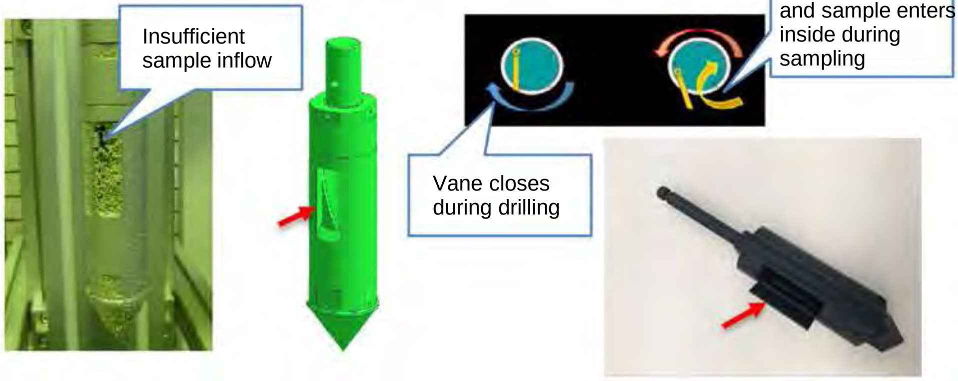


Figure 1. Zeolite sampling performance verification test



Before improvement

After improvement

Figure 2. Sampling head before and after improvement

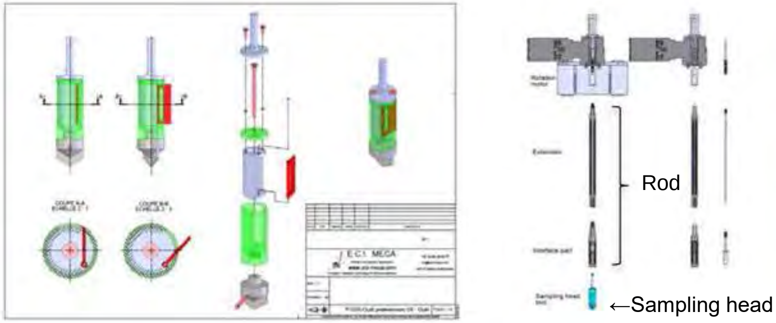


Figure 3. Example of sampling head design

(3) Development of sampling technology

– ① Sampling of secondary wastes generated from contaminated water treatment, including sludge (2/2)–

- The cost and processes required for the development of the sampling device were studied and a development plan was formulated. (Figure 1) (Table 1)
- Application to the SARRY adsorption vessel was studied based on the concept design of the sampling device for collecting samples from the KURION adsorption vessel, implemented during the FY2016 research.
- In order to handle the difference in KURION / SARRY dimensions, both the adsorption vessels can be handled by reviewing the shape of the components, such as the work stand, and by inserting spacers. (Figure 2)
- In order to access the inside of the adsorption vessel and to close the vessel after drilling and sampling, a conceptual design for drilling and closure appropriate to the upper structure of the SARRY adsorption vessel was implemented. (Figure 3)

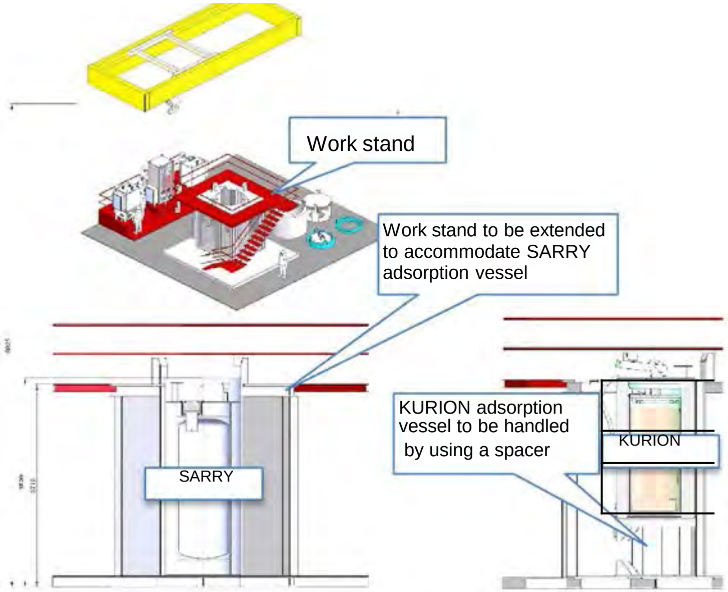


Figure 2 .SARRY/KURION layout study

MU装置設計
- 実機相当のMU装置を設計
- MU装置を製作する範囲の検討

→構成要素のうち、技術的にリスクの高い項目の選定、優先度の設定

→MU装置として全てを製作することが望ましいが予算の制約や、実作業のタイミングにより製作範囲を限定することを検討。

MU試験
- MU試験での課題の抽出
- 課題解決策の検討

MU装置改造
- 課題解決設計

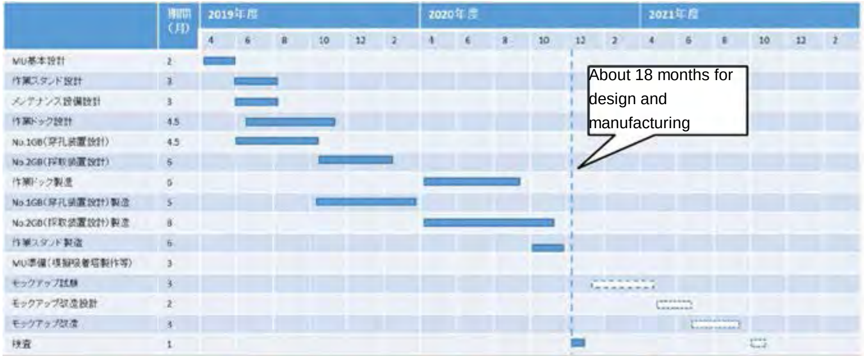
実機
- 検査
- 現場設置工事
- 作業員トレーニング

MU試験準備
- 試験項目
- 試験場所
- 模擬吸着塔の製作

詳細な条件が未定なため、確定の都度、設計に反映していく。

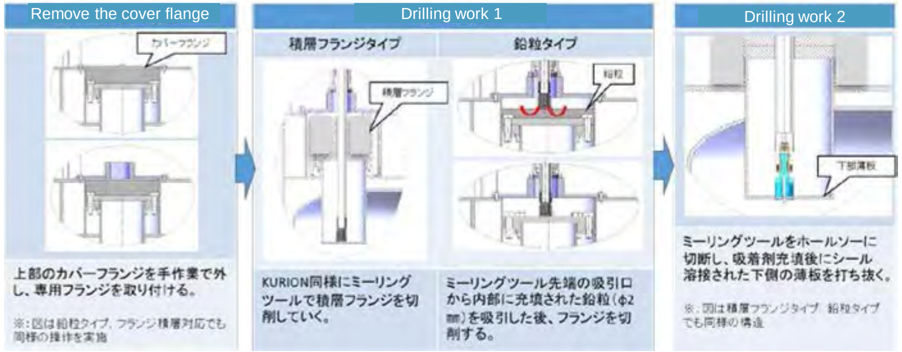
Figure 1. Flow of development

Table 1. Proposed development process



	期間（月）
MU基本設計	2
作業スタンド設計	3
メンテナンス設備設計	3
作業ドック設計	4.5
No.1GB（穿孔装置設計）	4.5
No.2GB（採取装置設計）	5
作業ドック製造	5
No.1GB（穿孔装置設計）製造	5
No.2GB（採取装置設計）製造	8
作業スタンド製造	6
MU準備（模擬吸着塔製作等）	3
モックアップ試験	3
モックアップ改造設計	2
モックアップ改造	3
検査	1

About 18 months for design and manufacturing



上部のカバーフランジを手作業で外し、専用フランジを取り付ける。

※：図は鉛粒タイプ、フランジ積層対応でも同様の操作を実施

KURION同様にミーリングツールで積層フランジを切削していく。

ミーリングツール先端の吸引口から内部に充填された鉛粒（φ2 mm）を吸引した後、フランジを切削する。

ミーリングツールをホールソーに切断し、吸着剤充填後にシール溶接された下側の薄板を打ち抜く。

※：図は積層フランジタイプ、鉛粒タイプでも同様の構造

Figure 3. Study of drilling method suitable to the SARRY adsorption vessel

(3) Development of sampling technology

– ② Study of sampling methods in Reactor Facilities building (1/2) –

FY	Implementation plan	Goal achievement index
2017	• Study on sampling technologies and target sampling locations depending on objectives and priorities will be conducted. Sampling is performed in sequence according to the analysis plan and depending on the state of readiness for the sampling at target locations.	• • Proposing sampling locations and sampling technologies according to objectives and priorities. Implementation of sampling in sequence at locations for which a sampling method has been established..
2018	• Study on target sampling locations and sampling technology is continuously conducted and samples are collected sequentially at target sampling locations based on the analysis plan.	• Implementation of sampling in sequence.

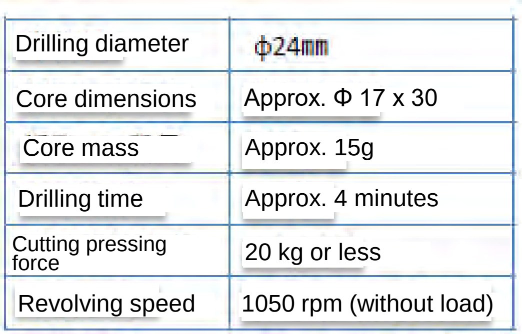
☐ During research in FY2016, a coring tool was developed for remote sampling. With the aim of confirming the effectiveness of the coring tool, the tool was used in the manual sampling work performed on the 1st to 4th floors of the Unit 4 R/B.

☐ In normal core drilling work, it is necessary to break and collect the core after drilling, but the developed coring tool can drill and collect core at the same time as the core gets meshed with the internal wedges. (Figure 1)

☐ Samples were collected from the concrete (including painted surfaces) on the floor inside the R/B. (Figure 2, Figure 3)

#: #: These photos have been taken while the coring tool was under development. The dimensions seen here differ from the actual tool.

Figure 1. Development status of core tool for remote sampling



Drilling diameter	ф24㎜
Core dimensions	Approx. Φ 17 x 30
Core mass	Approx. 15g
Drilling time	Approx. 4 minutes
Cutting pressing force	20 kg or less
Revolving speed	1050 rpm (without load)

Figure 2. Collected samples

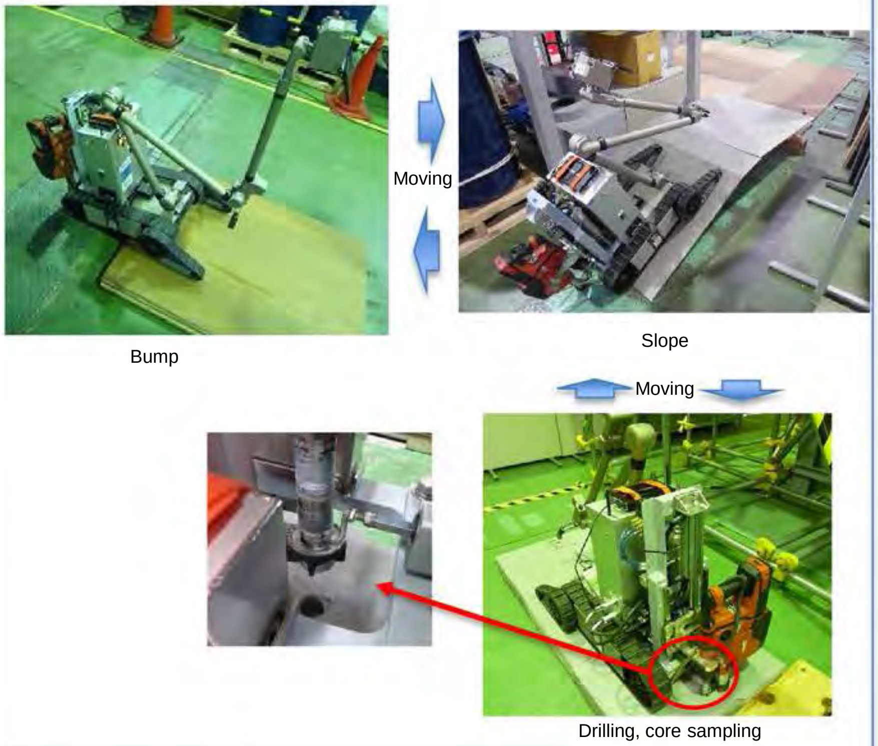
Figure 3. Sampling work inside Unit 4 R/B

(3) Development of sampling technology
– ② Study of sampling methods in Reactor Facilities building (2/2) –

- A prototype of the remote sampling device was mounted on Packbot, an environment simulating the R/B was set up, and a verification test of the remote sampling performance was conducted.
- The test confirmed that there was interference when riding over bumps and that there was a problem with the running balance, so the equipment was modified. (Figure 1) The verification test for remote sampling performance was conducted once again.
- It was confirmed that a series of remote sampling operations, including traveling to the sampling position, core sampling, and returning, could be performed. (Figure 2)
- Although there is a restriction on the possible sampling locations due to the circumstances inside the R/B, a technology has been established to enable remote collection of core samples from the floor surface.

Specifications of remote sampling prototype device (single)	
External dimensions	528 x 300 x 638mm
Mass	22kg
Drilling revolutions	1050 rpm (without load)
Dust collector flow rate	250 L/min (catalog value)
Output of parts	Air cylinder, tank capacity 0.75L Driving battery operation time: about 30 minutes Control battery operation time: 2 hours
Communication specifications	Communication distance: 60m (indoor) Radio format: 2.4GHz spread spectrum

Figure 1 Remote sampling device - Prototype (Single)



Travelling distance	80m
Number of passes with 25° slopes:	2
Number of passes with 70 mm bumps	2
Required time	40 minutes
Sample collected	Φ17 x 30 mm core x 1 sample

Figure 2 Verification test of remote sampling performance

(4) Analysis data management
– Analysis results database (1/2) –

FY	Implementation plan	Goal achievement index
2017	• A database through which all stakeholders involved in analysis can share data is established and used to streamline analysis work. • A database for the public is created to effectively utilize the accumulated analysis data for decommissioning.	• Creation and utilization of the analysis database.
2018	• Issues in operation are identified to improve and upgrade functions.	• Improvement of the database to solve issues identified during use.

- The analysis database "FRAnDLi"* has been created and released on the Internet in March 2018 (Figure 1), and the information is being gradually upgraded and improved.
- The sampling location and the number of samples stored were displayed (Figure 2), and the English version of the content was created (Figure 3).

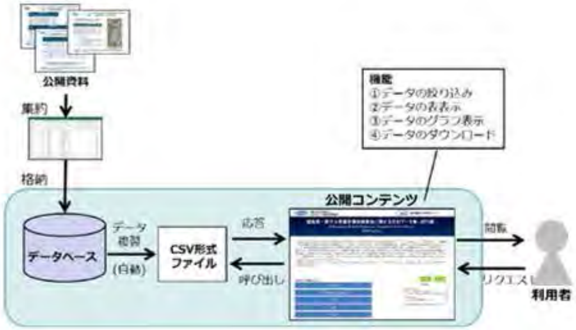


Figure 1 Analysis database configuration

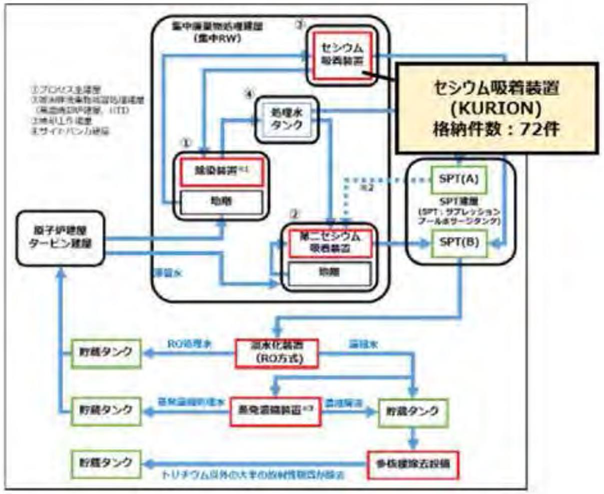


Figure 2 Example display of map of sampling locations and number of samples stored

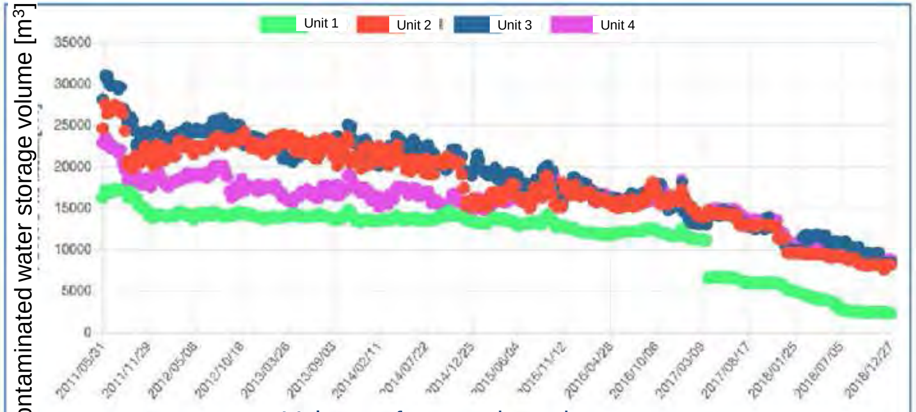

Fukushima Daiichi Radwaste Analytical Data Library
FRAnDLi

Figure 3 Example display of English content

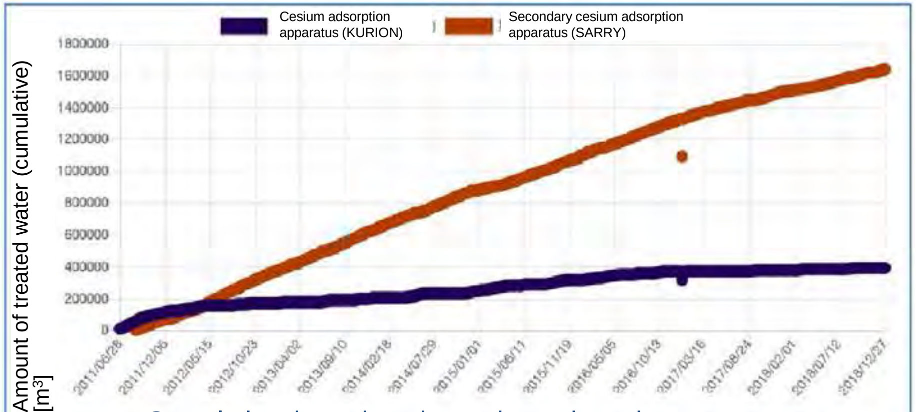
* Analysis data related to waste generated from the accident at the Fukushima Daiichi Nuclear Power Station. https:/frandli-db.jaea.go.jp/FRAnDLi/

(4) Analysis data management
– Analysis results database (2/2) –

- Public data on volume of stored contaminated water, treated water, and secondary wastes generated from contaminated water treatment, etc. was added and browsing was enabled (Figure 1) .

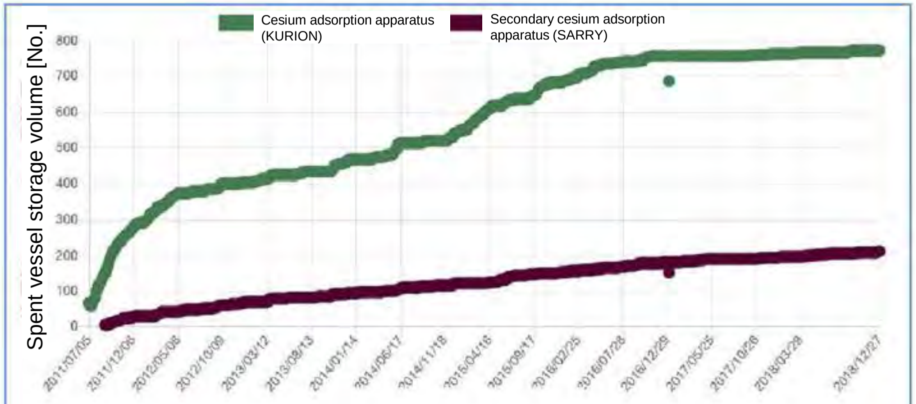


Volume of contaminated water



Cumulative throughput by cesium adsorption apparatus

Volume of treated water



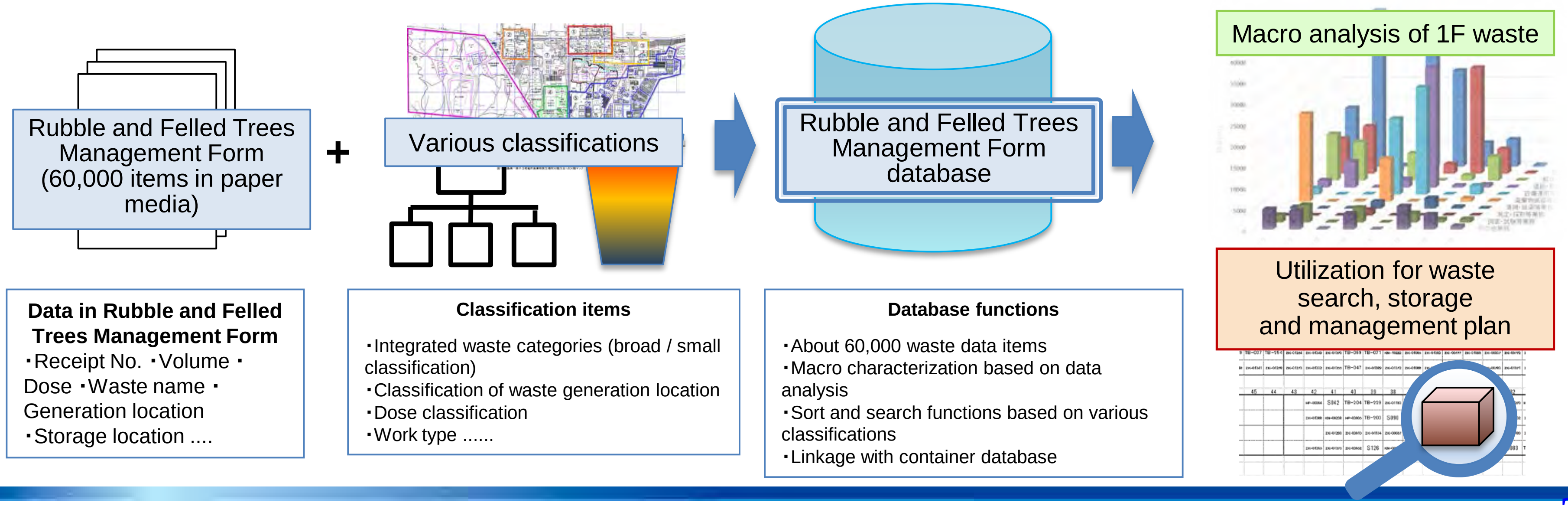
Spent vessels

Figure 1 Example display of storage volume

(4) Analysis data management
– Waste information database (1/2) –

FY	Implementation plan	Goal achievement index
2017 2018	• The latest waste analysis data is collected and the data obtained in the FY2016 project will be re-organized. Additional data is collected and updated accordingly.	• Update of the waste list with the latest waste data and analysis results.

- The "Rubble and Felled Trees Management Table", which was conventionally managed on paper media, has been converted to an electronic database. It will be used for the following studies:
  - Macro analysis of features such as amount of storage (volume) and dose rate
  - Identification of materials with impact on disposal
  - Utilization for waste storage, management, and sampling plan
- Entries have been made for waste data in "Rubble and Felled Trees Management Form" (Apr 2012 to Dec 2018) containing about 60,000 items. Each of about 60,000 waste data items have been newly classified as per integrated waste categories (broad classification into 8 types, small classification into 23 types), classification of waste generation locations (8 types), dose classification (5 types), and work type classification (10 types), enabling detailed data analysis of the waste.
- In addition, by linking the container number to the data on waste collected in containers and stored in the solid radioactive waste storage facility and combining it with a separately created container database, it is possible to identify the waste storage location.



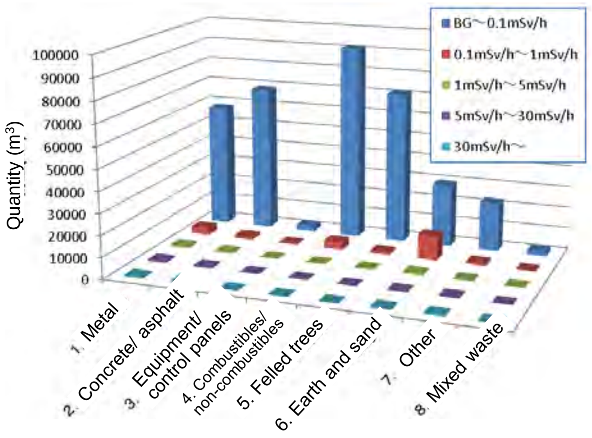
Data in Rubble and Felled Trees Management Form
・Receipt No. ・Volume ・Dose ・Waste name ・Generation location
・Storage location ....

Classification items
・Integrated waste categories (broad / small classification)
・Classification of waste generation location
・Dose classification
・Work type ......

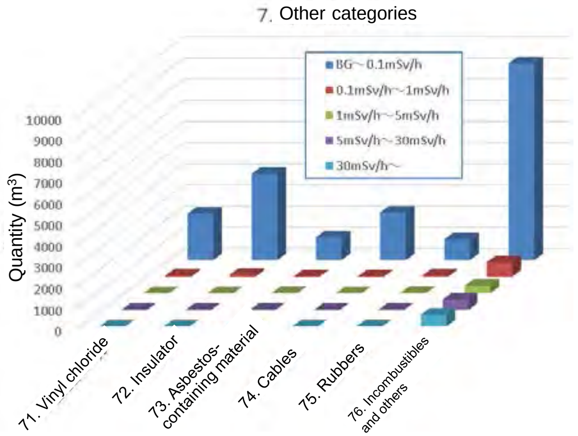
Database functions
・About 60,000 waste data items
・Macro characterization based on data analysis
・Sort and search functions based on various classifications
・Linkage with container database

(4) Analysis data management
– Waste information database (2/2) –

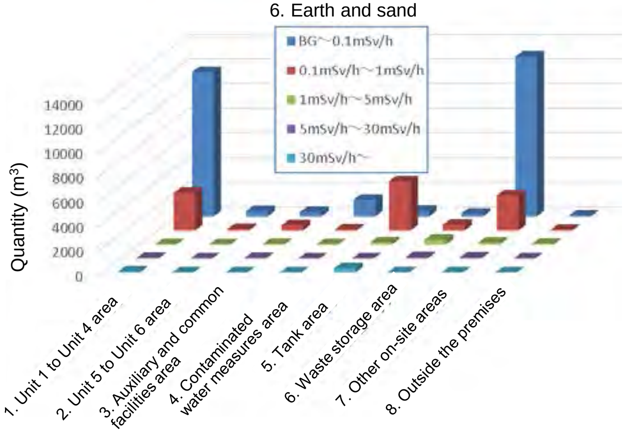
- Reference cases for macro analysis of 1F waste
  - ✓ Detailed data analysis of waste using the small classification category and classification of waste generation locations is possible.



Broad classifications into integrated categories for entire waste



Small classification for the "7. Other" category



Classification of "6. Earth and sand" generation locations

- Utilization for waste search, storage and management plan
  - ✓ Search for waste using classification items and identification of storage location due to linkage with container database is possible.

Search conditions

・Integrated categories - small classification: 75 (Rubbers)
・Classification of waste generation locations: 3
(Auxiliary and common facilities area)
・Storage location: Solid radioactive waste storage facility

Waste Search

1 hit

Search results (Contents of Rubble and Felled Trees DB)

・Receipt No.: 2017-05-329
・Waste generation location: On-site bunker building
・Stored waste name: Non-combustibles (Rubbers)......
・Surface dose: 10 mSv/h
・Container No.: **TB-021**, TB-014
......

Container search

Search results (Contents of container DB)

・Container No: TB-021
・Volume: 6m^3
・Weight: 3,300 kg
・Current storage address: **7-B2-5-27-A-2**
......

(5) Establishment of characterization method

- ① Study on the migration behavior and the contamination mechanism of radionuclides -

FY	Implementation plan	Goal achievement index
2017	• The contamination mechanism of radionuclides is estimated in reference to information about the positions (locations) and processes where and how waste was contaminated and information about the development of the situation after the occurrence of the accident, as well as knowledge about waste classification (composition of radionuclides that characterize the waste).	• Presentation of the estimated contamination mechanism based on analysis data.
2018	• The results of classification are reviewed as analysis data is accumulated.	• Same as above

- As a contamination mechanism, it is important to superimpose contamination from multiple source terms as well, together with pathways (air, water). Since the uranium isotopes are believed to be found even in nature along with those found in damaged fuel, the migration behavior of uranium was studied using the transport rate.
- Conventionally, the transport rate of uranium varied from one isotope to another (Figure 1), so the fuel composition used for calculating the transport rate was studied. The transport rate of uranium isotopes correlated in U-234, 235, and 238, while a difference was visible in U-236 (in the example of Unit 1 rubble, the contribution of natural uranium was large) (Figure 2) . This method using the transport rate as an index is considered to be useful in studying the source terms of uranium.

Source terms were studied again due to variation in U isotope transport rates

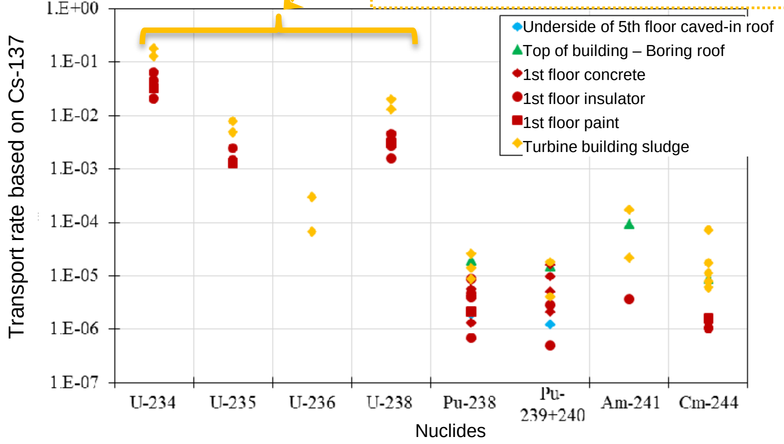


Figure 1 Transport rates of U isotopes for various Unit 1 samples (Based on conventional fuel composition calculations)

The U-234 value came closer to that of 235 and 238. However, the values did not match, suggesting the contribution of multiple source terms.

The U-236 value was smaller than that of others, indicating the contribution of natural U along with damaged fuel, rather, it can be said that the contribution of damaged fuel is small.

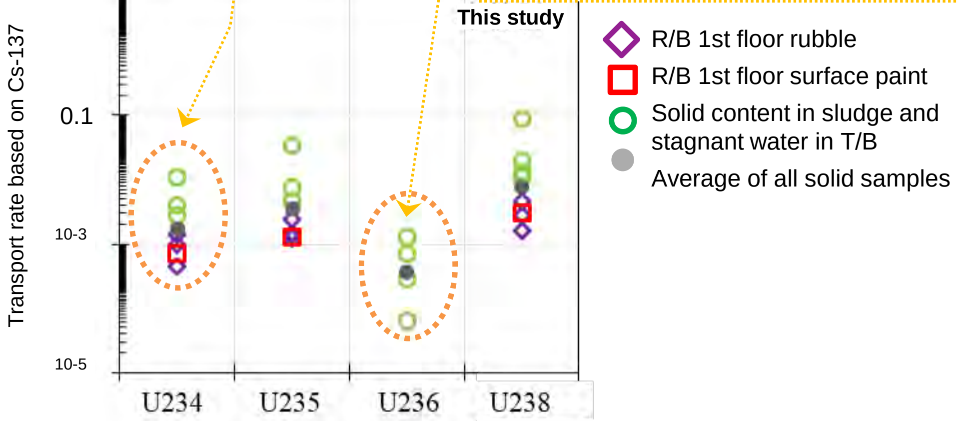
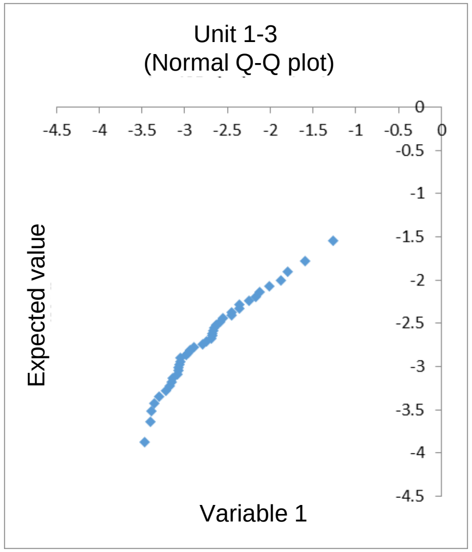


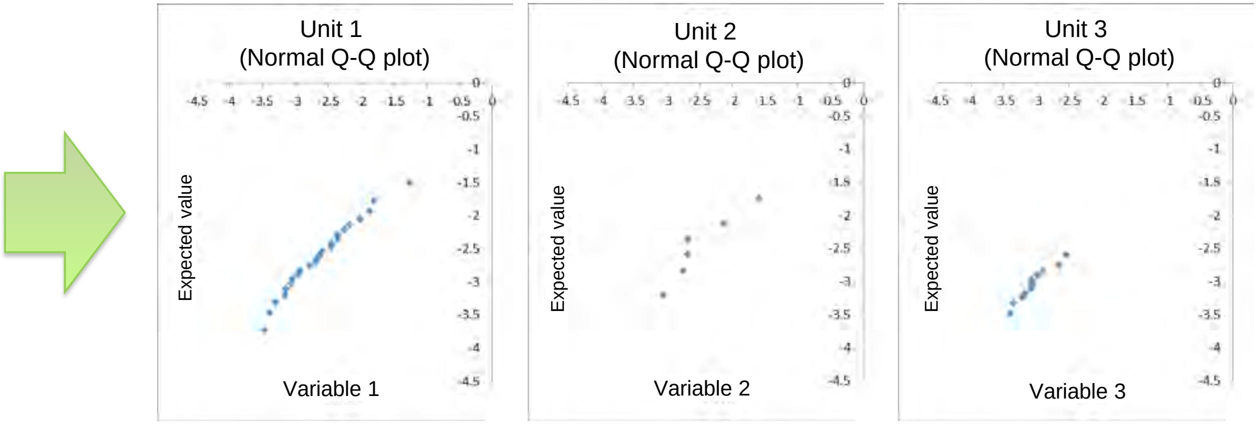
Figure 2 Transport rates obtained by recalculating the source term (damaged fuel)

(5) Establishment of characterization method
- ② Study of waste classification based on analysis data -

FY	Implementation plan	Goal achievement index
2017	• Radionuclide compositions that determine the characteristics of waste are identified. • Data analysis proceeds using the quantity (transport rate) standardized based on the correlation between concentrations of radionuclides, and the nuclide composition of the source terms.	• Proposal of waste classification based on analyzed data.
2018	• The results of classification are reviewed as analysis data is accumulated.	• Same as above

- Since the transport rate calculated from the analysis data takes a curve similar to log-normal distribution, work to determine the classification of waste using probability paper plot points was considered (Figure 1).
  - ✓ This policy seemed to be promising, and a method using Bayesian statistics was studied as shown below.
  - ✓ There were no findings that would require the classification studied in the previous fiscal year to be changed.





➢ In this case, it is believed that improvement in normality can be expected if plotting is done separately for each Unit.

⇒ Possibility of expressing differences between Units using the Bayesian statistical methods

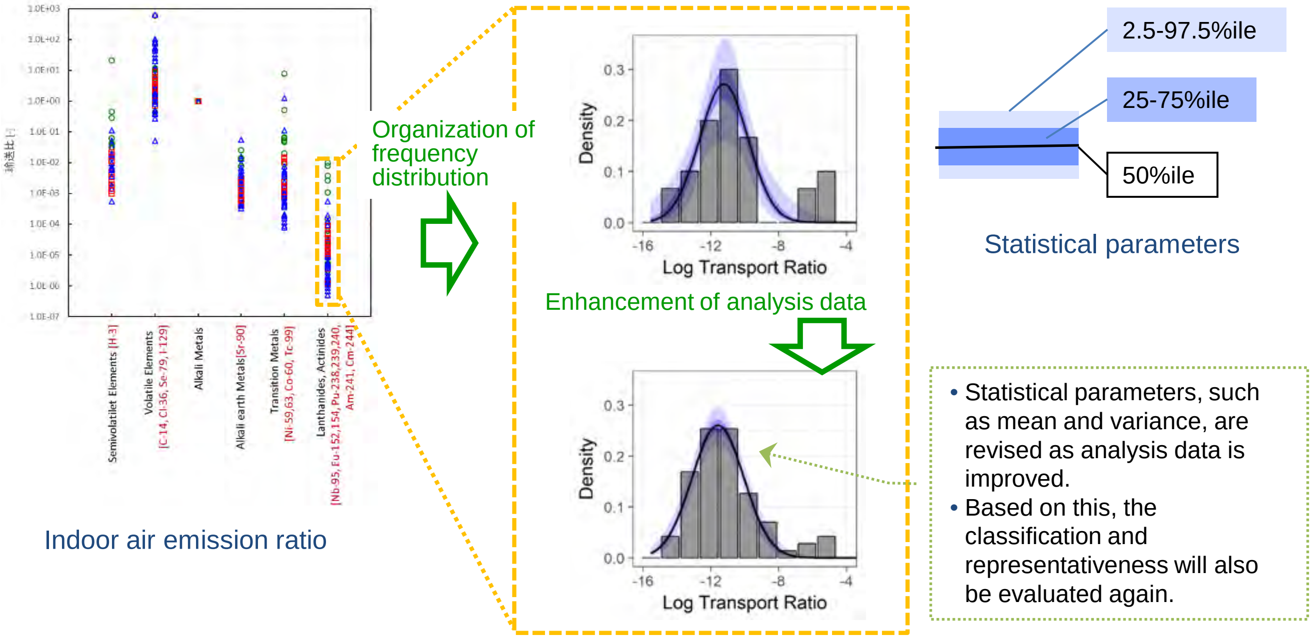
$\mu_{Unit} = \mu_{Average\ of\ 3\ reactors} + \varepsilon_{Unit}$

Figure 1 Image of the work of studying the dependence of Units (Using the transport rate distribution of alkali earth metal as an example)

(5) Establishment of characterization method
- ③ Study on the representativeness of analysis data (1/4) -

FY	Implementation plan	Goal achievement index
2017 2018	• Study of assessment methods for the representativeness of analysis data is conducted under the restriction condition that the amount of data and/or sampling locations are limited. Also, methods for estimating the distribution of waste contamination are studied based on the assessment method established by the aforementioned study.	• Proposal of the assessment method for the representativeness of analysis data and the method for estimating contamination distribution.

- Application of the conventional method[*1] of determining the activity concentration of waste seems to be difficult.
- It is, therefore, necessary to develop and establish new methods. Since the information and analysis data on waste gradually increases over a long period of time, a method that can estimate the change in statistical properties due to the increase in data, will be introduced.
  - ○ For this purpose, the use of Bayesian statistics is being studied instead of the conventional frequency distribution method (Figure 1).



- Statistical parameters, such as mean and variance, are revised as analysis data is improved.
- Based on this, the classification and representativeness will also be evaluated again.

Figure 1 Study on the method of statistical handling of analysis data

Bayesian inference*

- Refers to inferring things (initiating events that have caused the observed events) that have been estimated from observed events (observed facts) in terms of the probability of their occurrence, based on the concept of Bayesian probability.

* https://ja.wikipedia.org/wiki/Bayesian inference

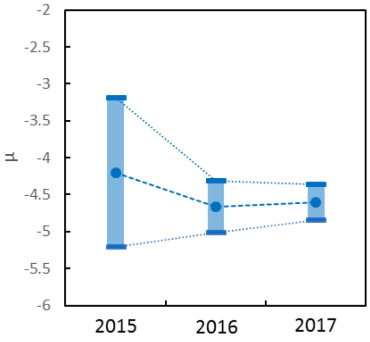
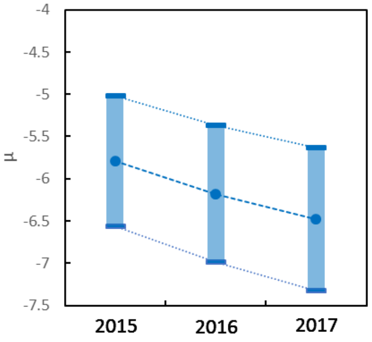
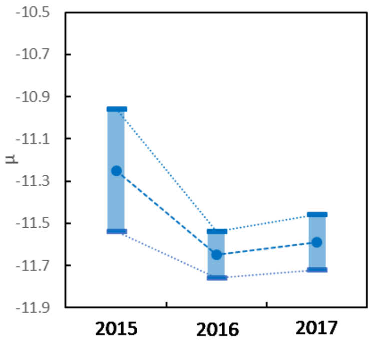
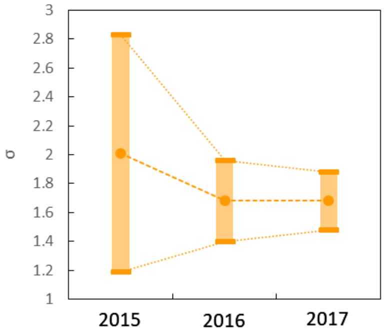
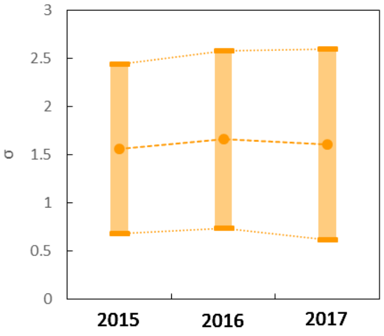
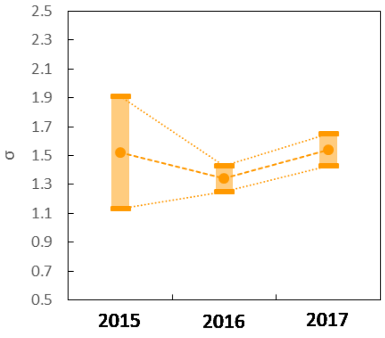
[*1] For example, "Basic procedure for determination of activity concentration of waste to undergo pit disposal and trench disposal: 2011 (AESJ-SC-F022:2011)"

(5) Establishment of characterization method

- ③ Study on the representativeness of analysis data (2/4) -

- To improve the accuracy of data, the frequency distribution of the radionuclide transport rate was determined, and the change in the parameters (mean and variance assuming a log-normal distribution) with the increase in data was investigated. (Table 1)
- The parameters generally improved with the accumulation of data, confirming that the conventional classification was valid from the viewpoint of nuclide composition. The variance of alkali earth metal elements, mainly composed of Sr, has not improved due to the change in the mean, and thus needs to be studied.

Table 1 Changes in parameters related to frequency distribution (log-normal distribution) of transport rate in R/B with the increase in data

Parameters	Volatile elements	Alkali earth metal elements	Lanthanide and actinide elements
Mean (μ)			
Variance (σ)			

(5) Establishment of characterization method

- ③ Study on the representativeness of analysis data (3/4) -

- Inventory is calculated using a contamination model based on waste information, analysis data, and progression of events after the accident. Here, the representativeness of the analysis data is studied by evaluating the probability density based on Bayesian statistics. The contamination model will applied based on the figure on the next slide as before.

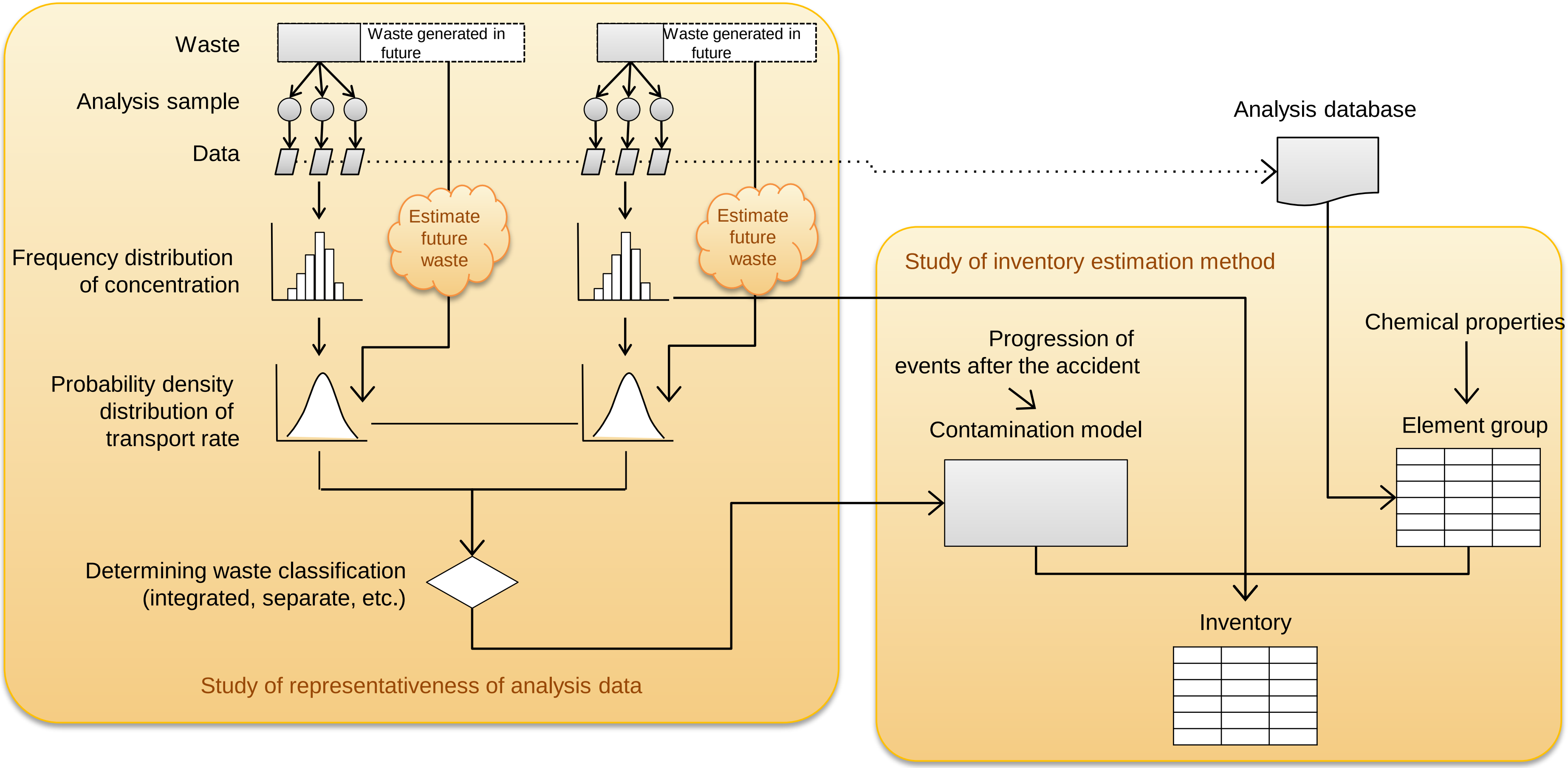


Figure 1 Conceptual flow of estimating waste inventory based on analysis data

(5) Establishment of characterization method

- ③ Study on the representativeness of analysis data (4/4) -

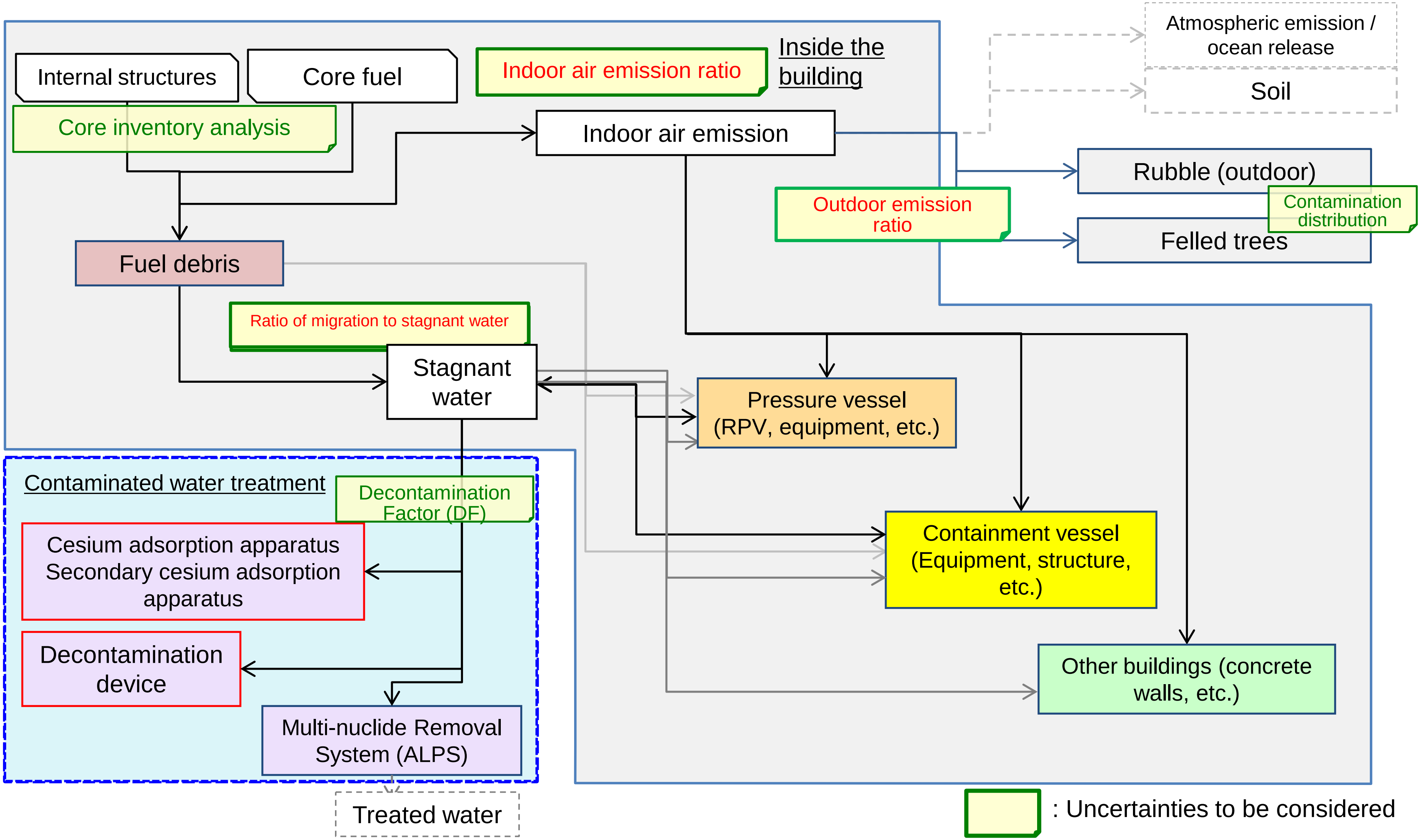
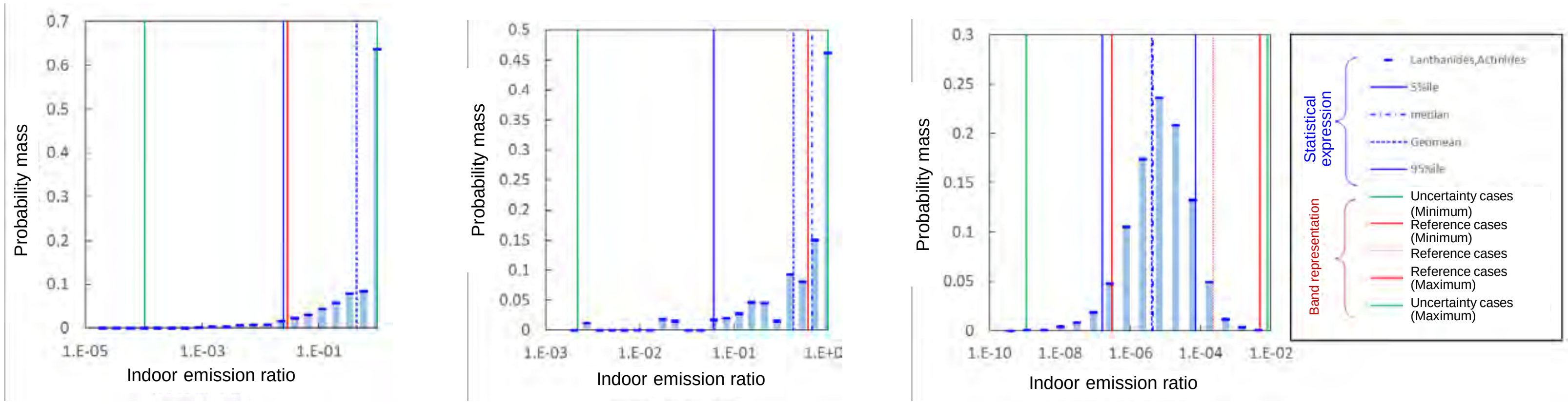


Figure 1 Contamination model to estimate waste inventory (Flow of material)

(5) Establishment of characterization method
- ④ Accuracy improvement of analytical evaluation methods -

FY	Implementation plan	Goal achievement index
2017 2018	• Methods necessary to improve the accuracy of inventory evaluation are studied based on the results of the studies on classification of waste (composition of radionuclides that characterizes waste), contamination mechanism of radionuclides, and representativeness of analysis data.	• Indicate the measures for improving analytical evaluation accuracy.
2017	• An environment for the analytical evaluation is established which incorporates methods required for the improvement of inventory evaluation accuracy (including calculation tools).	• Preparation of analytical evaluation tools.

- Using the classification of radionuclides specified on the basis of the analysis data and the parameters of log-normal distribution obtained based on Bayesian statistics, a method for obtaining the nuclide migration ratio was studied with the help of Monte Carlo calculation.
- The nuclide migration ratio could be expressed in terms of probability density distribution. By using this method, it is possible to obtain the activity inventory of various wastes and evaluate their certainty.



Volatile nuclides

Alkali metal nuclides

Lanthanide and actinide nuclides

Figure 1. Nuclide migration ratio obtained with the help of Monte Carlo calculations based on Bayesian statistics (expressed in terms of probability density distribution)

(5) Establishment of characterization method
– ⑤ Summary of comprehensive inventory evaluation –

FY	Implementation plan	Goal achievement index
2018	• The waste inventory used in the study of waste management is evaluated and set up using the environment and data prepared in the previous section. At the same time, the uncertainties in the obtained results are studied in consideration of the uncertainties in the analysis data and the analysis method.	• Presentation of estimated waste inventory.
2018	• The environment (including calculation tools) is improved and a manual created so that the evaluation method developed in the previous section can be easily re-evaluated.	• Presentation of procedures for inventory estimation.

- Activity inventory of various wastes was estimated using a model incorporating Bayesian statistics and calculation tools were developed. (Figure 1, Figure 2).

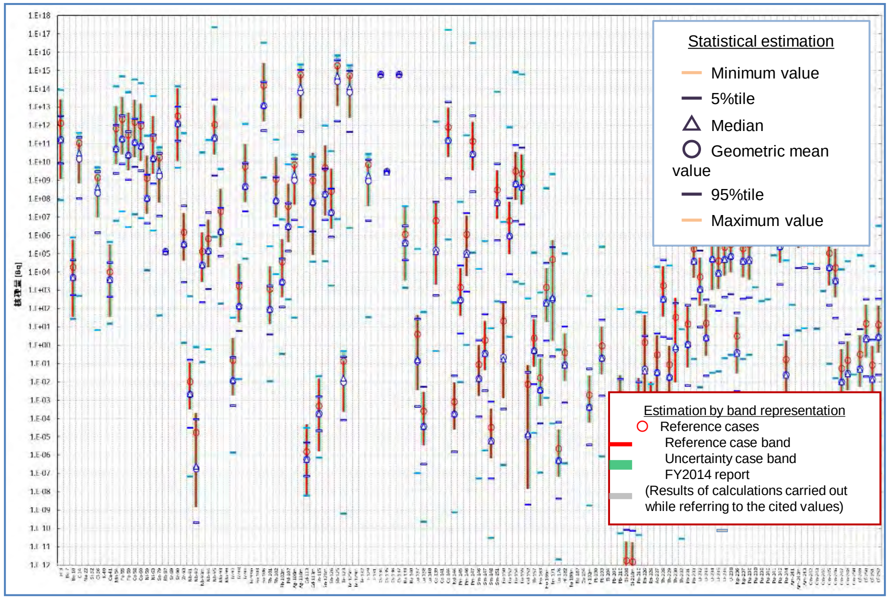


Figure 1. Statistically obtained inventory (Example of low dose rubble)

対象シート　：建屋内放出割合(2018) (J) (検出), 建屋内放出割合(2018) (J) (検出) (外れ値除去), 建屋内放出割合(2018) (A) (検出), 建屋内放出割合(2018) (A) (検出) (外れ値除去)

作業：

① 輸送比の対数の頻度分布の標準偏差を設定する。黄色ハッチのセルの値を、有効数字3桁で手入力して、黄色ハッチ右の数値(計算値と分析データの差の二乗の総和)が最小となる値を求める

② グラフ縦軸の設定値を適宜調整。めやすは145行目で計算できる。

Figure 2. Calculation tool developed on the basis of spreadsheet software

(5) Establishment of characterization method
– ⑥ Study of data collection methods to improve accuracy –

FY	Implementation plan	Goal achievement index
2017 2018	• Necessary data is collected based on the knowledge accumulated through studies.	• Collection of data that contributes to accuracy improvement.

- The sampling of zeolite, which is one of the secondary wastes generated from contaminated water treatment, is difficult due to high radiation. In order to improve the accuracy of indirect inventory estimation, distribution behavior of difficult-to-measure nuclides was investigated.
- Distribution data was obtained for the condition of the presence of competing cations (Figure 1) and the dependence on pH (Figure 2).
- In addition, data on Th with stable tetravalence like Pu was collected, and the competition between Eu and Cs with stable trivalence like Am and Cm was studied.

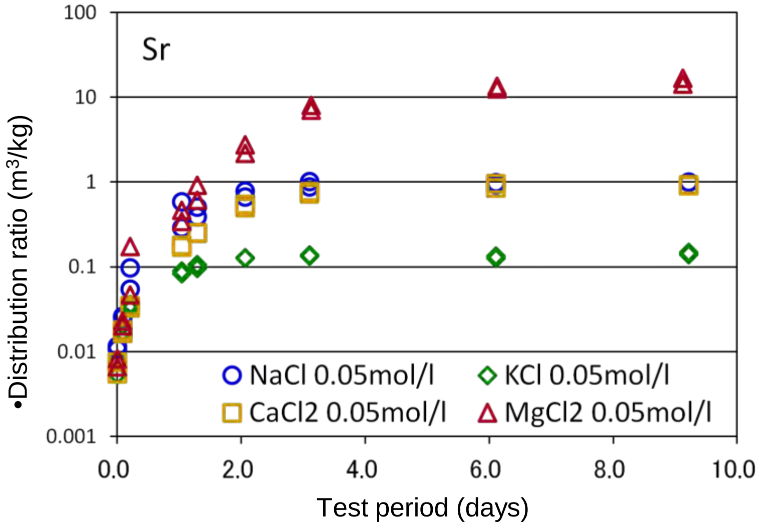


Figure 1. Temporal change in distribution ratio of Sr to zeolite

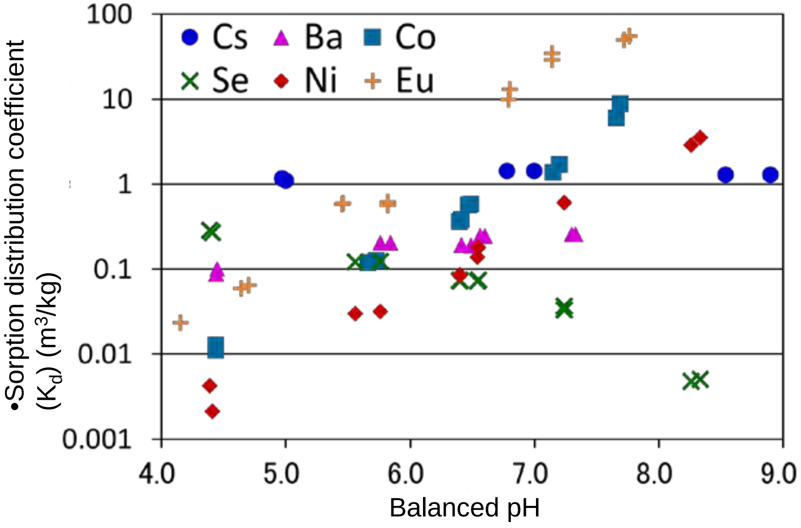


Figure 2. pH dependence of distribution coefficients of various elements

Re-selection of nuclides for analysis

[Reference: FY2017 results]

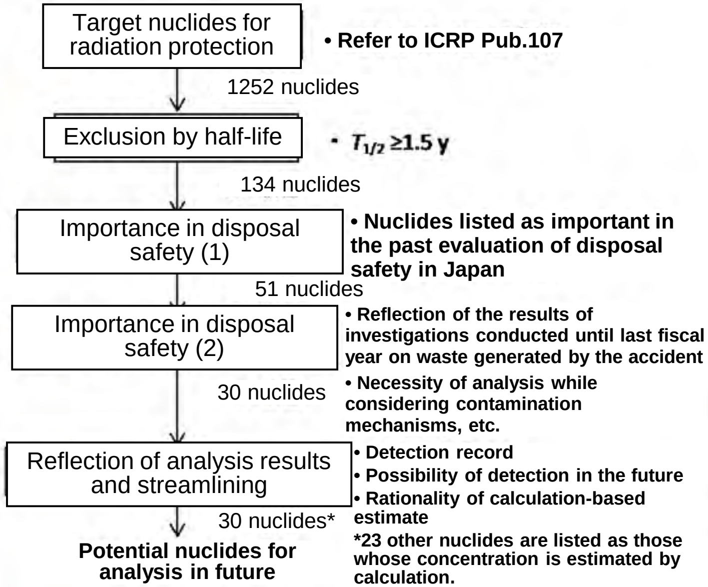
☐ ☐ The analysis of difficult-to-measure nuclides needs to be streamlined because it requires more resources (manpower, facilities, and time) than that for measuring typical nuclides. The list of nuclides to be analyzed was reviewed based on the accumulated analysis data to date and contamination behaviors (element groups) that were inferred from the analysis data.

☐ The concentration of some nuclides that weren't detected in the past (Table 1) can be estimated by the fuel consumption based-calculation, from the viewpoints of isotope and chemical similarity, not relying on analysis. In addition, the necessity of analysis and calculation was examined by taking into account the importance in disposal safety (Figure 1).

☐ Twenty-three (23) nuclides were listed as those whose concentration would be estimated by calculation, while the number of nuclides to be analyzed was reduced from 38 to 30 (Table 2).

Table 1. List of undetected nuclides

Element	Detected	Not detected
H	3H	
C	14C	
Cl		36Cl
Ca		41Ca
Ni	63Ni	59Ni
Tc	99Tc	135Cs
Cs	137Cs	
Eu	154Eu	152Eu
U	234,235,236,238U	
Np		237Np
Pu	238,239+240 Pu	241,242Pu
Am	241Am	242m,243Am
Cm	24Cm	245,246Cm



Target nuclides for radiation protection

• Refer to ICRP Pub.107

1252 nuclides

Exclusion by half-life

• $T_{1/2} \geq 1.5$ y

134 nuclides

Importance in disposal safety (1)

• Nuclides listed as important in the past evaluation of disposal safety in Japan

51 nuclides

Importance in disposal safety (2)

• Reflection of the results of investigations conducted until last fiscal year on waste generated by the accident

• Necessity of analysis while considering contamination mechanisms, etc.

30 nuclides

Reflection of analysis results and streamlining

• Detection record

• Possibility of detection in the future

• Rationality of calculation-based estimate

30 nuclides*

Potential nuclides for analysis in future

***23 other nuclides are listed as those whose concentration is estimated by calculation.**

Figure 1. Procedure to select nuclides to be analyzed considering the importance of safety in disposal

Table 2. Target nuclides for analysis and calculation

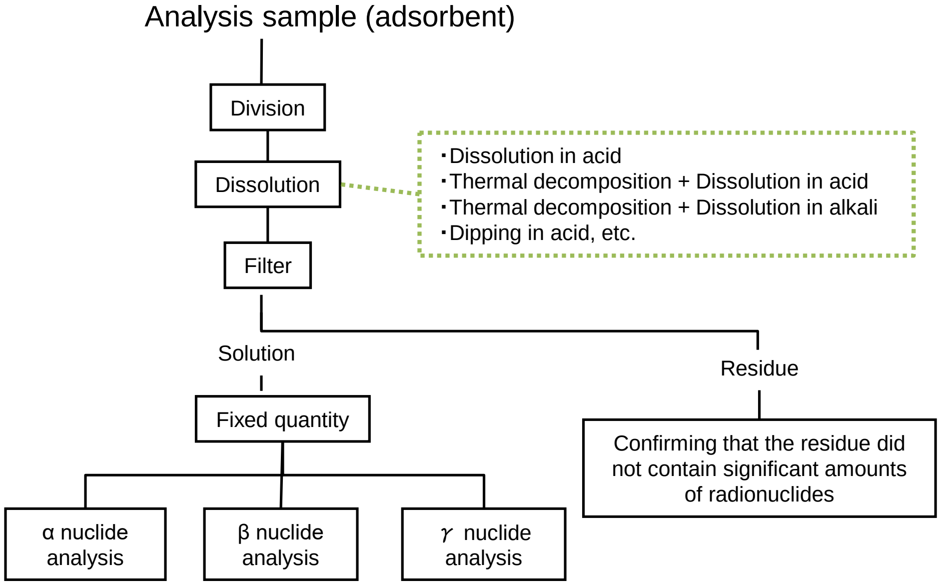
Element	Nuclides to be analyzed	Nuclide subject to calculation
H	3	
C	14	
Cl	36	
Ca	41	
Co	60	
Ni	63	59
Se	79	
Sr	90	
Zr	93	
Nb	94	93m
Mo	93	
Tc	99	
Ru	106	
Pd	107	
Ag	108m	
Sn	126	
Sb	125	
I	129	
Cs	137	135
Sm		151
Eu	154	152
Pb		210
Po		210
Ra		226, 228
Ac		227
Th		228, 229, 230, 232
Pa		231, 233
U	234, 235, 236, 238	233
Np	237	
Pu	238, 239, 240	241, 242
Am	241	242m, 243
Cm	244	245, 246
Number of nuclides	30	23

(6) Simplification and Speeding-up of Analysis Methods

– ① Study of more efficient and reasonable analysis methods –

FY	Implementation plan	Goal achievement index
2017	• Analysis methods that can be improved the efficiency and accelerated, are identified based on the analysis plan.	• Listing analysis methods to be streamlined and improved in efficiency
2018	• Applications of technologies expected to contribute to streamlining and improvement in efficiency, are studied.	• Presentation of the application scope of the listed analysis methods

- During the analysis of adsorbents, although the analysis sample was melted for pre-treatment (Figure 1), generation of residue was a problem (Figure 2). Since volatile ^{129}I, ^{106}Ru, etc. volatilize and are lost during the process of melting, it is necessary to determine the percentage of loss and make corrections accordingly by adding a standard material for quantification, but the process is complex as the conditions of melting vary according to the adsorbent, and need to be established depending on the type of nuclide.
- Quantification was carried out after confirming that the residue did not contain significant amounts of radionuclides, and when the concentration of ^{137}Cs was low, quantification using a solid standard radioactive source was introduced (Figure3). At the time of application, adjustments will be made beforehand so that the volume is equivalent to the standard radioactive source.



Analysis sample (adsorbent)

Division

Dissolution

・Dissolution in acid
・Thermal decomposition + Dissolution in acid
・Thermal decomposition + Dissolution in alkali
・Dipping in acid, etc.

Filter

Solution

Fixed quantity

α nuclide analysis

β nuclide analysis

γ nuclide analysis

Residue

Confirming that the residue did not contain significant amounts of radionuclides

Figure 1. Procedure of destructive analysis method for adsorbents

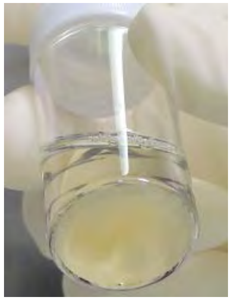


Figure 2. Non-dissolved residues of cerium oxide adsorbent

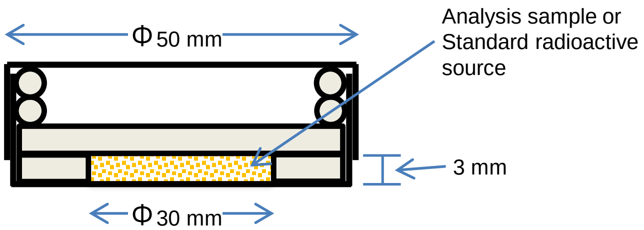
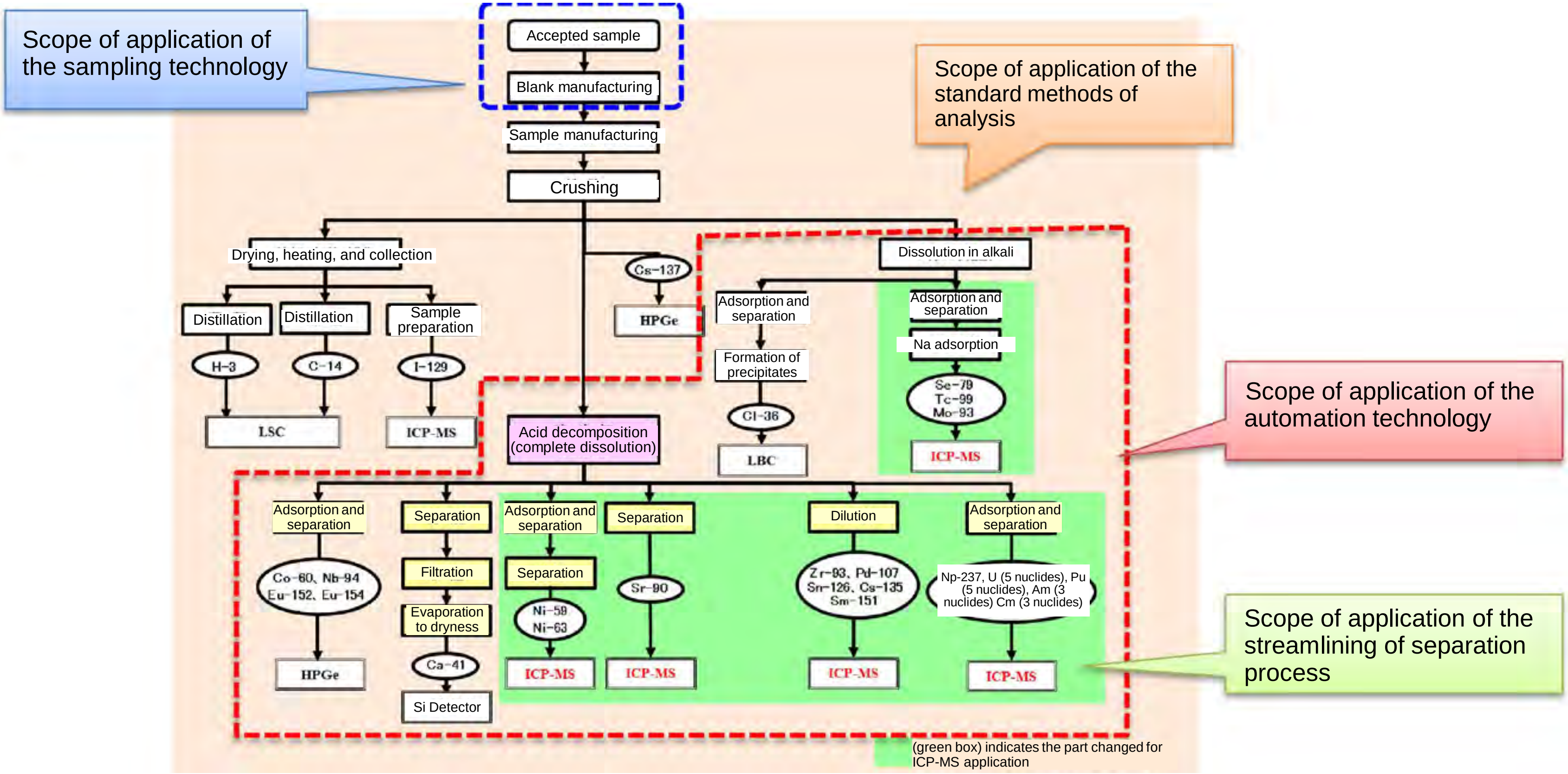


Figure3. Container for non-destructive measurement of solid samples (proposed)

(6) Simplification and Speeding-up of Analysis Methods

② Study of simple and quick analytical methods

☐ The simplification and speeding-up of the current analysis methods was studied with an aim to establish analysis methods that will be used regularly during the analysis of waste generated from the accident (Figure 1).



Scope of application of the sampling technology

Scope of application of the standard methods of analysis

Scope of application of the automation technology

Scope of application of the streamlining of separation process

Accepted sample

Blank manufacturing

Sample manufacturing

Crushing

Drying, heating, and collection

Distillation

H-3

LSC

Distillation

C-14

Sample preparation

I-129

ICP-MS

Cs-137

HPGe

Dissolution in alkali

Adsorption and separation

Formation of precipitates

Cl-36

LBC

Adsorption and separation

Na adsorption

Se-79
Tc-99
Mo-93

ICP-MS

Acid decomposition (complete dissolution)

Adsorption and separation

Co-60、Nb-94
Eu-152、Eu-154

HPGe

Separation

Filtration

Evaporation to dryness

Ca-41

Si Detector

Adsorption and separation

Separation

Ni-59
Ni-63

ICP-MS

Separation

Sr-90

ICP-MS

Dilution

Zr-93、Pd-107
Sn-126、Cs-135
Sm-151

ICP-MS

Adsorption and separation

Np-237, U (5 nuclides), Pu (5 nuclides), Am (3 nuclides) Cm (3 nuclides)

ICP-MS

🟩 (green box) indicates the part changed for ICP-MS application

Figure 1. Subjects of analysis and analysis methods that are to be improved

(6) Simplification and Speeding-up of Analysis Methods

② Study of simple and quick analytical methods

– Development of sampling technology –

FY	Implementation Plan	Goal achievement index
2018	• A sampling method is developed to ensure minimum sample quantities while ensuring the representativeness of the analytical values with respect to the samples, by evaluating the “distribution of the sample surface material” by means of non-destructive analysis. • A study on the prototype of sampling device is conducted.	• Presentation of a proposal for reasonable methods for sampling of analysis samples

- Analysis samples generally have non-uniform contamination, and hence it is necessary to carry out sampling at locations appropriate to the analysis and to carry out data evaluation beforehand. Accordingly, the contamination on the sample surfaces was examined, the methods to identify the sites to be sampled were studied, and the sampling device to be used for collecting samples from the target site was studied as well.
- In order to map the contamination status of the samples, a prototype of the device that can measure the distribution of the γ-ray releasing nuclides on the sample surface, was developed and samples with an embedded 137Cs radioactive source were measured (Figure 1). As a result, it was confirmed that it was possible to measure the differences in the activity concentrations of the sample surfaces as coefficient values, and the viability of the basic device was verified (Table 1). In order to be able to identify the differences between the high concentration parts and the low concentration parts more clearly, in the future, device improvements that would reduce the impact (background) other than on the measured parts, will need to be studied, along with optimizing the design in terms of the positional relationship between the sample and the detector or the size of the collimator, etc.
- Prototyping the sampling device, cutting up any place with an electric drill, and sucking and trapping the sample powder in a filter, helped to gain the insight that it was possible to easily obtain the sample in powder form instead of cutting out the required portion (Figure 2). The applicability to quantitative sampling and remote operations will need to be studied in the future.

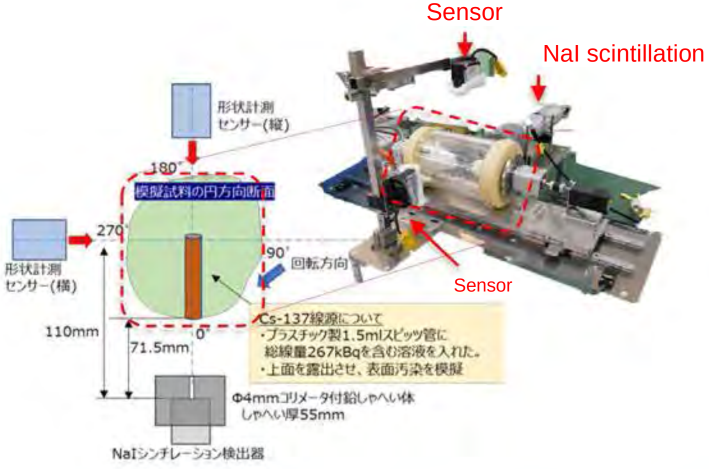
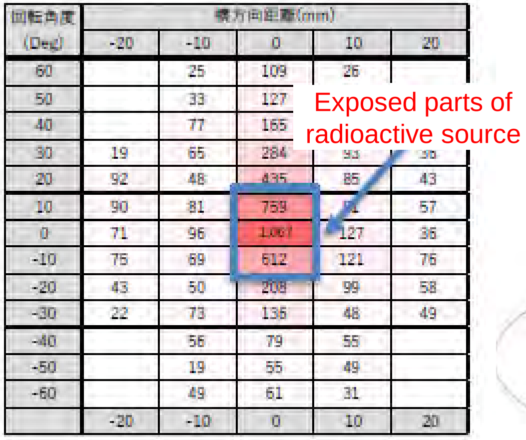


Figure 1. Prototype of mapping device and measurement method of distribution of contamination concentration

Table 1 Results of the measurements of contamination concentrations on the sample surfaces



回転角度 (Deg)	横方向距離(mm)				
	-20	-10	0	10	20
60		25	109	26	
50		33	127	[illegible]	[illegible]
40		77	165	[illegible]	[illegible]
30	19	65	284	93	36
20	92	48	435	85	43
10	90	81	759	[illegible]	57
0	71	96	1,067	127	36
-10	75	69	612	121	76
-20	43	50	208	99	58
-30	22	73	136	48	49
-40		56	79	55	
-50		19	55	49	
-60		49	61	31	
	-20	-10	0	10	20

・Numerical values are coefficients (Measuring time 300 seconds)

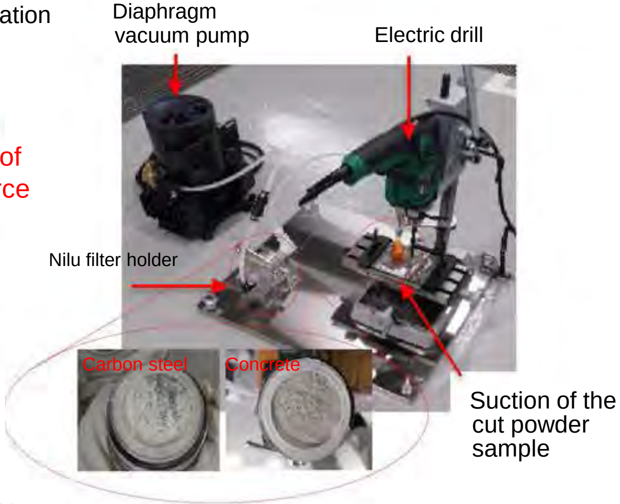


Figure 2. Prototype sampling device

(6) Simplification and Speeding-up of Analysis Methods

② Study of simple and quick analytical methods

– Study on streamlining the separation process –

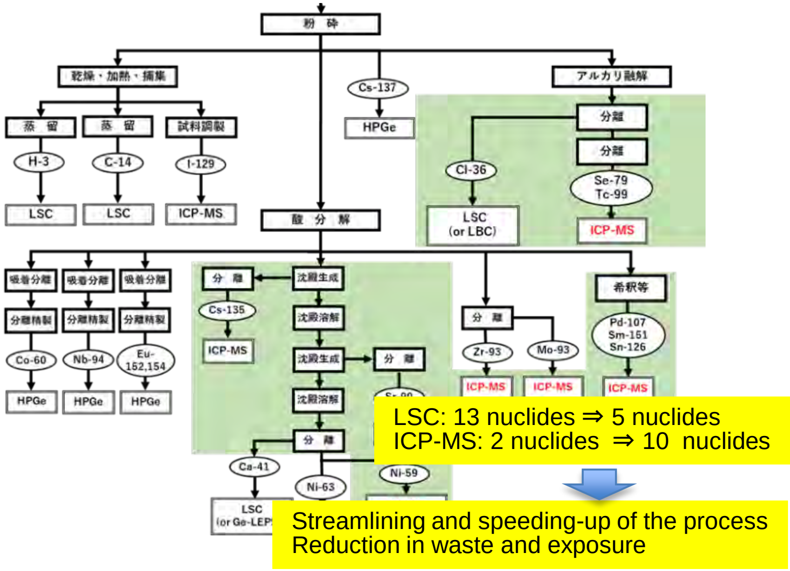
FY	Implementation Plan	Goal achievement index
2018	• The effective separation technologies are studied reflecting the latest findings assuming γ-ray spectrometry or ICP-MS, while examining the current separation technologies. • Measuring devices that do not use radioactive reference materials and their calibration methods are studied.	• Presentation of a list of existing analysis technologies • Presentation of a proposal for streamlined separation technologies • Presentation of a proposal for calibration methods of devices

- Triple Quadrupole ICP-MS (ICP-MS/MS) are able to reduce the impact of nuclides (isobars) with the same mass numbers due to their reaction with gas and are believed to be useful from the point of view of streamlining. Therefore, the latest findings (such as the information related to the lower limits of detection, effective solid-phase extracting agent, and effective reaction gas etc. (Table)) related to analysis using the ICP-MS method, were consolidated. As a result, a separation process with a simplified pre-treatment process could be proposed (Figure).
- It is believed that by means of the ICP-MS method, it is possible to conduct a mass analysis of ^{59}Ni, ^{79}Se, ^{93}Zr, ^{93}Mo, ^{126}Sn ,^{135}Cs, standard samples of which are difficult to obtain. Therefore, it is believed that quantification is possible without using a radioactive reference material by correcting the mass discrimination effects arising from the differences in the mass numbers, as against the analytical values obtained from the analytical curve using a readily available and stable standard isotope sample. In future, it is necessary to demonstrate using samples (simulated samples) that simulate the properties actually being handled.

Table 1.Reaction gases effective in the removal of the impact of isobars during the ICP-MS measurements

Selected nuclides	Isobars	Effective reaction gases	Reactions with the reaction gases
^{59}Ni	^{59}Co	N_2O	Removal by reaction of the isobars
^{79}Se	^{79}Br	O_2	Removal by reaction of the isobars
^{93}Zr	^{93}Nb,^{93}Mo	NH_3	$Zr^+ + 6NH_3 \rightarrow Zr(NH_3)_6^+$
^{93}Mo	^{93}Zr, ^{93}Nb	NH_3	Removal by reaction of the isobars
^{99}Tc	^{99}Ru	(#)	
^{107}Pd	^{107}Ag	NH_3	$Pd^+ + 3NH_3 \rightarrow Zr(NH_3)_3^+$
^{126}Sn	^{126}Te,^{126}Xe	(#)	
^{129}I	^{129}Xe	O_2	Removal by reaction of the isobars
^{135}Cs	^{135}Ba	N_2O	Removal by reaction of the isobars
^{151}Sm	^{151}Eu	NH_3, O_2	$Sm^+ + NH_3 \rightarrow Sm(NH_2)^+ + H$ $Sm^+ + O_2 \rightarrow SmO^+ + O$

It is necessary to conduct a study on effective gases by means of future investigations or testing



LSC: 13 nuclides ⇒ 5 nuclides
ICP-MS: 2 nuclides ⇒ 10 nuclides

Streamlining and speeding-up of the process
Reduction in waste and exposure

Figure 1. Overview of the separation process with the newly introduced ICP-MS method

ICP-MS: Inductively Coupled Plasma Mass Spectroscopy,
LSC: Liquid Scintillation Counter

(6) Simplification and Speeding-up of Analysis Methods

② Study of simple and quick analytical methods

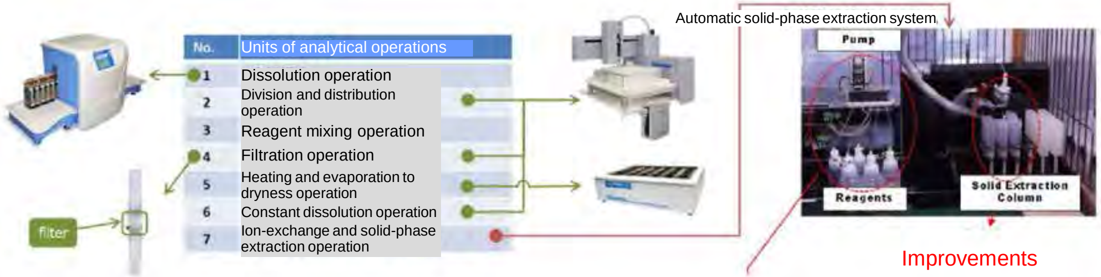
- Development of automation technologies -

FY	Implementation Plan	Goal achievement index
2018	• The existing separation technologies are improved to use automatic solid-phase extraction equipment. • The feasibility of the Ni nuclide separation operation, which is the most complex of the separation operations, is evaluated.	• Presentation of the feasibility assessment results of a series of separation operations concerning Ni nuclides

☐In recent years, the solid-phase extraction method, which has a high separation capability in chemical separation operations, is being used widely as it can be applied to various types of separations by changing the extracting agent or the eluant. However, the separation takes a lot of time and the analyst has to be retained for a long time. Meanwhile, as compared to the conventional solvent extraction method, this method is believed to be comparatively easier to automate as the system uses cartridges. Therefore, automation systems for analytical operations were studied focusing on the automatic solid-phase extraction equipment.

☐A device with the additions shown in Figure 1 was manufactured assuming the use of various aqueous or solid-phase extraction columns.

☐The performance of the prototyped automation system was compared with operations by experts. Assuming the separation of ^{63}Ni, when a series of analytical operations shown in Figure 1 for Ni were carried out, and the recovery rates were compared, it was found that the recovery rate and accuracy were equal, thereby demonstrating the usefulness of the improved device (Table 1). Since the reagent is passed using gravity, in order to further improve accuracy and speed, it is desirable to control the speed of passing liquid.



No.	Units of analytical operations
1	Dissolution operation
2	Division and distribution operation
3	Reagent mixing operation
4	Filtration operation
5	Heating and evaporation to dryness operation
6	Constant dissolution operation
7	Ion-exchange and solid-phase extraction operation

Improvements
The air plug is inserted so that the agents do not mix.

Improvements
Columns of three different sizes can be used.

Figure 1. Composition of automation technology and improved solid-phase extraction equipment

Table 1. Performance evaluation of the automation system

(Comparison of the recovery rates during Ni-63 analysis)

Operation	Ni recovery rate	Standard deviation (Analytical accuracy)
Automated system	**89.8%**	**2.9%**
Skilled analysts	**87.0%**	**2.2%**

(6) Simplification and Speeding-up of Analysis Methods

② Study of simple and quick analytical methods

- Establishment of standard analysis methods -

FY	Implementation Plan	Goal achievement index
2018	The feasibility of analysis technologies is evaluated based on the study on streamlining the analysis process for five β nuclides (36Cl,41Ca,59Ni,63Ni,and 90Sr). • The technologies for ensuring the reliability of the analytical values are studied and consolidated. • The training methods aimed at managing the accuracy of analysis and maintaining the skill levels of the analysts are studied in order to ensure the reliability of the analytical values	• Presentation of the feasibility evaluation results concerning the element separation of the nuclides to be measured • Creation of a draft guideline for site authentication levels to ensure the reliability of the analytical values • Presentation of a proposal for the methods of training & education

•In order to evaluate the feasibility of the proposed separation process, the separation and purification tests of the elements of target nuclides were performed, and the prospect of application to waste analysis was obtained. In addition, generally, in case of β nuclides, complex chemical separation operations are necessary prior to measurement, hence the technologies for training engineers, who will start analysis afresh, were studied from that perspective (Figure 1).

• The training program for the engineers has been improved as much as possible with respect to clarification of matters that cannot be judged simply on the basis of the understanding of the analysis principles (criteria for the success or failure of sample decomposition, etc.) (Figure 2).

•A draft version of the Quality Assurance Guidelines reflecting a system conforming with the ISO9001 Standards and taking into account the rapid validation of the standard analysis method for a wide variety of analysis samples that are characteristic of 1F radioactive waste, was created (Figure3).

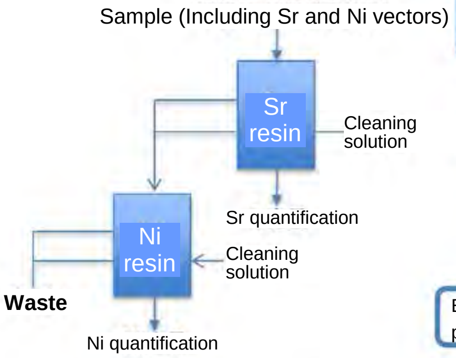
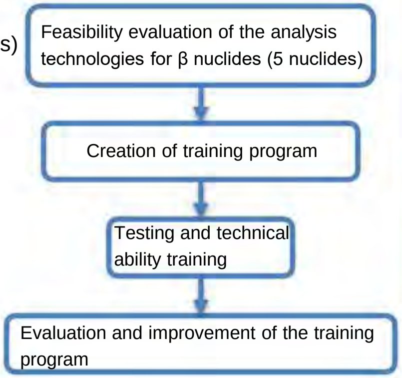


Figure 1. Example of study target (Analysis of Sr, Ni nuclides)



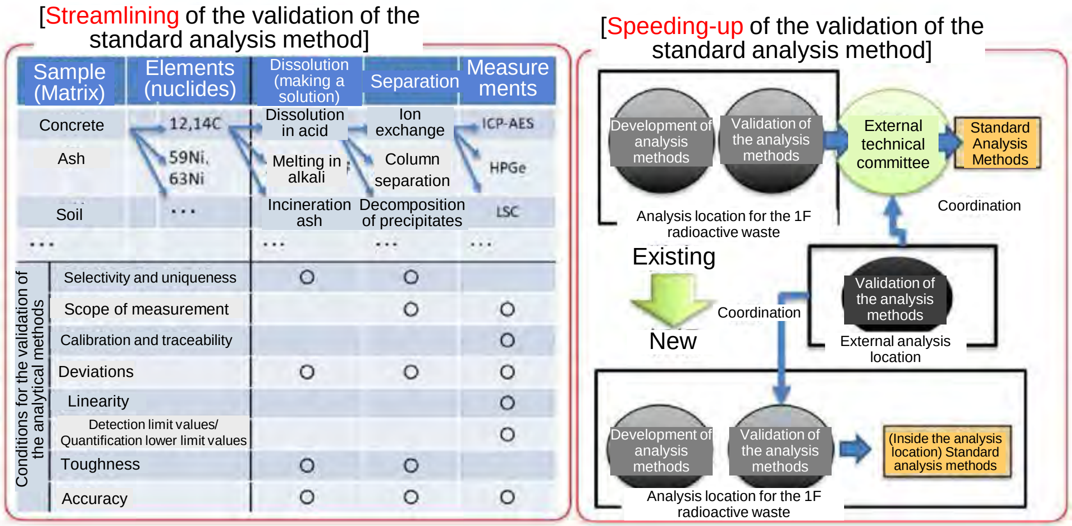
Feasibility evaluation of the analysis technologies for β nuclides (5 nuclides)

Creation of training program

Testing and technical ability training

Evaluation and improvement of the training program

Figure 2. Flow of the study on training methods



[Streamlining of the validation of the standard analysis method]

Conditions for the validation of the analytical methods	Dissolution (making a solution)	Separation	Measure ments
Selectivity and uniqueness	○	○	
Scope of measurement		○	○
Calibration and traceability			○
Deviations	○	○	○
Linearity			○
Detection limit values/ Quantification lower limit values			○
Toughness	○	○	
Accuracy	○	○	○

[Speeding-up of the validation of the standard analysis method]

Figure 3. Approach towards validation of the 1F radioactive waste standard analysis method

Summary of Results and Future Issues

	Summary of Results	Future Issues
(1) Study of analysis plan	• The annual analysis plan was drafted, and transportation and analysis was implemented. • Matters to be addressed in the mid-and-long term were studied in preparation for the next fiscal year.	• Revision of the mid-and-long-term analysis plan.
(2) Sampling and analysis	• The samples from contaminated water and secondary wastes generated from contaminated water treatment, were collected. • The samples were transported from 1F to the analysis facilities three times. • Rubble, contaminated water, secondary wastes generated from contaminated water treatment, and soil were analyzed, the data was accumulated, and offered for the study of treatment and disposal.	• Continuation of sampling of secondary wastes generated from contaminated water treatment. • Securing the analysis samples in view of completion of the Okuma Analysis and Research Center.
(3) Development of sampling technology	• The method of collecting sludge from decontamination systems was studied and executed. The element device for zeolite sampling was manufactured and tested. • The element device for sampling inside the R/B was tested at the actual site.	• Gaining an insight into the zeolite sampling technology.
(4) Analysis data management	• An analysis results database was created and made public. • The waste information being managed by TEPCO was computerized.	• Steady expansion of the database. • Utilization of the waste information.
(5) Establishment of characterization method	• Based on the analysis data, information on the contamination inside R/B, uranium and neptunium contamination, etc. was gathered. • Based on the analysis data, contamination classification and waste classification was specified for the elements. • Bayesian inference was confirmed to be useful as the method for evaluating the representativeness of analysis data and the certainty of inventory estimation. • Analytical evaluation technologies of the inventory were improved and tools were developed.	• Steady creation of a model for contamination mechanism. • An analysis planning method that introduces Bayesian statistics has not been established, and this needs to be studied while planning mid-and-long-term analysis. • Proceeding with the study of contamination behavior in accordance with the accumulation of analysis data, and incorporation of the results of progression of the accident.
(6) Simplification and speeding-up of analysis methods	• The sampling technologies of the analysis samples, analysis by the application of ICP-MS, and automation of the chemical separation operations were studied, and each was confirmed to have good prospects.	• Standardization of the analysis methods in view of the completion of the Okuma Analysis and Research Center.

3. Research on Storage and Management

Contents of Report

(1) Measures for hydrogen gas generation

(2) Measures for wastes generated by fuel debris retrieval

(3) Development of contamination evaluation technology for solid waste segregation

(1) Measures for hydrogen gas generation

- Implementation plan and goal achievement index -

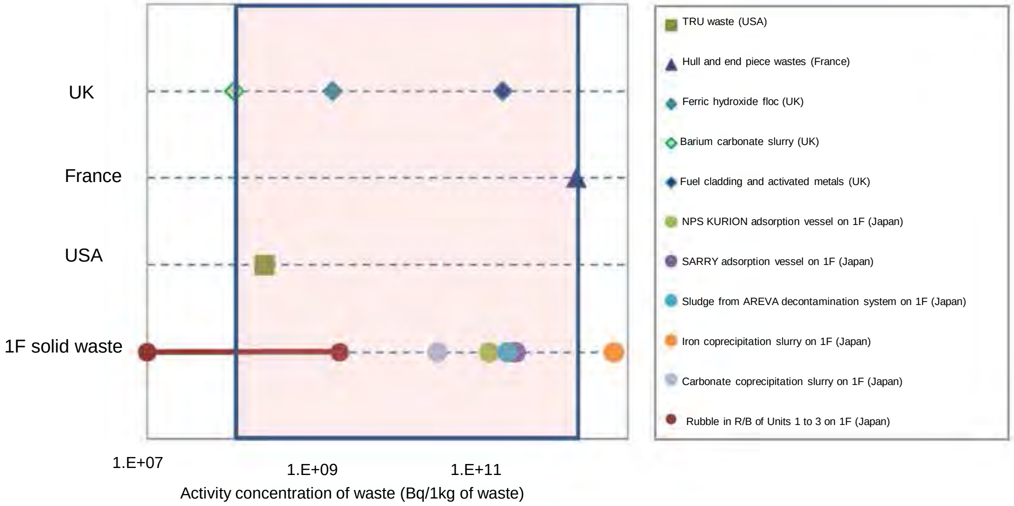
Year	Implementation Plan	Goal achievement index
2017	• Expertise on the method for assessing hydrogen gas generated during the storage of high radiation solid waste containing water, and storage container requirements such as vents, etc. pertaining to the hydrogen gas generated, from Japan and overseas (the UK, the USA, France) are surveyed.	• Presentation of knowledge concerning hydrogen gas generation assessment methods and requirements for the storage container such as vents
2018	• Based on the results of research on hydrogen gas generation conducted in FY2017, which were collected from overseas and Japan, the applicability to 1F is studied to clarify potential issues.	• Presentation of the 1F site applicability and issues

In FY2017, the survey on concepts of generated hydrogen gas, hydrogen gas generation assessment methods, container specifications, and measures for hydrogen gas generation was conducted, focusing on differences with Japan and including reasons for the differences.

[Survey items in FY2017]

1. Survey on concepts of hydrogen gas generation in each country (regulations and technical requirements)
   ☐ Concepts of hydrogen gas generation in each country (regulations and technical requirements) were surveyed with respect to storage, treatment, disposal and transport phases.
2. Survey of evaluation methods for hydrogen gas generation
   ☐ G -value settings and concepts were mainly investigated.
3. Investigation of required functions for a solid waste container
   ☐ Types and materials of containers were broadly investigated focusing on measures for hydrogen gas generation.
4. Measures for hydrogen gas generation
   ☐ Measures for reducing hydrogen gas generation were investigated.

The solid waste with activity concentration closest to that of the solid waste at 1F and which is expected to necessitate hydrogen gas management, was selected from each country.



Activity concentration of 1F waste: From the FY2015 findings of "R&D Project on Solid Waste Treatment and Disposal"

(1) Measures for hydrogen gas generation

- Survey on concepts of hydrogen gas generation in each country (regulations and technical requirements) -

Although there are no specific legal restrictions in foreign countries, the requirements for storage, transportation, and disposal can be met by following the manuals, guidance or the radioactive waste specifications at the disposal sites.

Note that transportation in all countries is regulated by the ‘Regulations for the Safe Transport of Radioactive Material (SS R -6)’ formulated by IAEA.

	USA	UK	France
Storage	Vent mechanism is required for all TRU waste as per the DOE*1 enacted "Radioactive Waste Handling Manual".	There are no specific regulations in the UK laws for hydrogen gas. However, it is possible to deal with the requirements concerning transportation to the disposal sites and disposal by following the radioactive waste specifications or guidance formulated by RWM Ltd.*6. This is systematically executed by using RWM’s evaluation process known as LoC*7.	There are no specific regulations in the French laws for hydrogen gas. However, the French nuclear facilities safety bureau (DSIN) has taken the decision to approve the specifications package presented by CIGEO (deep geological repository)*8. These specifications lay down the requirements which need to be fulfilled for acceptance at the CIGEO disposal site.
Treatment	None in particular (Handled by ventilation and air conditioning in the treatment system)		
Disposal	None in particular (Ventilation prior to closure by means of the ventilation system and no ventilation after closure)		
Transportation	DOT*2 has stipulated regulations similar to the IAEA formulated ‘Regulations for the Safe Transport of Radioactive Material (SS R -6)’. (LSA*3, SCO*4, Type*5A, Type B, Type C etc.) In addition, NRC has made regulations for the Type B transportation containers.	Moreover, The Office for Nuclear Regulation (ONR) exercises control on the basis of the regulations laid down by IAEA.	The L'Autorite de Surete Nucleaire (ASN) exercises control on the basis of the regulations laid down by IAEA.

*1: USA Department of Energy

*2: USA Department of Transportation

*3: Low Specific Activity (indicates low concentrations or that nuclear fuel material is not included) A detailed definition is available in 49CFR173.403.

*4: Surface Contaminated Objects (Objects with contaminated surfaces)

*5: Note the objects are other than those belonging to the radioactive waste classification (Class A, B, C).

*6: Radioactive Waste Management Ltd. (not a regulatory authority but a company that manages geological disposal facilities (GDF disposal sites))

*7: Letter of Compliance (Disposal evaluation process formulated by RWM Ltd.)

*8: Reported in the Code of Environment L542 -12.

(1) Measures for hydrogen gas generation

- Evaluation methods for hydrogen gas generation - Evaluation parameters -

The evaluation formula for hydrogen gas generation is common to the three countries.
In addition, it was confirmed that the hydrogen gas generation speed is assessed using the inventory and G-values.

		USA	UK	France
Evaluation Formula		Speed of hydrogen gas generation = Σi.j Decay heat of nuclide i x G-value of type of radioactive ray j x Absorption efficiency of type of radioactive ray j Decay heat of nuclide i = Σj Inventory of type of radioactive ray i x Release rate of type of radioactive ray j x Released energy of type of radioactive ray j (Red text: Variable values, Black text: Fixed values)		
Parameters	Inventory of type of radioactive ray i	• Verification by document inspection E.g. AK (Acceptable Knowledge) • Sampling measurement depending on the situation • Assessment by maximum concentration in case of non-uniform waste	• Managed through database UKRWI*1 • Sampling measurement depending on the situation • Assessment by maximum concentration in case of non-uniform waste	• Document inspection • Sampling measurement depending on the situation • Assessment by maximum concentration in case of non-uniform waste
	Release rate of type of radioactive ray j	Depends on the contained nuclide	Depends on the contained nuclide	Depends on the contained nuclide
	Released energy of type of radioactive ray j	Depends on the contained nuclide	Depends on the contained nuclide	Depends on the contained nuclide
	Remarks	• The decay heat is assessed with software such as Radcalc*2 • Sampling measurement is used to verify the validity of the range of inventory assessed	• Information such as types of waste, quantity of waste, storage locations, generation history, radioactivity etc. in UK is collectively managed through a database.	・The decay heat is calculated by an authenticated code α ray: CESAR *3 β ray: MCNP*4 γ ray: MCNP*4

*1 UK Radioactive Waste Inventory *2 RadCalc® (LIfeline Software Inc.)
*3 CESAR (Simplified Evolution Code Applied to Reprocessing). Code developed by CEA and COGEMA.
*4 Monte Carlo Neutron and Photon Transport Code System. Transportation calculation code of radiation by the Monte Carlo method.

(1) Measures for hydrogen gas generation

- Evaluation methods for hydrogen gas generation – G-value for evaluation -

The G-value was confirmed to be set according to the radioactive waste classification and the state of water.

		USA	UK	France
G-value (H_2)	Carbonate slurry	・When dry (5 to 20 wt.%): 1.6 ・When cement solidifies: 0.6 to 0.85*1	Established based on discussions with the regulatory authorities (Example of initial settings is 0.4 or 0.45 for free water)	・Free water, cement hydration water: 0.452 (Documented value) ・$Mg(OH)_2$:0.051 (Documented value)
	Iron co - precipitation slurry	Same as above	Same as above	・Free water, Cement hydration water: 0.452 (Documented value) ・Fe(OH), H_2O: 0.00529 (Actually measured value)
	Internal structures	・Adhesive water:1.6 (After drying: 0)	Same as above	・Adhesive water: 0.45
Concept of the G-value (H_2)		• Organized as per the waste properties (presence of organic matter, presence of solidification, moisture content etc.).*2 • Even if the waste does not contain α nuclides, the α ray G-value is conservatively assumed to be the base.	• There are records where the G-value has been set as 0.05 to 0.5 considering the change of state of water due to cement solidification. • Whether to adopt the reference value or the actually measured value is discussed with the regulatory authorities.	• G-value of free water is used even after cement solidification. • A lower G-value can be set when actual measurement is carried out. (0.032 for the DSC dry sludge) • The G-value of waste is calculated from the sum of products of the mass fraction of the generation source and each G-value.

*1 Set according to the solidification conditions (depends on the type of cement material). In the case of Type I (OPC), G-value of 0.6 is used when the ratio of water to cement by weight is 0.45. In the case of Type V (ultrafine grout), G-value of 0.85 is used when the ratio of water to cement by weight is 0.8.

*2 CH -TRU Payload Appendices (Book)

*3 Dry Storage Container

(1) Measures for hydrogen gas generation

- Investigation of required functions for a solid waste container -

During the present investigation, the same containers were being used for storage and disposal in the three countries. Therefore, the storage containers satisfied the requirements of the disposal sites. In addition, sealed containers were used for all transportation.

	USA	UK	France
Storage	In the USA, the containers that store the waste are used until waste disposal. • External dimensions: Various sizes in cylindrical shape (Φ460 x h680[mm] to Φ2080 x h2740[mm]) • Material: Carbon steel, stainless steel, high density polyethylene (HDPE), etc. • The container is filled with various materials other than waste (coagulant, granular or powdered resin, cement shield), and these are considered as waste bodies. Moreover, at the WIPP disposal site, there is a list of certified vent filters[*1] to match the containers.	The requirements (Waste Package Specifications (WPS)) created by RWM Ltd. concerning the safe operations of disposal facilities have been systematized[*2] and have become the standard in the UK. In WPS, requirements other than measures for generated gas, such as those concerning mechanical strength, shielding, thermal performance, and deterioration resistance, etc., account for a large portion. Moreover, the sizes have been decided in detail[*4] in order to enable transportation and geological disposal at GDF[*3].	[CSD -C[*6]] ・External dimensions: Φ430 x h1335 [mm] ・Material: Walls and bottom: Equivalent to SUS316L [DSC] ・External dimensions: about Φ580 x about h1000 [mm] (about 250L) ・Material: Equivalent to SUS316L ・In both the cases, sintered metallic filter[*8] similar to CSD-C is installed in order to maintain the hydrogen gas concentration at less than 4Vol% for 150 years[*7].
Disposal			
Transport	The sealed transportation casks are classified into Type A, LSA (Low Specific Activity) and Type B.	Type B casks are used for the transportation of radioactive waste, and the requirements concerning the management of the generated gas are stipulated[*5].	[CSD -C] Various types of transportation containers manufactured by Transnuclear Ltd., such as TN81, TN843, TN28T etc., have been approved. Moreover, depending on the transportation scenario (1 year at 120℃ under routine conditions and 7 days at 150℃ in case of accident situations), documents are checked to confirm that the hydrogen gas inside the transportation containers is maintained at less than 4vol%.

*1: A minimum hydrogen diffusion factor has been stipulated in CH -TRAMPAC (book) for containers (e.g.: 55 Gallon drum) and the filter is selected from the approved filter list by comparing the performances.

*2: For instance, the "Radioactive waste Specifications" are listed in the WPS/300 series and WPS/300/03 specifies the technical requirements for 500 Liter drums.

*3: Geological Disposal Facility

*4: During transportation, the containers should not exceed the overall dimensions of 6.058 m x 2.438 m x height 2.591 m. In addition, while using railways, it should not exceed width 2.67 m or height 2.40 m.

*5: Maximum internal pressure (7Bar) and cumulative loss etc. (10 -6A2/1h, A2/1W) of radioactivity content during normal times or during accidents, have been stipulated.

*6: Solid container containing end piece wastes and miscellaneous solid waste compressed and sealed in a stainless steel container

*7: Assumed as the tentative operation period at the final disposal site in France.

*8: The PORAL filter model sold by Sintertech has been approved and is being used in both CSD-C and DSC.

(1) Measures for hydrogen gas generation

-Survey of measures for hydrogen gas generation -

In the three countries, the moisture content (free water) is reduced to the extent possible by means of drying and cement solidification, etc. and the generated hydrogen gas is passed through a filter, released from the vent, and managed in the building.

	USA	UK	France
Measures for hydrogen gas generation	・At both the WCS and the WIPP disposal sites, a moisture content of 1vol% or less is acceptable. (Documents are checked at the disposal sites) ・The installation of a vent filter is mandatory. (Although TRU waste was disposed in sealed containers in the past, there are instances where the containers were retrofitted with vent filters thereafter)	・ Ferric hydroxide sludge After cement solidification, the waste surface is capped with grout and then covered with a lid that is designed to diffuse hydrogen through the screw threads. ・Barium carbonate slurry The process is almost similar to the process for the ferric hydroxide sludge. A lid integrated with the filter is installed. ・Mixed legacy waste Intermediate storage in 3 m³ containers (with a double wall to ease the risk of swelling, lined with concrete to prevent corrosion, and with a filter installed on the lid to release the gas) for several decades. ・Plutonium-contaminated material Several super-compacted 200 Liter drums are stored in 500 Liter drums and stuffed with grout. A lid integrated with the filter is installed.	・Moisture content is decreased by drying (CSD -C: Operation results are available for moisture content of 5% or less in the hull and end piece wastes compressed body) Although the execution in case of DSC (sludge waste) is undecided, a drying process wherein the moisture content will reduce to 5% or less is under R&D.

(1) Measures for hydrogen gas generation

-Summary of the FY2017 investigation results -

Hydrogen gas measures based on investigations in this fiscal year are summarized below from the aspect of reduction of free water, use of adequate G-values depending on materials and the type of rays, and storage using containers with vents.
Further, operators in all three countries determined reasonable methods of treatment, storage, and disposal, and coordinated with the regulatory authorities for their approval.

① Reduction of free water

- In the hydrogen gas generation evaluation, all three countries have been considering reduction of free water by drying or cement-solidification of waste, since decomposition of free water is basically pre-dominant.
- The handling of free water and other water (example; cement crystallization water) varied by country.

Example)

U.S and UK: Generated hydrogen is estimated taking into account the decrease or state change of free water by cement solidification

France : G-value of crystallization water was set to estimate the source of hydrogen gas.

② Use of adequate G-values depending on materials and the type of rays

- All three countries classify the G-values for the estimation of the generated hydrogen gas depending on the characteristics of waste (such as water state, the type of organic materials, and the type of radiation)

③ Storage in containers with vent filters

- All three countries stored the waste investigated in this research in containers with vent filters and implemented gas measures such as ventilation in the storage facilities.
- Beside hydrogen gas, public exposure to fission products (H-3, Kr-85, etc.) was also considered.

(1) Measures for hydrogen gas generation

-FY2018 Implementation Details -

In FY2018, the measures for hydrogen gas generation were studied together with the manufacturers from all three countries on the basis of regulations and past results in the three countries during each phase from temporary storage until disposal, in the context of slurry waste and internal structures that form the 1F solid waste. In addition, the applicability to the 1F solid waste and related challenges were organized based on these results.

No.	Selected waste	Reasons
1	Slurry waste (Carbonate slurry and iron co-precipitation slurry in HIC)	The operators are studying dehydration treatment, and measures for hydrogen generation will become very essential during storage after the dehydration treatment. There are similar experiences in all three countries and knowledge can be expected to be obtained.
2	Internal structures	The metallic internal structures were selected as waste expected to be generated at the time of fuel debris retrieval. Waste was assumed to have moisture adhering to the surface. There are similar experiences in all three countries and knowledge can be expected to be obtained.

(1) Measures for hydrogen gas generation

- Results of study on slurry waste by manufacturers from the three countries -

Phase	USA	UK	France
Temporary storage (20 to 40 years)	Stored*2 in containers with vent filters after drying*1	Stored in containers with vent filters or non-sealed tanks after dehydration	Stored in containers with vent filters or large tanks (silo) after dehydration
Treatment	• Cement solidification • Glass solidification *3	• Cement solidification • Glass solidification*3	• Drying*4 • Cement solidification
Predisposal storage (about 100 years)	• Similar to temporary storage (However over packing is recommended to prevent leakage into the environment)	• Similar to temporary storage	• Similar to temporary storage
Disposal	• Disposal in the containers with vent filter ✓ In case of near surface disposal: No special ✓ hydrogen measures are taken*5 ✓ In case of geological disposal: During operations, the concentration of hydrogen is kept below the combustible limit by means of the ventilation system	• Disposal with the waste retained in the containers with vent filter • During operations, the concentration of hydrogen is kept below the combustible limit by means of the ventilation system	• Disposal in the containers with vent filter

*1 For instance, the moisture content is dried to up to 5 to 20% with the horizontal thin-film-concentrator. However, this is mainly for volume reduction.

*2 In the USA, after the waste is generated, it is promptly transported to the disposal site. As per Generic Letter 81-38 and NRC Info Notice 90-09, the regulatory authorities require that storage should in principle not exceed five years.

*3 Hydrogen measures are found to be unnecessary in the case of glass solidification.

*4 In France, the method of drying with a thin-film dryer and then compressing with a pressing machine is being researched. The drying tests were performed on various types of sludges and it was confirmed that the moisture content became 1 to 5% in all cases.

*5 The generated hydrogen gas diffuses in the covering soil or in the synthetic liner and is released into the environment.

The slurry waste is stored in containers with vent filters from the time of temporary storage until disposal.

(1) Measures for hydrogen gas generation

- Results of study on internal structures by manufacturers from the three countries -

Phases		USA	UK	France
Temporary storage (20 to 40 years)	Containers with vent filters	Scavenging by ventilation system or outdoor storage (However, in the US, the structures retrieved from the reactor are immediately dismantled and put in to the final disposal containers)	Scavenging by ventilation system [Results] Yes Proven track record regardless of the presence of cement solidification	Scavenging by ventilation system
	Sealed containers	Drying treatment [Results] Yes (GTCC*1, use of sealed casks similar to those used for spent fuel)	Drying treatment [Results] No	Drying treatment [Results] No
Treatment	Common	There is no special treatment for the measures against hydrogen gas generation (severing, etc.)		
Predisposal storage (About 100 years)	Containers with vent filters	Similar to temporary storage	Similar to temporary storage	Similar to temporary storage
	Sealed containers	Similar to temporary storage	Similar to temporary storage	Similar to temporary storage
Disposal	Containers with vent filters	[Results] Yes If structure is Class C or lower, near surface disposal is carried out, and there are no measures against hydrogen gas generation (released by diffusion)	[Results] No The disposal site is at the design stage	The structure must meet the disposal site acceptance standards (10[(NL/y/container]) by drying
	Sealed containers	[Results] No When classified as GTCC*1, the structures are placed in sealed containers and geological disposal is carried out. E.g.: Yucca Mountain (safety evaluation is underway)	[Results] No (However, can be disposed in sealed containers as long as the waste is sufficiently dry and is not cement solidified.)	[Results] No (However, can be disposed in sealed containers as long as the waste is sufficiently dry and is not cement solidified.)

*1 Waste Greater than Class C. Dried waste is stored in sealed casks and kept outdoors for dry storage.

Internal structures are generally managed in containers with vent filters,

but dry treatment is necessary when the structures must be managed in sealed containers.

(1) Measures for hydrogen gas generation

- Summary of the results of studies by manufacturers from the three countries -

[Slurry waste]

- As seen from the results of the three countries, the accumulation of hydrogen gas inside the containers was suppressed below the explosion limit by storing the waste in containers with vent filters from the time of temporary storage until disposal.
- Certified vent filters are being used. (examples of USA and France).

[Internal structures]

- The need for dry treatment is determined depending on the requirements of the disposal site.

✓ Cases when dry treatment is carried out:

⇒ For instance, when there is a requirement for storage in sealed containers or when the volume of hydrogen generation permitted at the disposal site is low etc.

[Common]

- The vent filter was selected by evaluating the hydrogen generation speed based on the set G-value.
- During the storage facility or disposal site operations, the hydrogen gas was scavenged using the ventilation system.

In all three countries, the containers with vent filters were used in general from the time of storage until disposal.

(1) Measures for hydrogen gas generation

- Challenges in application to 1F -

<Containers with vent filters>

① Performance requirements for vent filters and establishment of methods for securing their performance

- The vent filter is required to release the gases including hydrogen without releasing the solid waste from the container during a stipulated period, and these performance requirements need to be formulated.
- Establishing methods to secure performance requirements, including those related to lifetime and corrosion.

<Measures for hydrogen gas generation during storage>

① Development of drying methods and control values

- Formulating the control values for moisture content, drying methods to satisfy these control values, and methods to verify the control values.

② Setting of G-values according to waste classification

- Formulating the methods for setting G-values and waste classification and carrying out a reasonable evaluation of hydrogen gas generation.

③ Feedback to the ventilation systems of the storage facilities

- Providing feedback on the hydrogen gas generation speed to the ventilation systems of the storage facilities.

<Measures for hydrogen gas generation during disposal>

① Feedback for safety evaluation at the disposal sites

Evaluating the impact of using containers with vent filters for post-closure safety evaluation

(2) Measures for wastes generated by fuel debris retrieval (1/8)

FY	Implementation Plan	Goal achievement index
2017	• The latest information on wastes generated by fuel debris retrieval work is collected and organized based on study results from other projects conducted for fuel debris retrieval (such as the project of fuel debris retrieval, and containment, transport and storage of fuel debris). The proposed waste storage and management methods are studied based on collected and organized information.	• Presentation of the latest information of projected wastes generated by fuel debris retrieval work based on study results from other projects conducted for fuel debris retrieval (such as the fuel debris retrieval project and the containment, transport and storage project).
2018	• The latest information is collected and organized in cooperation with other projects conducted for fuel debris retrieval (such as the fuel debris retrieval project, and the containment, transport and storage project). All proposed reasonable methods to store and manage wastes generated by fuel debris retrieval work are consolidated and the recommendable methods will be presented taking into account the fuel debris retrieval process as well as the collected and organized information.	• Consolidation of all proposed reasonable methods to store and manage wastes generated by fuel debris retrieval work and presentation of recommendable methods taking into account fuel debris retrieval process as well as the collected and organized information.

■ Progress status

○ The waste generated by fuel debris retrieval was classified into four categories and the waste information, such as the estimated generation volume, the estimated dose etc. was consolidated.

○ A safety functions requirements list stating the safety functions required at various steps until storage, was compiled for the internal structures, and multiple, feasible storage and management flows were created.

○ Based on the storage and management flow, a study was conducted on the proposed functional requirements of containers and storage buildings.

○ Based on the functional requirements of containers and storage buildings, the proposed outline specifications were studied.

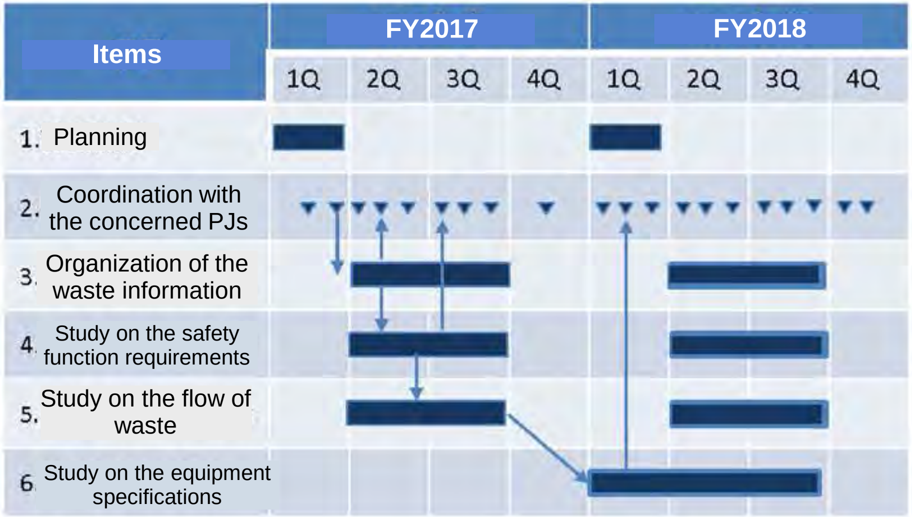


Figure 1 Implementation Schedule

(2) Measures for wastes generated by fuel debris retrieval (2/8)

<Organization of waste information>

- The waste generated before and during fuel debris retrieval was classified into four categories and the waste information generated by fuel debris retrieval was organized. (Table 1)

Table 1. Types of waste generated by fuel debris retrieval

Classification of generated waste	Generated waste	Estimated generation volume (Per reactor)	Estimated dose
Objects removed from 1FL refueling floor	Equipment, piping, walls, floors, pillars etc.	3700 t	3E+11Bq/t or less (Presumed to be equivalent to L3 to L2)
Internal structures	Shield plug PCV head RPV insulator RPV head Steam dryer separator, etc.	・Top debris retrieval: 670 t ・Side debris retrieval: 67 t	3.4E+12~1E+16Bq/t (Presumed to include L1 equivalence)
Retrieval equipment	Drill manipulator camera, etc.	TBD (Depends on the retrieval method)	Presumed to be equivalent to L3 to L1
Air-conditioning and water treatment system waste	HEPA filter Water treatment filter Waste adsorbent, etc.	About 170 t/year	Presumed to be equivalent to L3 to L1

It is assumed that the conventional storage and management methods can be applied. In the future, the applicability will be verified by investigating the properties of the waste.

Waste that requires high radiation waste measures

Events that must be taken into account and the main countermeasures

・External exposure → Shield
・Internal exposure → Confinement
・Hydrogen measures → Venting etc.
・Heat measures → Air cooling
(・Criticality Control)*

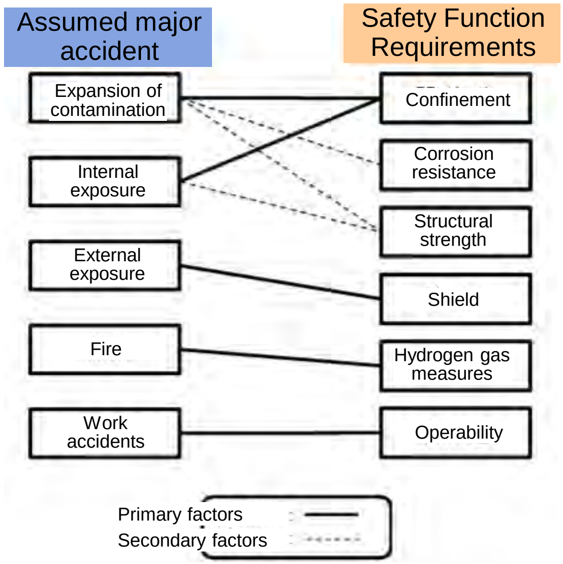
*It is assumed that objects that need criticality control are stored in canisters.

(2) Measures for wastes generated by fuel debris retrieval (3/8)

<Organization of waste information>

“Safety Function Requirements List”

The risks and the safety function requirements at each work step were studied assuming major accidents.



Clarification of safety functions required at individual work steps (during collection, transfer and storage)

Risks and safety function requirements "During transport" from the Safety Function Requirements List

	Major accident	Assumed reference cases	Risks		Countermeasures (examples)
During transport	Spread of contamination	・Transportation container falls due to which it gets damaged and contents leak out.	High	・If contamination spreads within the premises, the impact is huge.	・To ensure structural strength such that the transportation container does not get damaged if it falls.
	Internal exposure	・Workers exposed to radiation due to inhalation when the α nuclides leak out from a container.	High	・The possibility of internal exposure is high when dust containing α nuclides leaks out.	・To ensure the confinement performance of the transportation container.
	External exposure	・Worker close to the transportation container directly impacted and exposed to radiation.	High	・The possibility of external exposure is high when the ransportation container does not have the appropriate shielding ability.	・To ensure shielding by means of the shield thickness of the transportation container. ・To carry out unmanned transportation if the surface dose is high.
	Fire	・Hydrogen gas permeates inside the transportation container and ignites.	High	・The hydrogen concentration might rise if moisture and α nuclides are present inside the sealed container.	・To manage the time such that the hydrogen concentration stays below the lower limit of explosion.
	Work accidents	・Worker injured due to the falling of a transportation container.	Low	・Carries the same level of work risk as the usual freight transportation.	・To carry out fall prevention measures for the transportation container.

The most important problem is the study of methods compatible with the following

- ・Prevention of nuclide dispersion (ensuring sealability)
- ・Release of hydrogen gas (ensuring permeability)

Conflicting safety function requirements

Study of specific measures

(2) Measures for wastes generated by fuel debris retrieval (4/8)

<Existing technological investigations>

☐ An investigation of past reference cases concerning the processes from transportation to storage of nuclear fuel, fuel debris and internal structures was carried out.

☐ Although there are examples of temporary wet storage, in most cases, the final stage is dry storage. In the case of wet storage at 1F, securing the pools or the operation of the water treatment system poses a challenge.

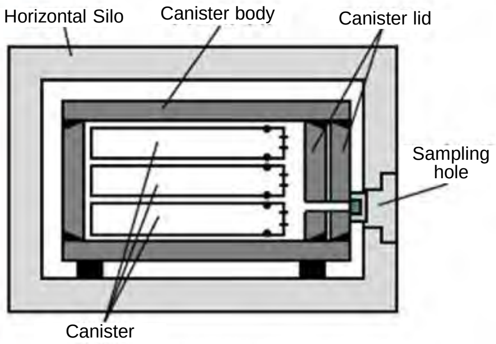
☐ In the case of dry storage, containers with filter vents or dry treated + sealed containers are used as hydrogen measures. (Table 1)

☐ IAEA recommends the use of containers with vents as a hydrogen measure.*1

☐ There are cases where the waste containing nuclear fuel material is stored in containers with vents. Especially, at TMI-2, containers with vents have been used for dry storage when complete dryness could not be confirmed due to uncertain debris properties.

Table 1. Hydrogen measures during storage

No.	Storage Methods	Hydrogen measures	Main application examples	Challenges in 1F application
1	Drying / no venting	Completely dried + sealed storage container	Zion (USA)	･Development of complete drying technology and equipment scale and time associated with drying
2	Drying / venting	Exhaust by means of filter vent	・TMI-2 (USA)	・Development of filter vent which prevents dispersion of nuclides and prevents hydrogen retention
3	Wet storage/no venting	Submersion + Open storage container	Replacement of 1F shroud	･Contamination of the pool due to nuclear fuel material ･Securing the pool and water treatment system are necessary
4	Wet storage / venting	Vent piping/Compensator	･Paks-2 (Hungary)	･Vent structure is necessary to prevent the contamination of the pool water ・Securing the pool and the water treatment system is necessary



Dry storage (Horizontal Silo)
1999 onwards: Start of dry storage

Schematic diagram of TMI-2 fuel debris dry storage

(Reference: Subsidy Project of Decommissioning and Contaminated Water Management in the FY2015 Supplementary Budgets, Development of Technology for Collection, Transfer and Storage of Fuel Debris)

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*1.IAEA, *Containers for Packing of Solid Low and Intermediate Level Radioactive Waste*, IAEA Technical Reports Series No.355, 1993.

(2) Measures for wastes generated by fuel debris retrieval (5/8)

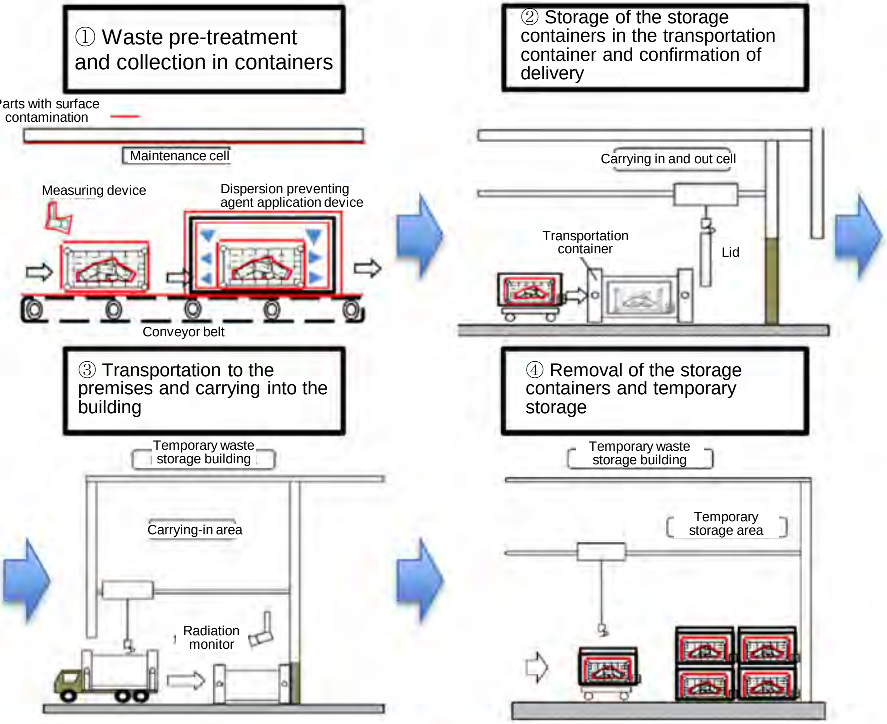
<Study on the storage and management flow>

☐ Based on the study results of the safety function requirements, storage and management flow charts that can meet the safety function requirements at each step (① to ④) were created. (Figure 1)

☐ The basic policy is to use storage containers with vents and during transportation, the storage containers will be loaded with sealed transportation containers.

<Study on equipment specifications>

☐ Based on the created storage and management flows, a study on the functional requirements of the containers and storage buildings was conducted. (Table 1)



① Waste pre-treatment and collection in containers

② Storage of the storage containers in the transportation container and confirmation of delivery

③ Transportation to the premises and carrying into the building

④ Removal of the storage containers and temporary storage

Figure 1. Example of storage and management procedure of highly radioactive internal structures (Overview)

Table 1. Example of the safety function requirements for the waste storage containers (Overview)

Items	Requirement specifications
Shape	To be decided after considering the equipment weight limitations, etc.
Material quality	Corrosion-resistant material
Confinement function	Should have the confinement function
Shielding	Should have shielding functions that meet the acceptance criteria of the storehouse
Hydrogen measures	Should have the filter vent function
Operability	Should be easy and safe to handle
Structural strength	Should have the structural strength to bear stacking, fall

(2) Measures for wastes generated by fuel debris retrieval (6/8)

<Study on equipment specifications>

☐Waste storage container (Concept of a lightweight container)

・Dimensions are set so that the maximum shielding container does not exceed the forklift weight limit (7.5 t) when collecting waste.

・ Four shielding thicknesses are available depending on the dose level of the waste.

・Shielding thickness is set such that the surface dose is less than 10 Sv/h when collecting waste with maximum dose at each dose level.

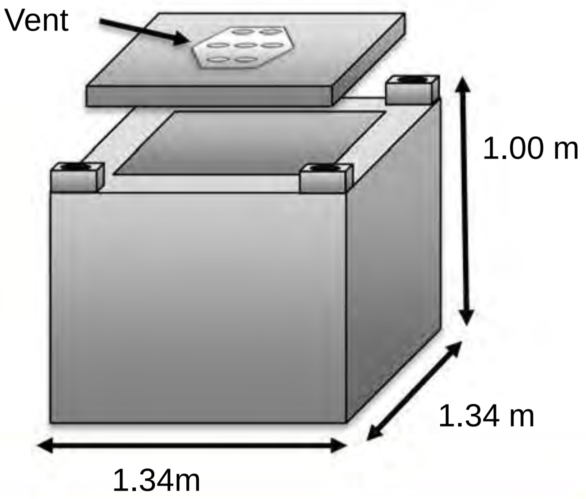


Table 1. Estimated weight and required number of lightweight containers

Shielding thickness (lining)	Weight of container (t)	Internal volume (m³)	Dose of contents (Sv/h)	Total weight (t) (Container + waste)	Estimated necessary nos. (For 3 reactors)
180 mm	7.1	0.33	400 to 1000	7.3	About 40
140 mm	6.0	0.46	40 to 400	6.4	About 400
60 mm	3.2	0.77	10 to 30	3.8	About 300
0 mm	0.35	1.19	<10	1.3	About1300

<Reference> Other ideas for storage containers

1. Present dimensions and size of the 1F waste container: 2.1 x 2.1 x 1.49m
・Shielding thickness: 0, 60, 140, 180 mm
・Maximum total weight: 23.7 t
・Containers with vents

2. Type and size of L1 disposal container : 1.6 x 1.6 x 1.6m
・Shielding thickness: 50, 100, 150, 200 mm
・Maximum total weight: 20.3 t
・Sealed container

(2) Measures for wastes generated by fuel debris retrieval (7/8)

<Estimated volume of waste generated during debris retrieval and the required scale of storage facilities (Total for 3 reactors)>

Classification of generated waste	Estimated generation volume (for 3 reactors)	Estimated dose	Storage containers	Required number of containers	Estimated dose limits for the storage buildings	Total floor space required for storage buildings
Objects removed from 1FL refueling floor	11100 t	Equivalent to L3 to L2	Present waste containers (No shielding) (ILW containers for some portion of the high radiation dose piping, etc.)	4200 units	Less than 30 mSv/h [*1]	14000 m^2 or more[*3]
Internal structures	2010 t	Equivalent to L1	Lightweight containers	Shielding thickness / units 180 mm / 40 units 140 mm / 400 units 60 mm / 300 units 0 mm / 1300 units	Less than 10 Sv/h [*2]	3100 m^2 or more[*3]
Retrieval equipment	TBD	Equivalent to L2 to L1	Lightweight containers	-	Less than 10 Sv/h[*2]	-
Air-conditioning and water treatment system waste	510 t/year	Equivalent to L3 to L1	Light-weight containers (Some filters etc. may be treated as debris)	-	Less than 10 Sv/h[*2]	-

*1: Equivalent to the basement first floor of the solid radioactive waste storage facility No. 9.

*2: Equivalent to the basement second floor of the solid radioactive waste storage facility No. 9.

*3: The bottom area x 1.5, rounded up to two significant digits, when the required numbers of each container are placed in a two-tier stack without gaps.

*4 : It is assumed that the solid waste containers used at 1F presently are used for the low radiation waste.

a. Study of safety measures required for the storage of highly radioactive waste (b) Measures for wastes generated by fuel debris retrieval (8/8)

<Summary of Results>

① Based on the study of other projects on fuel debris retrieval, the waste generated by retrieval of fuel debris was classified into four categories and the latest information was consolidated.

② Taking the consolidated waste information and fuel debris retrieval methods into account, the methods to safely collect, transfer and store the internal structures were studied and a proposal for the flow of processes until the point of storage was presented.

③ Based on the proposal for the flow of processes until the point of storage, the functional requirements of storage containers were consolidated and examples of storage containers that satisfy the functional requirements were presented.

<Challenges>

① It is estimated that as the study on fuel debris retrieval methods progresses, the waste information will gradually become more detailed and specific. The information must continue to be consolidated in the future as well.

② It has become apparent from the consolidated waste information that waste is generated by the retrieval equipment and the air conditioning and the water treatment systems, and it is necessary to study the methods to safely collect, transfer and store this waste.

③ The hydrogen gas measures need to be put into practice (assessment of the amount generated, containers with filter vents, drying facilities) and the functions required of the facilities related to the hydrogen gas measures need to be studied.

④ Consolidation of the management items of waste, and study on the measurement and evaluation methods.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

ーFY2018 Implementation Details -

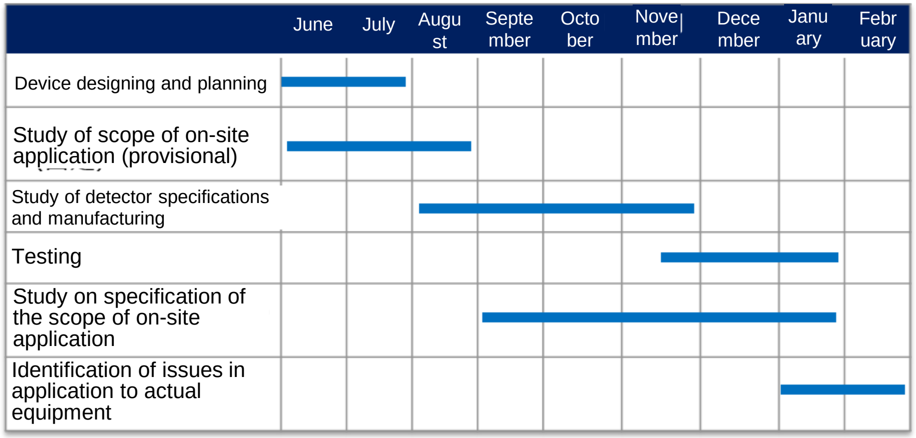
Public invitation details

- Development of technology related to measurement and evaluation methods for surfaces, such as concrete, contaminated (α-contamination) by α-ray releasing radionuclides, and the extent of penetration through such surfaces (depth and volume of penetrated contamination), based on applicability to the site, so that solid waste can be segregated reliably.

Details of implementation in 2018 (Cited from supplementary documents in the public invitation proposal)

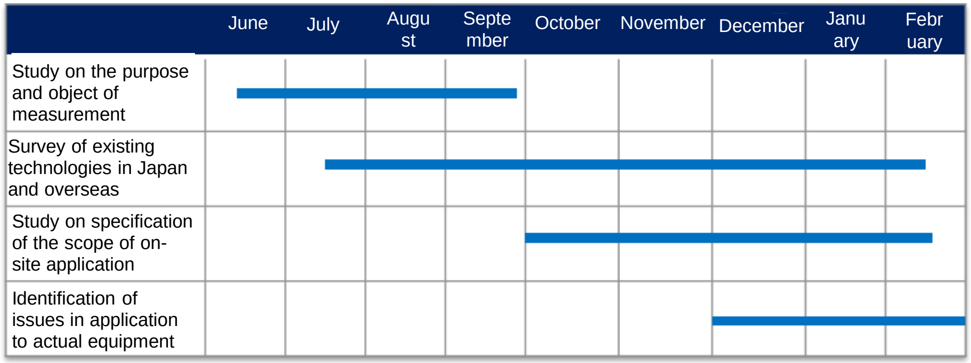
- For the α-contamination of surfaces, a detector will be prototyped for the surface α-contamination measurement device and element tests will be conducted based on the study results of “Research on Technologies for Reducing Waste Production” in the Subsidy Project of Decommissioning and Contaminated Water Management “R&D for Treatment and Disposal of Solid Radioactive Waste” in FY2017. Based on the test results, issues will be identified with respect to the actual application to 1F.
- For the α-contamination penetrating through the surface, the use cases for the technology for measuring the penetration depth of α-nuclides and the penetrated contamination level will be assumed in the procedure from the generation of waste until its disposal. In addition, the technology which can be applied in the assumed cases will be selected and the issues in the actual application of the selected technology will be identified.

Schedule



	June	July	August	September	October	November	December	January	February
Device designing and planning	■	■							
Study of scope of on-site application (provisional)	■	■	■						
Study of detector specifications and manufacturing			■	■	■	■			
Testing						■	■	■	
Study on specification of the scope of on-site application				■	■	■	■	■	
Identification of issues in application to actual equipment								■	■

Study on surface α-contamination



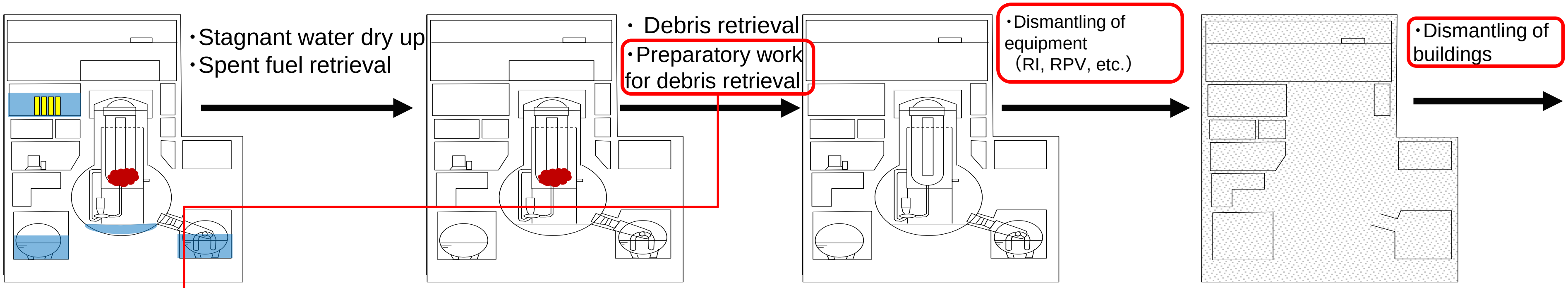
	June	July	August	September	October	November	December	January	February
Study on the purpose and object of measurement	■	■	■	■					
Survey of existing technologies in Japan and overseas		■	■	■	■	■	■	■	■
Study on specification of the scope of on-site application					■	■	■	■	■
Identification of issues in application to actual equipment							■	■	■

Study on penetration of α-contamination

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation
- Study on scope of on-site application -

Waste to be segregated and targets for application of measurement technologies

[Assumed Decommissioning Flow (Example: R/B)]

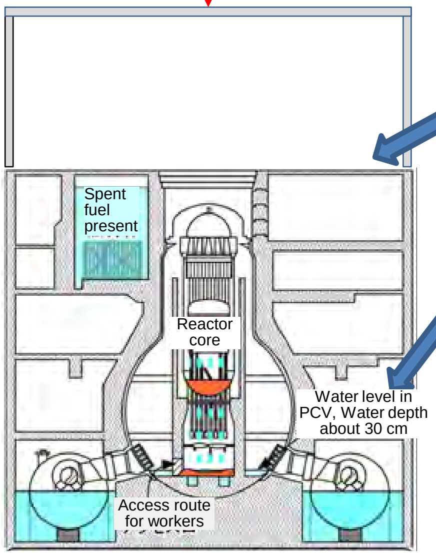


- Stagnant water dry up
- Spent fuel retrieval

- Debris retrieval
- Preparatory work for debris retrieval

- Dismantling of equipment （RI, RPV, etc.）

- Dismantling of buildings



Cross-sectional view of R/B
(Example of Unit 2)

R/B Fifth Floor (Refueling floor)
Top retrieval of fuel debris and the area where its preparatory work is carried out

R/B First Floor
Side retrieval of fuel debris and the area where its preparatory work is carried out

In the area mentioned above, the concrete and metal lining in the PCV penetration parts, and inspection equipment used for the investigation inside PCV, etc. is assumed to be the waste that gets generated.

Study the segregation of solid waste that will be generated in the future (waste after dismantling reactor and buildings).

Target of surface α-contamination measurement
As the target includes metal and concrete, the waste generated in the preparatory work related to retrieval of fuel debris is assumed as minimum applicable target based on assumed decommissioning flow

Target of penetrated α-contamination measurement
Only concrete is considered as the target, therefore, the waste generated during the dismantlement of building concrete is assumed.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Purpose of this research-

Current status and issues related to α-contamination waste management

□ Current status of α-contamination waste management

When α-nuclide contamination with surface contamination density of 0.4 Bq/cm2 or more is detected by smear measurement, the waste is stored in storage containers.

However, in the future, large quantity of waste will be generated as the decommissioning work gathers momentum. Therefore, considering the measurement time and exposure, it will not be realistic to segregate all the waste by smear measurement after dismantlement.

□ Needs related to waste segregation technology

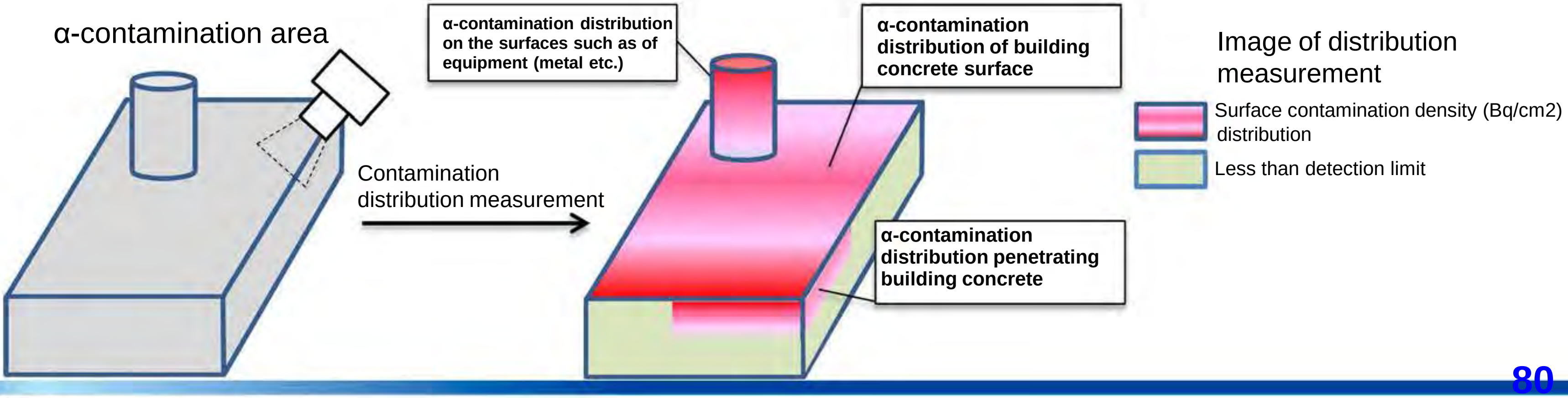
□ To be able to understand the contamination distribution of targets before dismantling the same. (4[#1] Bq/cm2, 40[#2] Bq/cm2 to be set as standards required for the waste segregation technology)

□ To minimize the measurement time and reduce the exposure involved in the measurement work.

#1: Set as a criteria for α-contamination waste equivalent to L3
#2: Criteria for α-contamination waste equivalent to L2

□ Purpose of this research

To develop a technology that can **comprehensively and in a short time** measure items (or area) to be dismantled, before the dismantling operation, considering the measurement environment and accessibility, with respect to applicability of the technology to the site.



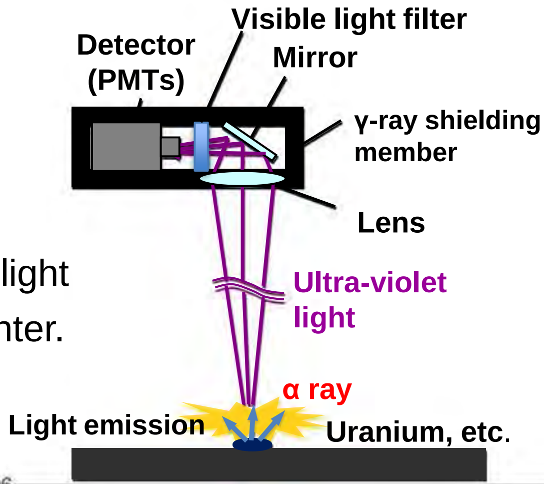
(3) Development of Contamination Evaluation Technology for Solid Waste Segregation
-Study on surface α-contamination-
Overview of the technology selected in FY2017

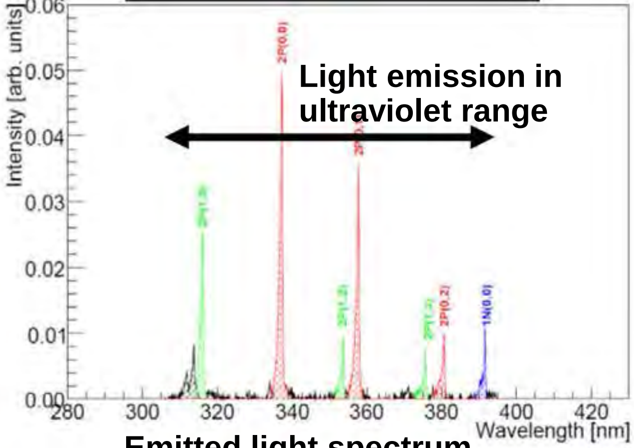
Surface α-contamination measurement technology (hereinafter referred to as "alpha camera") using excitation of nitrogen was selected based on the study results of requirements in light of the accessibility and measurement environment on the site.

Measurement principle

① An α particle reacts with nitrogen in its flying distance (a few centimeters) and generates a few hundred photons of ultra-violet light.

② The strength of α-rays is measured by collecting generated ultra-violet light through a lens and counting the number of photons using a photon counter.





Emitted light spectrum

Cited from J. Sand, Remote Optical Detection of Alfa Radiation. IAEA－CN-184/23.

Example of publication of results related to alpha camera

1. Kume N(2013),"Remote Detector of Alpha-Ray Using Ultraviolet Ray Emitted by Nitrogen in Air",IEEE2013NSS
2. Kume N(2015),"REMOTE DETECTION OF ALPHA RADIATION USING UV PHOTONS EMITTED BY NITROGEN, ICONE-23"
3. Naoto Kume (2013) "Remote Measurement Technology for Alpha Radioactivity", 2013 Spring Meeting of Atomic Energy Society of Japan
4. Naoto Kume (2014) "Remote Measurement Technology for Alpha Radioactivity - Application to Lighting Environment-" 2014 Fall Meeting of Atomic Energy Society of Japan

There was no experience of application of alpha camera on the site, therefore, in FY2018, an element test simulating the 1F measurement environment will be implemented, and issues in application to actual equipment will be identified.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

Existing alpha camera issues with respect to requirement specifications

- Requirement specifications for devices are assumed based on the study results of the measurement environment.
- In order to deal with the issues, ① the alpha camera is improved based on the requirement specifications, and ② the tests (basic performance test, element test) necessary for assessing the detection performance are identified.

	Item	Requirement specifications	Existing alpha camera	Issues	Test items
Accessibility	Measurement Distance	Maximum 3m	Implemented up to 1 m	Assessing device composition that obtains detection performance equivalent to 1 m in the measurement distance of 3 m	Basic performance test: Lens assessment
	Measurement target shape	Spherical surface, uneven, plane surface	Not implemented	Acquiring data dependent on the shape of the contaminated surface	Element test: Complex source assessment
	Weight	Depends upon the trolley	Weight of shielding member not assessed	Designing of shielding member considering the weight loaded on the trolley	Element test: Test related to impact of environmental dose rate
Measurement environment	Environmental dose rate	About 50 mSv/h (Maximum about 150 mSv/h)	Assessed in part	･Prototyping of environment monitor, performance assessment ･Acquiring data related to impact of environmental dose rate, temperature, humidity, ambient light, and dust	
	Environmental temperature	-5℃ to 35℃	Implemented only with a detector		Element test: Temperature test
	Environmental humidity	Maximum100%	Not assessed		Element test: Humidity test
	Lighting	Lighting present depending on the situation	Implemented in part (Red light)		Basic performance test: Optical filter assessment
	Dust	More than outdoor dust	Not assessed		Element test: Test related to impact of dust
	βγ nuclide concentration	α / βγ＝1 / $10^{6\sim8}$*	Assessed in part	･ Acquiring sensitivity data with respect to βγ rays	Element test: Impact assessment test for βγ nuclide concentration

* Set on the basis of results obtained from the characterization in this project

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

FY2018 Implementation Details

① Improvement in alpha camera based on requirement specifications

A) Attained high sensitivity and low noise to obtain detection performance equal to that of the existing alpha camera even in the case of extended measurement distance.

B) Added a function to understand the measurement distance up to the measurement target assuming various shapes, in two dimensions.

C) Reduced weight of moving parts (reviewed the shielding member) so that the device weight takes accessibility into account.

② Assessment of detection performance

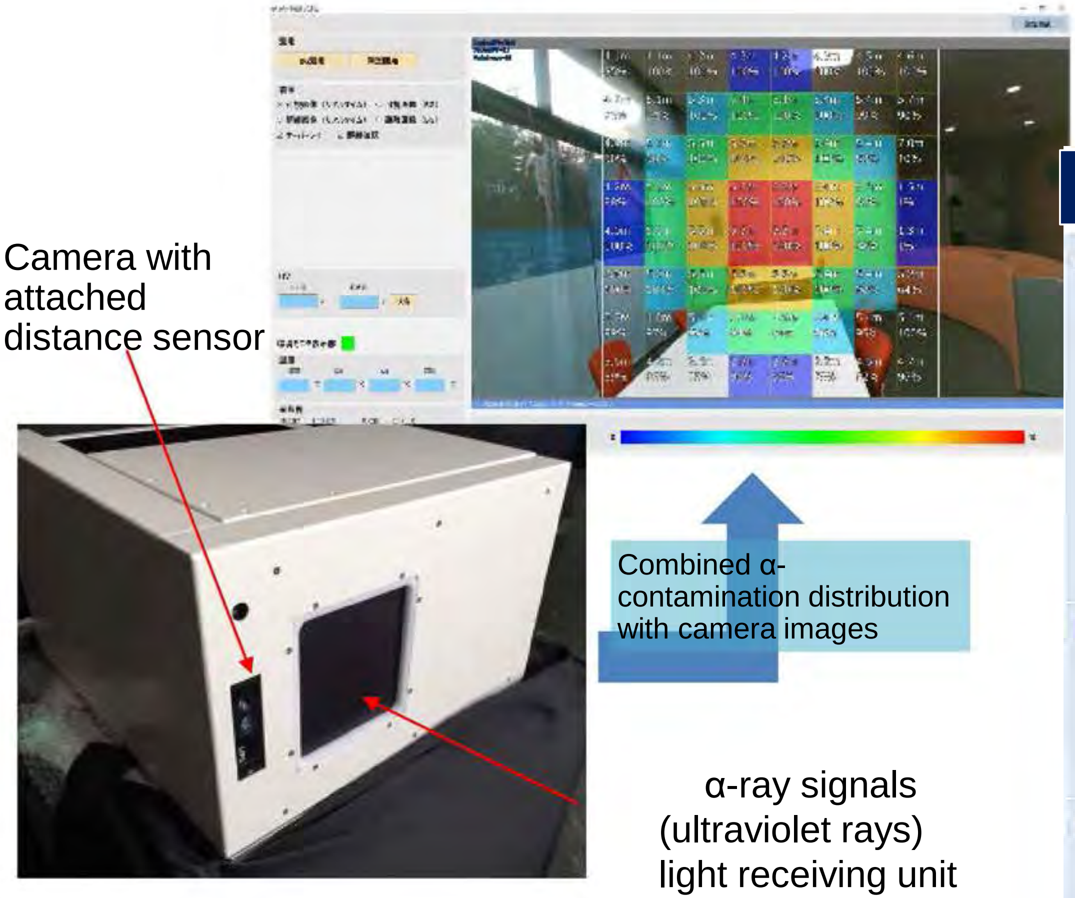
- Basic performance tests were conducted to determine the composition of devices such as optical systems, and element tests were conducted in accordance with environmental conditions to assess the limitations of this method.
- The detection performance was assessed based on the results of element tests and compared with the standards (4 Bq/cm^2, 40 Bq/cm^2) required in waste segregation technology.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

① Improvements in alpha camera based on requirement specifications

- Existing alpha camera was improved based on the requirement specifications arising from accessibility assuming on-site application.



Camera with attached distance sensor

Combined α-contamination distribution with camera images

α-ray signals (ultraviolet rays) light receiving unit

Overview of improved alpha camera

Main points of improvement

	Required functions	Items	Points of improvement
A	• High sensitivity • Low noise	Lower limit of detection 4 Bq/cm2 assuming measurement environment	a) Increase the size of lens ・Lens aperture diameter to be changed from φ50 mm to φ100 mm b) Study on shielding structure ・Tungsten (3 cmt) c) Thermal noise reduction through temperature control function ・Control the temperature so that it is always at 25℃ or less
B	Understand the distance up to the target in two dimension	Measurement of contamination distribution on object surface	Use a camera with attached distance sensor to obtain image and distance information
C	Reduce the weight of moving parts	Accessibility	Separate the power source so that it can be placed on the fixed part of the trolley

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation
-Study on surface α-contamination-

②Assessment of detection function: Overview of basic performance test and element results of the improved alpha camera

	Items	Requirement Specifications	Test Items	Overview of results
Basic performance test	Measurement distance	Maximum 3m	Basic performance test: Lens assessment	• Sensitivity is inversely proportional to the square of the distance • Confirmed a case where the location with no surface α-contamination attained a peak (ghost). • There was a case where 4 Bq/cm2 could be measured by using Φ100mm lens and by extending the measurement time.
	Lighting	Lighting present depending on the situation	Basic performance test: Optical filter assessment	Sensitivity decreases to 78% with the use of optical filter
Element test	Measurement target shape	Spherical surface, uneven, plane surface	Element test: Complex source assessment	• Impact is low if measurement direction (spherical surface) is 0 to 90° • Sensitivity degrades to 71% at the time of measurement of contamination of concave portion with a depth of 25 mm. At a depth of 50 mm, it degrades by 67%.
	Weight	Depends upon the trolley	Element test: Test related to impact of environmental dose rate	Confirmed Y-ray sensitivity of 3.3 [s-1/mSv/h] #Confirmed locations where the shielding effect was weak at some angles of incidence. Improvement required.
	Environmental dose rate	About 50 mSv/h, (Maximum about 150 mSv/h)		
	Environmental temperature	-5℃-35℃	Element test: Temperature test	There is no impact on noise if temperature control mechanism is used.
	Environmental humidity	Maximum 100%	Element test: Humidity test	Even if humidity is 95%, decline in sensitivity is 3% or less. #Sensitivity shows a declining trend if water is added to the source
	Dust	More than outdoor dust	Element test: Test related to impact of dust	Variation in sensitivity even in outdoor environment is 1% or less. Variation in sensitivity is 2% or less even in environments where the double-digit dust density is more common than in outdoor environments
	βγ nuclide concentration	$\alpha/\beta\gamma = 1/10^{6\sim8}$ *	Element test: Impact assessment test for βγ nuclide concentration	Obtained relative sensitivity to α-rays β-ray (Co-60): 0.36% γ-ray (Cs-137): 0.009%

* Set on the basis of results obtained from the characterization in this project

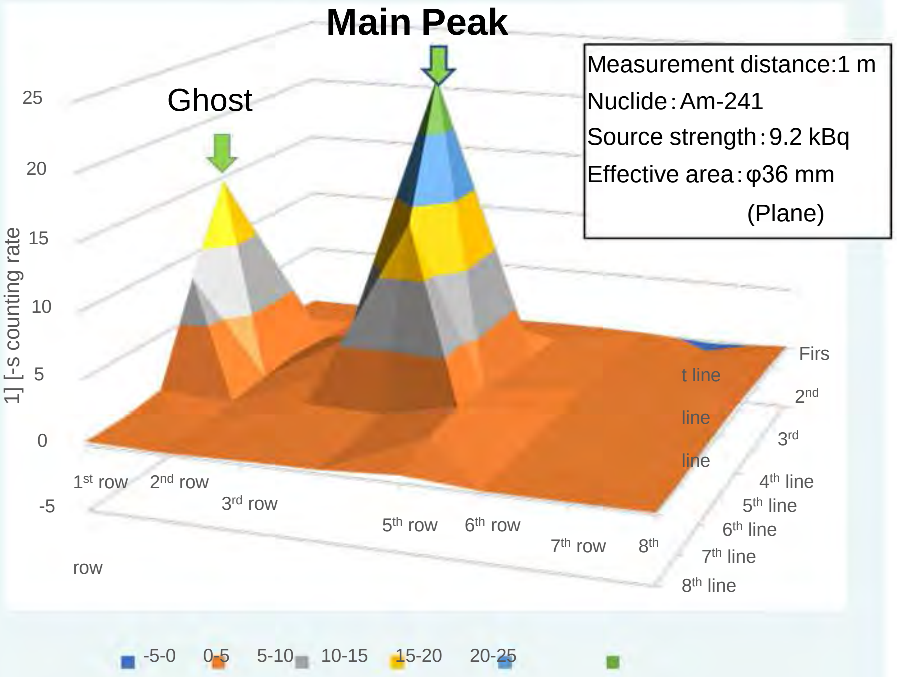
(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

② Assessment of detection performance: Test results (Example)

Basic Performance Test (Lens assessment)

・Confirmed the peak derived from α-rays. However, ghost constantly exists. (It is necessary to investigate the cause in the future.)

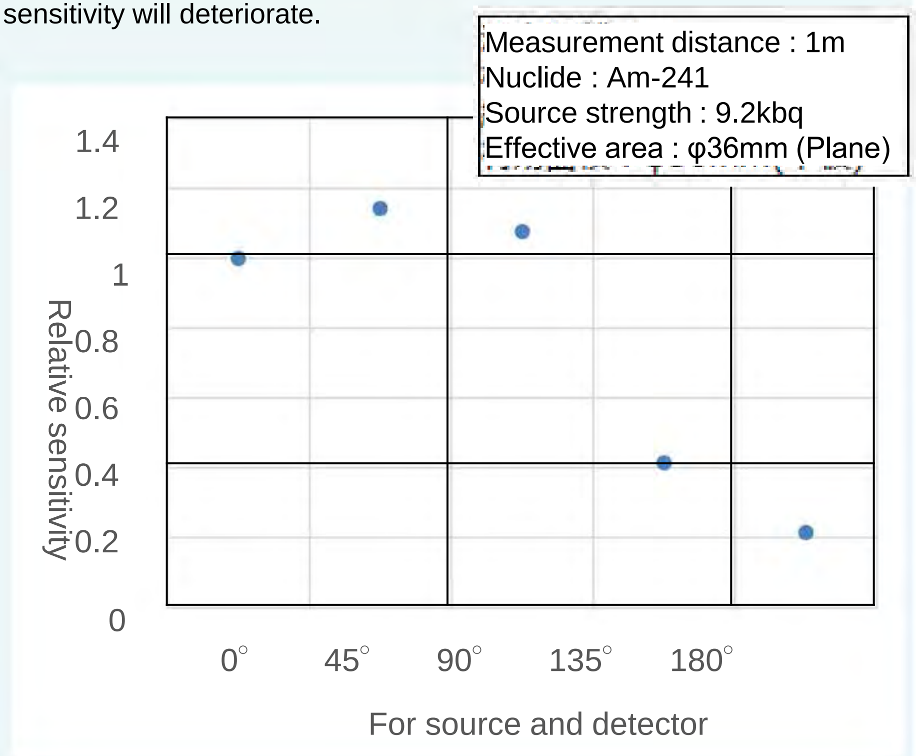


Measurement distance:1 m
Nuclide:Am-241
Source strength:9.2 kBq
Effective area:φ36 mm (Plane)

Distribution when a lens with aperture diameter Φ100 mm and focal distance f45.5 mm is used

Test to confirm the impact of measurement target shape

・Even if measured from 0° (face to face) to 90° (directly horizontal), if the relative angle is more than 90°, the source itself will be shaded and sensitivity will deteriorate.



Measurement distance : 1m
Nuclide : Am-241
Source strength : 9.2kbq
Effective area : φ36mm (Plane)

Dependency on source for measurement sensitivity with respect to α-rays

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

② Assessment of detection performance: Assessment of measurement performance

The lower limit of detection at conditions assumed for on-site application is calculated using the Currie equation.

(The detection sensitivity is assessed anticipating a situation where the dummy peak can be correctly focused.)

☐ **Lower limit of detection**

Calculated from signal S[s-1/(Bq/cm2)]* derived from α-rays, and from another signal N.

*Reference area for calculating the surface contamination density (Bq/cm^2) is 100 cm^2 (10 cm x 10 cm) .

Lower limit of detection X is calculated by the Currie equation

$$X = \frac{\sigma^2 + 2\sigma\sqrt{2N \cdot t}}{S \cdot t}$$

t: Measurement time (s)

σ = 1.65 (95% reliability)

Parameters that influence the detection performance (Temperature, humidity, and dust are not included as they do not affect the performance)

- **Measurement distance**
- **Environmental dose rate at the location where the alpha camera is installed**
- **βγ surface contamination density in the field of vision measured by the alpha camera**

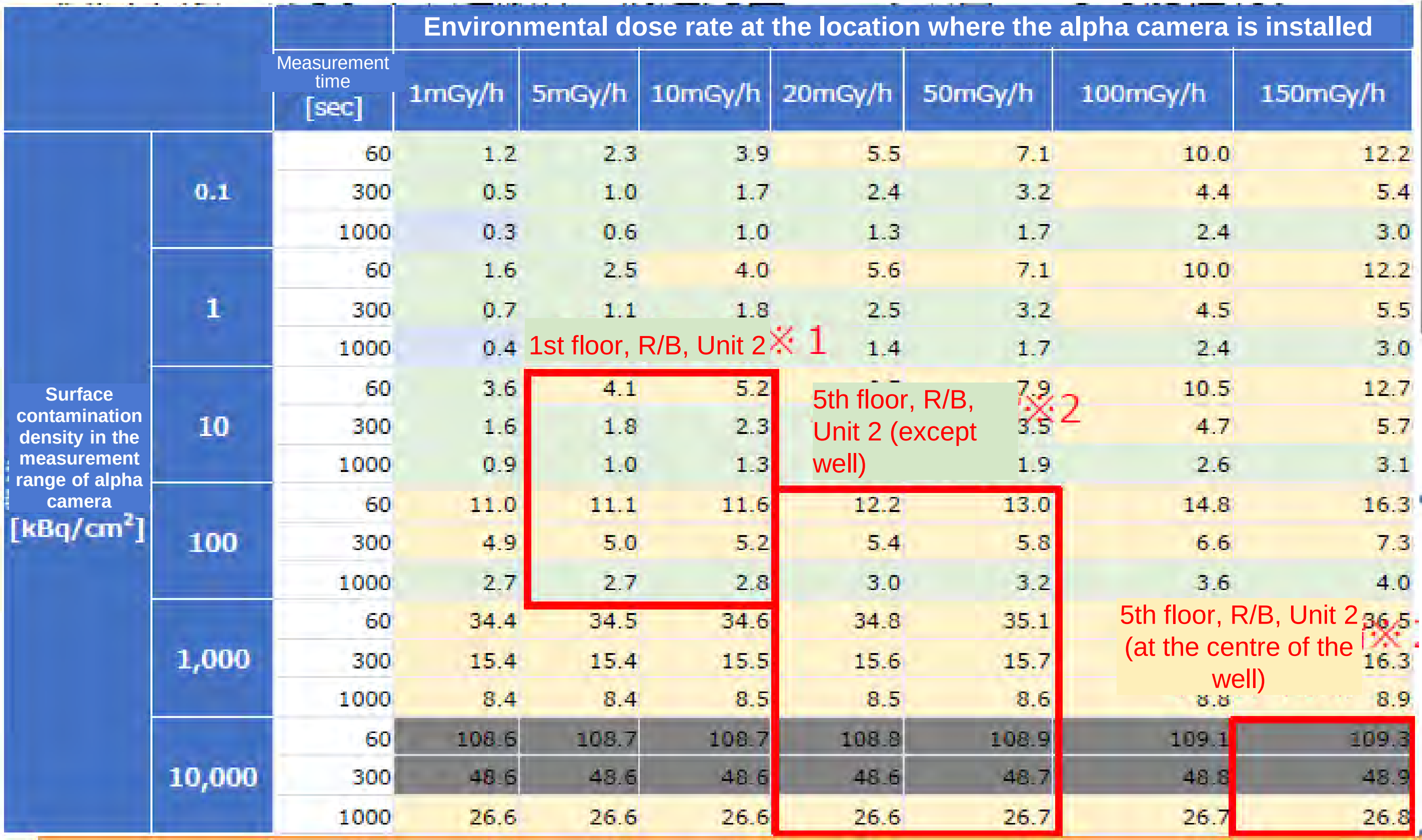
Measurement distance	Assumed environmental dose rate	βγ Surface contamination density	Measurement time	Lower limit of detection
1 m	3 mSv/h	1 kBq/cm2	30 sec	2.6 Bq/cm2
3 m	3 mSv/h	1 kBq/cm2	1000 sec	4 Bq/cm2
0.5 m	15 mSv/h	31 kBq/cm2	1000 sec	0.4 Bq/cm2
1 m	15 mSv/h	31 kBq/cm2	1000 sec	1.8 Bq/cm2
1 m	50 mSv/h	31 kBq/cm2	1000 sec	2.3 Bq/cm2

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

② Assessment of detection performance: Details of performance assessment results

- The lower limit of detection was assessed by fixing the measurement distance at 1m and using the measurement time, environmental dose rate, and surface contamination density as parameters.
- The lower limit of detection may be improved by reviewing the optical system and the structure of shielding member.



Surface contamination density in the measurement range of alpha camera [kBq/cm²]		Measurement time [sec]	Environmental dose rate at the location where the alpha camera is installed						
			1mGy/h	5mGy/h	10mGy/h	20mGy/h	50mGy/h	100mGy/h	150mGy/h
	0.1	60	1.2	2.3	3.9	5.5	7.1	10.0	12.2
		300	0.5	1.0	1.7	2.4	3.2	4.4	5.4
		1000	0.3	0.6	1.0	1.3	1.7	2.4	3.0
	1	60	1.6	2.5	4.0	5.6	7.1	10.0	12.2
		300	0.7	1.1	1.8	2.5	3.2	4.5	5.5
		1000	0.4	[illegible]	[illegible]	1.4	1.7	2.4	3.0
	10	60	3.6	4.1	5.2	[illegible]	7.9	10.5	12.7
		300	1.6	1.8	2.3	[illegible]	3.5	4.7	5.7
		1000	0.9	1.0	1.3	[illegible]	1.9	2.6	3.1
	100	60	11.0	11.1	11.6	12.2	13.0	14.8	16.3
		300	4.9	5.0	5.2	5.4	5.8	6.6	7.3
		1000	2.7	2.7	2.8	3.0	3.2	3.6	4.0
	1,000	60	34.4	34.5	34.6	34.8	35.1	[illegible]	36.5
		300	15.4	15.4	15.5	15.6	15.7	[illegible]	16.3
		1000	8.4	8.4	8.5	8.5	8.6	8.8	8.9
	10,000	60	108.6	108.7	108.7	108.8	108.9	109.1	109.3
		300	48.6	48.6	48.6	48.6	48.7	48.8	48.9
		1000	26.6	26.6	26.6	26.6	26.7	26.7	26.8

1st floor, R/B, Unit 2※1

5th floor, R/B, Unit 2 (except well)※2

5th floor, R/B, Unit 2 (at the centre of the well)※

Legend: Lower limit of detection

🟦	0.4 Bq/cm² or less
🟩	4 Bq/cm² or less
🟨	40 Bq/cm² or less
⬛	More

There is little variation in the lower limit of detection even if the environmental dose rate increases.

This assessment shows the alpha camera may have applicability in the assumed target range (Unit 2 R/B 1st and 5th floors) when extending the measurement time. In future, improvement of the optical system and the shielding structure will be promoted to improve the lower limit of detection

#1: Cited from "Implementation Report of decontamination inside the ducts at Unit 2 R/B 1st floor, and Progress report of dose reduction at Units 1~3 R/B 1st floor", Tokyo Electric Power Company Holdings, Inc. (2016)

#2: Cited from "Results of survey conducted after moving and clearing remaining objects on the Operating Floor of Unit 2 R/B", Tokyo Electric Power Company Holdings, Inc. (2019)

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on surface α-contamination-

Challenges related to on-site application

<Main body of alpha camera>

1. Improvement of the device using basic data acquired this year (dependency on sensitivity of lens aperture, etc.)
    - Improvement in sensitivity by improving the optical system (lens and filter)
    - Selection of a detector in accordance with the optical system (focal length and aperture of the lens)
2. Improving issues observed in the improved alpha camera
    - Ghost (peak generated in places other than the source location) management
    - Reducing the noise from the direction where the shielding effect is low
3. Assessment of distribution measurement performance (resolution) when measuring α-ray source of complex shapes
4. Implementation and assessment of correction methods for measurement distance and environment

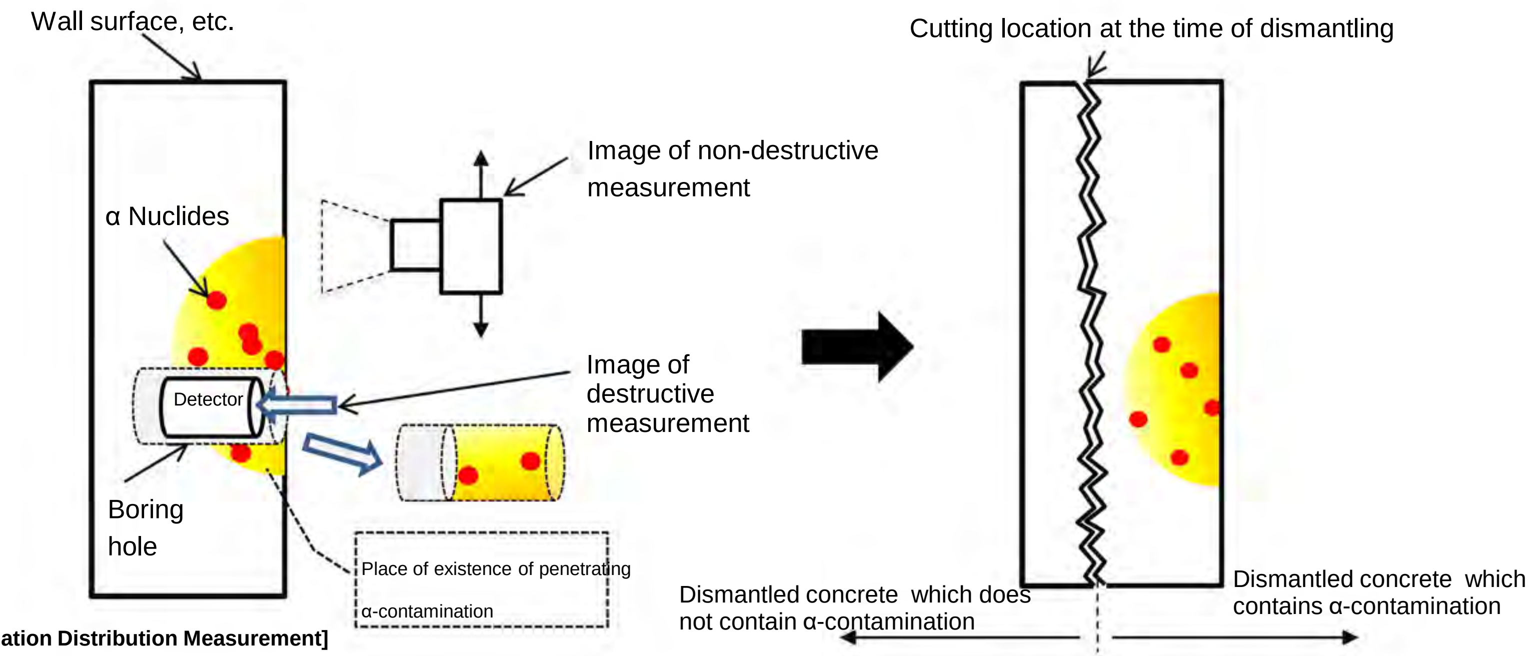
<Measurement system (In combination with remote control device)>

1. Implementation and assessment of algorithms that can comparatively assess the results of complex measurement points (positional accuracy, environmental correction, etc.)
2. Implementation of functions required in a measurement system (three-degree-of-freedom travelling trolley, tilt mechanism, lifting function), and performance assessment

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation
-Study on penetrating α-contamination-
Purpose of measurement and policy for investigation of technology

□ Purpose of measurement

To understand the depth of penetrating α-contamination before dismantlement, in places associated with building concrete dismantlement, and to segregate contaminated and non-contaminated building concrete so as reduce α-contamination waste.



[Contamination Distribution Measurement]

□ Policy for investigation of technology

- □ Destructive measurement: Investigate measurement technology by measuring inner surface of boring hole and outer surface of boring core.
- □ Non-destructive measurement: Direct measurement is difficult because α-rays cannot permeate up to the concrete surface, so investigate indirect measurement technology.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

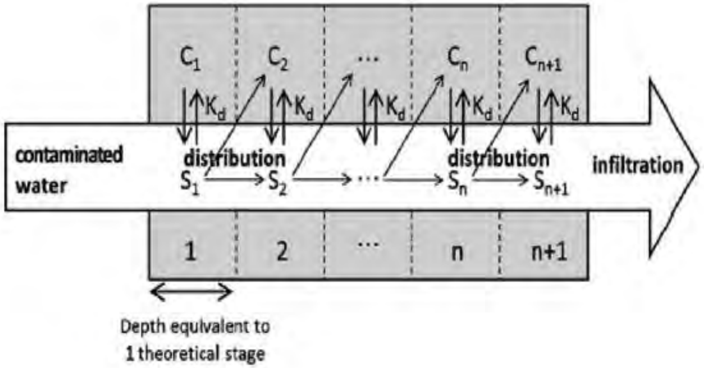
-Study on penetrating α-contamination-

Assessment of penetration behaviour of nuclide

As it is difficult to measure penetration of α-contamination directly, assessment of γ-nuclides, which penetrate more easily than α-nuclides, was studied.

☐ Penetration model of nuclides

It is known that nuclides penetrate into concrete by repeated dissolution in the liquid phase (such as contaminated water) and adsorption to a solid phase, and the extent of penetration depends on the distribution coefficient Kd of the nuclides for concrete.*1



Penetration model of nuclides

☐ Penetration behaviour of nuclides

As for the distribution coefficient of typical α-nuclides (U,Pu), β-nuclides (Sr), and γ-nuclides (Cs) with respect to concrete in 1F, it has been reported that the coefficient of U and Pu is at least two-digit larger than that of Cs and Sr.*2

From the distribution coefficient for concrete, it can be assumed that compared to α-nuclides, fission products such as Cs have penetrated into concrete.

Distribution coefficient Kd with respect to concrete composition

	NaO,KO	Ca(OH)2	CSH,AFm,AFt	CaCO3
U	U(IV) : 2E+03 U(VI) : 3E+04	U(IV) : 3E+04 U(VI) : 3E+04	U(IV) : 3E+04 U(VI) : 3E+04	U(IV) : 5E+01 U(VI) : 3E+04
Pu	Pu(IV) : 5E+03 Pu(VI) : 2E+03	Pu(IV) : 3E+04 Pu(VI) : 3E+04	Pu(IV) : 3E+04 Pu(VI) : 3E+04	Pu(IV) : 3E+02 Pu(VI) : 5E+01
Cs	—	2E+00	2E+01	—
Sr	1E+02	3E+01	1E+02	1E+00

In case of penetrating α-contamination inside the concrete, penetration depth can be conservatively assessed by measuring γ-rays from the fission products such as Cs (Cs-137), which have penetrated very deep into the concrete.

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*1 Kinoshita et al. Estimation of penetration distribution of each element in concrete penetrated with various nuclides, Journal of Japanese Society of Radiation Safety Management, Vol. 15, No. 1, 2016

*2 Michel Ochs et al, "Radionuclide and Metal Sorption on Cement and Concrete"(2015)

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation
-Study on penetrating α-contamination-

Details of investigation of measurement technologies

- **Overview of investigation of technologies**

Sampling analysis is common, but there are issues such as high cost and time, and difficulty in showing the representativeness of the sample. The following methods were investigated as alternative technologies for on-site measurement (In Situ measurement).

① Estimating penetration depth by measuring γ-rays released from 235U and attendant γ-nuclides
- Method using scattered ray / direct ray ratio
  →If penetration is deeper, the direct rays tend to attenuate, and the scattering component increases. Penetration depth is calculated from the ratio of direct ray and Compton scattering.
- Method using multiple gamma ray ratios
  →Ratio of each γ-ray depends upon the penetration depth due to difference in permeability rate of γ-rays (or K-X rays) with different energies.

② Boring measurement
→ Boring at representative points to measure (insert a detector) the distribution inside the boring hole

- **Viewpoints on applicability assessment of investigated technologies**

➢ Common to destructive measurement and non-destructive measurement
  - As there is a possibility of using multiple technologies according to the operating procedures, individual technologies were assessed qualitatively without narrowing down to a single technology.
  - The technologies applied in the decommissioning of nuclear facilities were mainly investigated. When applying the technology to 1F (~ several mSv/h), re-designing the shielding member, collimator, etc. was considered as a prerequisite (issue).
  - Penetration depth was not only calculated for the penetration of the sound concrete surfaces, but also for presumed cracks and buried objects (pipes, etc), and a width from surface to 20 cm or more was assumed.

➢ Destructive measurement
  - Issues such as representativeness of sampling points and cross-contamination of the drilled surfaces, at the time of application of conventional methods, were also assessed.

➢ Non-destructive measurement
  - Mainly, penetrating contamination measurement technologies for Cs-137 were targeted based on the assessment results of penetration behavior.

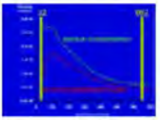
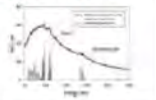
(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on penetrating α-contamination-

Comparison of investigated technologies

- Penetrating contamination measurement of a wide area including concrete floors, ceilings, and walls, etc. after removal of dismantled equipment from inside the building, was assumed.
- Domestic*1, and overseas technologies focusing on Russia for the non-destructive and destructive measurement technologies were investigated.

The method using the scattered ray / direct ray ratio is the most applicable non-destructive method.
The destructive method can be used as a supplementary method in combination with deep penetration and sampling analysis.

分類	手法	α核種評価	測定対象	測定手順	測定原理	装置例	検出器・装置構成例	適用事例	1F適用課題等	適用性
非破壊測定	CORAD法 （散乱線／直接線比率）	間接	対象物内部で散乱したγ線と、対象物内部からの直接γ線。	コリメートしたγ線検出器を対象物に向けて配置し、スペクトル測定する。	散乱領域の計数率とピーク計数率の比率から浸透深さを算出	 CORAD-M(LaBr3)	・γ線検出器 （測定対象で異なる） ・NaI(Tl)、CsI、 ・HPGe、LaBr3 ・コリメータ ・波高分析装置 ・架台（三脚等） ・PC＋専用ソフト	・ロシア国内 汚染調査 廃止措置 ・仏EDF及びCEAでも評価	・γ核種とα核種の濃度及び、浸透度（拡散）の比率。 ・ジオメトリ変更に伴うモデルと、ソフトの修正。	コンクリートへの実績があり（表面～数10cmの深さ）、複数の検出器にも対応しているので、Cs-137を対象とすれば適用性有り。（技術としては成熟） ○
	散乱線／直接線比率 γ線／β線比率法	間接	対象物内部からの直接・散乱γ線と、対象物表面から放出されるβ線。	コリメートしたγ線検出器と、薄型のβ線検出器を対象物に密着し、β線及びγ線スペクトルを測定する。	γ線の散乱領域の計数率とピーク計数率の比率から浸透深さを算出し、β線とγ線スペクトルの比較で、表面、内面、浸透を判定する。		・ホスイッチ型 β／γ線検出器 （NaI/PLS検出器）	・Nupec確証試験 （H4～15年度）	・γ核種とα核種の濃度及び、浸透度（拡散）の比率。 ・対象面への密着が必要となる。	密着型で感度は良好。機器撤去後で、数cmの範囲であれば確証試験での実績があり、Cs-137を対象とすれば適用性有り。 ○
	複数γ線比率法	間接	対象物内部からの異なる複数のエネルギーの直接γ線（または蛍光X線）。	コリメートしたγ線検出器を対象物に向けて配置し、スペクトル測定する。	γ線のエネルギー毎の透過率の違いから、浸透深さを算出 		・ISOCSシステム ・HPGe ・コリメータ ・架台 （キャンベラ製）	・SCK-CEN BR3廃止措置 （ベルギー）	・γ核種とα核種の濃度及び、浸透度（拡散）の比率。 ・Cs-137のX線エネルギーが小さく、深い浸透には対応できない。 ・Ba同位体をもつ材質はに適用できない。	市販の実績あるシステムがベースなので、Cs-137を対象とした場合、表層近くは良好であるが、深い浸透には適用できない。また、Baを含む重コンクリートにも適用できず、制限有り。 △
	蛍光X線法	直接	γ線で励起されたUまたはPuから放出される蛍光X線。	外部線源または、同時に存在するCs-137等のγ線で励起しKβ-X線を測定する。	X線のエネルギー毎の透過率の違いから、浸透深さを算出 	 UWTRシステム	・CdZnTl検出器 ・ビデオカメラ ・遮へい/コリメータ ・MCA/PC	・ロシア MR炉プール （ただし、濃度は、185keVγ線による。また、浸透は評価していない。）	・プール内の使用済燃料が対象、励起線源の強度、精度等に依存するため定量性に課題。 ・エネルギーが小さいので、深い浸透には対応できない。	使用済燃料を対象とした手法で感度が不足しており、エネルギーも小さいため、深い浸透には適用できない。（将来のデブリ探査には適用可能性あり） ×
破壊測定	ボーリング孔挿入法	直接/間接	ボーリング孔内表面から放出されるα線またはβ線、γ線。	ボーリング孔にコリメートした検出器を挿入し、直接表面を走査測定する。	予め標準線源等で校正された検出器で測定された測定単位（深さ）毎の計数から深さ方向の計数率分布を算出、更に、校正定数で表面汚染密度または濃度に換算する。	 ホスイッチ型  γスペクトル型（ロシア）	・Nupec ・CsI検出器（γ）+ PLS検出器（β） ホスイッチ型 ・ロシア ・CsI検出器 ・コリメータ ・α線直接計測 ・ZnS検出器	・Nupec確証試験 測定ステップ1mm ・ロシア 空間分解能5cm	・サンプリングポイントの選定と、掘削面のクロスコンタミ。 ・深さ方向はスキャン距離分の測定回数が必要になる。 ・α線用挿入型検出器は開発が必要。	挿入測定自体は従来法である。サンプリングの代表性と断面のクロスコンタミの可能性が常にあり対策（開発）が必要となる。 △

○:Applicable
△: Controlled
×: Not applicable

*1 Mainly based on investigation report related to confirmatory testing for decommissioning facilities of commercial nuclear power reactors, and contamination penetration measurement technology (1995 to 2003)

*2 In accordance with the investigation report of penetrating contamination measurement technology requested to Russia.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

-Study on penetrating α-contamination-

Identification of issues in on-site application

<Technical Issues>

◆ Indirect measurement using Cs-137

During actual application, in order to prove the validity of the estimated value of the penetration depth of an α-nuclide, not only is the data on penetration behaviour for every nuclide obtained from literature necessary, but many measurement values are also required for each concrete condition for the ratio of concentration of α-nuclides and γ-nuclides such as Cs-137 and the ratio of degree of penetration.

◆ Development of devices suitable to the environment specific to 1F

The devices (software and hardware) need to be changed in accordance with the ratio of concentration of α-nuclides and γ-nuclides such as Cs-137, and the environmental dose rate, as well as the structure and dimensions of the measurement location.

<Issues in application>

◆ Establishing specific operation methods

The environmental conditions at the time of measurement (mainly during the dismantlement of buildings) may differ significantly than the current assumptions and it is necessary to select the detector and study the structure in accordance with the conditions.

Moreover, it is necessary to study not only the non-destructive method, but also the detailed procedures related to distinguishing between the use of sampling analysis and destructive methods such as boring.

(3) Development of Contamination Evaluation Technology for Solid Waste Segregation

- Conclusion -

- **Study of surface α-contamination**
  - A detector was prototyped in accordance with the device requirement specifications summarized from the study results of the scope of on-site application.
  - Tests assuming on-site environment were conducted and the conditions to obtain the target lower limit of detection (0.4 Bq/cm2, 4 Bq/cm2, and 40 Bq/cm2) were assessed.
  - The reassessment of the impact of the shapes of measurement targets on on-site application was identified as a future issue.

- **Study on penetrating α-contamination**
  - On investigating the penetration behavior of α-nuclides, the technology that can assess the penetration depth of α-nuclides was investigated.
  - The on-site applicability of the measurement technology was assessed and prospective technologies were shortlisted for non-destructive and destructive methods.
  - For the on-site application of the investigation technology, the changes in devices (modification of models and software due to geometrical changes) in accordance with the unique environment at 1F and collection of data on the penetrating nuclide composition, were identified as issues.

4. Research on Disposal

Implementation Details

(1) Study of Disposal Concept and Safety Evaluation Methods for Solid Waste

(2) Measures for Materials with Impact on Disposal

(3) Clarification Items Having Impacts on Safety Evaluation of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

(1) Study of Disposal Concept and Safety Evaluation Methods for Solid Waste

-Implementation Plan and Goal Achievement Index-

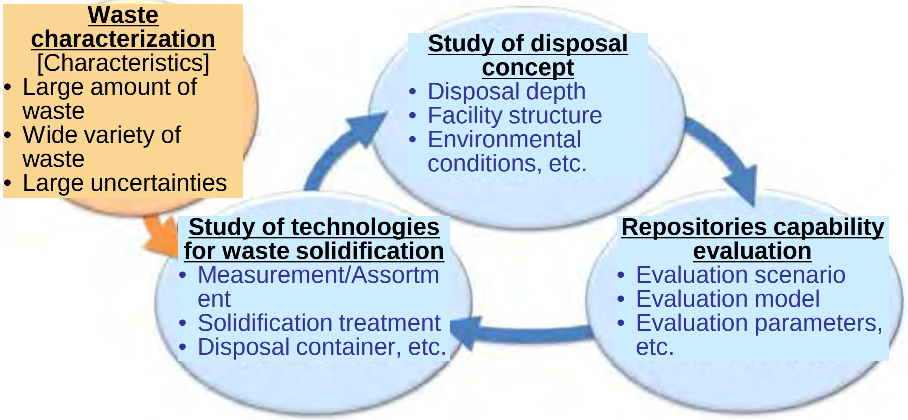
FY	Implementation Plan	Goal Achievement Index
2017	• The disposal concept and safety assessment methods are investigated from multiple points of view such as technical aspects and institutional aspects identifying representative examples from the waste disposal facilities of other countries. Based on the investigation results, the FY2018 investigation plan (scope of investigation and investigation methods) is developed.	• Presentation of FY2018 investigation plan (scope of investigation and investigation methods).
2018	• The disposal concept and safety assessment methods are investigated from multiple points of view such as technical aspects and institutional aspects for the waste disposal facilities of other countries, based on the FY2017 plan. Safe and reasonable disposal concept and safety assessment methods are studied based on the results of investigation and considering the characteristics of 1F solid waste.	• Presentation of a safe and reasonable disposal concept and a proposal for safety assessment methods considering the characteristics of 1F solid waste.

☐ Overview of Results

- A list of reference cases to be noted at overseas disposal facilities was created and their applicability to 1F solid waste and related issues were organized.
- Methods to study the disposal concept considering characteristics of waste were organized (Figure 1).
- Case studies of multiple disposal concept were implemented by this method and it was confirmed that it is possible to study the policy of waste treatment and disposal in accordance with the characteristics of the waste.

☐ Future Plan

- In future, image of waste needs to be clearly specified and multiple disposal methods must be established for each 1F waste and safety assessment methods must be established for each disposal method .



Waste characterization
[Characteristics]
- Large amount of waste
- Wide variety of waste
- Large uncertainties

Study of disposal concept
- Disposal depth
- Facility structure
- Environmental conditions, etc.

Repositories capability evaluation
- Evaluation scenario
- Evaluation model
- Evaluation parameters, etc.

Study of technologies for waste solidification
- Measurement/Assortment
- Solidification treatment
- Disposal container, etc.

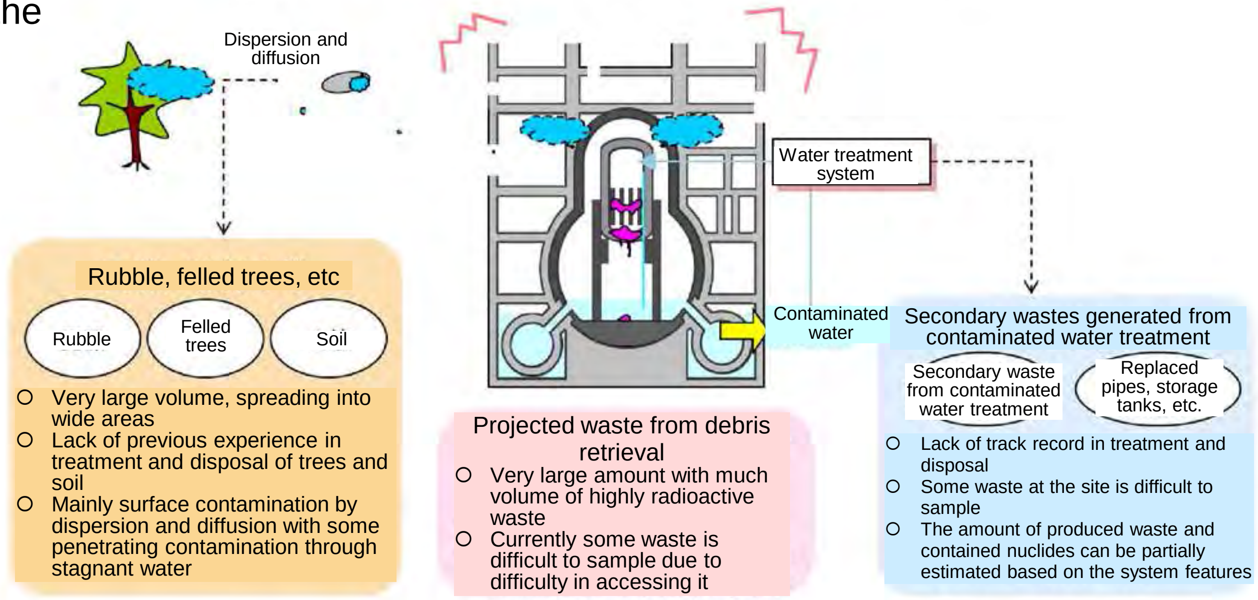
Figure 1. Process of study of disposal concept considering characteristics of waste

(1) Study of Disposal Concept and Safety Evaluation Methods for Solid Waste

-Implementation Details-

a. Results of investigation of overseas reference cases
-Identifying characteristics of Solid Waste in Fukushima Daiichi-

■Characteristics of the Solid Waste in Fukushima Daiichi



Rubble, felled trees, etc

Rubble | Felled trees | Soil

- ○ Very large volume, spreading into wide areas
- ○ Lack of previous experience in treatment and disposal of trees and soil
- ○ Mainly surface contamination by dispersion and diffusion with some penetrating contamination through stagnant water

Projected waste from debris retrieval

- ○ Very large amount with much volume of highly radioactive waste
- ○ Currently some waste is difficult to sample due to difficulty in accessing it

Secondary wastes generated from contaminated water treatment

Secondary waste from contaminated water treatment | Replaced pipes, storage tanks, etc.

- ○ Lack of track record in treatment and disposal
- ○ Some waste at the site is difficult to sample
- ○ The amount of produced waste and contained nuclides can be partially estimated based on the system features

■ Needs for safe and reasonable solid waste disposal, considering the characteristics of waste

Investigations and studies were conducted from the three perspectives shown on the right considering the characteristics of waste

Increase the capacity of disposal facilities

Acceptability of diverse waste

Response to uncertain risks

a. Results of investigation of overseas reference cases
-Overview of investigation of overseas reference cases-

Research was conducted on the low-level waste disposal facilities outside Japan, which are available for various kinds of wastes and for which detailed data has been published.


LLWR*1 Disposal facility (UK)


SFR*2 Disposal facility (Sweden)


WCS*3 Disposal facility (USA, Texas)

*1: Low Level Waste Repository *2: Final Repository for Short-lived Radioactive Waste *3: Waste Control Specialists

■Contents of research

①Brief survey on disposal facilities
②Research on waste characteristics
③Research on waste pretreatment
④Research on waste containers
⑤Research on waste treatment
⑥Research on waste storage
⑦Research on acceptability of waste at disposal facilities
⑧ Research on disposal concepts
⑨Survey on safety assessment methods
⑩ Research on safety cases
⑪ Research on process of optimization of economic performance

Systematic research was conducted.

■ Study on research results

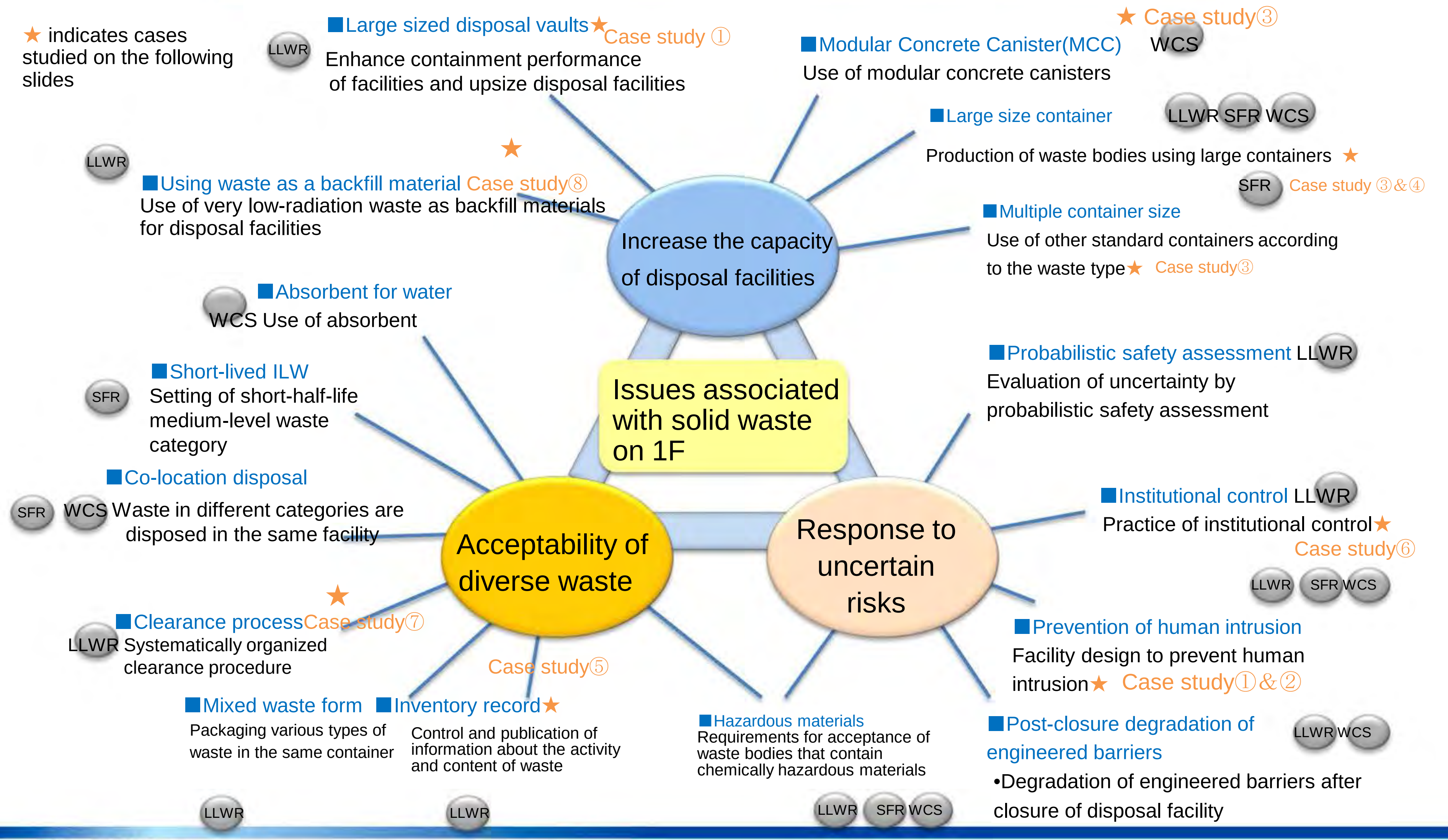
・Comparison with previous cases in Japan
・Importance determined based on needs of 1F waste

Listing of important reference cases (LLWR and SFR: 25 cases, WCS: 16 cases)

a. Results of investigation of overseas reference cases

- Focused important reference cases and examples of those reflected to 1F needs -

Selection of useful technology and assessment methods to be noted at overseas disposal facilities



★ indicates cases studied on the following slides

Issues associated with solid waste on 1F

Increase the capacity of disposal facilities

- ■Large sized disposal vaults★ Case study ① LLWR
  Enhance containment performance of facilities and upsize disposal facilities
- ■Using waste as a backfill material Case study⑧ ★ LLWR
  Use of very low-radiation waste as backfill materials for disposal facilities
- ■Modular Concrete Canister(MCC) ★ Case study③ WCS
  Use of modular concrete canisters
- ■Large size container LLWR SFR WCS
  Production of waste bodies using large containers ★ SFR Case study ③&④
- ■Multiple container size
  Use of other standard containers according to the waste type★ Case study③

Acceptability of diverse waste

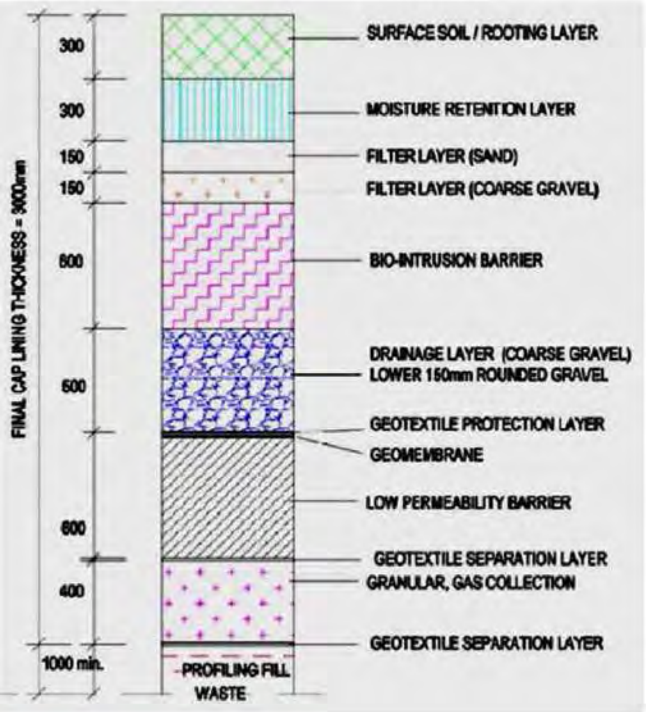
- ■Absorbent for water
  WCS Use of absorbent
- ■Short-lived ILW SFR
  Setting of short-half-life medium-level waste category
- ■Co-location disposal SFR WCS
  Waste in different categories are disposed in the same facility
- ■Clearance process Case study⑦ ★ LLWR
  Systematically organized clearance procedure
- ■Mixed waste form LLWR
  Packaging various types of waste in the same container
- ■Inventory record★ Case study⑤ LLWR
  Control and publication of information about the activity and content of waste
- ■Hazardous materials LLWR SFR WCS
  Requirements for acceptance of waste bodies that contain chemically hazardous materials

Response to uncertain risks

- ■Probabilistic safety assessment LLWR
  Evaluation of uncertainty by probabilistic safety assessment
- ■Institutional control LLWR
  Practice of institutional control★ Case study⑥ LLWR SFR WCS
- ■Prevention of human intrusion
  Facility design to prevent human intrusion★ Case study①&②
- ■Post-closure degradation of engineered barriers LLWR WCS
  •Degradation of engineered barriers after closure of disposal facility

■Case study①　a. Results of investigation of overseas reference cases -Disposal Facility with Cap System- (UK LLWR) -

Cap Structure



Control water permeation and human intrusion using the Cap System
⇒Strengthen nuclide confinement performance of the facility

(However, it is necessary to construct the facility above the water table)

Overall structure

- ・Cap (prevention of water permeation from the upper area and prevention of human intrusion) and wall (prevention of lateral water permeation within the facility)
- ・Bottom plate (prevention of upward water permeation from under the facility)

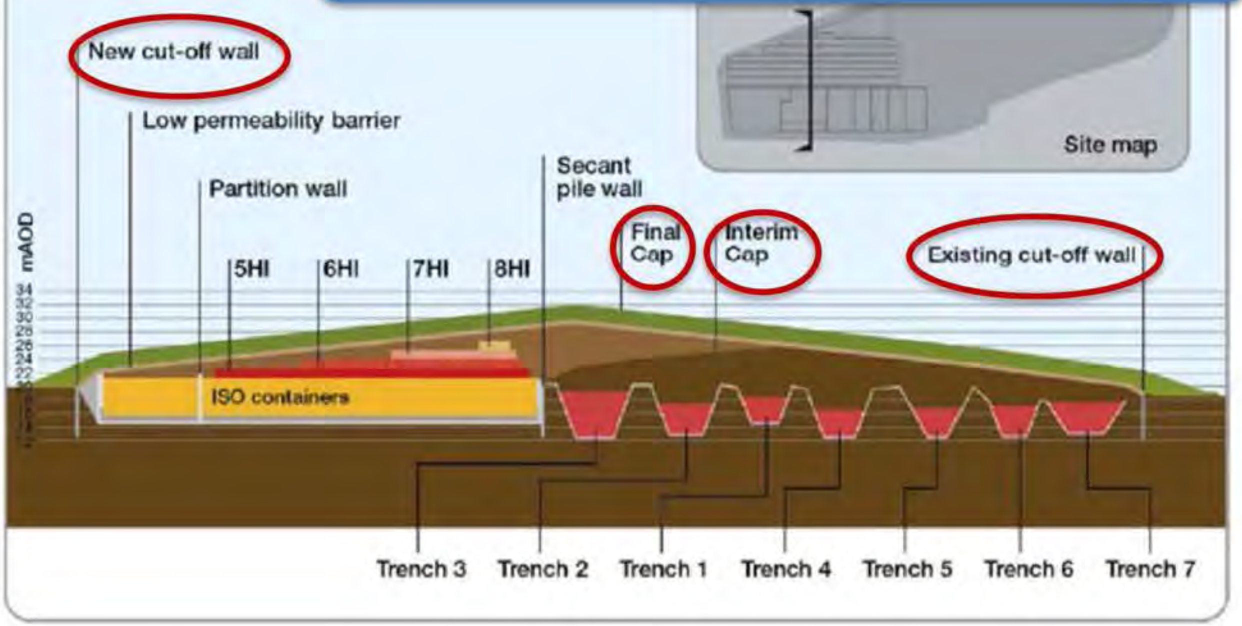


Figure 4.7: The preliminary design of the final cap for the LLWR at closure. *1

Appearance of geomembrane (asphalt sheet))

*1: LLWR,*The2011ESC: Engineering Design*, LLWR/ESC/R(11)10020,May 2011.

■Case study② a. Results of investigation of overseas reference cases

-Structure of Facility Controlling Human Intrusion-

LLWR in UK

● A cap with a bio-intrusion barrier (Bio-intrusion Layer) built on a bed of round rocks with a diameter of 600 mm is employed as a measure to enhance protection against human intrusion by excavation

⇒Improves protection against human intrusion based on the regulatory requirements

WCS Texas in USA

●Class C waste is buried at a depth of 5 m or more from the surface to protect unintended intruders according to the Texas State Code.

●The modular concrete canister (MCC) used at WCS has a structural strength that prevents human intrusion to Class C waste.

⇒Inhibits human intrusion for 300 years

SFR in Sweden

●The coastal submarine installation prevents human intrusion.

● Assuming an uplift over a 1,000-year period, the disposal facility was built at a depth of 60 m from the seafloor.

⇒ Inhibits human intrusion for 1000 years

a. Results of investigation of overseas reference cases

■ Case study ③

- Large-size Containers -

Effective utilization of limited disposal facility space by the use of large disposal containers

Item	LLWR in UK	SFR in Sweden	WCS Texas in USA
Appearance	 ISO Container or half height ISO (HHISO) container	 ・Drum ・Mold ・Concrete tank ・ISO container	 Modular concrete canisters (MCC)
Dimensions	Height 1.32 m x Width 2.5 m x Length 6.06 m (HHISO)	Various dimensions	Inner diameter 2 m x inner height 2.8m
Strength	9-level stack is assumed	Up to 42-level stack is assumed	34.5 MPa (up to 6-level stack)
Solidification agent	Superplasticizer-containing PFA + Portland cement	Asphalt Concrete	High-strength grout (compressive strength after 28 days : 2,000 psi)
Notes	A HHISO container is used more often because of its handleability.	Containers are put in a silo and continuously grouted with cement.	A layer of fluid sand or soil is added in between every stacked MCC.

■ Case study ④ a. Results of investigation of overseas reference cases

- Solidification of Large Containers (LLWR in UK) -

<<Characteristics of large container solidification>>

● Use of specially formulated, high fluidity, cement solidification material

● In order to inject cement in every corner of the container, it is necessary to tilt the container and inject the cement through multiple injection holes.

Cutting a solidified container

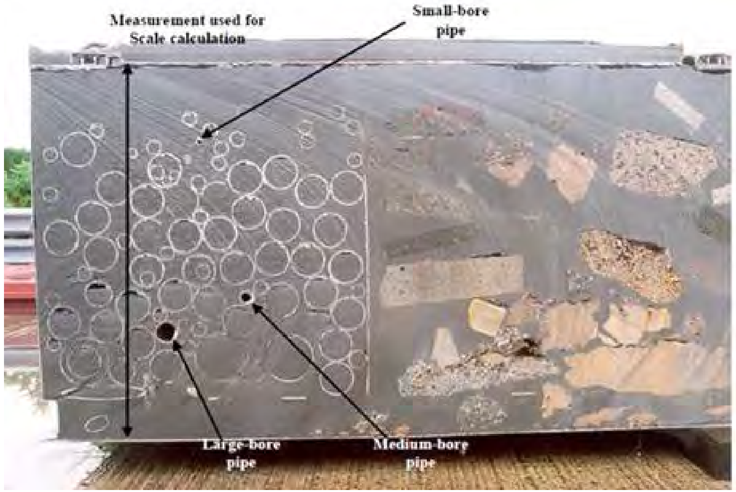
Cut cross-section of a container containing a compressed drum

●Multiple wastes with different properties are mixed and form a waste body, but the inventory of each waste is managed by UKRWI (next slide) from the initial stage of generation, and the inventory of a mixed waste body can also be known.

<u>Solidification in a large container requires the following technology and method</u>

・Technology to realize the solidification of waste in the container

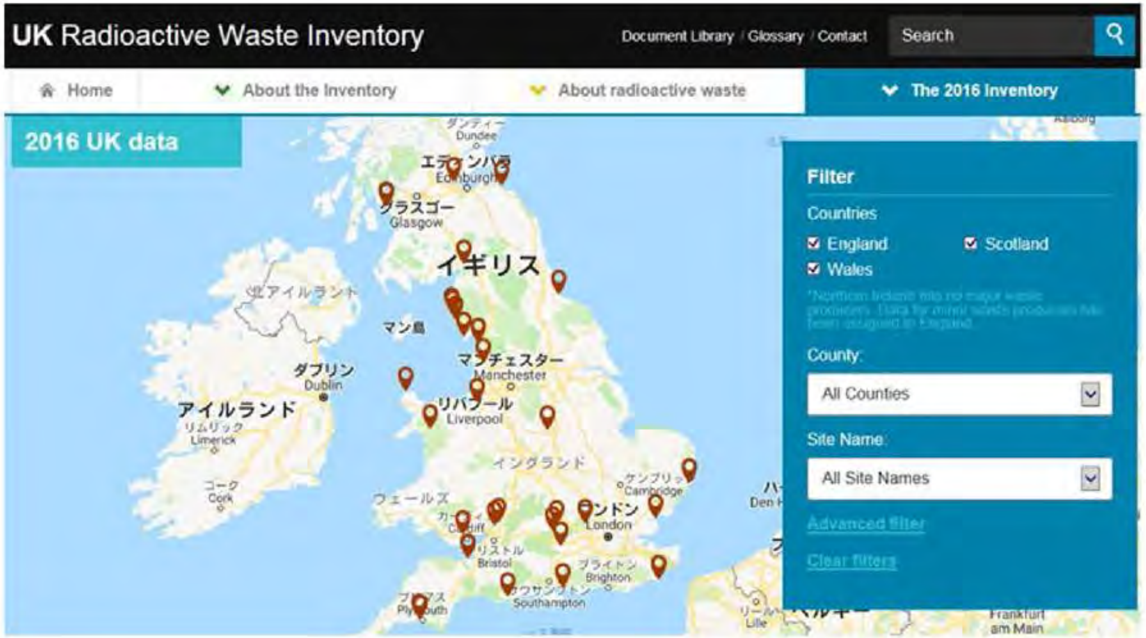
・Method to determine inventory of waste body



Cut cross-section of a container containing multiple solidified waste

■Case study ⑤ a. Results of investigation of overseas reference cases

- Inventory Management System (UK: UKRWI*1) -



Filter

Countries

☑ England ☑ Scotland

☑ Wales

County:

All Counties

Site Name:

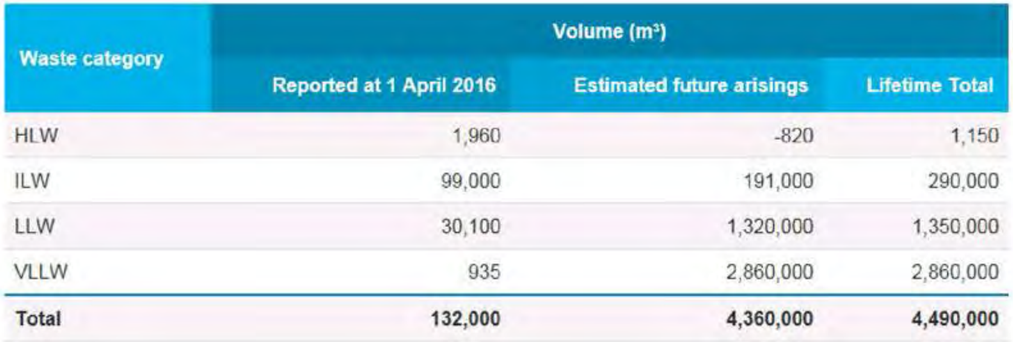
All Site Names

●Inventory of all waste streams of every power station can be traced.

●Waste generated over the long term is estimated, and the fluctuation margin, nuclides, and chemical mass of the generated waste is also managed in an integrated manner.

●As the inventory is clarified, mixed wastes are easy to dispose.

<<Projected waste generation in UK>>



Waste category	Volume (m³)		
	Reported at 1 April 2016	Estimated future arisings	Lifetime Total
HLW	1,960	-820	1,150
ILW	99,000	191,000	290,000
LLW	30,100	1,320,000	1,350,000
VLLW	935	2,860,000	2,860,000
Total	**132,000**	**4,360,000**	**4,490,000**

The System can be used for long-term waste management until the time of disposal

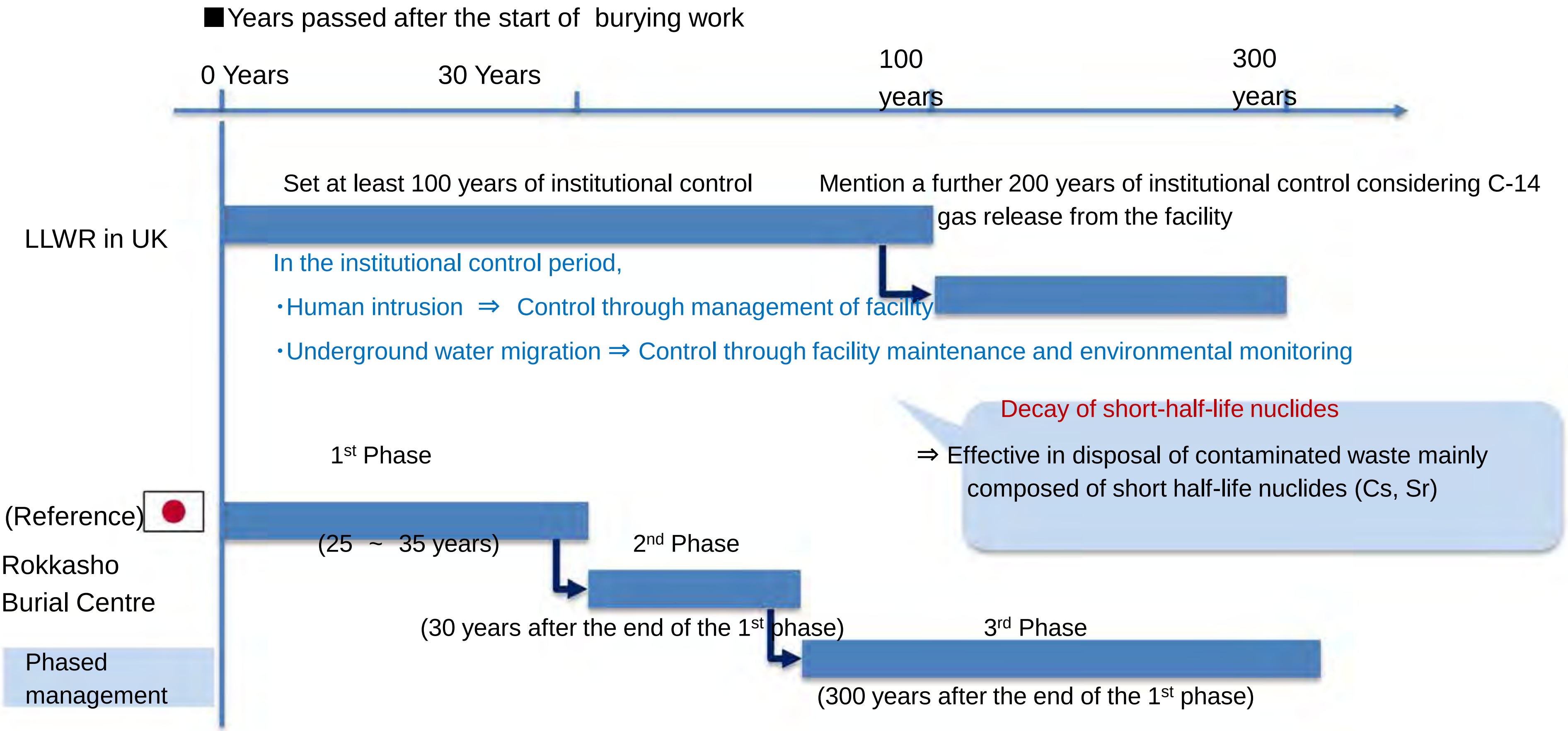
⇒ However, it must be applicable to the actual condition of the1F wastes.

*1: UK Radioactive Waste Inventory

■Case study ⑥ a. Results of investigation of overseas reference cases

-Institutional Control (UK LLWR)-

Decay of short-half-life nuclides by setting the time period for “institutional control”



■Years passed after the start of burying work

In the institutional control period,

- ・Human intrusion ⇒ Control through management of facility
- ・Underground water migration ⇒ Control through facility maintenance and environmental monitoring

Decay of short-half-life nuclides

⇒ Effective in disposal of contaminated waste mainly composed of short half-life nuclides (Cs, Sr)

■Case study ⑦ a. Results of investigation of overseas reference cases

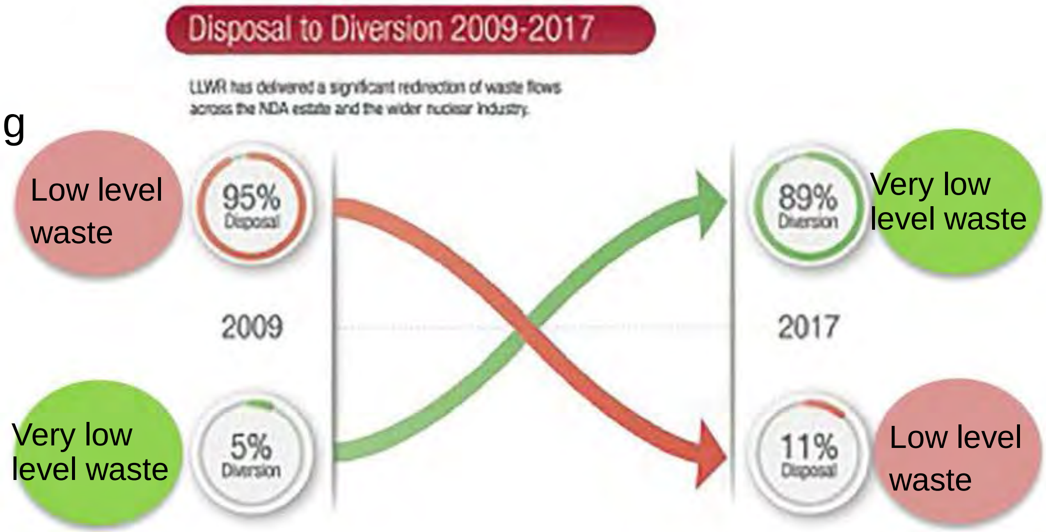
-Waste disposal strategy of UK-

Issues

Huge amounts of low-level waste will be generated in the UK with decommissioning

National strategy

- Application of waste hierarchy
- Increase in reuse and recycling
- Expansion of disposal at VLLW disposal facility



[Concept of waste hierarchy]

■ **Waste prevention:** Preventing and reducing waste generation in the planning phase

■**Minimization of waste:** Minimizing amount and radioactivity (Segregation, separation, decontamination, characterization, etc.)

■ **Reuse of waste:** Transfer of assets, and use of soil and rubble as backfill material

■ **Recycling**: Recycling of metal, concrete and rubble (Decontamination, melting and crushing)

■ Case study ⑧ a. Results of investigation of overseas reference cases -Using Very Low Level Waste as Backfill Material (LLWR in UK)-

The possibility of using some of the very low level waste as a filling material between containers is under study.

●Cement and aggregates (sand and gravel) are used as filling material for containers at the LLWR disposal facility.

●The method of using the disposal facility effectively by reusing sand and concrete fragments in the very low level waste, in these aggregates, was studied.

● It was concluded that the use of above-mentioned very low level waste as filling material in the containers would affect the current waste acceptance standards and would not be the BAT*.

●As an alternative, a proposal for the use of the VLLW as a filling material between containers and as a backfill material for the cap layer, is being considered.

Containers of waste bodies placed at the LLWR disposal facility

*BAT: Best Available Technique

a. Results of investigation of overseas reference cases

-Applicability of important overseas reference cases to waste disposal in Fukushima Daiichi -

Important overseas references cases can be applied to waste disposal in Fukushima Daiichi

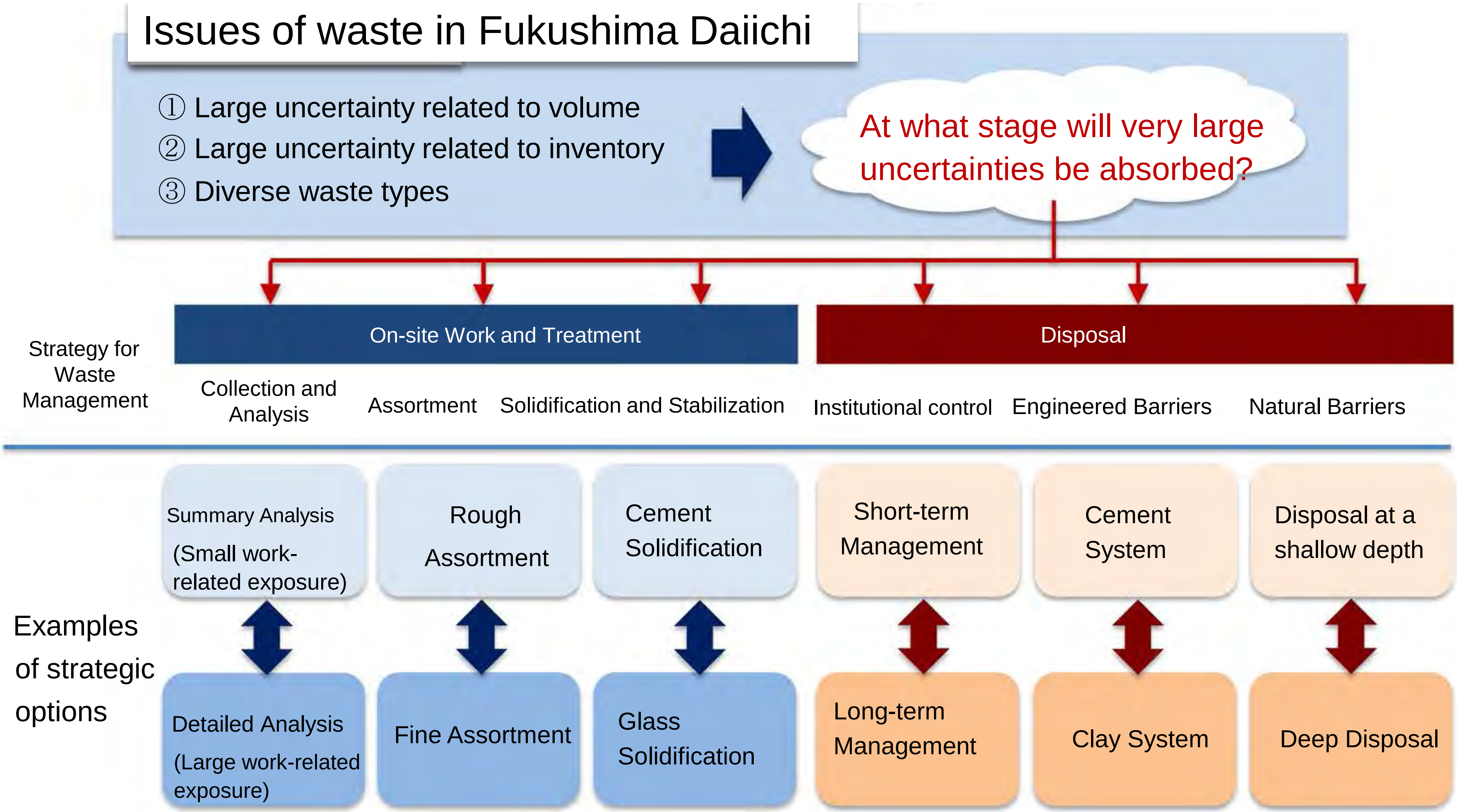
⇒ Incorporated in the study of disposal concept of 1F waste

Various categories influence the disposal concept

No.	Issues to be dealt with	Important reference cases	Past domestic results	Applicability to 1F waste disposal	Category
1	Increasing the capacity of disposal facilities	Facility structure with a Cap System	Not implemented in Japan (Not effective below the water table)	Possible (Depends on the location)	Disposal facilities
2		Facility structure to control human intrusion	Not implemented in Japan	Possible (Technical study required)	
3		Use of very low level waste as a backfill material	Not implemented in Japan	Possible (Evaluation required)	
4		Large size disposal containers	L1 disposal container	Possible	Disposal containers
5		Other types of standard containers	200 liter drum, L1 disposal container, etc.	Possible	
6		Concrete containers	Not implemented in Japan	Possible (Technical study required)	
7		UK waste disposal strategy	Not implemented in Japan	Possible (Technical study required)	Pre-treatment
8		Large size container solidification	Not implemented in Japan	Possible (Technical study required)	Solidification
9	Acceptability of diverse waste	Mixed waste solidification	Not implemented in Japan	Possible (Change the inventory management)	
10		Settings of short-half-life medium-level waste category	Not implemented in Japan	Possible (Technical study required)	Control and management
11		Inventory management system	Not implemented in Japan	Possible (Change the inventory management)	
12	Responding to uncertain risks	Institutional control	Rokkasho low level waste burial centre, etc.	Applied	
13		Acceptance of waste containing materials with impact	HLW disposal, TRU disposal, LLW disposal	Possible (Partially applied)	Evaluation method
14		Evaluation of long-term degradation of engineered barriers	HLW disposal, TRU disposal, LLW disposal	Applied	
15		Probabilistic safety assessment	Research cases available	Possible (Technical study required)	

b. Study process of disposal concept considering waste characteristics

- Selecting a disposal concept-



Issues of waste in Fukushima Daiichi

① Large uncertainty related to volume
② Large uncertainty related to inventory
③ Diverse waste types

At what stage will very large uncertainties be absorbed?

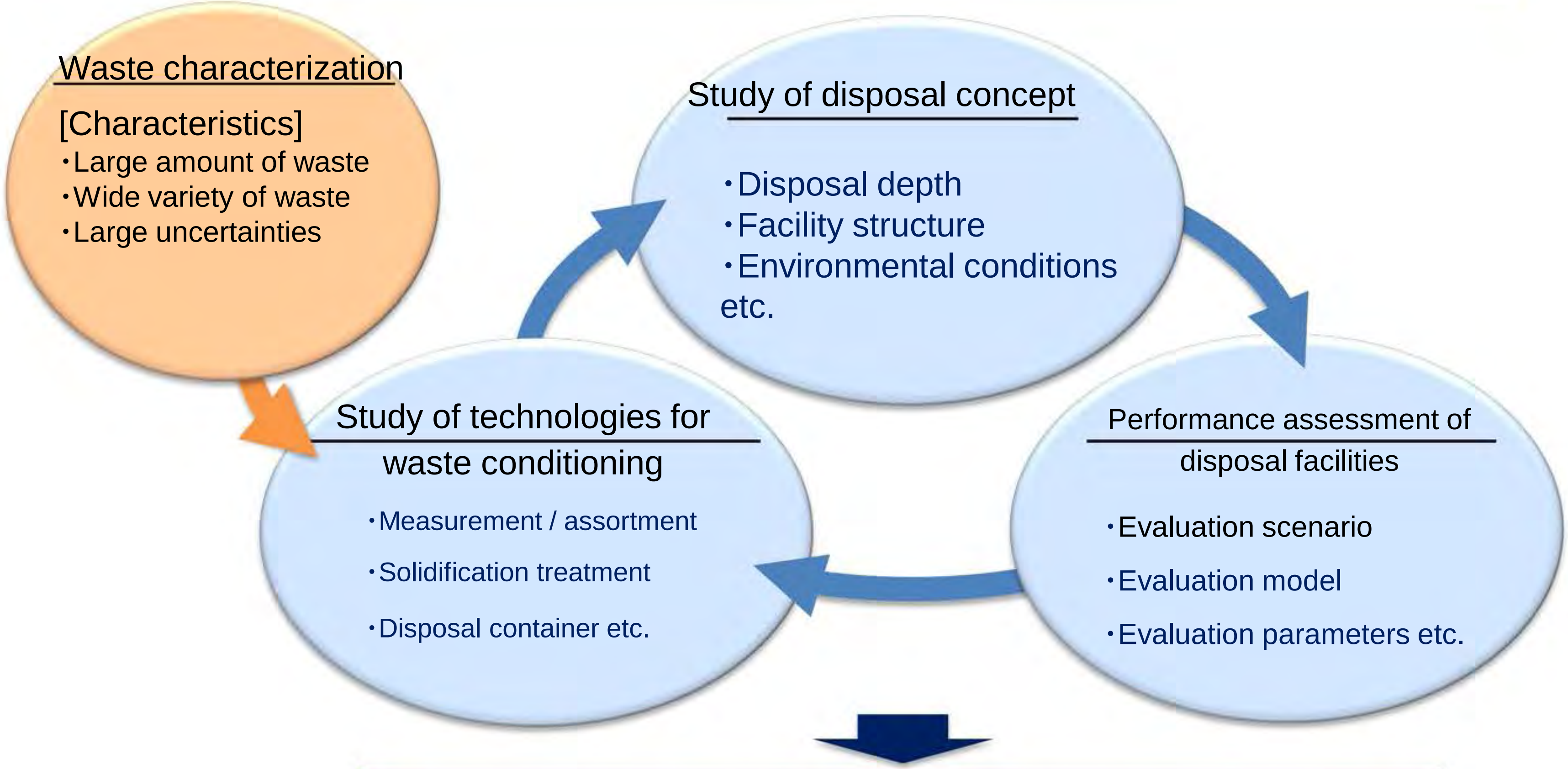
	On-site Work and Treatment			Disposal		
Strategy for Waste Management	Collection and Analysis	Assortment	Solidification and Stabilization	Institutional control	Engineered Barriers	Natural Barriers
Examples of strategic options	Summary Analysis (Small work-related exposure)	Rough Assortment	Cement Solidification	Short-term Management	Cement System	Disposal at a shallow depth
	Detailed Analysis (Large work-related exposure)	Fine Assortment	Glass Solidification	Long-term Management	Clay System	Deep Disposal

⇒Utilized in the “Waste Management Strategy” that provides an overview of the entire process from treatment to disposal

b. Study process of disposal concept considering waste characteristics

-Study process related to disposal concept considering waste characteristics-

Development of a study process that can extensively evaluate various options from treatment to disposal in accordance with the characteristics of waste



Waste characterization

[Characteristics]

- Large amount of waste
- Wide variety of waste
- Large uncertainties

Study of disposal concept

- Disposal depth
- Facility structure
- Environmental conditions

etc.

Study of technologies for waste conditioning

- Measurement / assortment
- Solidification treatment
- Disposal container etc.

Performance assessment of disposal facilities

- Evaluation scenario
- Evaluation model
- Evaluation parameters etc.

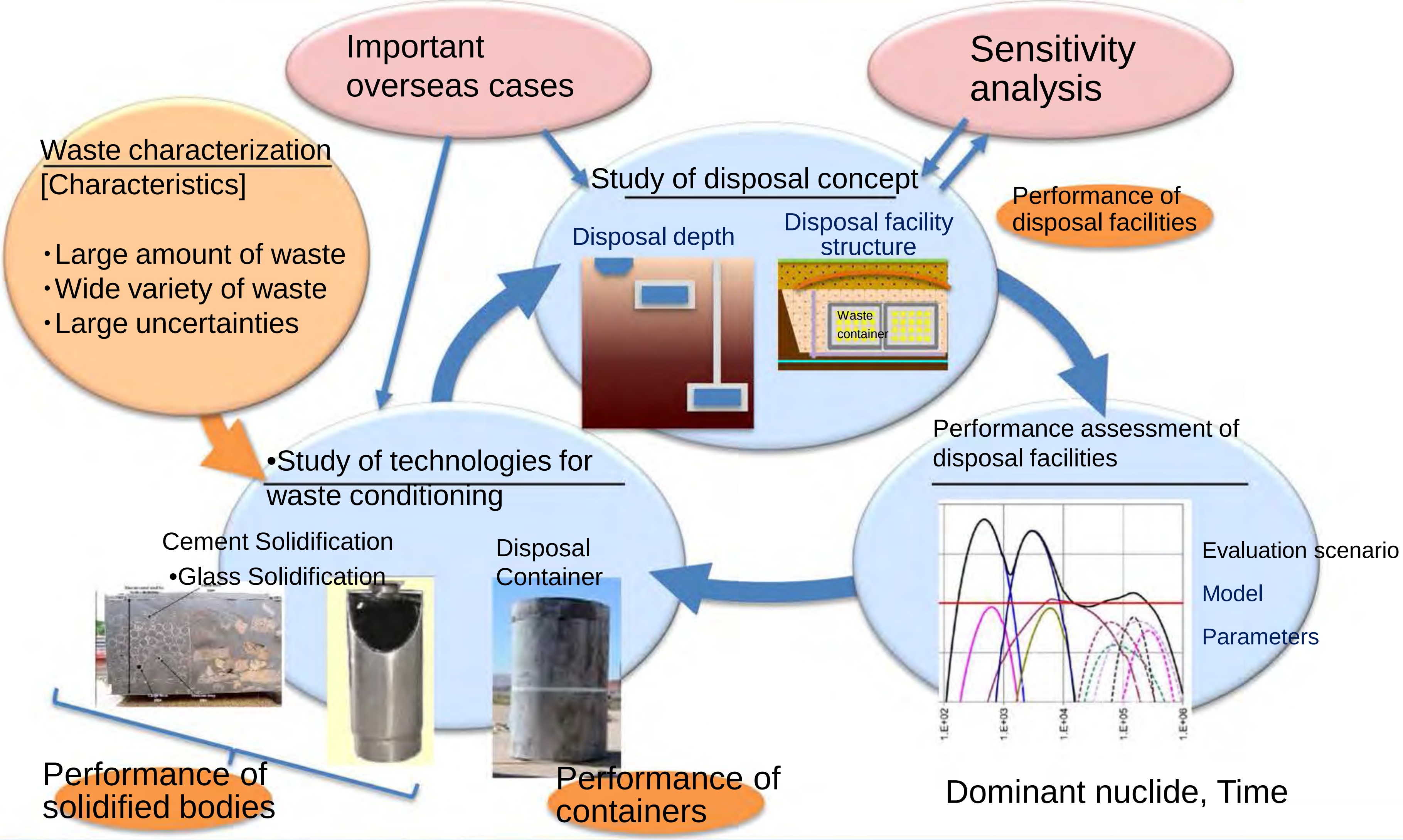
Establishment of the study process methodology was confirmed this time.

⇒ Case studies were implemented for typical disposal concept that have been proposed.

b. Study process of disposal concept considering waste characteristics

- Example of options for the study of disposal concept-

Implementing sensitivity analysis beforehand to conduct effective case studies



Important overseas cases

Sensitivity analysis

Waste characterization
[Characteristics]

- Large amount of waste
- Wide variety of waste
- Large uncertainties

Study of disposal concept

Disposal depth

Disposal facility structure

Performance of disposal facilities

Performance assessment of disposal facilities

Evaluation scenario

Model

Parameters

Dominant nuclide, Time

•Study of technologies for waste conditioning

Cement Solidification

•Glass Solidification

Disposal Container

Performance of solidified bodies

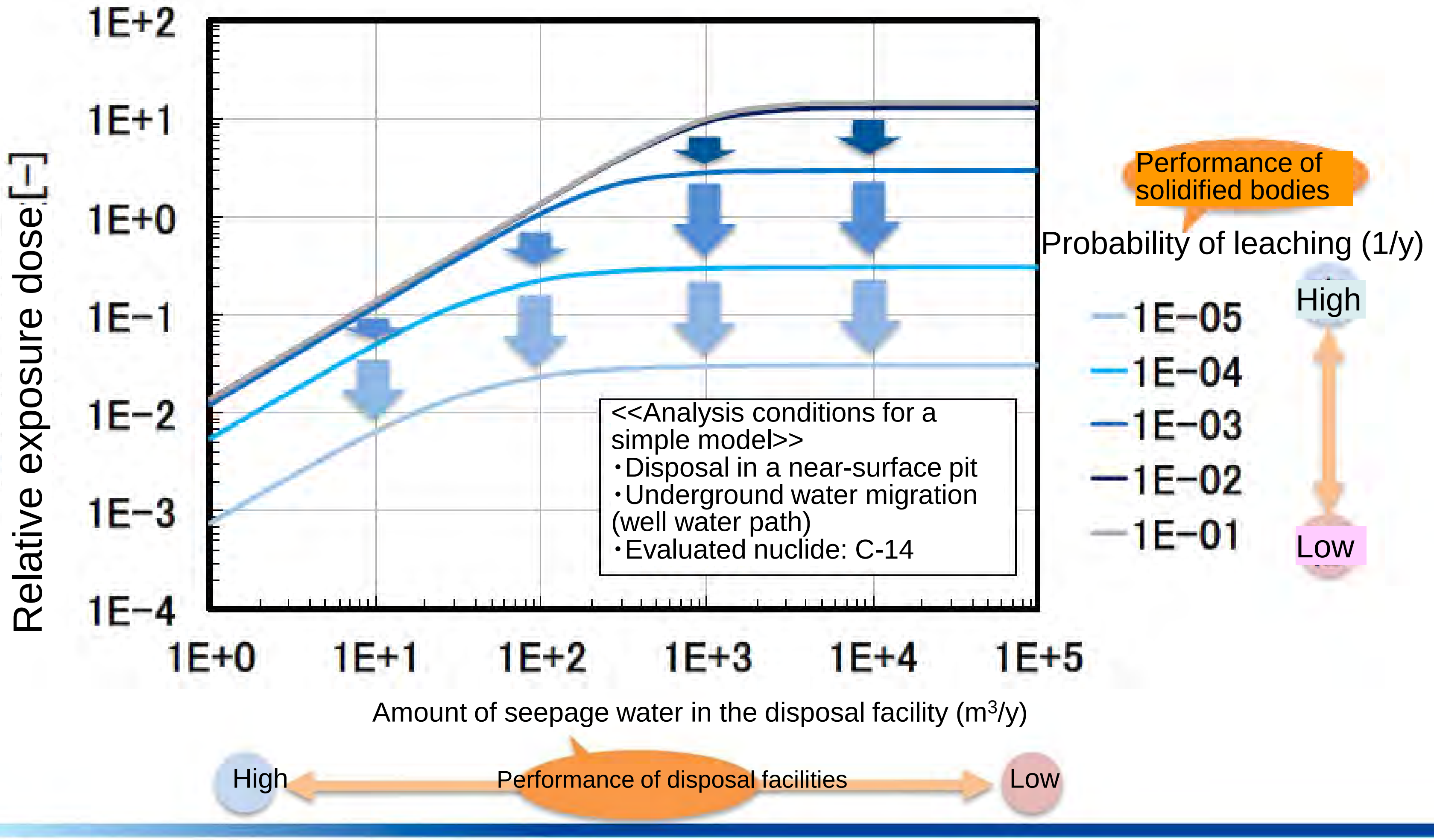
Performance of containers

b. Study process of disposal concept considering waste characteristics

-Example of Sensitivity Analysis: Performance of solidified materials-

Effect of solidification performance changes depending upon performance of disposal facilities

⇒ Performance of solidified bodies is required to be in accordance with the concept for the disposal facility



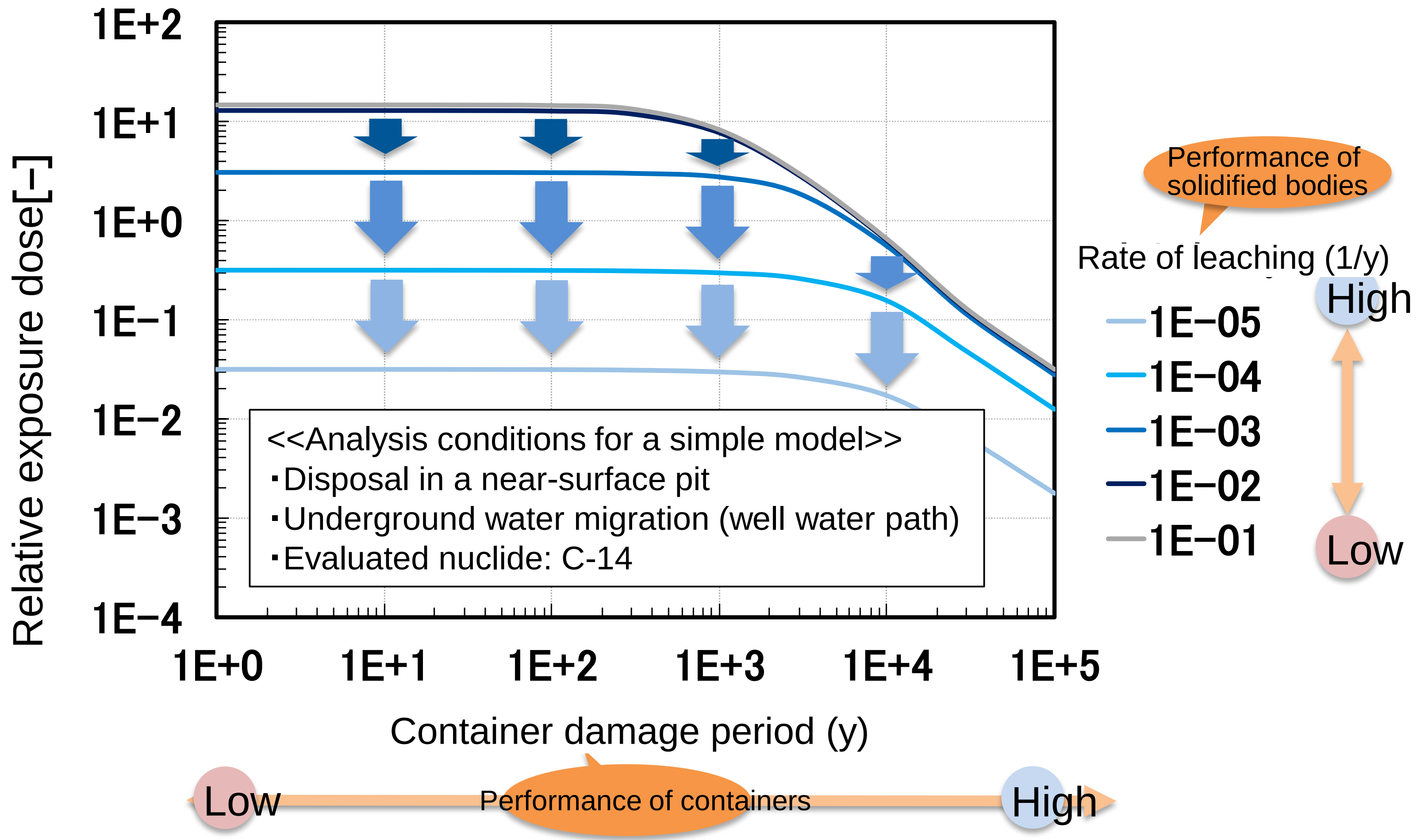
<<Analysis conditions for a simple model>>
・Disposal in a near-surface pit
・Underground water migration (well water path)
・Evaluated nuclide: C-14

b. Study process of disposal concept considering waste characteristics

-Example of Sensitivity Analysis: Performance of containers-

Effectiveness of container performance changes depending upon the disposal facility and solidification performance as well.

⇒ In this example, the process is seen to be effective in maintaining the integrity of the container for 1000 years or more



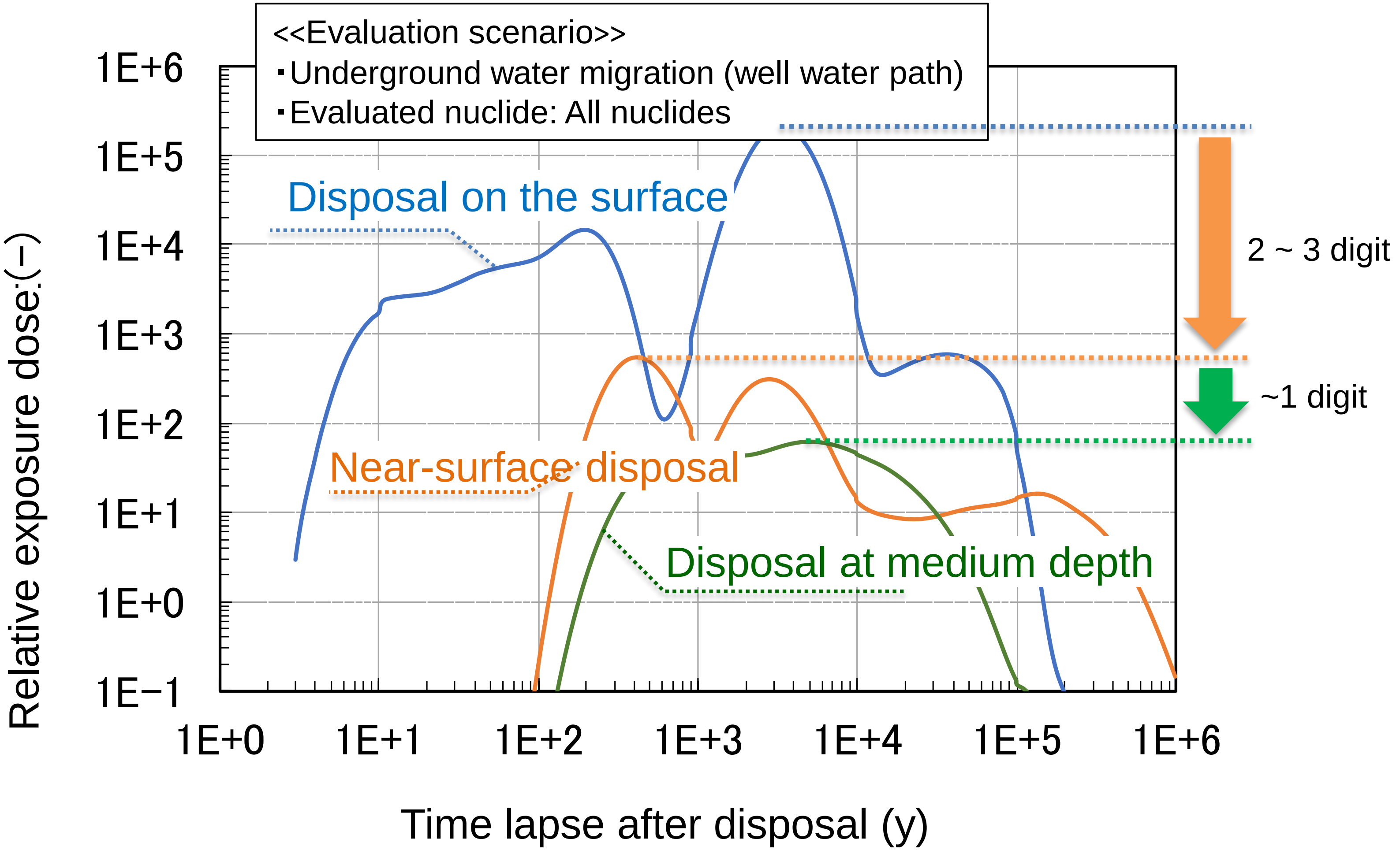
<<Analysis conditions for a simple model>>
- Disposal in a near-surface pit
- Underground water migration (well water path)
- Evaluated nuclide: C-14

b. Study process of disposal concept considering waste characteristics

-Example of Sensitivity Analysis: Performance of disposal facilities-

Significant dose reduction effect can be achieved by increasing the disposal depth

⇒ Reducing the burden of waste segregation



b. Study process of disposal concept considering waste characteristics

-Summary of Sensitivity Analysis-

Understanding the main performance factors and their effects and limitations to be considered during treatment and disposal

⇒ Incorporate into case study settings to confirm the effectiveness of the study process

Item	Performance of solidified bodies	Performance of containers	Performance of disposal facilities
Short-half-life nuclides such as Co-60, Sr-90, Cs-137, Ni-63	• Approach scenario (construction, housing, agriculture, etc.) is dominant over underground water migration scenario. • Institutional controls and barriers would be effective in reducing the possibility of human intrusion in facilities and containers.		
Long-half-life low-sorption performance nuclides such as C-14, Cl-36, Se-79, Tc-99, I-129	0~2 digit*1 •Controlling the probability of leaching •The effect is determined in combination with the facility, container, and natural barrier performance	0~1 digit*1 • Container confinement • Dispersion during confinement period and diffusion inside container •The effect is determined in combination with the facility, solidification, and natural barrier performance	0~2 digit*1 • Controlling the quantity of water permeation •Diffusion barrier •The effect is determined in combination with the solidification, container, and natural barrier performance
Long-half-life sorption performance nuclides such as Ni-59, Nb-94, Sn-126, Cs-135, TRU	<0~2 digit*1 • Controlling the probability of leaching •The effect is difficult to detect as the effect of sorption and natural barrier is significant	<0~1 digit*1 • Container confinement • Dispersion during confinement period • Diffusion inside container • The effect is difficult to detect as the effect of sorption and natural barrier is significant	<0~2 digit*1 • Controlling the quantity of water permeation • Diffusion barrier • The effect is difficult to detect as the effect of sorption and natural barrier is significant

*1: Criterion for reduced relative exposure dose

c. Case studies of multiple disposal concepts

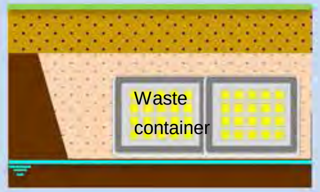
-Purpose of case studies-

Presentation of primary proposals for disposal concept and study of methodologies considering the characteristics of waste

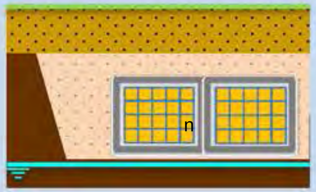
Four concepts set up for near-surface disposal

Examples of disposal concepts

Basic Cases



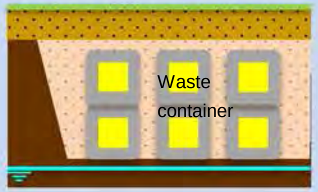
Improvement in performance of solidified bodies



Controlling leaching by means of the solidification treatment

Case

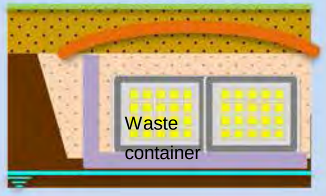
Improvement in performance of containers



Controlling diffusion by means of concrete containers

Improvement in performance of disposal facilities

Case



Controlling the amount of seepage water by means of the cap structure

Study of Methodologies

● How are the effects of the treatment or disposal concept evaluated?

- Evaluation of the exposure dose (human intrusion / underground water migration scenario)
- Evaluation of the amount of waste for each disposal class
- Identification of important nuclides and important scenarios

● How to provide a feedback on the results obtained?

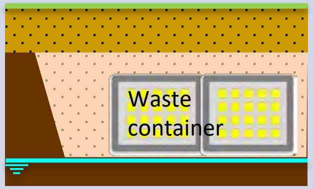
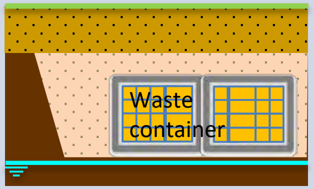
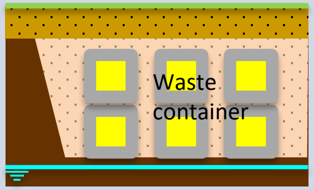
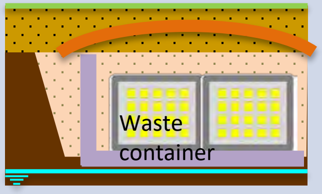
- Feedback for treatment and disposal concept(use of important overseas reference cases)
- Feedback for waste characterization (important nuclides, important waste)
- Feedback for treatment technologies (waste conditioning technologies)

Reflection in the Waste Management Strategy

c. Case studies of multiple disposal concepts

- Features of disposal concept for which case studies were conducted-

- Four near-surface disposal concepts were set up based on the results obtained from sensitivity analysis

Items		Reference case	Improvement in performance of solidified bodies	Improvement in performance of containers	Improvement in performance of disposal facilities
Conceptual diagram					
Features	Disposal facilities	Pit structures	Pit structures	Pit structures	Pit structures + Cap structures
	Disposal containers	Not assumed	Not assumed	Diffusion of the concrete container wall is assumed	Not assumed
	Presence of solidification	Not assumed	Assumed leaching rate of solidified bodies is 10^{-4} [1/y]	Not assumed	Not assumed

c. Case studies of multiple disposal concepts

-Analytical conditions for the case studies-

- The main conditions for dose evaluation are as follows:

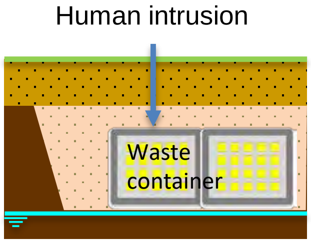
Set items	Set values
① Settings for the waste amount and inventory ⇒ 27 kinds of wastes are set	Use of analytical estimates value of nuclide concentrations in accident waste* Although these values are obtained from conservative evaluation of uncertainties (there are some wastes with a nuclide concentration that is several digits higher) by referring to the information as of FY2016, note that these will be continuously updated in the future as well according to the improvements in the analysis data on rubble or contaminated water, etc.
② Settings for the waste containers (disposal containers) (Only for the cases of improvement in performance of containers) ⇒ Thickness and diffusion coefficient settings	A concrete container is assumed. The nuclides migrate through the container wall by diffusion. The diffusion coefficient is 1E-12 (m^2/s), and the thickness of the container is 15 cm.
③ Settings for performance of waste bodies (Only for the cases of improvement in performance of solidified bodies) ⇒ Settings for the leaching probability	The leaching probability is set to 10^{-4} (1/y) on the basis of the sensitivity analysis results.
④ Settings for the environmental conditions for disposal ⇒ Settings of flow velocity and migration distance of the underground water	For this study, it has been set to surface (flow velocity 10 m/y and migration distance 100 m) and near surface / medium depth (flow velocity 0.1 m/y and migration distance 100 m)

c. Case studies of multiple disposal concepts

- Evaluation scenarios used for the case studies -

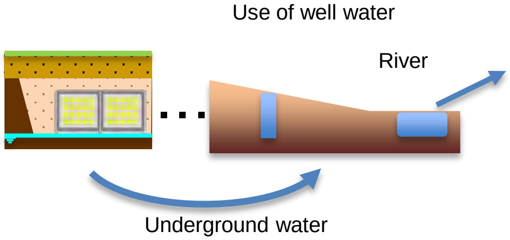
Main scenario

① Human intrusion scenario



Exposure route
- Site residents
- Digging workers
- Geo-technology engineer
- Laboratory analyst

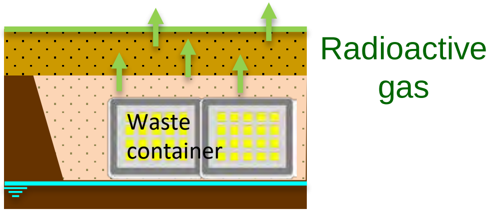
② Underground water migration scenario



Fishermen

Sub-scenario

③ Gas suction scenario

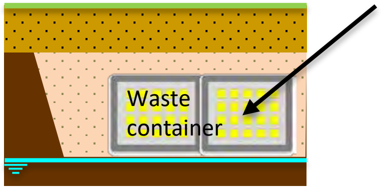


Exposure route
- Site residents

Inventory settings

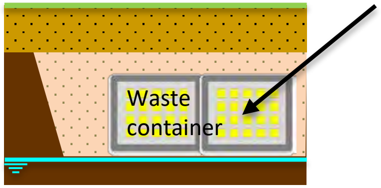
The inventory is set according to the purpose.

- Evaluation of **activity concentration** dependence of the human intrusion scenarios etc.



Individual waste inventory is set up

- Evaluation of the **amount of radioactivity** dependence of the underground water migration scenarios etc.



Inventory for all wastes is set up

■**Case Study①**

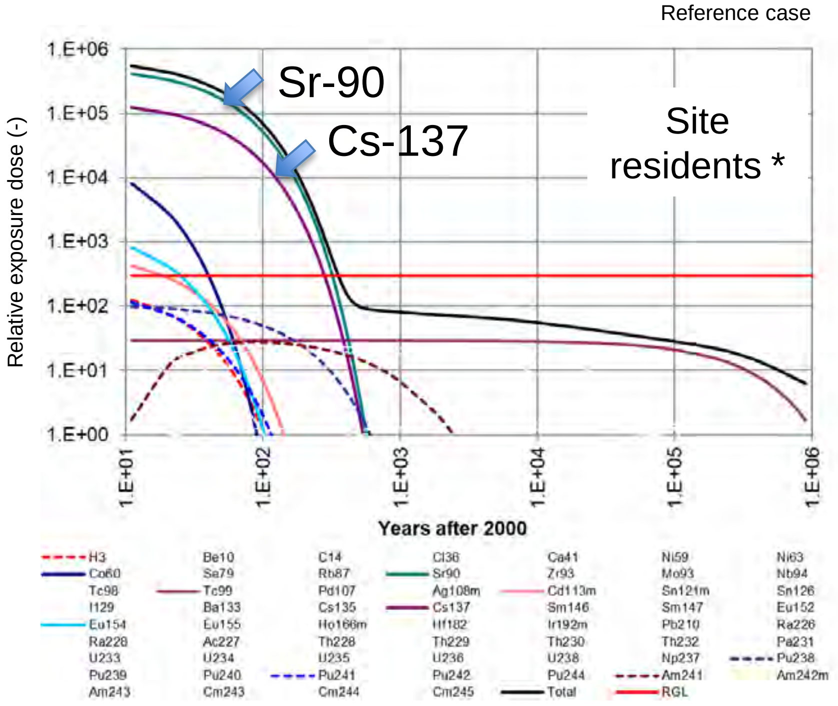
c. Case studies of multiple disposal concepts

- Study of the dominant nuclides -

- In the human intrusion scenario, the short half-life nuclides Sr-90 and Cs-137 are the dominant nuclides
- In the underground water migration scenario, the long half-life nuclides C-14 and I-129 are the dominant nuclides

} Measures need to be undertaken for each of these.

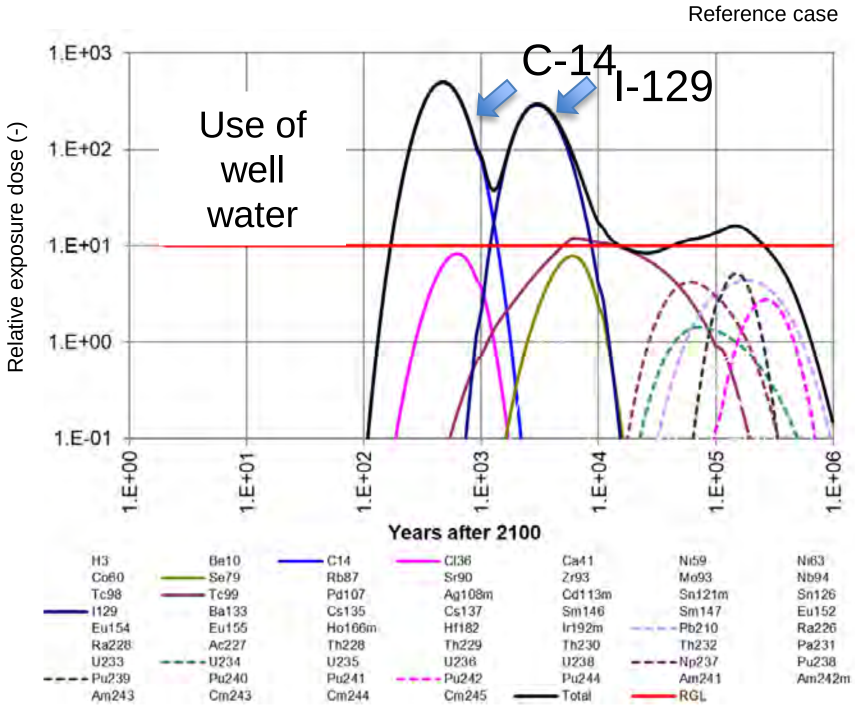
Human intrusion scenario



*Ingestion by agriculture and livestock, external exposure etc.

Sr-90 and Cs-137 are the dominant nuclides

Underground water migration scenario



C-14 and I-129 are the dominant nuclides

■Case Study②

c. Case studies of multiple disposal concepts

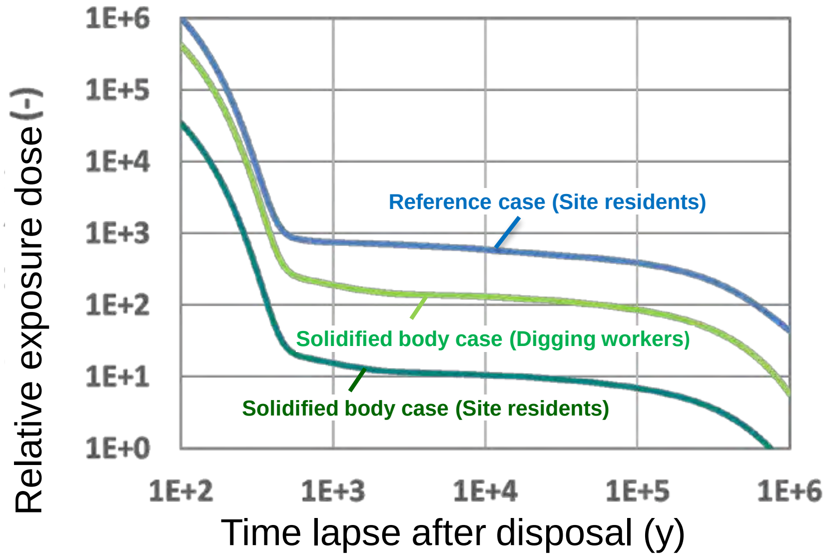
- Effects of the performance of the solidified bodies -

● Dose decreased in both the scenarios by improving the performance of the solidified bodies.

⇒ The effects of solidification and pre-treatment etc. can also be evaluated.

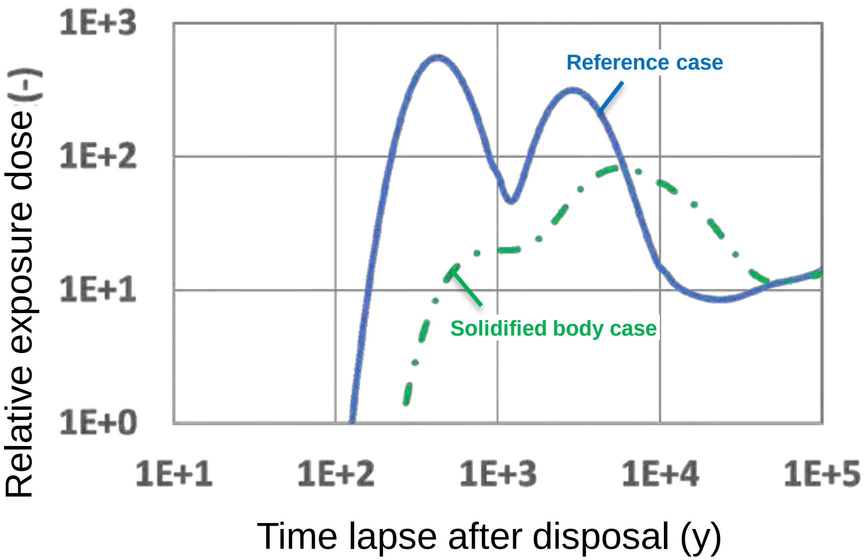
Human intrusion scenario

- In this case, it is assumed that during the production of the solidified body, C-14 vaporizes from the solidified body because of the high temperature heating.



Underground water migration scenario

- In this case, vaporization of C-14 is not considered and only the leaching rate (10^{-4} 1/y) of the solidified body is considered.
- The dose decreases due to the performance of the solidified body.



■ Case Study ③

c. Case studies of multiple disposal concepts

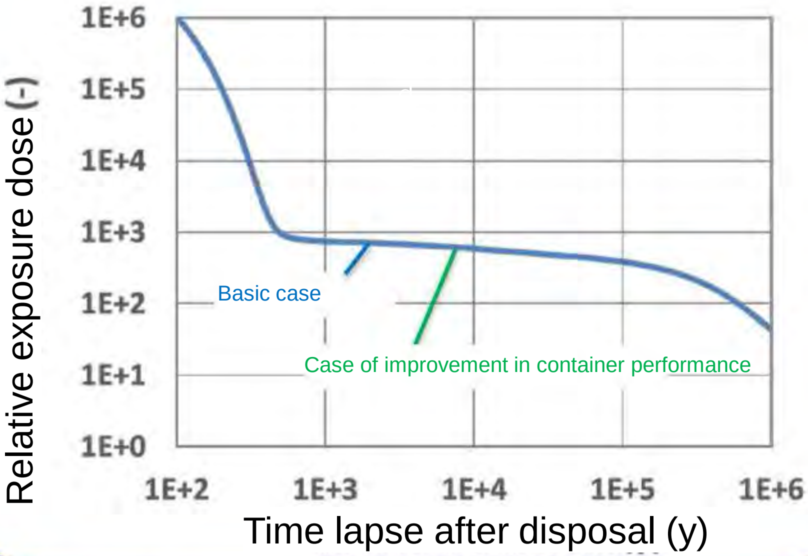
- Effects of performance of containers -

●Dose decreased in the underground water migration scenario due to improvement in the performance of the containers ⇒ In the human intrusion scenario, although the dose is the same, intrusion could be controlled.

Human intrusion scenario

☐ Intrusion is assumed even if it is a container, so there is no effect on the dose.

☐ However, the standard dose may be increased in consideration of the isolation effect of the containers.

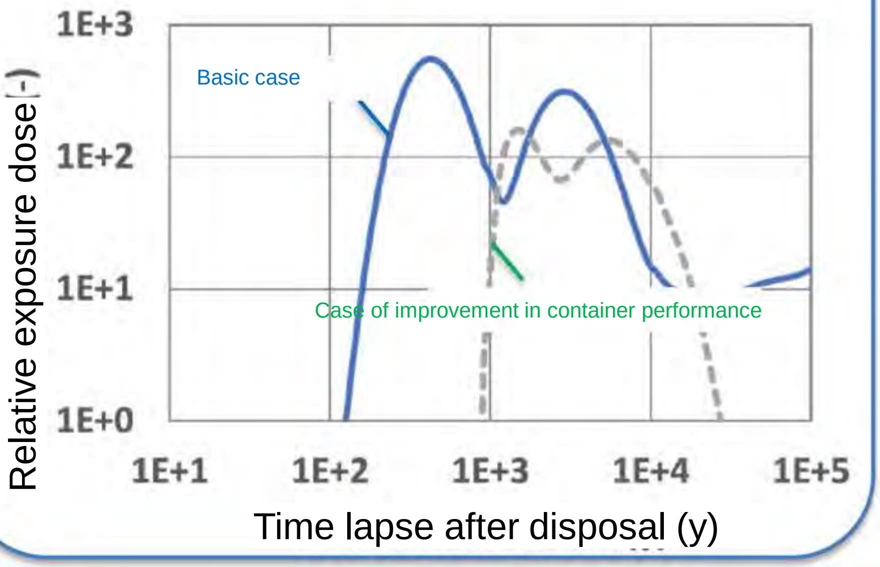


Underground water migration scenario

☐ Due to diffusion control, the nuclides migrate inside the container.

☐ Diffusion coefficient 10-12 m/s and container thickness 15 cm.

☐ The dose decreases due to the performance of the containers.



c. Case studies of multiple disposal concepts

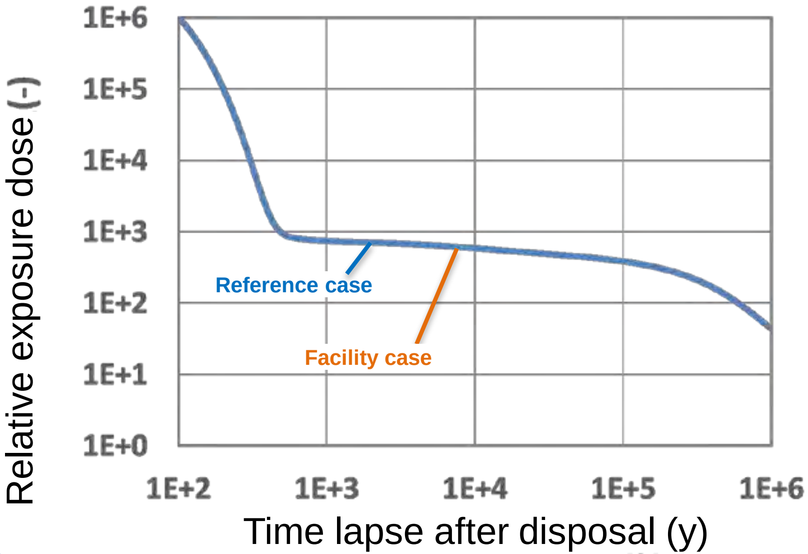
- Effects of performance of facilities -

● Effectiveness of facility performance revealed in comparison with performance of natural barriers

⇒ A study of the disposal facilities in accordance with the assumed natural barrier conditions is important.

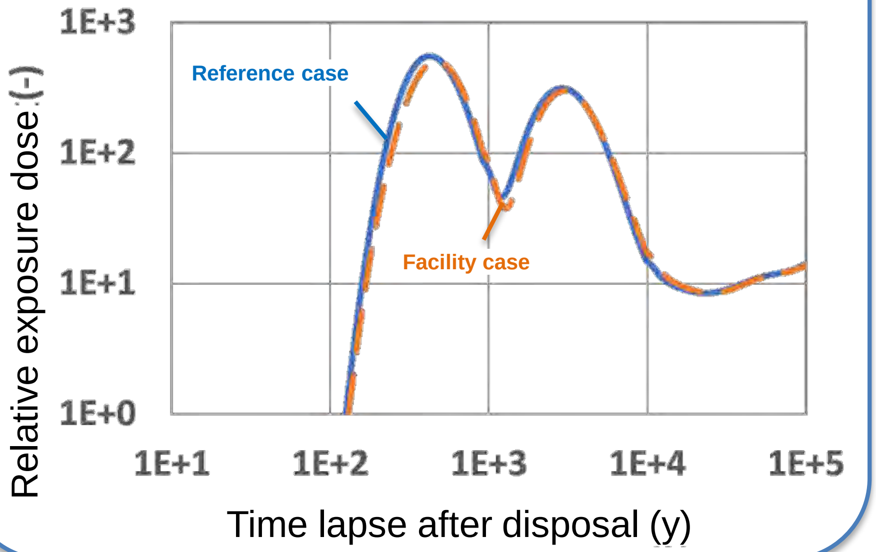
Human intrusion scenario

- Intrusion is assumed even if there is a cap layer, so there is no effect on the dose.
- However, the standard dose may be increased in consideration of the isolation effect of the facilities.



Underground water migration scenario

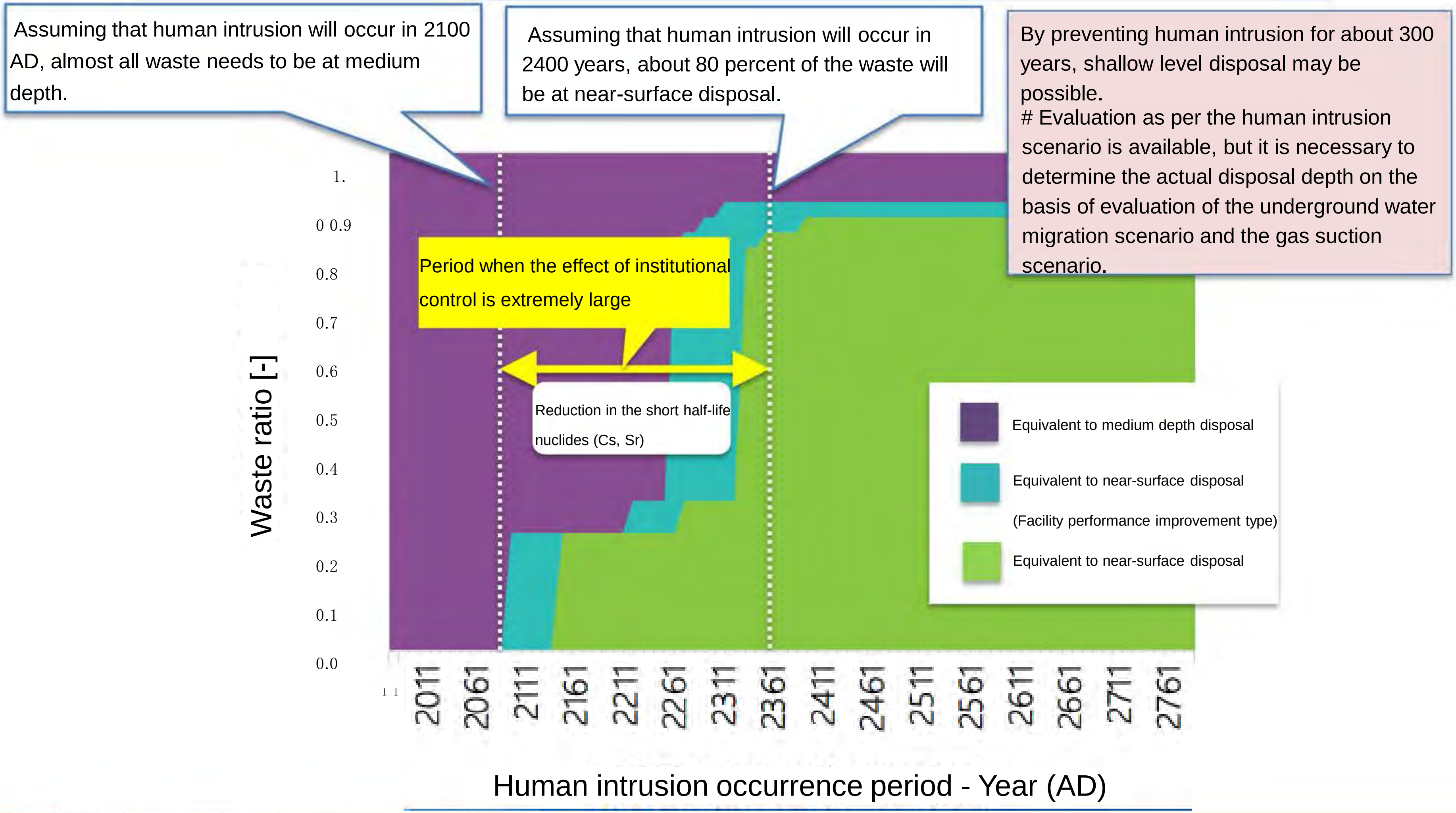
- The improvement in the performance of facilities is reflected in the differences in the amount of seepage water.
- In this case, since the settings for the performance of natural barriers was set high, the effect of facilities could not be seen.



■ Case Study ⑤ c. Case studies of multiple disposal concepts

- Relation between disposal classification and the institutional control period -

● Big change in the ratio of the waste classification due to the effective use of institutional control.
⇒ The maximum effect is in the decrease of dose in the human intrusion scenario.



Assuming that human intrusion will occur in 2100 AD, almost all waste needs to be at medium depth.

Assuming that human intrusion will occur in 2400 years, about 80 percent of the waste will be at near-surface disposal.

By preventing human intrusion for about 300 years, shallow level disposal may be possible.
Evaluation as per the human intrusion scenario is available, but it is necessary to determine the actual disposal depth on the basis of evaluation of the underground water migration scenario and the gas suction scenario.

Period when the effect of institutional control is extremely large

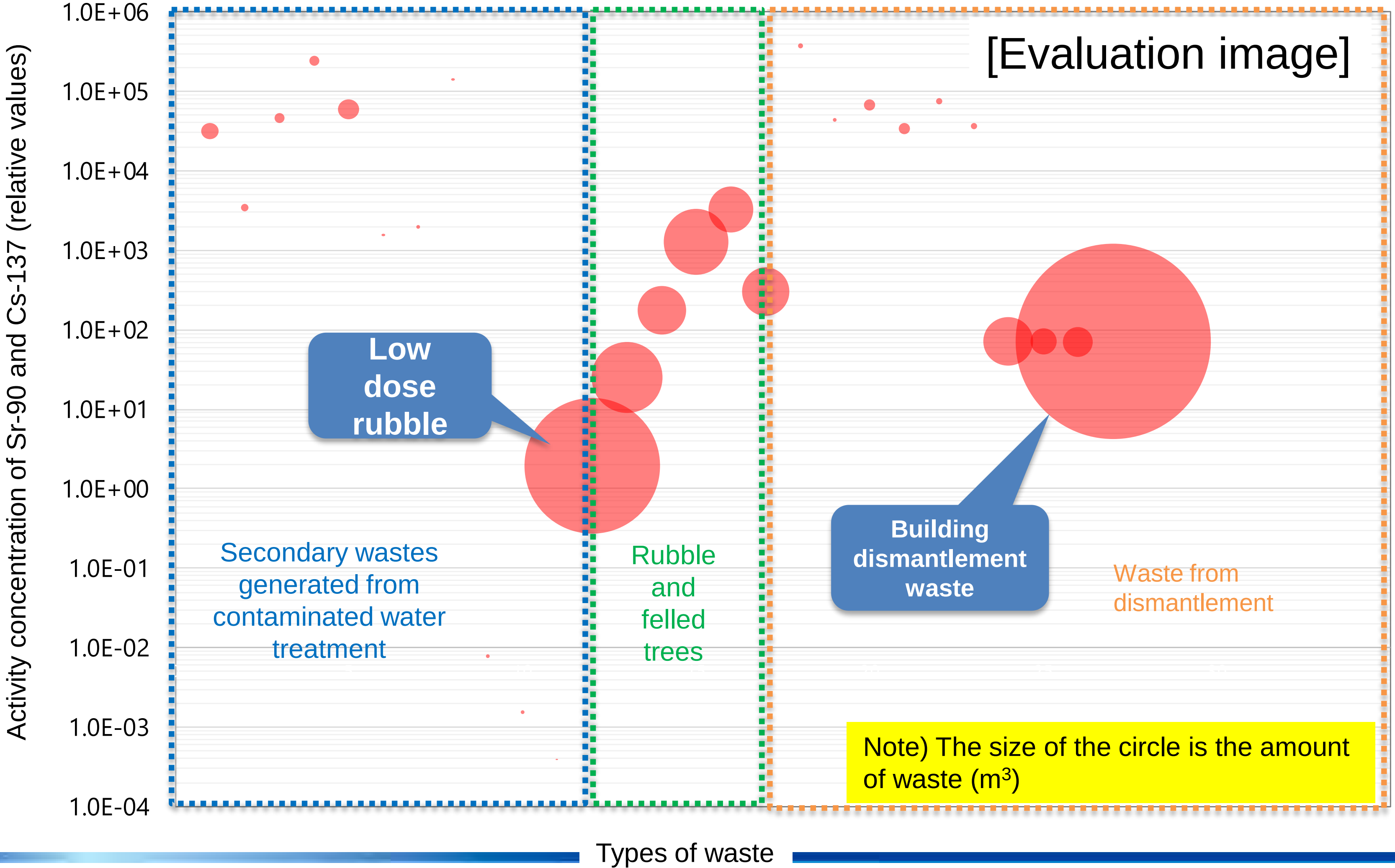
Reduction in the short half-life nuclides (Cs, Sr)

■ Case Study ⑥

c. Case studies of multiple disposal concepts

- Dose and amount of waste -

- The high-dose waste tends to be comparatively low in amount.
- The “building dismantlement waste" that has a high dose and exists in large amounts is especially important from the viewpoint of waste management.



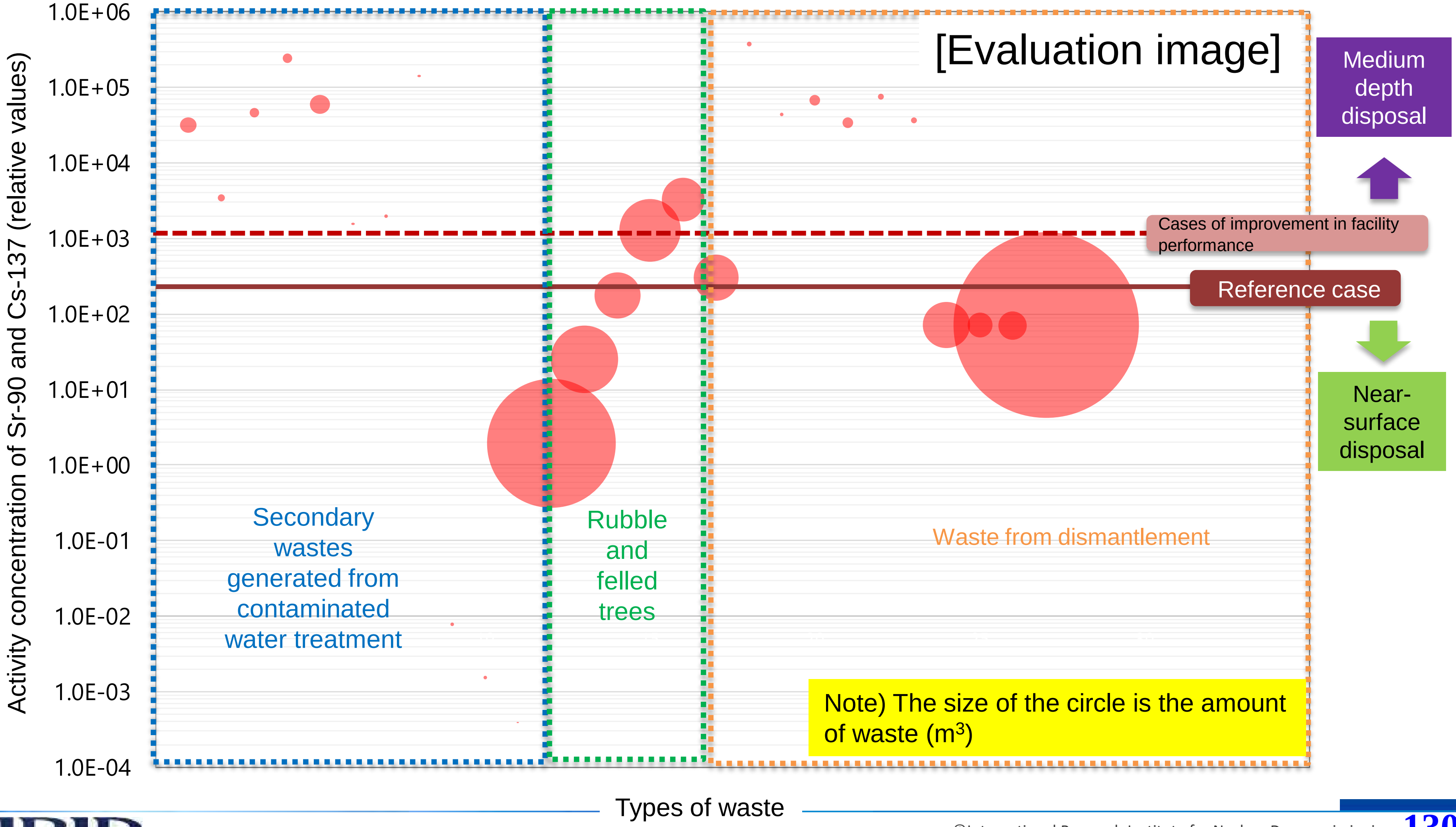
Note) The size of the circle is the amount of waste (m^3)

■ Case Study ⑦

c. Case studies of multiple disposal concepts

- Examples of evaluation of the human intrusion scenario -

- Due to the improvement in the performance of facilities, the waste for near-surface disposal tends to increase.
- Since medium depth disposal is also necessary, multiple concepts need to be studied.



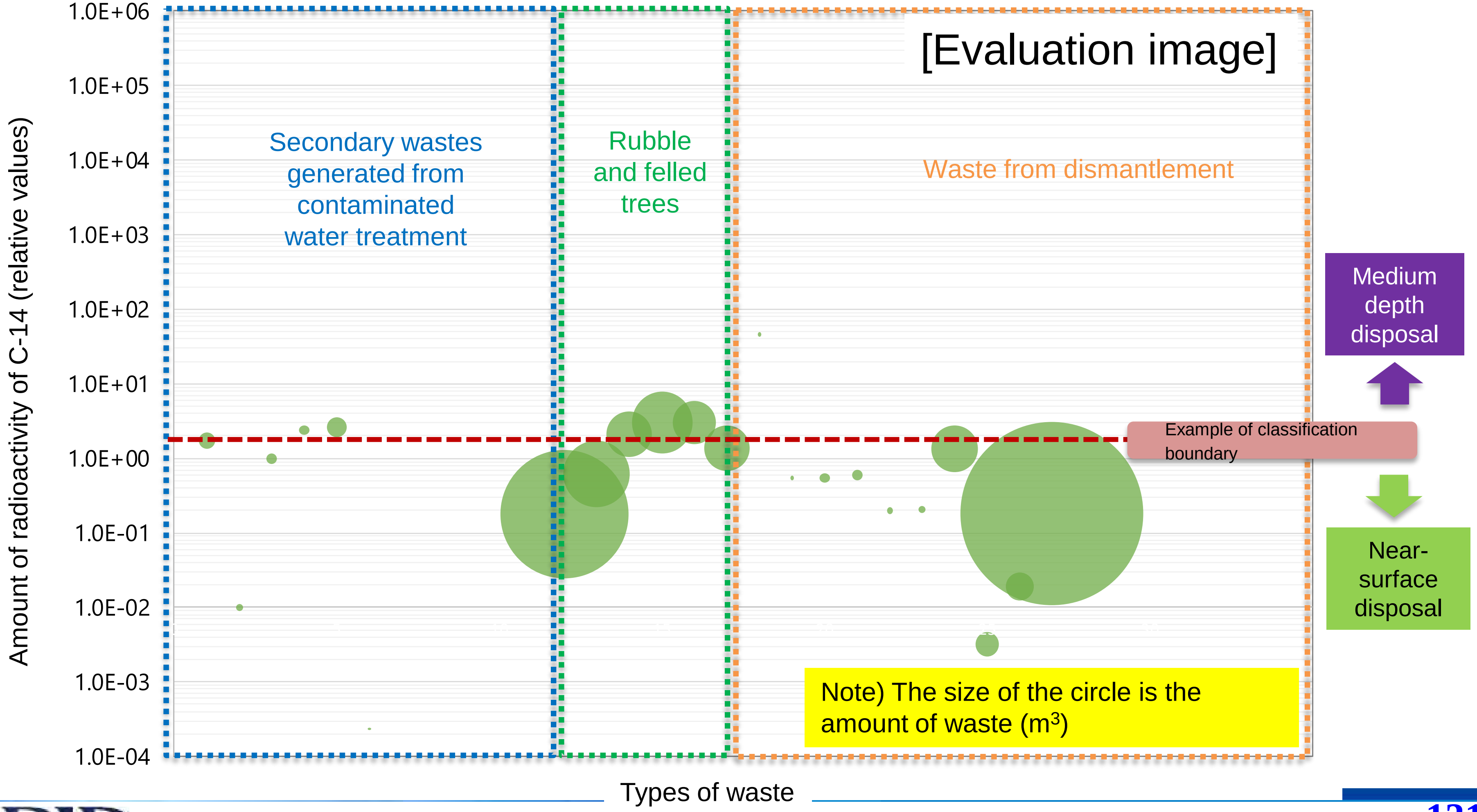
Note) The size of the circle is the amount of waste (m^3)

■ Case Study ⑧

c. Case studies of multiple disposal concepts

- Examples of evaluation of the underground water migration scenario (C-14) -

- In the underground water migration scenario, the amount of radioactivity is important rather than the activity concentration.
- Among the rubble waste, the high-dose waste is likely to be contaminated with C-14.



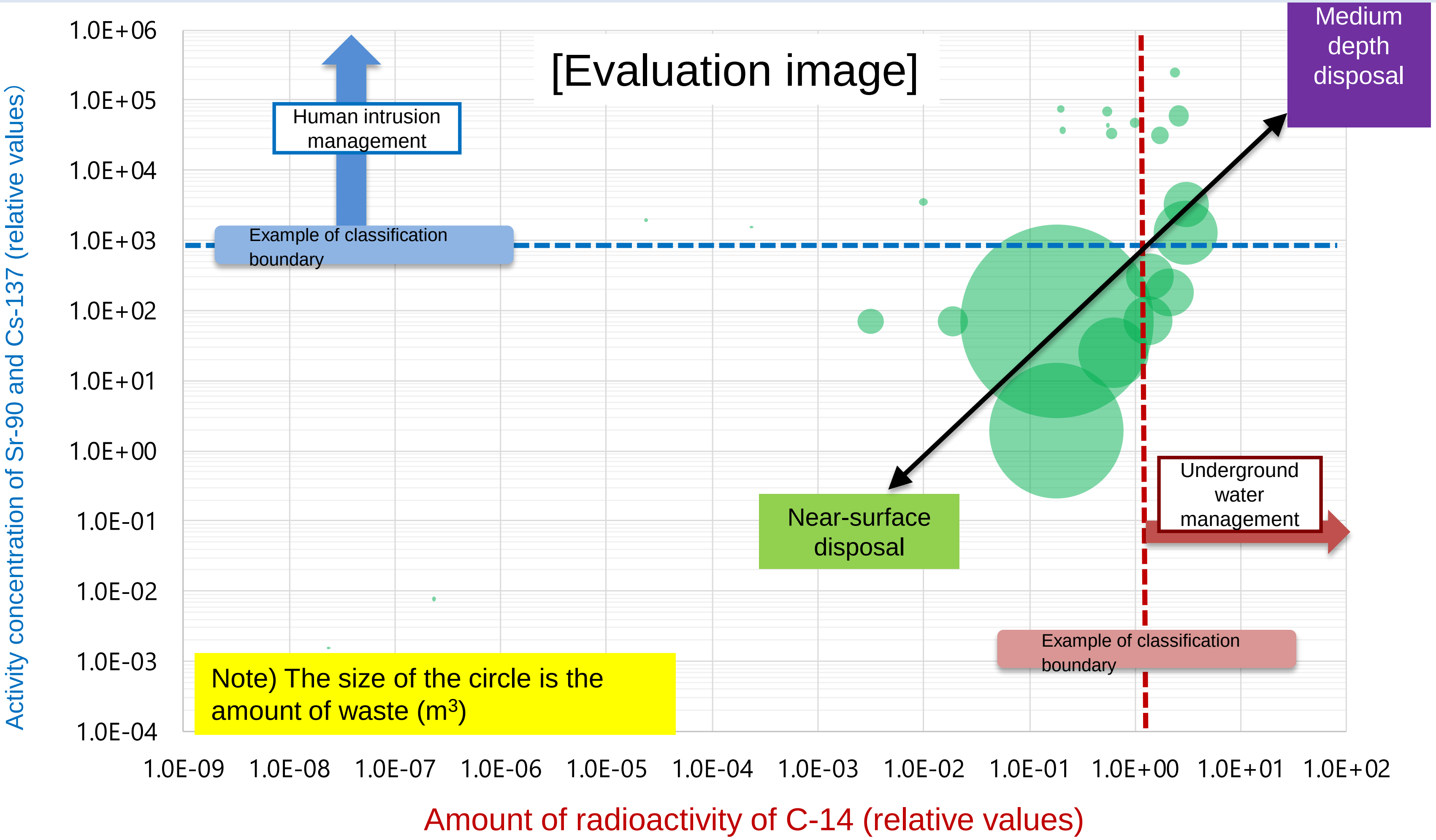
Note) The size of the circle is the amount of waste (m^3)

■ Case Study ⑨

c. Case studies of multiple disposal concepts

−Concept of waste classification−

- By organizing the waste with the concentration of the short half-life nuclides and the amount of the long half-life nuclides on the axes, it is possible to study the management of each waste (using sensitivity analysis results or important overseas reference cases).
- Moreover, the priority levels of waste and nuclide analysis can be set.



Note) The size of the circle is the amount of waste (m^3)

■ Case Study ⑩

c. Case studies of multiple disposal concepts

-Study of management proposals using important overseas reference cases-

Important overseas reference cases can be used to study management for each of the evaluation scenarios

No.	Important reference cases	Applicability to 1F waste disposal	Category	Human intrusion scenario	Underground water migration scenario	Others (Efficiency improvement etc.)
1	Facility structure with a Cap System	Possible (Depends on the location)	Disposal facilities	○	○	
2	Facility structure to control human intrusion	Possible (Technical study required)	Disposal facilities	○		
3	Use of very low level waste as a backfill material	Possible (Evaluation required)	Disposal facilities			○
4	Large size disposal containers	Possible	Disposal containers			○
5	Other standard containers	Possible	Disposal containers			○
6	Concrete containers	Possible (Technical study required)	Disposal containers	○	○	
7	UK waste disposal strategy	Possible (Technical study required)	Pre-treatment			○
8	Large size container solidification	Possible (Technical study required)	Solidification	○	○	
9	Mixed waste solidification	Possible (Change the inventory management))	Solidification			○
10	Settings of short-half-life medium-level waste category	Possible (Technical study required)	Control and management	○		
11	Inventory management system	Possible (Change the inventory management)	Control and management			○
12	Institutional control	Applied	Control and management	○		
13	Acceptance of waste containing materials with impact	Possible (Partially applied)	Evaluation method			○
14	Evaluation of long-term degradation of engineered barriers	Applied	Evaluation method		○	
15	Probabilistic Safety Assessment	Possible (Technical study required)	Evaluation method			○

c. Case studies of multiple disposal concepts

-Summary of Case Study Results-

Study of Methodologies

● How are the effects of the treatment or disposal concepts evaluated?

- The effects of the treatment or disposal options can be evaluated with the dose.
- However, since the parameters are mutually related, it is necessary to take a note of this while evaluating the results.
- It is also possible to evaluate each disposal concept by the amount of waste in each disposal classification.
- Important nuclides and important scenarios can be specified.
- Operating methods such as institutional control etc. can also be considered.

● How to provide a feedback for the results obtained?

- It is possible to study the management of evaluation scenarios by means of using important overseas reference cases etc.
- The waste can be organized with the short half-life nuclide concentrations and the long half-life nuclide amounts on the axes.
- By organizing in this manner, it is possible to specify important nuclides and important waste having a higher study priority.
- The performance requirements of the waste can be evaluated.

d. Summary of Results

1. Results of investigation of overseas reference cases

- Important overseas reference cases were selected and along with evaluating these cases for applicability to 1F waste disposal, they were reflected in the study of disposal concepts.

2. Study process of disposal concept considering waste characteristics

- A disposal concept study process was developed in order to study the “Waste Management Strategy" that provides an overview of the entire process from treatment to disposal.

3. Case studies of multiple disposal concepts

- Case studies were carried out on cases where the confinement performance for the disposal facilities, disposal containers, and solidified bodies had been improved, and it was confirmed that it was possible to verify the effects and provide feedback.

(2) Measures for Materials with Impact on Disposal

-Implementation plan and Goal achievement index-

FY	Implementation plan	Goal achievement index
2017	• Case studies on acceptance criteria of waste inside and outside Japan will be surveyed, regarding not only radionuclides but also materials that impact treatment and disposal methods.	• Presentation of cases that address the acceptance criteria of waste in terms of the content such as materials with impact on disposal.
2018	• Case studies on acceptance criteria of waste inside and outside Japan will be surveyed. • Based on the survey results, concepts regarding the acceptable concentrations and contents of materials with impact on disposal etc. in the waste which are presumed to mix up in the waste at the predisposal management and disposal facilities, will be consolidated.	• Presentation of concepts regarding the acceptable concentrations and contents of materials with impact on disposal etc. in the waste at Fukushima Daiichi Nuclear Power Station.

(2) Measures for Materials with Impact on Disposal
-Concepts of Acceptable Concentration Settings-

① Materials with a potential adverse impact on the human body and the environment

・In the USA and UK, controlled substances and their concentrations have been stipulated by regulations (such as 40CFR261 etc.).
・However, in the UK, there are examples of classifying the target materials and implementing control requirements / segregation requirements (Table 1) as well.

② Materials with impact on migration of nuclides

・ Although there are examples where the target materials have been indicated by the Standard Review Plan (NUREG/CR-6758) etc., the handling differs according to the safety assessment by each disposal facility.

Table 1 Example of category-wise requirement levels in UK

Category	Requirement level	Typical materials
Category 1	Requirement of control only without any specific restrictions or segregation requirements. The amount of the materials concerned needs to be recorded in the inventory.	Halogenated plastics, asphalt, copper, stainless steel, etc.
Category 2	Segregation required. Waste with the content of the materials concerned equal to or within the criteria for acceptance can be accepted. The amount of the materials needs to be recorded in the inventory.	Arsenic, lead, mercury, electronic parts, etc.
Category 3	Materials classified as hazardous materials. Special management is required for these materials until disposal.	Asbestos, oil, solution, etc.

Table 2 Example of regulations for materials which impact migration of nuclides

◆WCS disposal facility (US):
- Chelating material must not exceed 8% of the disposal facilities (mass) at the most.

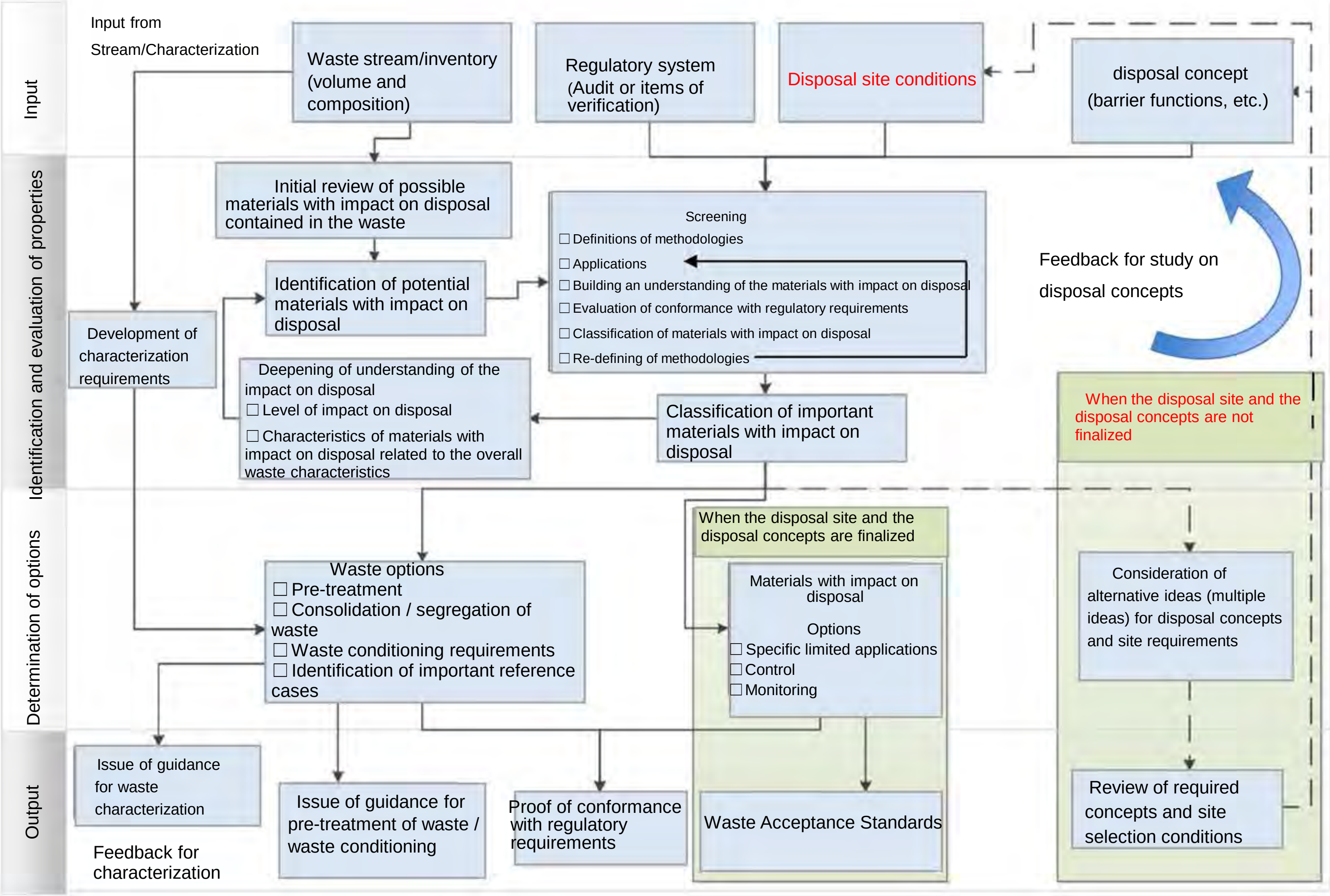
◆LLWR disposal facility (UK):
- Classification into control requirement or the segregation requirement depending on the chelating material.
- Application of the Best Available Method (BAT[*1]).
- In the safety assessment, long-term decomposition is assumed while the impact is not considered.

◆ RWM disposal facility (UK) (Planning stage: HLW[*2], ILW[*3] and some of the LLW[*4] are the targets):
- Selecting ISA (iso-saccharin acid) as a representative of the chelating material and assessing safety by revising the solubility and distribution coefficient is being planned.

*1 Best Available Technique *2 High level waste *3 Intermediate level waste *4 Low level waste

(2) Measures for Materials with Impact on Disposal
-Concepts of Acceptable Concentration Settings-

Proposed flow chart of the evaluation process of materials with impact on disposal etc.



Input

Input from Stream/Characterization

Waste stream/inventory (volume and composition)

Regulatory system (Audit or items of verification)

Disposal site conditions

disposal concept (barrier functions, etc.)

Identification and evaluation of properties

Initial review of possible materials with impact on disposal contained in the waste

Identification of potential materials with impact on disposal

Development of characterization requirements

Screening
- ☐ Definitions of methodologies
- ☐ Applications
- ☐ Building an understanding of the materials with impact on disposal
- ☐ Evaluation of conformance with regulatory requirements
- ☐ Classification of materials with impact on disposal
- ☐ Re-defining of methodologies

Feedback for study on disposal concepts

Deepening of understanding of the impact on disposal
- ☐ Level of impact on disposal
- ☐ Characteristics of materials with impact on disposal related to the overall waste characteristics

Classification of important materials with impact on disposal

When the disposal site and the disposal concepts are not finalized

Determination of options

When the disposal site and the disposal concepts are finalized

Waste options
- ☐ Pre-treatment
- ☐ Consolidation / segregation of waste
- ☐ Waste conditioning requirements
- ☐ Identification of important reference cases

Materials with impact on disposal

Options
- ☐ Specific limited applications
- ☐ Control
- ☐ Monitoring

Consideration of alternative ideas (multiple ideas) for disposal concepts and site requirements

Output

Issue of guidance for waste characterization

Feedback for characterization

Issue of guidance for pre-treatment of waste / waste conditioning

Proof of conformance with regulatory requirements

Waste Acceptance Standards

Review of required concepts and site selection conditions

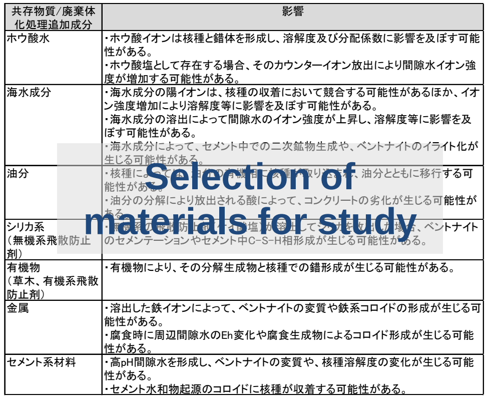
(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Implementation plan and goal achievement index-

FY	Implementation plan	Goal achievement index
2017 2018	· Methods of quantitative evaluation will be studied for the impact of components that are known to have an impact on barrier performance (structural and nuclide migration-related chemical properties transformation) and nuclide migration (nuclide migration-related chemical properties transformation) at the time of disposal . · To consolidate the waste characteristics and materials with impact on disposal and select the materials with impact, which will be targeted in this project. · To study the proposed impact assessment methods in accordance with the understanding or basic information about the impacting processes of the typical materials with impact, etc. · To study the quantitative methods of impact assessment by conducting investigations and data collection concerning mutual interaction between the nuclides and the main materials with impact · A predictive study of evaluation methods concerning specification items, which should be considered on the basis of the developed impact assessment methods	· Presentation of quantitative evaluation indices for impact on barrier performance or for impact on nuclide migration at the time of disposal. · Presentation of a list of the materials with impact · Presentation of proposed common evaluation method for assessment of impact on disposal · Presentation of data and trial results intended for impact assessment of the nuclides and main materials with impact · Presentation of predictive evaluation results of specification items which should be considered during disposal

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal
-Flow of Study-

Table List of materials with impact (Consolidated examples of impact)



共存物質/廃棄体化処理追加成分	影響
ホウ酸水	・ホウ酸イオンは核種と錯体を形成し、溶解度及び分配係数に影響を及ぼす可能性がある。 ・ホウ酸塩として存在する場合、そのカウンターイオン放出により間隙水イオン強度が増加する可能性がある。
海水成分	・海水成分の陽イオンは、核種の収着において競合する可能性があるほか、イオン強度増加により溶解度等に影響を及ぼす可能性がある。 ・海水成分の溶出によって間隙水のイオン強度が上昇し、溶解度等に影響を及ぼす可能性がある。 ・海水成分によって、セメント中での二次鉱物生成や、ベントナイトのイライト化が生じる可能性がある。
油分	・核種によっては、油分の有機相に核種が取り込まれ、油分とともに移行する可能性がある。 ・油分の分解により放出される酸によって、コンクリートの劣化が生じる可能性がある。
シリカ系（無機系飛散防止剤）	・無機系の飛散防止剤（ケイ酸塩）が溶出してシリカを放出した場合、ベントナイトのセメンテーションやセメント中C−S−H相形成が生じる可能性がある。
有機物（草木、有機系飛散防止剤）	・有機物により、その分解生成物と核種での錯形成が生じる可能性がある。
金属	・溶出した鉄イオンによって、ベントナイトの変質や鉄系コロイドの形成が生じる可能性がある。 ・腐食時に周辺間隙水のEh変化や腐食生成物によるコロイド形成が生じる可能性がある。
セメント系材料	・高pH間隙水を形成し、ベントナイトの変質や、核種溶解度の変化が生じる可能性がある。 ・セメント水和物起源のコロイドに核種が収着する可能性がある。

Selection of materials for study

- Target materials: 6 materials are selected (Organic materials, sea water elements, boric acid, ferrocyanide, sulfate and carbonate)

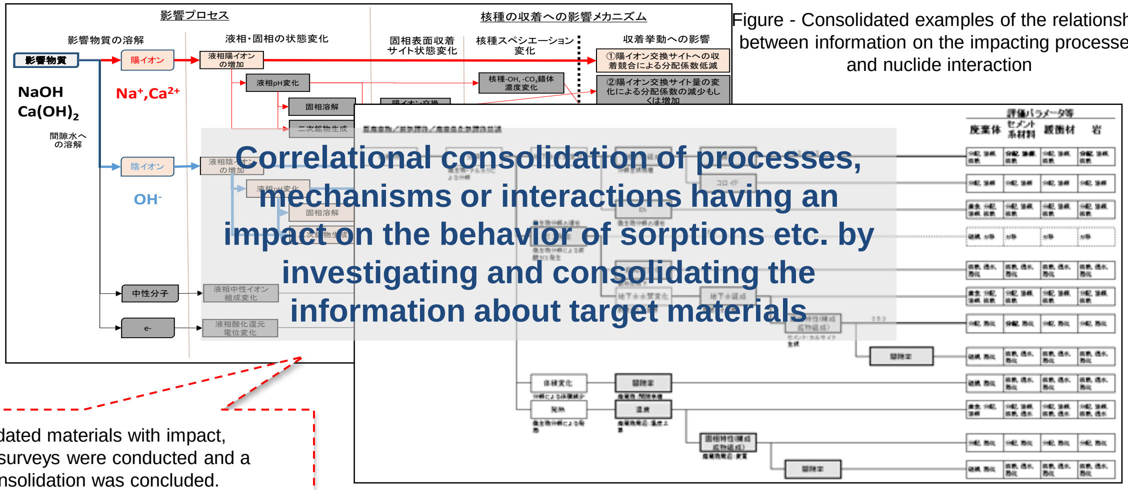


Figure - Consolidated examples of the relationship between information on the impacting processes and nuclide interaction

Correlational consolidation of processes, mechanisms or interactions having an impact on the behavior of sorptions etc. by investigating and consolidating the information about target materials

- With regards to consolidated materials with impact, exhaustive information surveys were conducted and a generally correlating consolidation was concluded.

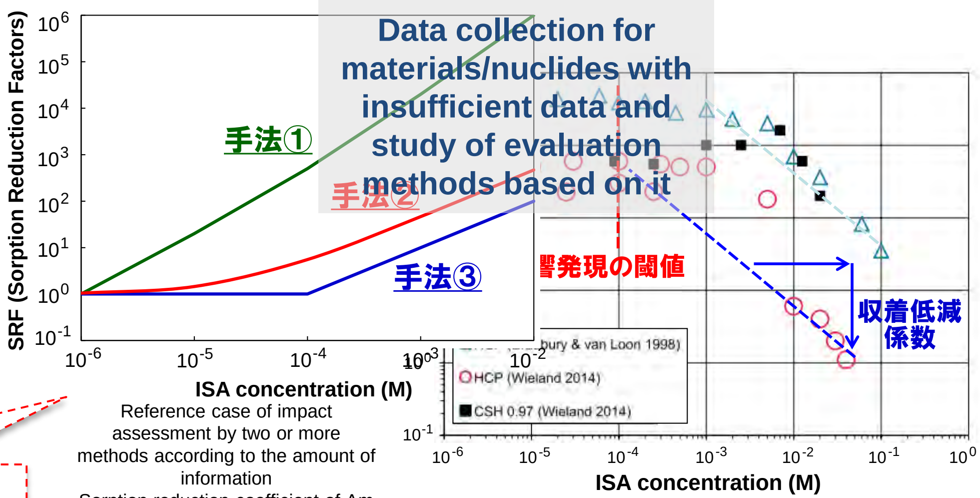
Element group	Typical elements	Sorption Reduction Factor (SRF)					
		Material A	Material B	Material C	Material D	Material E	Material F
Alkali metals	Cs	1	2	2	1	2	46
Alkali earth metals	Sr	1	7	3	10	8	31
II-valent transition metals	Ni(II)	1	10	35	1	12	1
IV-valent transition metals	Zr(IV)	1	10	10	10^3	12	109
V-valent transition metals	Nb(V)	1	10	10	1	12	10
III-valent actinide	Am(III)	1	10	10	10^2	12	1
IV-valent actinide	Th(IV)	1	10	10	10^6	12	1
V-valent actinide	Np(V)	1	100	10	10^2	12	1
VI-valent actinide	U(VI)	1	100	10	10^2	12	1
Halogen	I	–	–	–	1	–	–
Types of anions	Se	–	–	–	–	–	–

Presentation of impact assessment data of materials with impact on disposal to contribute to safety assessment

Consolidated image of the Sorption Reduction Factors for the barrier material with respect to the impacting factors

- Data collection of sorption impact centering on ferrocyanide and sulfate for which there is insufficient data or no data
- Study or evaluation of evaluation methods corresponding to the amount of data

Data collection for materials/nuclides with insufficient data and study of evaluation methods based on it



Reference case of impact assessment by two or more methods according to the amount of information
Sorption reduction coefficient of Am to cement in a system coexisting with organic material (ISA)

Reference case of evaluation based on existing data
Organic material impact of Am on Kd

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Selection of materials with impact to be considered for investigation and evaluations-

■ Classification of materials with impact

○ The accident waste is classified into 4 types namely, secondary waste generated from contaminated water treatment, rubble/felled trees etc., fuel debris, waste from dismantlement, and then consolidated by dividing the materials with impact, assumed to be contained in the above waste, in two divisions namely, components of sources of waste and coexisting materials.

■ Selection of targets for investigation and evaluation

○ Organic materials, sea water elements and boric acid solution are selected as coexisting materials commonly contained in most of the accident waste.

○ Ferrocyanide, sulfate and carbonate are selected as components of sources of waste with concerns about impact, from amongst the secondary waste generated from water treatment and which have a comparatively high priority although there is not much commonality.
⇒ Investigation and evaluation were conducted this year for these six types of materials with impact.

Sources of waste			Secondary waste generated from contaminated water treatment												Rubble/Felled trees etc.						Fuel debris	Waste from dismantlement		
			Cesium adsorption tower	Secondary Cesium adsorption tower	Sludge from decontamination systems	Iron coprecipitation slurry	Carbonate slurry	Ag impregnated carbon	Titanate	Titanium oxide	Ferrocyanide	Chelate resin	Resin-based adsorbent (Column)	Filter	Rubble (concrete)	Rubble (metallic)	Rubble (other)	Felled trees	Soil	Used protective clothing	Fuel debris	Waste from dismantlement (concrete)	Waste from dismantlement (metallic)	Waste from dismantlement(others)
Materials with impact	Components of sources of waste	Zeolite	○	○																				
		Silica-based materials	○		○																			
		Iron hydroxide			○	○																		
		Carbonate					○																	
		Magnesium hydroxide					○																	
		Sulfate			○																			
		Activated carbon						○																
		Organic materials			○	○	○	○	○	○	○	○	○	○			○	○	○	○				○
		Titanium-based materials		○					○	○														
		Ferrocyanide			○						○													
		Metals	○	○		○	○	○	○	○	○	○	○		○	○					○	○	○	
		Concrete													○							○		
		Debris																			○			
		MCCI Debris																			○			
		Borides & Carbides																			○			
	Coexisting materials	Sea water elements	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○		○	○	○	○
		Boric-acid solution	○	○	○	○	○	○	○	○	○	○	○	○							○	○	○	○
		Oil	○	○	○	○	○	○	○	○	○	○	○	○							○	○	○	○
		Organic materials	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○			○	○	○
		Silica-based materials													○	○	○							
		Products with fuel deposits																				○	○	○

○: Materials with impact contained in the source of waste

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Selection of nuclide migration parameters intended for investigation and evaluation-

☐ Consolidation of effects of materials with impact on nuclide migration during disposal

☐ The barrier compositions, the safety functions expected from the various barriers, nuclide migration parameters and impacting factors of the materials with impact on the parameters, in the earlier disposal concepts, were consolidated (Figure 1 is an example of marginal depth disposal).

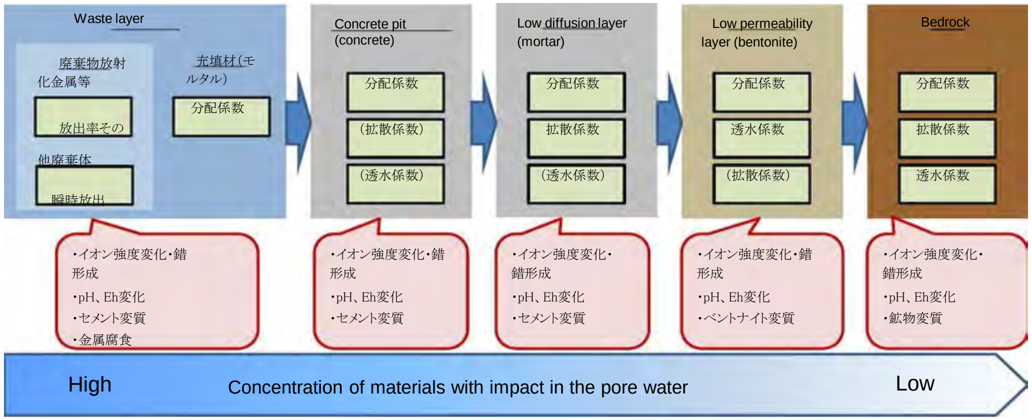


Figure 1 Disposal barrier composition and impacting factors

☐ Selection of nuclide migration parameters and barrier materials that must be studied on priority

And, those barrier materials and nuclide migration parameters, which were expected to be significantly affected by the materials with impact in the area close to the waste, were selected (Table 1).

- ■Sorption parameter
- ■Cement-based materials and bentonite based materials

Table 1 Parameters related to barrier materials of each disposal concept

	Waste layer (vitrified waste and over packing)	Waste layer (filler, pit)	Low diffusion layer	Buffer material / Impervious soil	Bedrock/Soil
	Glass/Carbon steel	Cement-based materials	Cement-based materials	Bentonite-based materials	
Trench disposal	-	(Release rate) Distribution coefficient	-	-	Distribution coefficient Diffusion coefficient Permeability coefficient
Concrete pit disposal	-	(Release rate) Distribution coefficient	-	Distribution coefficient Permeability coefficient (Diffusion coefficient)	Distribution coefficient Diffusion coefficient Permeability coefficient
Marginal depth disposal	-	Release rate Distribution coefficient	Distribution coefficient Diffusion coefficient (Permeability coefficient)	Distribution coefficient Permeability coefficient	Distribution coefficient Diffusion coefficient Permeability coefficient
Geological disposal (TRU)	-	Release rate Distribution coefficient Solubility Diffusion coefficient	-	Distribution coefficient Permeability coefficient Diffusion coefficient	Distribution coefficient Diffusion coefficient Permeability coefficient
Geological disposal (HLW)	Glass dissolution speed Metal corrosion speed	-	-	Distribution coefficient Solubility Permeability coefficient Diffusion coefficient	Distribution coefficient Diffusion coefficient Permeability coefficient

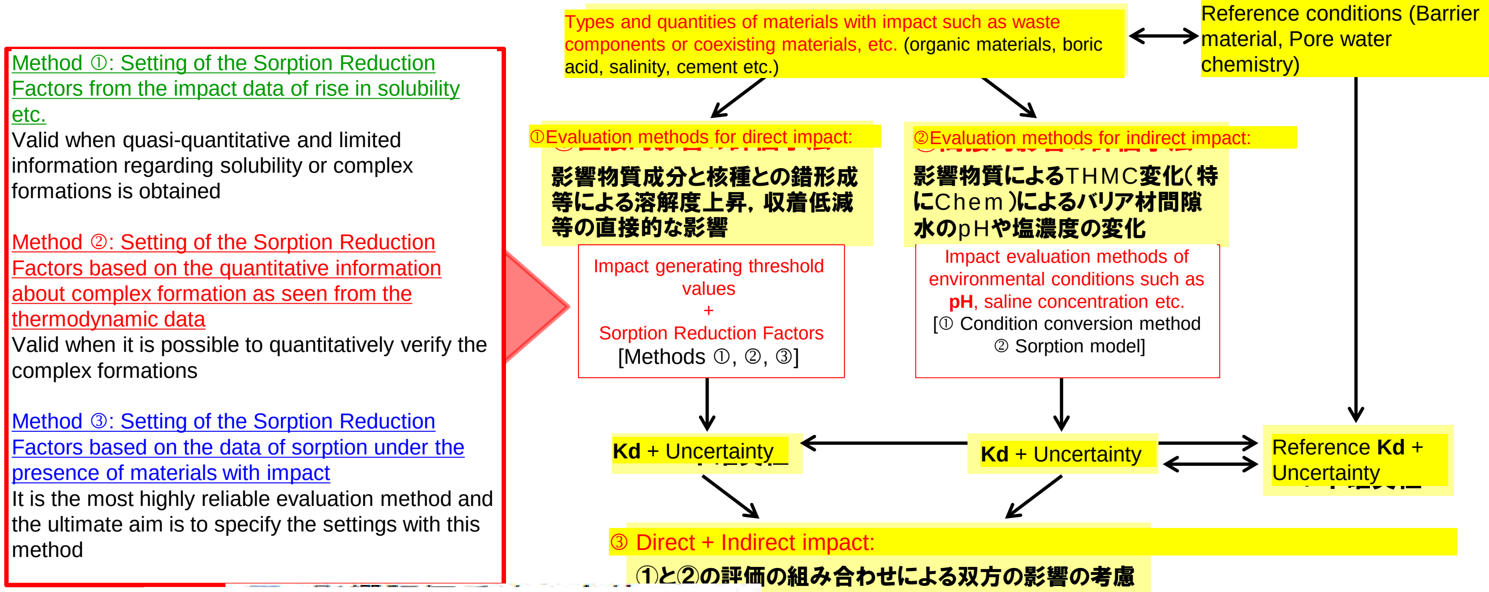
(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Approach pertaining to assessment of impact exerted by materials with impact on nuclide sorption-

- The impact of the materials with impact on nuclide sorption is divided into direct impact and indirect impact
- The "Sorption Reduction Factors" is applied as the assessment method for direct impact, and depending on the amount of information available, three methods can be used

$K_d' = K_d^0 / (SRF)$

- So far applicability has been confirmed for the organic materials (In the figure below: Example of assessment of Cement-Am-Iso-saccharin acid (ISA) system)



Method ①: Setting of the Sorption Reduction Factors from the impact data of rise in solubility etc.
Valid when quasi-quantitative and limited information regarding solubility or complex formations is obtained

Method ②: Setting of the Sorption Reduction Factors based on the quantitative information about complex formation as seen from the thermodynamic data
Valid when it is possible to quantitatively verify the complex formations

Method ③: Setting of the Sorption Reduction Factors based on the data of sorption under the presence of materials with impact
It is the most highly reliable evaluation method and the ultimate aim is to specify the settings with this method

Figure 1 Overall flow of impact assessment methods

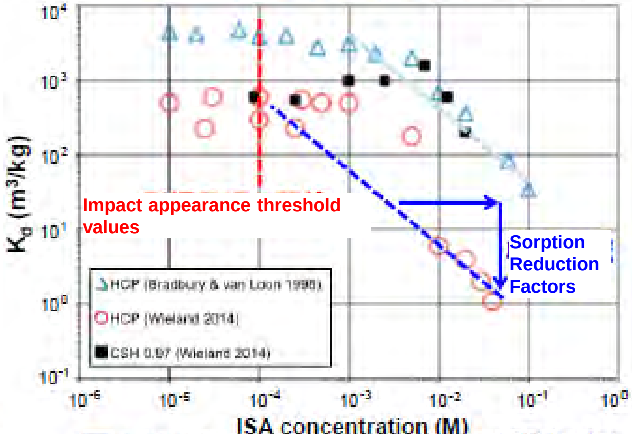


Figure 2 Example of evaluation of SRF based on actual measurement data

Am-ISA (Method ③)

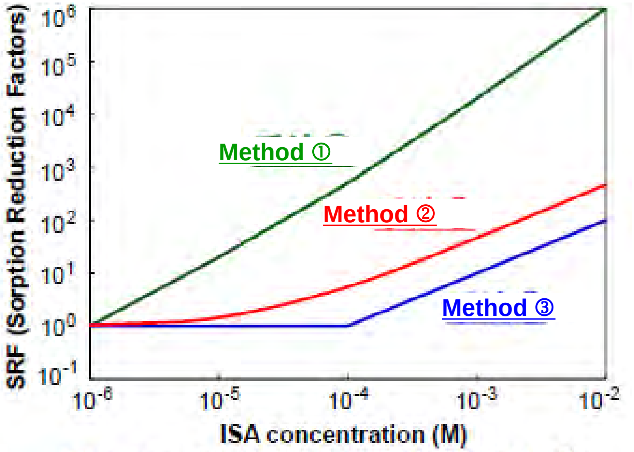


Figure 3 Comparison of SRF methods for Am-ISA

* K_d' : Sorption impact-added sorption parameter
K_d^0 : Sorption parameter values in a general underground environment

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Consolidation of the process of impact of each material with impact on nuclide sorption-

- Study of the process of impact (Direct and Indirect impact) of the materials with impact on nuclide sorption
- In case of organic materials, as shown in the flow chart on the right, the impact due to complex formation and the competitive sorption between cation/anion are selected as direct impact.
- Consolidation of the impact process of each material with impact in a tabular form

⇒ Identification of the "Direct impact" impact process of six materials with impact, which are the focus of this project

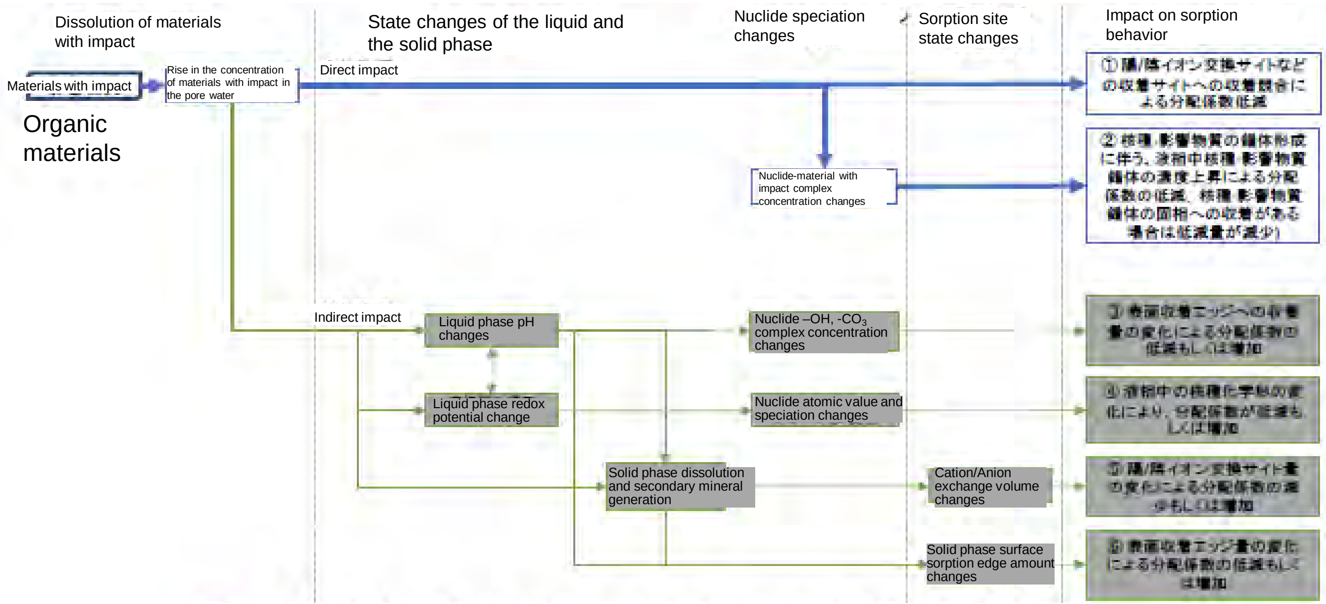
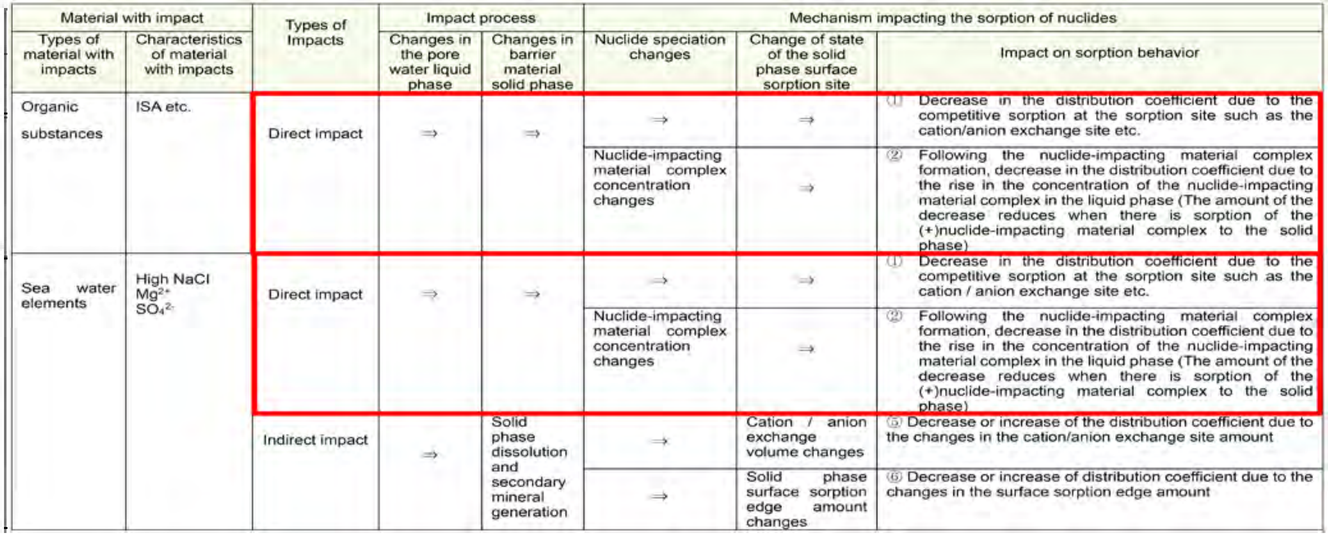


Figure 1 Process diagram of impact on nuclide sorption due to materials with impact (E.g.: Organic materials)

Table. 1 Consolidated tabular example of the process of impact on nuclide sorption due to materials with impact



Material with impact		Types of Impacts	Impact process		Mechanism impacting the sorption of nuclides		
Types of material with impacts	Characteristics of material with impacts		Changes in the pore water liquid phase	Changes in barrier material solid phase	Nuclide speciation changes	Change of state of the solid phase surface sorption site	Impact on sorption behavior
Organic substances	ISA etc.	Direct impact	⇒	⇒	⇒	⇒	① Decrease in the distribution coefficient due to the competitive sorption at the sorption site such as the cation/anion exchange site etc.
					Nuclide-impacting material complex concentration changes	⇒	② Following the nuclide-impacting material complex formation, decrease in the distribution coefficient due to the rise in the concentration of the nuclide-impacting material complex in the liquid phase (The amount of the decrease reduces when there is sorption of the (+)nuclide-impacting material complex to the solid phase)
Sea water elements	High NaCl Mg^{2+} SO_4^{2-}	Direct impact	⇒	⇒	⇒	⇒	① Decrease in the distribution coefficient due to the competitive sorption at the sorption site such as the cation / anion exchange site etc.
					Nuclide-impacting material complex concentration changes	⇒	② Following the nuclide-impacting material complex formation, decrease in the distribution coefficient due to the rise in the concentration of the nuclide-impacting material complex in the liquid phase (The amount of the decrease reduces when there is sorption of the (+)nuclide-impacting material complex to the solid phase)
		Indirect impact	⇒	Solid phase dissolution and secondary mineral generation	⇒	Cation / anion exchange volume changes	⑤ Decrease or increase of the distribution coefficient due to the changes in the cation/anion exchange site amount
					⇒	Solid phase surface sorption edge amount changes	⑥ Decrease or increase of distribution coefficient due to the changes in the surface sorption edge amount

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

- Information survey and data collection necessary for impact assessment -

☐ Based on the predominant direct impact process of each material with impact, a document survey of the information essential for quantitative assessment of the Sorption Reduction Factors was conducted (Table 1).

☐As insufficient sorption data, the impact exerted on sorption by ferrocyanide, etc. was focused on and the sorption data was obtained.

Nuclides: U(VI), Np(V), Th(IV), Am(III), Ni(II), Sr(II), Cs(I)

Barrier material: Ordinary portland cement (OPC) and Montmorillonite

☐ Some actinides show distinct ferrocyanide concentration dependence (Figure 1, Figure 2) ⇒ Reflection in the Sorption Reduction Factors

Table 1 Details of investigation and data collection on each target material with impact

Materials with impact	Details of investigation analysis and data collection
Organic materials	• Expansion of data related to the complex formation or distribution coefficient of EDTA-actinide nuclide • Analysis of thermodynamic data of ISA for the study of uncertainties in TDB • Consolidation of the characteristics and impacts of various organic materials
Sea water elements	• Selection of data from the Sorption Data Base (SDB), which can enable the quantitative evaluation of impact of sea water elements on the K_d of cement-based materials
Boric-acid solution	• Consolidation of sorption test data of nuclides obtained in previous projects with respect to the cement-based and bentonite-based materials and understanding the impacts
Ferrocyanide	• Collection of K_d data of nuclides with respect to the cement-based and bentonite-based materials under the presence of ferrocyanide
Sulfate	• Consolidation of existing information related to the K_d of nuclides with respect to the cement-based and bentonite-based materials • Collection of ternary compound system sorption data under constant ionic strength conditions
Carbonate	• Consolidation of actual K_d measurement values of bentonite based material under the presence of carbonic acid • Verification of impact of carbonic acid by calculating speciation by means of the TDB

EDTA: Ethylenediaminetetraacetic acid, TDB: Thermodynamic Data Base

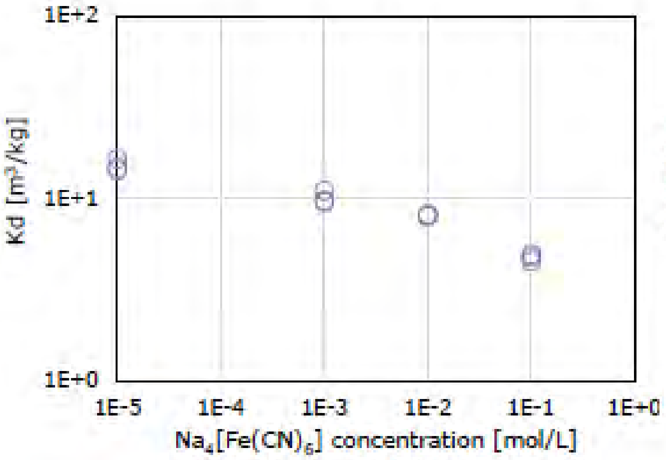


Figure 1 Test results of sorption of U(VI) in cement under the presence of ferrocyanide

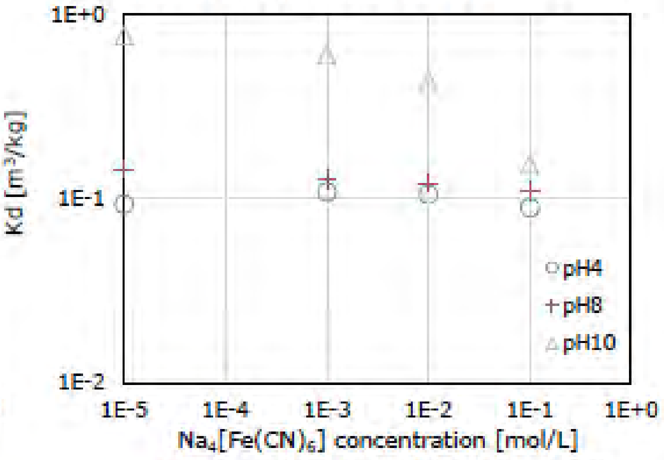


Figure 2 Test results of sorption of Np(V) in Montmorillonite under the presence of ferrocyanide

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

- Development and trial of Sorption Reduction Factor evaluation methods -

☐ Organic materials (EDTA)

☐ The data on sorption impact of organic materials other than iso-saccharin acid (ISA) is limited, but if data is available, SRF can be evaluated in the same manner. (Figure 1).

☐It is necessary to note the uncertainty of the thermodynamics data in view of the complexity of complex formation of the organic materials during evaluations based on the thermodynamics data (Method ②).

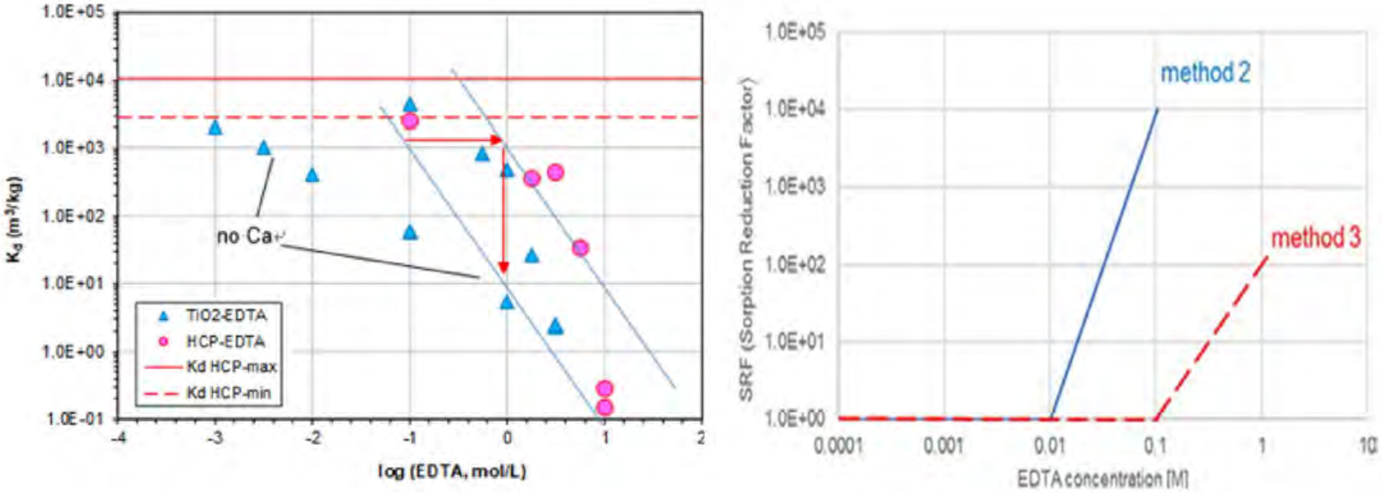


Figure 1 Sorption data of Am(III)/Eu(III) in cement under the presence of EDTA based on document information and evaluation results of Sorption Reduction Factors

Ferrocyanide

☐ A Sorption Reduction Factor having a high reliability can be set by acquiring the actual measurement data (Figure 2)

☐However, reliability of the collected data and sufficient understanding of the impact process (for instance, pH dependency in the figure on the right) is important.

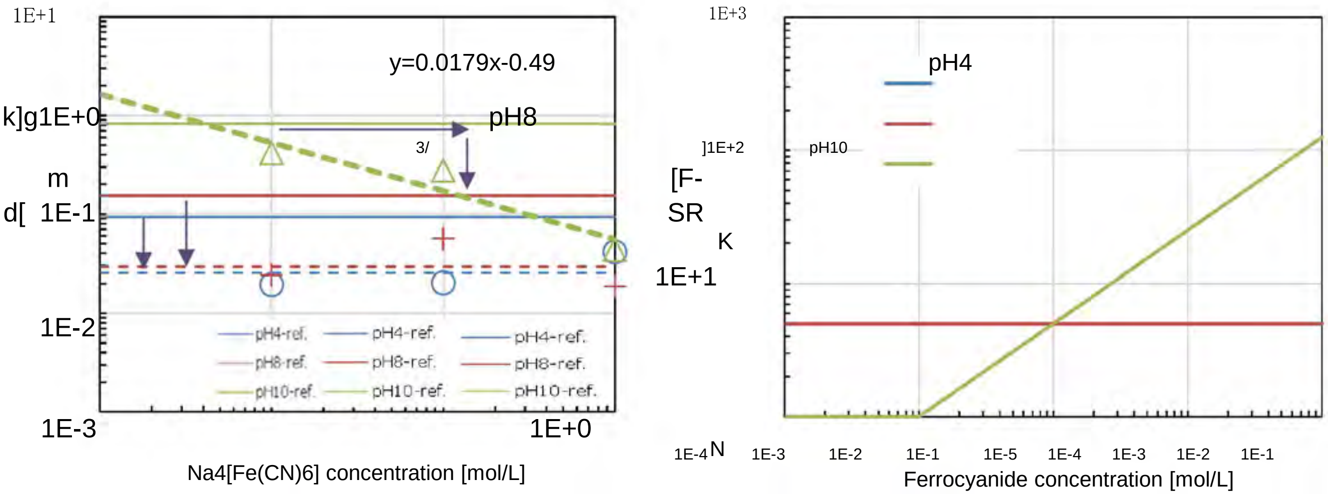
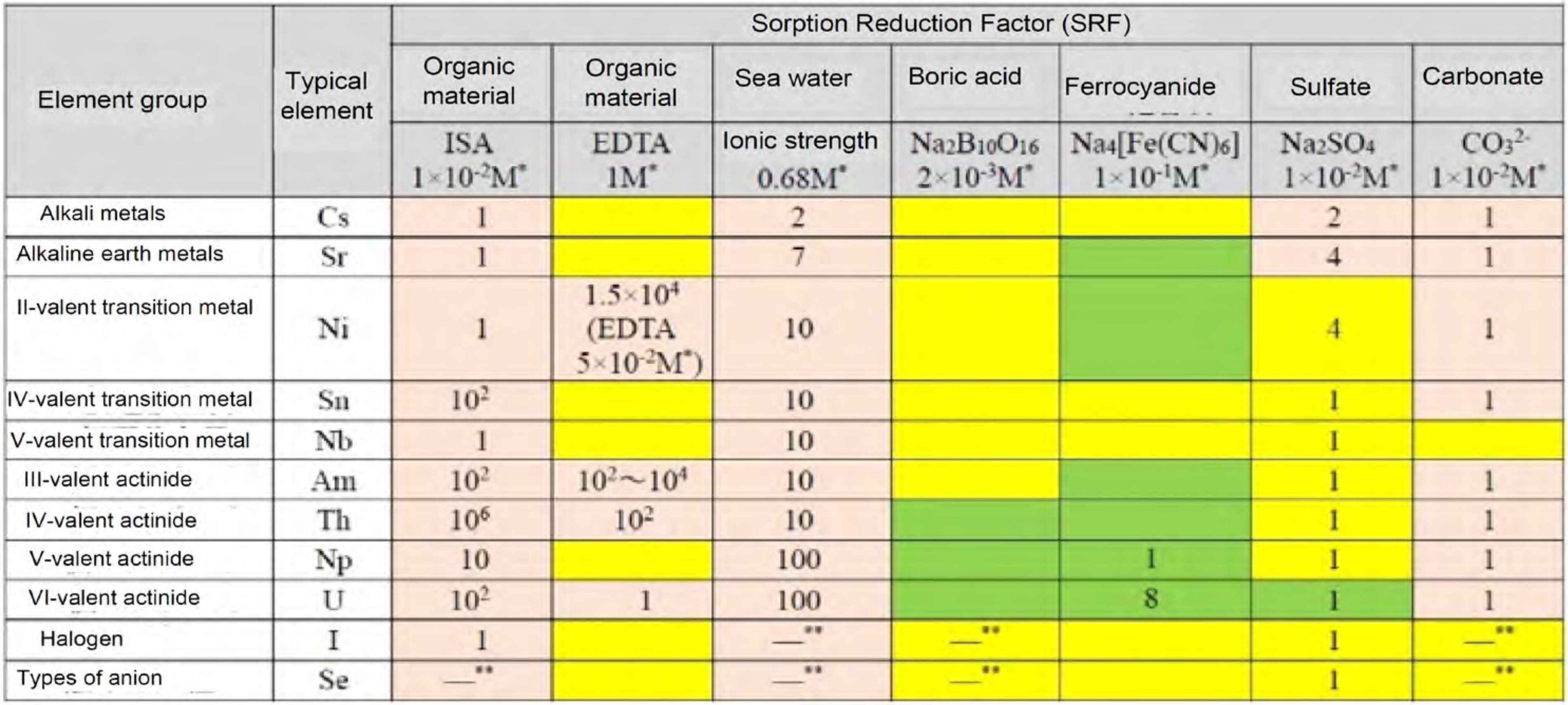


Figure 2 Sorption data of Np(V) in Montmorillonite under the presence of ferrocyanide based on the collected data and evaluation results of Sorption Reduction Factors

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

- Summary of results of trial settings of sorption reduction factors at present (Example of cement) -



Element group	Typical element	Sorption Reduction Factor (SRF)						
		Organic material	Organic material	Sea water	Boric acid	Ferrocyanide	Sulfate	Carbonate
		ISA 1×10^{-2}M*	EDTA 1M*	Ionic strength 0.68M*	$Na_2B_{10}O_{16}$ 2×10^{-3}M*	$Na_4[Fe(CN)_6]$ 1×10^{-1}M*	Na_2SO_4 1×10^{-2}M*	CO_3^{2-} 1×10^{-2}M*
Alkali metals	Cs	1	🟨	2	🟨	🟨	2	1
Alkaline earth metals	Sr	1	🟨	7	🟨	🟩	4	1
II-valent transition metal	Ni	1	1.5×10^{4} (EDTA 5×10^{-2}M*)	10	🟨	🟩	4	1
IV-valent transition metal	Sn	10^{2}	🟨	10	🟨	🟨	1	1
V-valent transition metal	Nb	1	🟨	10	🟨	🟨	1	🟨
III-valent actinide	Am	10^{2}	$10^{2}\sim10^{4}$	10	🟨	🟩	1	1
IV-valent actinide	Th	10^{6}	10^{2}	10	🟩	🟩	1	1
V-valent actinide	Np	10	🟨	100	🟩	1	1	1
VI-valent actinide	U	10^{2}	1	100	🟩	8	1	1
Halogen	I	1	🟨	—**	—**	🟨	1	—**
Types of anion	Se	—**	🟨	—**	—**	🟨	1	—**

*M: mol/L, $^{**}K_d = 0\ (m^3\ kg^{-1})$ is set.

🟧 : Set on the basis of past information survey results.

🟩 : Set on the basis of data acquired from sorption tests. (Items that have not yet been set, will be set in the future or after expanding the data)

🟨 :There is no past information survey and data collection. (Includes items for which absence of investigation results and data, etc. is verified)

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Summary of impact on disposal and issues (1/2)-

Materials with impact	Impact on sorption during disposal and points to be noted
Organic materials	・As regards the impact of organic materials, since the past findings are comparatively substantial, the impact of EDTA on sorption was studied in addition to the impact of the cellulose decomposition product namely, iso-saccharin acid (ISA). ・Although the degree of impact differs according to the types of organic materials or nuclides, there is a high possibility that the impact of organic materials on disposal will be significant compared to other materials with impact on disposal as well. ・It is necessary to study the application of evaluation methods, including methods that consider thermodynamic data, for the evaluation of the combination of various organic materials and nuclides, while assuming organic materials and their decomposition products that may be contained in the accident waste.
Sea water elements	・As regards the impact that sea water elements have on nuclide sorption, since the past findings are comparatively substantial, a fairly quantitative evaluation is possible and a fairly large sorption reduction impact is anticipated depending on the nuclide. ・It is necessary to conduct a detailed investigation of the sorption mechanisms of each nuclide and the impact of the sea water elements, because in addition to the impact of competitive sorption or complex formations with the sea water elements, in the case of cement, even the changes during the sorption phase are likely to have an impact. ・ It is necessary to pay attention to the realistic evaluation of sea water element deposits based on the characterization of waste, and to the study of waste conditioning when the concentration of the deposits is high, and in addition, it is also necessary to note that the sea water elements can cause changes in quality of cement-based materials.
Boric-acid solution	・As regards the impact of boric acid, since the past data is extremely limited, the data of impact on sorption was collected and based on these results, it was confirmed that boric acid has very little impact on alkali metals and the alkali earth metals, but in case of actinides, boric acid had an impact to some extent. ・As the collection of sufficiently accurate test data pertaining to nuclides having a high sorption performance, such as the actinide nuclides, is a challenge, study of the evaluation of the impact of complex formations by boric acid and its correlation with sorption reduction, the evaluation of competition with other ligands such as carbonate complexes etc., and the evaluation of the sorption reduction factor, considered substantially even the correlation of impact between nuclides, needs to be continued. ・ In addition to the fact that boron is a standard environmental substance, when the boric acid deposition is high based on waste characterization, it is necessary to appropriately consider the evaluation of boric acid concentration and the impact of nuclide migration in the vicinity of the waste.

(3) Clarification Items Having Impacts on Disposal Safety Evaluation Methods of Solid Waste Disposal / Study of Analytical Evaluation Methods for Materials in Solid Waste with Impact on Disposal

-Summary of impact on disposal and issues (2/2)-

Materials with impact	Impact on sorption during disposal and points to be noted
Ferrocyanide	・Since there are almost no past findings with respect to ferrocyanide, sorption data under the presence of ferrocyanide was collected during this project and using these results, the impact of actinides on sorption with respect to cement and bentonite, was assessed. ・It has been surmised that the impact due to nuclide or pH conditions is complicated, therefore, it is necessary to understand the relationship between the impact of complex formations and sorption reduction by ferrocyanide, expand knowledge such as the correlation of impact between nuclides, and continue to study the evaluation of the sorption reduction factors reflecting this knowledge. ・In addition to the fact that all cyanogens are standard environmental substances, it is necessary to evaluate the behavior of the ferrocyanide itself inside the waste or in the disposal environment and conduct a study that includes management during pre-treatment.
Sulfate	・From the evaluations based on the thermodynamic data, while it has been presumed that sulfate complexes have hardly any impact on nuclide sorption, since the dependence of Kd on sulfuric acid concentration during relatively high sulfuric acid concentrations has been confirmed during the sorption tests of U(VI) to cement-based materials under the presence of sulfuric acid during this project, a further study is necessary in view of this variation. ・ The sulfate in the accident waste exists chiefly as barium sulfate, its solubility is low and is highly likely to be below the concentration at which the impact manifests; therefore, it can be said that the priority of expanding the data is comparatively low. ・Although ettringite and cracks are likely to be generated due to the reaction between the cement components and sulfuric acid during cement solidification, as mentioned above, it is presumed that it does not pose a problem if the sulfuric acid concentration is low.
Carbonate	・As regards the impact of carbonate, since it is an element that is originally found in nature in rocks or underground water environments, its impact assessment methods have also been studied during research in the past. ・Calcite is a component in both cement-based as well as bentonite-based materials, and the pore water is in equilibrium with calcite; therefore, it is assumed that calcium carbonate from accident waste is unlikely to dissolve. ・Even when no carbonates are derived from accident waste, the impact of carbonic acid concentration in pore water is taken into account, and the need to further consider the impact of carbonates contained in accident waste is considered to be unlikely.

5. Research on Waste Stream

Contents of Report

(1) Integration of R&D Results (Establishment of Waste Stream)

- What is integration of R&D results?
- Results of past studies on waste stream
- Implementation plan and overview of FY2017 - FY2018
- Action items for FY2018
  - Review of waste classification
  - Study on the background and purpose of R&D
  - Study on the concept of input information management sheet
- Summary of integration into waste stream

(1) Integration of R&D Results (Establishment of Waste Stream)

-What is Integration of R&D Results (Waste Stream)?-

Background

- In Fukushima Daiichi, there are various types of solid wastes (all waste other than debris) that are of a wide variety, with unknown characteristics, and have different urgency levels (high and low).
- All of these solid wastes will eventually need to be disposed.
- However, completing the research on characterization and disposal of waste requires time.

Against this background, the following specific methodologies for integration of R&D results (waste stream) were studied.

- Consolidating the flow (waste stream) from solid waste generation to treatment (segregation / volume reduction / stabilization), storage and up to disposal.
- Rationally and effectively promoting R&D by providing feedback on information (characterization, disposal, etc.) to R&D, along with getting an overview of the overall system.

(1) Integration of R&D Results (Establishment of Waste Stream)

-Results of Past Studies on Waste Stream-

I. Creating a list of all solid wastes

In order to exhaustively study the solid wastes, wastes identified as solid wastes in 1F were compiled into a waste list.

II. Classification of solid wastes

Solid wastes listed in the waste list were classified based on their “characteristics”, “contamination category” and “contamination source / contamination history”.

III. Study on the treatment options for each classification

The treatment options for the classified solid wastes were studied and their treatment flows were developed.

IV. Study on the technologies for refining the treatment options

Methods for refining the treatment options pertaining to the treatment flow (BPEO：Best Practical Environmental Option) were studied, and the necessary actions for refining were consolidated.

V. Refinement of treatment options from research results, and integrating them as a whole

The treatment options were refined based on research results and new issues, and the waste stream was established through overall integration.

(1) Integration of R&D Results (Establishment of Waste Stream)

-Implementation Plan and Overview of FY2017 to FY2018 -

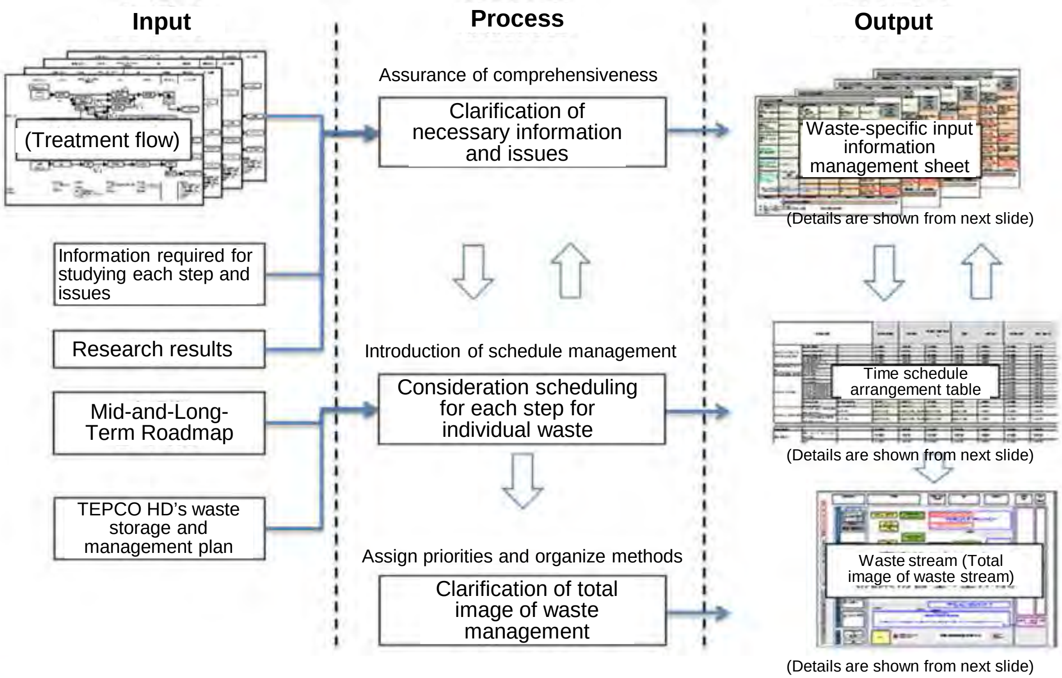
FY	Implementation plan	Goal achievement index
2017	• The promising waste streams presented in FY2016 are comprehensively evaluated with respect to the progress, consistency of the outcomes, and remaining issues by reflecting the latest results obtained in previous research.	• Presentation of the progress, the consistency of the outcomes, and remaining issues.
2018	• The waste streams are repeatedly examined by reflecting issues and research results obtained in FY2017, and evaluation results are presented based on it.	• Establishment of comprehensive methods to evaluate progress, consistency, and issues and the presentation of evaluation results based on them.

□ Summary of results for FY2017 and FY2018

□ Methods to comprehensively manage the progress and issues in R&D were designed and tried (Figure).

- In order to ensure the comprehensiveness of target waste, necessary information and issues were identified using the classification of treatment flows established, based on the list that enumerates all types of waste on 1F (waste list), and a waste-specific input information management sheet and a list to verify matching between issues and outcomes were created.
- In order to introduce schedule management, consideration time schedules were set for each step of waste management process for individual waste based on the Mid-and-Long-Term Roadmap and the storage and management plan, and a time schedule arrangement table was created.
- In order to assign priorities and organize methods, the total image of waste management is clarified from the result of organization as listed above and flows are integrated into the form of a waste stream.

□ The progress, the consistency of the outcomes, and remaining issues were clarified using the established method.



Input

(Treatment flow)

Information required for studying each step and issues

Research results

Mid-and-Long-Term Roadmap

TEPCO HD's waste storage and management plan

Process

Assurance of comprehensiveness

Clarification of necessary information and issues

Introduction of schedule management

Consideration scheduling for each step for individual waste

Assign priorities and organize methods

Clarification of total image of waste management

Output

Waste-specific input information management sheet

(Details are shown from next slide)

Time schedule arrangement table

(Details are shown from next slide)

Waste stream (Total image of waste stream)

(Details are shown from next slide)

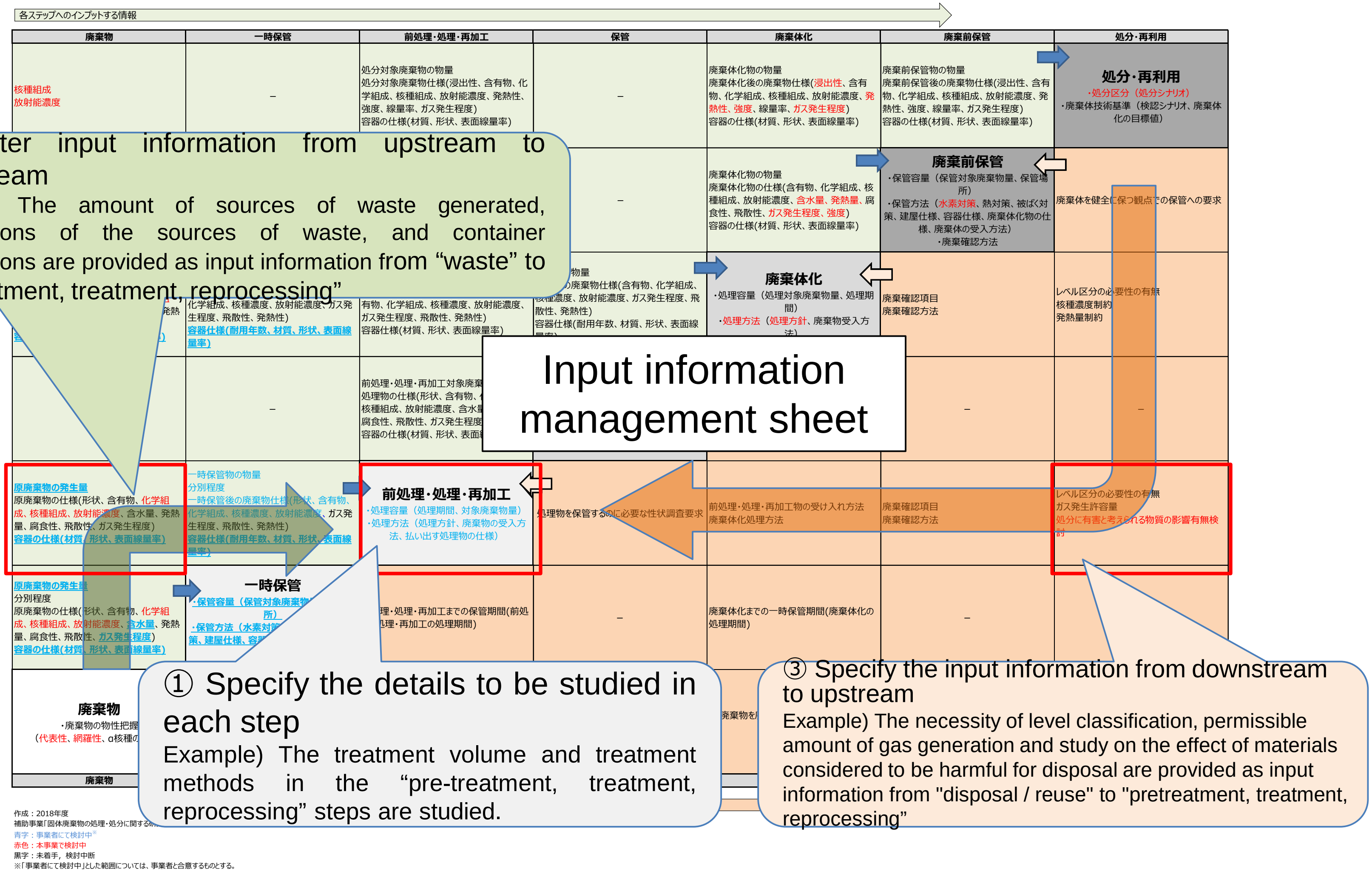
Figure Overview of the study on waste stream

(1) Integration of R&D Results (Establishment of Waste Stream)

- Implementation Plan and Overview of FY2017 to FY2018 -

Information required for studying each step and consolidation of issues

Consolidate the flow of information between steps and create input information management sheet.



各ステップへのインプットする情報

廃棄物	一時保管	前処理･処理･再加工	保管	廃棄体化	廃棄前保管	処分･再利用
核種組成 放射能濃度	–	処分対象廃棄物の物量 処分対象廃棄物仕様(浸出性、含有物、化学組成、核種組成、放射能濃度、発熱性、強度、線量率、ガス発生程度) 容器の仕様(材質、形状、表面線量率)	–	廃棄体化物の物量 廃棄体化後の廃棄物仕様(浸出性、含有物、化学組成、核種組成、放射能濃度、発熱性、強度、線量率、ガス発生程度) 容器の仕様(材質、形状、表面線量率)	廃棄前保管物の物量 廃棄前保管後の廃棄物仕様(浸出性、含有物、化学組成、核種組成、放射能濃度、発熱性、強度、線量率、ガス発生程度) 容器の仕様(材質、形状、表面線量率)	**処分･再利用** ・処分区分（処分シナリオ） ・廃棄体技術基準（検認シナリオ、廃棄体化の目標値）
			–	廃棄体化物の物量 廃棄体化物の仕様(含有物、化学組成、核種組成、放射能濃度、含水量、発熱量、腐食性、飛散性、ガス発生程度、強度) 容器の仕様(材質、形状、表面線量率)	**廃棄前保管** ・保管容量（保管対象廃棄物量、保管場所） ・保管方法（水素対策、熱対策、被ばく対策、建屋仕様、容器仕様、廃棄体化物の仕様、廃棄体の受入方法） ・廃棄確認方法	廃棄体を健全に保つ観点での保管への要求
発熱	化学組成、核種濃度、放射能濃度、ガス発生程度、飛散性、発熱性) 容器仕様(耐用年数、材質、形状、表面線量率)	有物、化学組成、核種濃度、放射能濃度、ガス発生程度、飛散性、発熱性) 容器仕様(材質、形状、表面線量率)	物量 の廃棄物仕様(含有物、化学組成、核種濃度、放射能濃度、ガス発生程度、飛散性、発熱性) 容器仕様(耐用年数、材質、形状、表面線量率)	**廃棄体化** ・処理容量（処理対象廃棄物量、処理期間） ・処理方法（処理方針、廃棄物受入方法）	廃棄確認項目 廃棄確認方法	レベル区分の必要性の有無 核種濃度制約 発熱量制約
	–	前処理･処理･再加工対象廃棄 処理物の仕様(形状、含有物、 核種組成、放射能濃度、含水量 腐食性、飛散性、ガス発生程度 容器の仕様(材質、形状、表面			–	–
原廃棄物の発生量 原廃棄物の仕様(形状、含有物、化学組成、核種組成、放射能濃度、含水量、発熱量、腐食性、飛散性、ガス発生程度) 容器の仕様(材質、形状、表面線量率)	一時保管物の物量 分別程度 一時保管後の廃棄物仕様(形状、含有物、化学組成、核種濃度、放射能濃度、ガス発生程度、飛散性、発熱性) 容器仕様(耐用年数、材質、形状、表面線量率)	**前処理･処理･再加工** ・処理容量（処理期間、対象廃棄物量） ・処理方法（処理方針、廃棄物の受入方法、払い出す処理物の仕様）	処理物を保管するのに必要な性状調査要求	前処理･処理･再加工物の受け入れ方法 廃棄体化処理方法	廃棄確認項目 廃棄確認方法	レベル区分の必要性の有無 ガス発生許容量 処分に有害と考えられる物質の影響有無検討
原廃棄物の発生量 分別程度 原廃棄物の仕様(形状、含有物、化学組成、核種組成、放射能濃度、含水量、発熱量、腐食性、飛散性、ガス発生程度) 容器の仕様(材質、形状、表面線量率)	**一時保管** ・保管容量（保管対象廃棄物 所） ・保管方法（水素対 策、建屋仕様、容	理･処理･再加工までの保管期間(前処 理･処理･再加工の処理期間)	–	廃棄体化までの一時保管期間(廃棄体化の処理期間)	–	
廃棄物 ・廃棄物の物性把握 （代表性、網羅性、α核種の				廃棄物を		
廃棄物						

作成：2018年度

補助事業「固体廃棄物の処理・処分に関する研

青字：事業者にて検討中※

赤色：本事業で検討中

黒字：未着手，検討中断

※「事業者にて検討中」とした範囲については、事業者と合意するものとする。

② Enter input information from upstream to downstream

Example) The amount of sources of waste generated, specifications of the sources of waste, and container specifications are provided as input information from “waste” to “pre-treatment, treatment, reprocessing”

Input information management sheet

① Specify the details to be studied in each step

Example) The treatment volume and treatment methods in the “pre-treatment, treatment, reprocessing” steps are studied.

③ Specify the input information from downstream to upstream

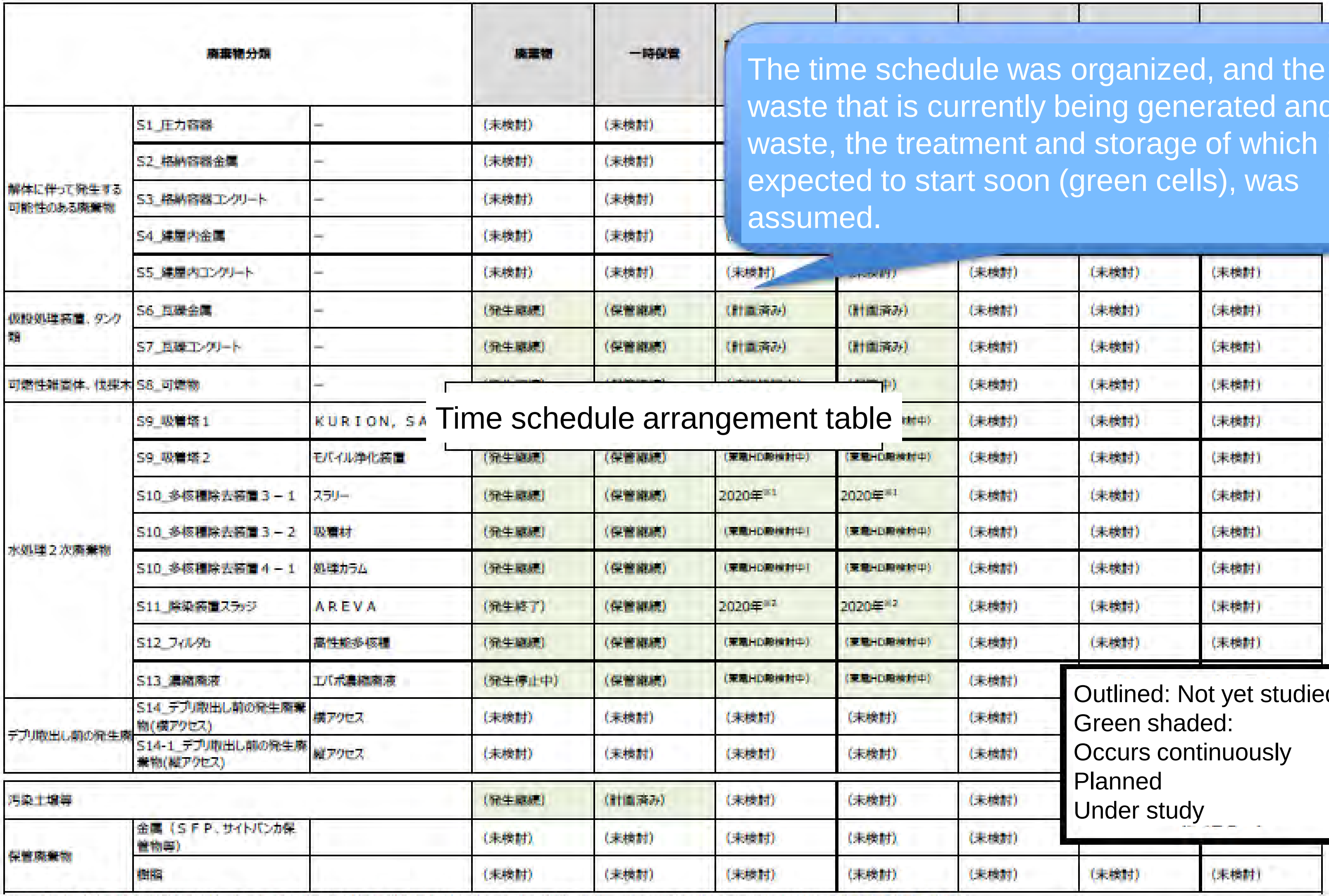
Example) The necessity of level classification, permissible amount of gas generation and study on the effect of materials considered to be harmful for disposal are provided as input information from "disposal / reuse" to "pretreatment, treatment, reprocessing”

(1) Integration of R&D Results (Establishment of Waste Stream)

-Implementation Plan and Overview of FY2017 to FY2018 -

Setting the start time of each step for each type of solid waste

Create a time schedule arrangement table stating the start time of treatment and storage, based on the Mid-and-Long-Term Roadmap and the storage management plan of TEPCO HD. Ensure that there is no change in the plans.



廃棄物分類			廃棄物	一時保管	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
解体に伴って発生する可能性のある廃棄物	S1_圧力容器	–	(未検討)	(未検討)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S2_格納容器金属	–	(未検討)	(未検討)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S3_格納容器コンクリート	–	(未検討)	(未検討)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S4_建屋内金属	–	(未検討)	(未検討)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S5_建屋内コンクリート	–	(未検討)	(未検討)	(未検討)	[illegible]	(未検討)	(未検討)	(未検討)
仮設処理装置、タンク類	S6_瓦礫金属	–	(発生継続)	(保管継続)	(計画済み)	(計画済み)	(未検討)	(未検討)	(未検討)
	S7_瓦礫コンクリート	–	(発生継続)	(保管継続)	(計画済み)	(計画済み)	(未検討)	(未検討)	(未検討)
可燃性雑固体、伐採木	S8_可燃物	–	[illegible]	[illegible]	[illegible]	[illegible]	(未検討)	(未検討)	(未検討)
水処理２次廃棄物	S9_吸着塔１	ＫＵＲＩＯＮ，ＳＡ	[illegible]	[illegible]	[illegible]	[illegible]	(未検討)	(未検討)	(未検討)
	S9_吸着塔２	モバイル浄化装置	(発生継続)	(保管継続)	(東電HD殿検討中)	(東電HD殿検討中)	(未検討)	(未検討)	(未検討)
	S10_多核種除去装置３－１	スラリー	(発生継続)	(保管継続)	2020年※1	2020年※1	(未検討)	(未検討)	(未検討)
	S10_多核種除去装置３－２	吸着材	(発生継続)	(保管継続)	(東電HD殿検討中)	(東電HD殿検討中)	(未検討)	(未検討)	(未検討)
	S10_多核種除去装置４－１	処理カラム	(発生継続)	(保管継続)	(東電HD殿検討中)	(東電HD殿検討中)	(未検討)	(未検討)	(未検討)
	S11_除染装置スラッジ	ＡＲＥＶＡ	(発生終了)	(保管継続)	2020年※2	2020年※2	(未検討)	(未検討)	(未検討)
	S12_フィルタ類	高性能多核種	(発生継続)	(保管継続)	(東電HD殿検討中)	(東電HD殿検討中)	(未検討)	(未検討)	(未検討)
	S13_濃縮廃液	エバポ濃縮廃液	(発生停止中)	(保管継続)	(東電HD殿検討中)	(東電HD殿検討中)	(未検討)	[illegible]	[illegible]
デブリ取出し前の発生廃	S14_デブリ取出し前の発生廃棄物(横アクセス)	横アクセス	(未検討)	(未検討)	(未検討)	(未検討)	(未検討)	[illegible]	[illegible]
	S14-1_デブリ取出し前の発生廃棄物(縦アクセス)	縦アクセス	(未検討)	(未検討)	(未検討)	(未検討)	(未検討)	[illegible]	[illegible]
汚染土壌等			(発生継続)	(計画済み)	(未検討)	(未検討)	(未検討)	[illegible]	[illegible]
保管廃棄物	金属（ＳＦＰ、サイトバンカ保管物等）		(未検討)	(未検討)	(未検討)	(未検討)	(未検討)	[illegible]	[illegible]
	樹脂		(未検討)	(未検討)	(未検討)	(未検討)	(未検討)	(未検討)	(未検討)

※1：東京電力ホールディングス株式会社，特定原子力施設放射性廃棄物規制検討会（第６回）資料２ スラリー，スラッジの安定化処理に向けた検討状況，２０１７年７月２５日

※2：東京電力ホールディングス株式会社，特定原子力施設放射性廃棄物規制検討会（第５５回）資料４ 地震・津波対策の進捗状況，２０１７年８月３０日

The time schedule was organized, and the waste that is currently being generated and waste, the treatment and storage of which is expected to start soon (green cells), was assumed.

Time schedule arrangement table

Outlined: Not yet studied
Green shaded:
Occurs continuously
Planned
Under study

(1) Integration of R&D Results (Establishment of Waste Stream)

- Action Items for FY2018 -

In FY2018, the following was implemented in relation to the operational issues identified in FY2017 and integrated into the waste stream.

① Review of waste classification

With the waste list as the base, as before, the solid wastes were classified and managed based on the contamination route and waste characteristics, by keeping pace with research related to the characterization project that is being carried out in parallel with the R&D for the treatment and disposal of solid wastes. Also, when solid wastes needed to be classified from the viewpoint of treatment and disposal, the options were indicated on the waste stream treatment flow so that they could be linked.

② Study on the background and purpose of R&D

In FY2017, the background and purpose of past R&D was consolidated, and it was confirmed that the issues can be appropriately identified by means of the created method. Meanwhile, it was realized that the background and purpose of R&D needs to be consolidated based on the research subject in order to mutually share feedback between projects. Therefore, in FY2018, in this project we tried to check the progress on input information management sheets across IRID.

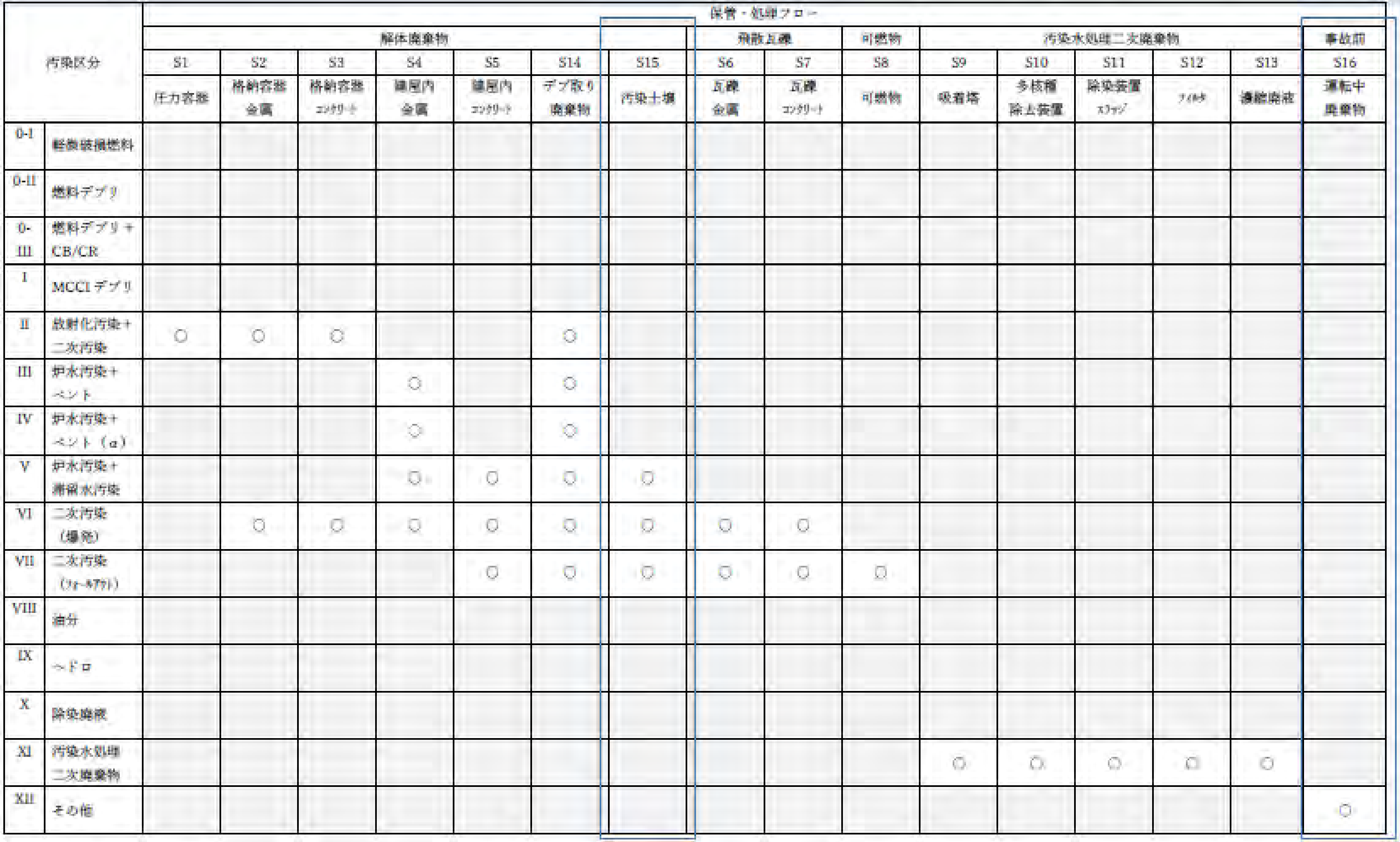
③Study of the concept of input information management sheet

The concepts were examined so that the input information management sheet can be reviewed and revised appropriately by the concerned personnel in the future.

(1) Integration of R&D Results (Establishment of Waste Stream)
-Action Items for FY2018-

Review of waste classification (1/2)

In accordance with the R&D related to characterization, contaminated soil (S15) was added to waste from dismantlement and operational waste (S16) was added as solid waste existing at the site before the accident.

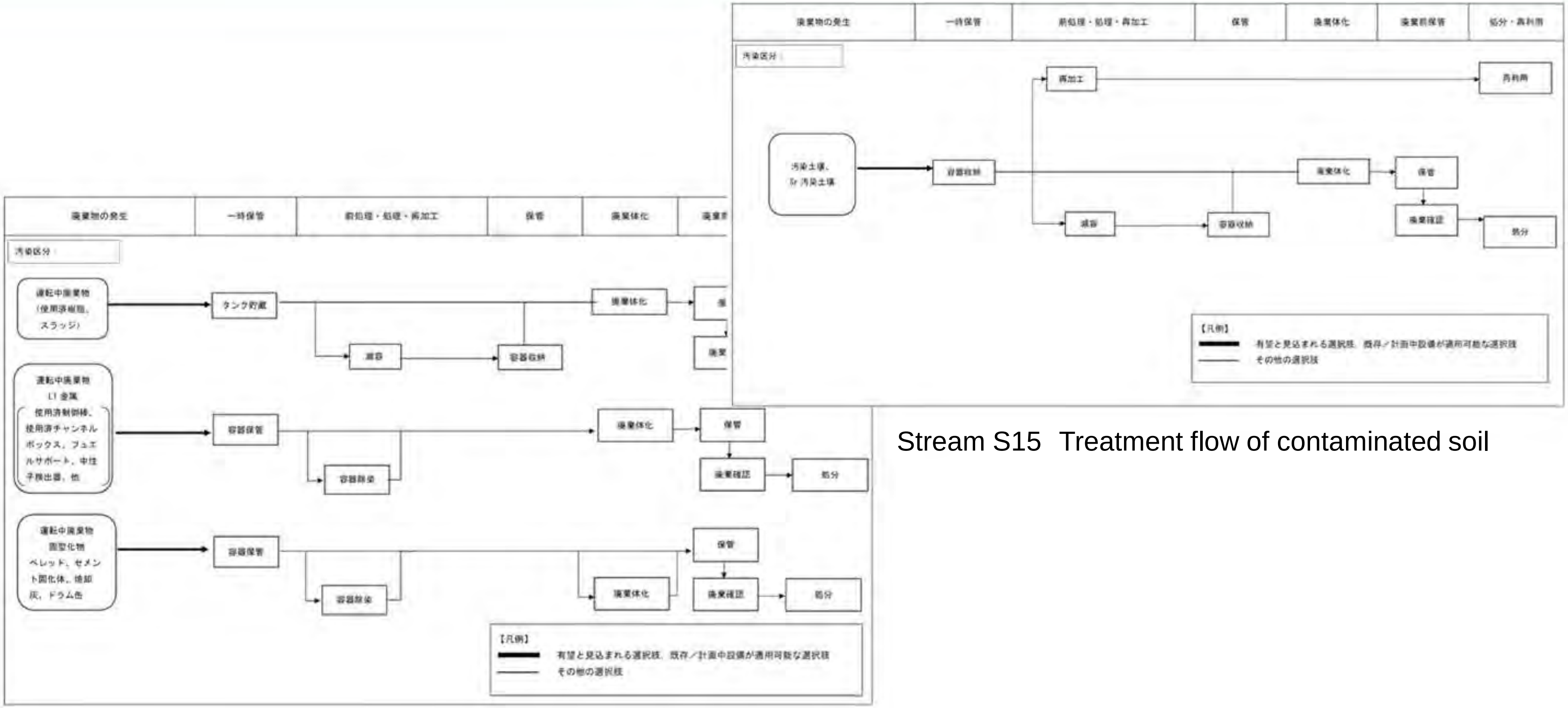


汚染区分		保管・処理フロー															
		解体廃棄物							飛散瓦礫		可燃物	汚染水処理二次廃棄物					事故前
		S1	S2	S3	S4	S5	S14	S15	S6	S7	S8	S9	S10	S11	S12	S13	S16
		圧力容器	格納容器 金属	格納容器 ｺﾝｸﾘｰﾄ	建屋内 金属	建屋内 ｺﾝｸﾘｰﾄ	デブ取り 廃棄物	汚染土壌	瓦礫 金属	瓦礫 ｺﾝｸﾘｰﾄ	可燃物	吸着塔	多核種 除去装置	除染装置 ｽﾗｯｼﾞ	ﾌｨﾙﾀ	濃縮廃液	運転中 廃棄物
0-I	軽微破損燃料																
0-II	燃料デブリ																
0-III	燃料デブリ＋CB/CR																
I	MCCIデブリ																
II	放射化汚染＋二次汚染	○	○	○			○										
III	炉水汚染＋ベント				○		○										
IV	炉水汚染＋ベント（α）				○		○										
V	炉水汚染＋滞留水汚染				○	○	○	○									
VI	二次汚染（爆発）		○	○	○	○	○	○	○	○							
VII	二次汚染（ﾌｫｰﾙｱｳﾄ）					○	○	○	○	○	○						
VIII	油分																
IX	ヘドロ																
X	除染廃液																
XI	汚染水処理二次廃棄物											○	○	○	○	○	
XII	その他																○

(1) Integration of R&D Results (Establishment of Waste Stream)
-Action Items for FY2018-

Review of waste classification (2/2)

Contaminated soil (S15) and operational waste (S16) were added and treatment flow was updated

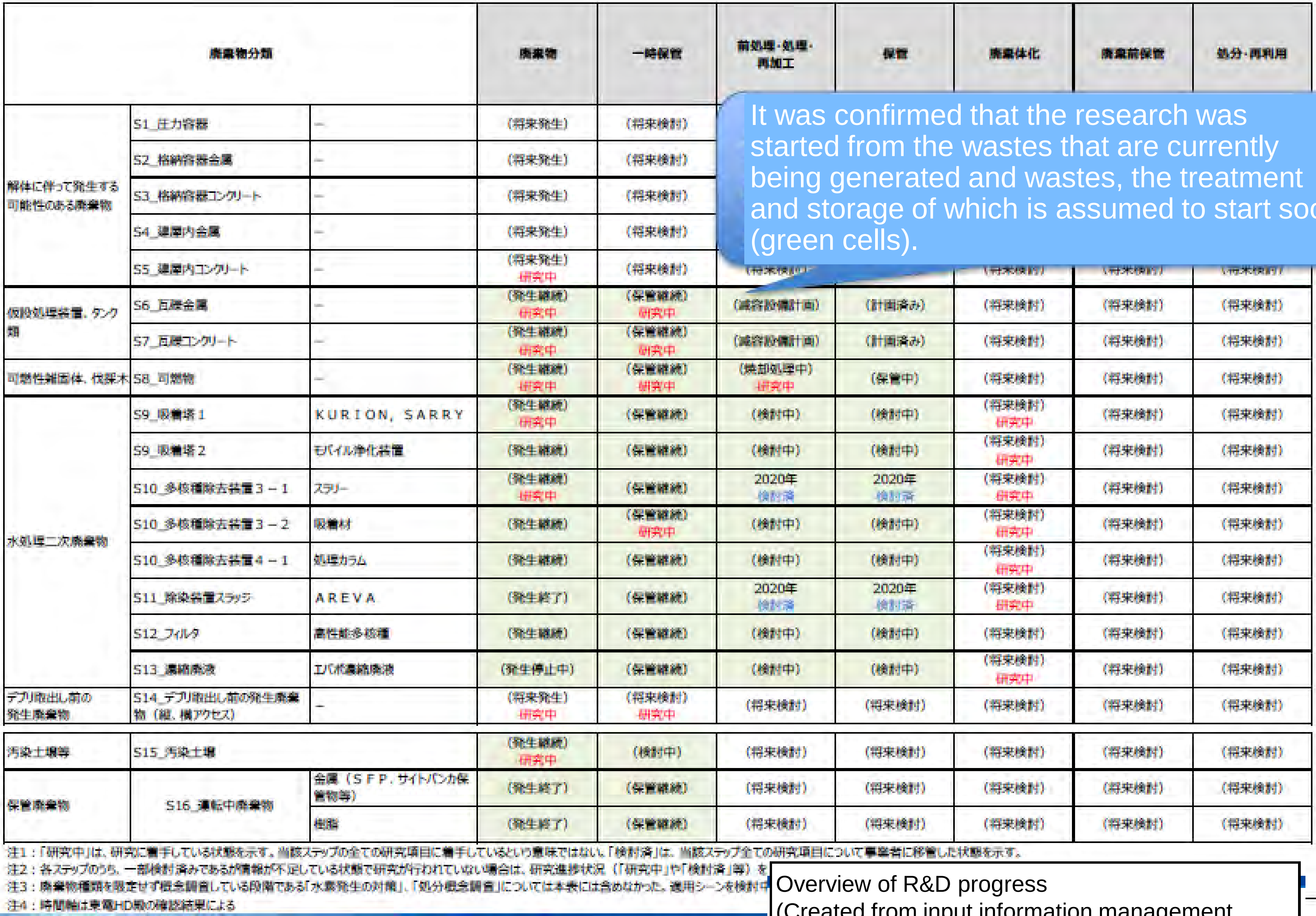


Stream S15 Treatment flow of contaminated soil

Stream S16 Treatment flow of operational waste

(1) Integration of R&D Results (Establishment of Waste Stream)
-Action Items for FY2018-

Study on the background and purpose of R&D (1/6)



廃棄物分類			廃棄物	一時保管	前処理・処理・再加工	保管	廃棄体化	廃棄前保管	処分・再利用
解体に伴って発生する可能性のある廃棄物	S1_圧力容器	－	（将来発生）	（将来検討）					
	S2_格納容器金属	－	（将来発生）	（将来検討）					
	S3_格納容器コンクリート	－	（将来発生）	（将来検討）					
	S4_建屋内金属	－	（将来発生）	（将来検討）					
	S5_建屋内コンクリート	－	（将来発生） 研究中	（将来検討）	（将来検討）		（将来検討）	（将来検討）	（将来検討）
仮設処理装置、タンク類	S6_瓦礫金属	－	（発生継続） 研究中	（保管継続） 研究中	（減容設備計画）	（計画済み）	（将来検討）	（将来検討）	（将来検討）
	S7_瓦礫コンクリート	－	（発生継続） 研究中	（保管継続） 研究中	（減容設備計画）	（計画済み）	（将来検討）	（将来検討）	（将来検討）
可燃性雑固体、伐採木	S8_可燃物	－	（発生継続） 研究中	（保管継続） 研究中	（焼却処理中） 研究中	（保管中）	（将来検討）	（将来検討）	（将来検討）
水処理二次廃棄物	S9_吸着塔１	ＫＵＲＩＯＮ，ＳＡＲＲＹ	（発生継続） 研究中	（保管継続）	（検討中）	（検討中）	（将来検討） 研究中	（将来検討）	（将来検討）
	S9_吸着塔２	モバイル浄化装置	（発生継続）	（保管継続）	（検討中）	（検討中）	（将来検討） 研究中	（将来検討）	（将来検討）
	S10_多核種除去装置３－１	スラリー	（発生継続） 研究中	（保管継続）	2020年 検討済	2020年 検討済	（将来検討） 研究中	（将来検討）	（将来検討）
	S10_多核種除去装置３－２	吸着材	（発生継続）	（保管継続） 研究中	（検討中）	（検討中）	（将来検討） 研究中	（将来検討）	（将来検討）
	S10_多核種除去装置４－１	処理カラム	（発生継続）	（保管継続）	（検討中）	（検討中）	（将来検討） 研究中	（将来検討）	（将来検討）
	S11_除染装置スラッジ	ＡＲＥＶＡ	（発生終了）	（保管継続）	2020年 検討済	2020年 検討済	（将来検討） 研究中	（将来検討）	（将来検討）
	S12_フィルタ	高性能多核種	（発生継続）	（保管継続）	（検討中）	（検討中）	（将来検討）	（将来検討）	（将来検討）
	S13_濃縮廃液	エバポ濃縮廃液	（発生停止中）	（保管継続）	（検討中）	（検討中）	（将来検討） 研究中	（将来検討）	（将来検討）
デブリ取出し前の発生廃棄物	S14_デブリ取出し前の発生廃棄物（縦、横アクセス）	－	（将来発生） 研究中	（将来検討） 研究中	（将来検討）	（将来検討）	（将来検討）	（将来検討）	（将来検討）
汚染土壌等	S15_汚染土壌		（発生継続） 研究中	（検討中）	（将来検討）	（将来検討）	（将来検討）	（将来検討）	（将来検討）
保管廃棄物	S16_運転中廃棄物	金属（ＳＦＰ，サイトバンカ保管物等）	（発生終了）	（保管継続）	（将来検討）	（将来検討）	（将来検討）	（将来検討）	（将来検討）
		樹脂	（発生終了）	（保管継続）	（将来検討）	（将来検討）	（将来検討）	（将来検討）	（将来検討）

注1：「研究中」は、研究に着手している状態を示す。当該ステップの全ての研究項目に着手しているという意味ではない。「検討済」は、当該ステップ全ての研究項目について事業者に移管した状態を示す。

注2：各ステップのうち、一部検討済みであるが情報が不足している状態で研究が行われていない場合は、研究進捗状況（「研究中」や「検討済」等）を

注3：廃棄物種類を限定せず概念調査している段階である「水素発生の対策」、「処分概念調査」については本表には含めなかった。適用シーンを検討中

注4：時間軸は東電HD殿の確認結果による

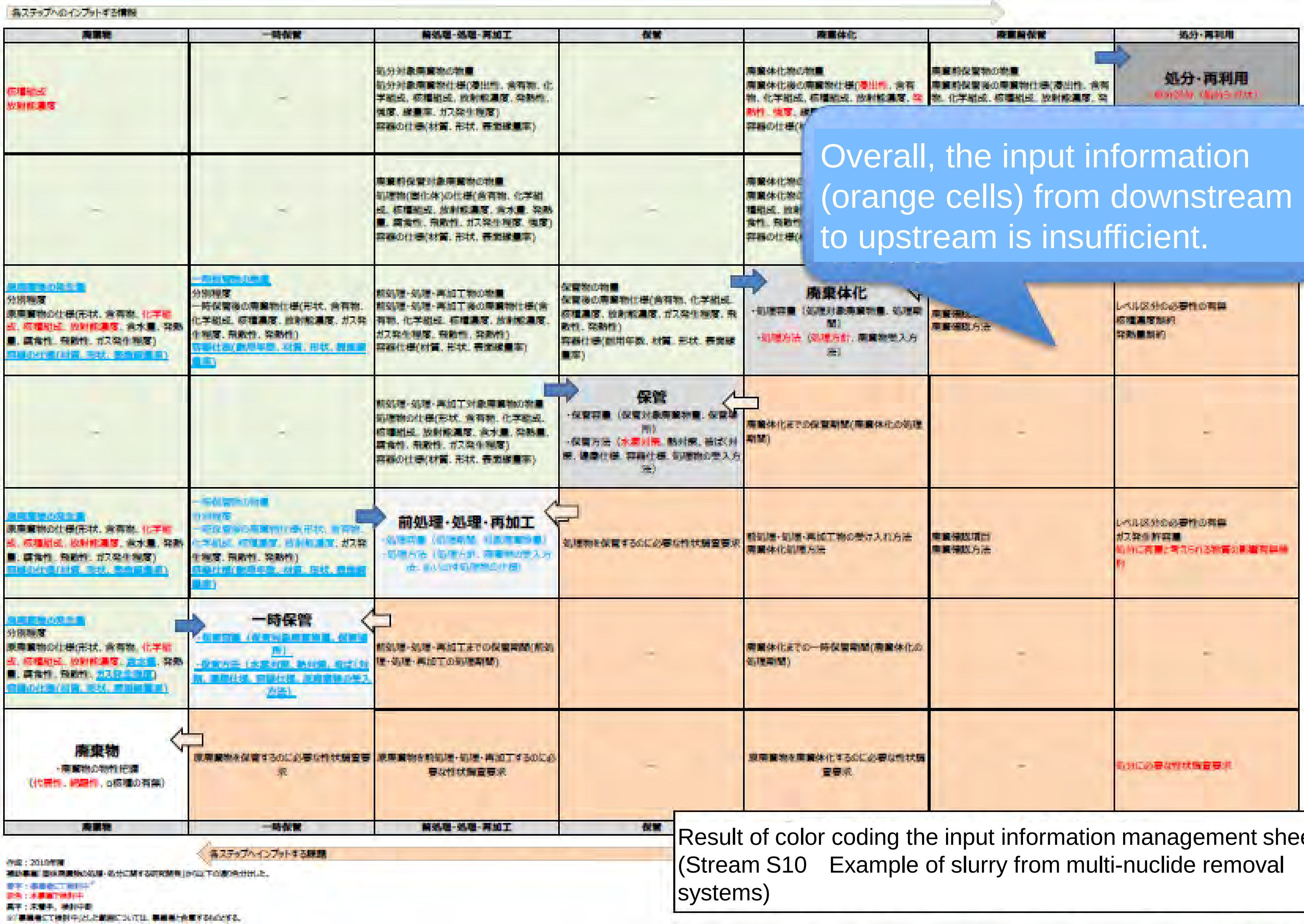
It was confirmed that the research was started from the wastes that are currently being generated and wastes, the treatment and storage of which is assumed to start soon (green cells).

Overview of R&D progress
(Created from input information management sheet and time schedule arrangement table)

(1) Integration of R&D Results (Establishment of Waste Stream)

-Action Items for FY2018-

Study of the background and purpose of R&D (2/6)



Overall, the input information (orange cells) from downstream to upstream is insufficient.

Result of color coding the input information management sheet (Stream S10 Example of slurry from multi-nuclide removal systems)

(1) Integration of R&D Results (Establishment of Waste Stream)

- Action Items for FY2018 -

Study of the background and purpose of R&D (3/6)

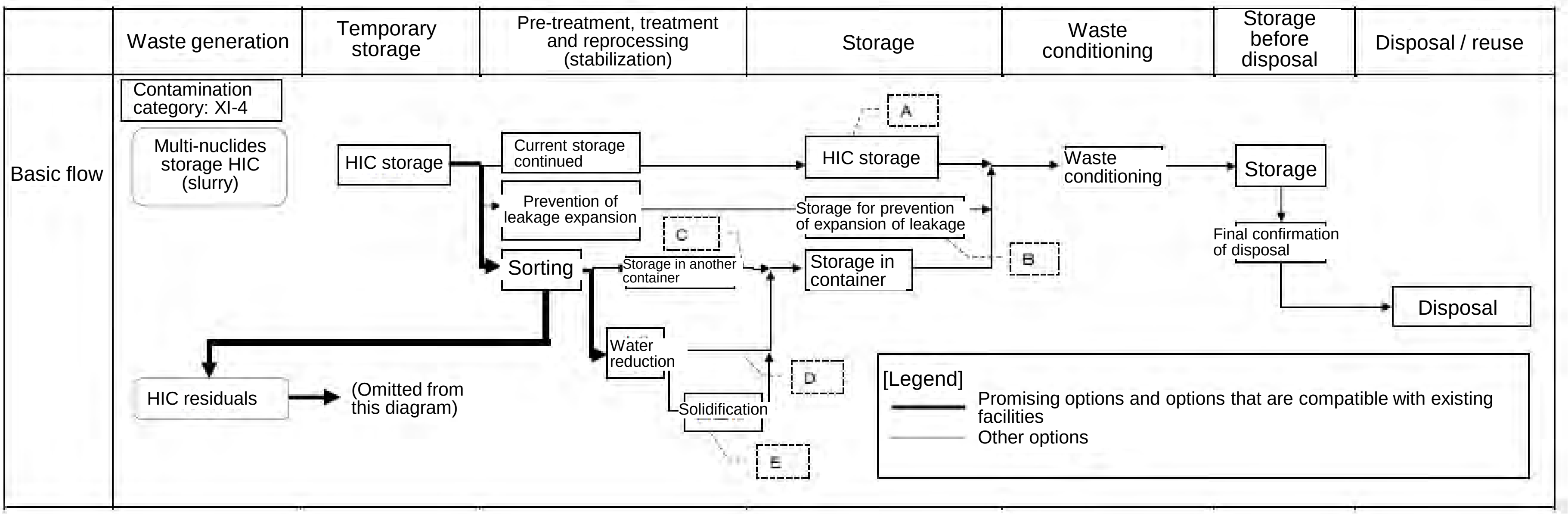
(Research on characterization of “Stream S10 Slurry from multi-nuclide removal system” and example of measures for hydrogen generation)

(Example of measures for hydrogen generation)

What is Stream S10 Slurry from multi-nuclide removal system?

Sr-based waste with a moisture content of about 90%, collected in a high integrity containers (HIC) and stored at a temporary storage facility.

Until FY2017, options such as pre-treatment, treatment, reprocessing and storage were provided by means of the waste stream. The Subsidized Project suggested that the water reduction treatment (drying / dehydration, etc.) would be promising.



Waste generation

Temporary storage

Pre-treatment, treatment and reprocessing (stabilization)

Storage

Waste conditioning

Storage before disposal

Disposal / reuse

Basic flow

Contamination category: XI-4

Multi-nuclides storage HIC (slurry)

HIC storage

Current storage continued

Prevention of leakage expansion

Sorting

Storage in another container

Water reduction

Solidification

HIC storage

Storage for prevention of expansion of leakage

Storage in container

Waste conditioning

Storage

Final confirmation of disposal

Disposal

A

B

C

D

E

HIC residuals

(Omitted from this diagram)

[Legend]

Promising options and options that are compatible with existing facilities

Other options

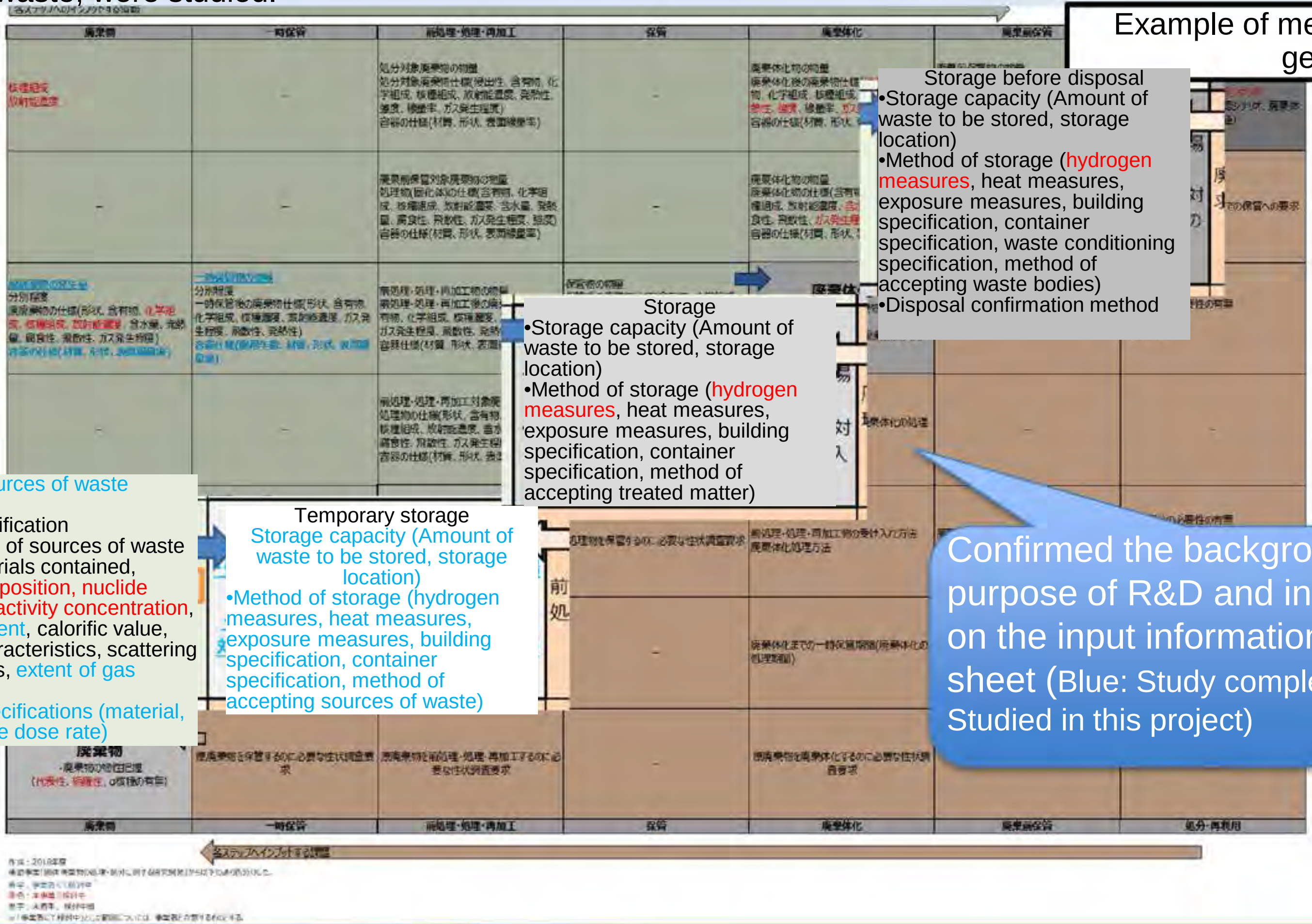
(1) Integration of R&D Results (Establishment of Waste Stream)

- Action Items for FY2018 -

Study on the background and purpose of R&D (4/6)

esearch on characterization of “Stream S10 Slurry from multi-nuclide removal system” and example of measures for hydrogen generation)

While studying measures for hydrogen generation, based on the characteristics of sources of waste collected in the research related to characterization, the ideas pertaining to treating that waste and measures for hydrogen generation from the treated material and waste, were studied.



Example of measures for hydrogen generation

Amount of sources of waste generated
Level of classification
Specifications of sources of waste (Shape, materials contained, chemical composition, nuclide composition, activity concentration, moisture content, calorific value, corrosion characteristics, scattering characteristics, extent of gas generation)
Container specifications (material, shape, surface dose rate)

Temporary storage
Storage capacity (Amount of waste to be stored, storage location)
- Method of storage (hydrogen measures, heat measures, exposure measures, building specification, container specification, method of accepting sources of waste)

Storage
- Storage capacity (Amount of waste to be stored, storage location)
- Method of storage (hydrogen measures, heat measures, exposure measures, building specification, container specification, method of accepting treated matter)

Storage before disposal
- Storage capacity (Amount of waste to be stored, storage location)
- Method of storage (hydrogen measures, heat measures, exposure measures, building specification, container specification, waste conditioning specification, method of accepting waste bodies)
- Disposal confirmation method

Confirmed the background and purpose of R&D and information flow on the input information management sheet (Blue: Study completed, Red: Studied in this project)

(1) Integration of R&D Results (Establishment of Waste Stream)

- Action Items for FY2018 -

Study on the background and purpose of R&D (5/6)

Research on characterization of “Stream S10 Slurry from multi-nuclide removal system” and example of measures for hydrogen generation)

Example of measures for hydrogen generation

The study of measures for hydrogen generation involved the following:

i. In this project, the concept of hydrogen generation from solid wastes, hydrogen generation evaluation methods, and measures for hydrogen generation were studied.

ii. Findings from other countries on regulations and technical requirements were investigated during the study.

iii. An overview of the characteristics of solid wastes in Fukushima Daiichi had to be provided while investigating the findings from other countries.

iv. While providing the characteristics, the findings obtained through characterization in this project (chemical composition, nuclide composition, activity concentration, etc.) and information provided by the operators was used (moisture content, etc.)

v. Although the methods for storage, treatment, transfer, and disposal of individual wastes (≒ refinement of treatment flow) have not been determined because the provided information is still being studied for its representativeness, etc., it was suggested that the concepts from other countries can be applied to Fukushima Daiichi as well.

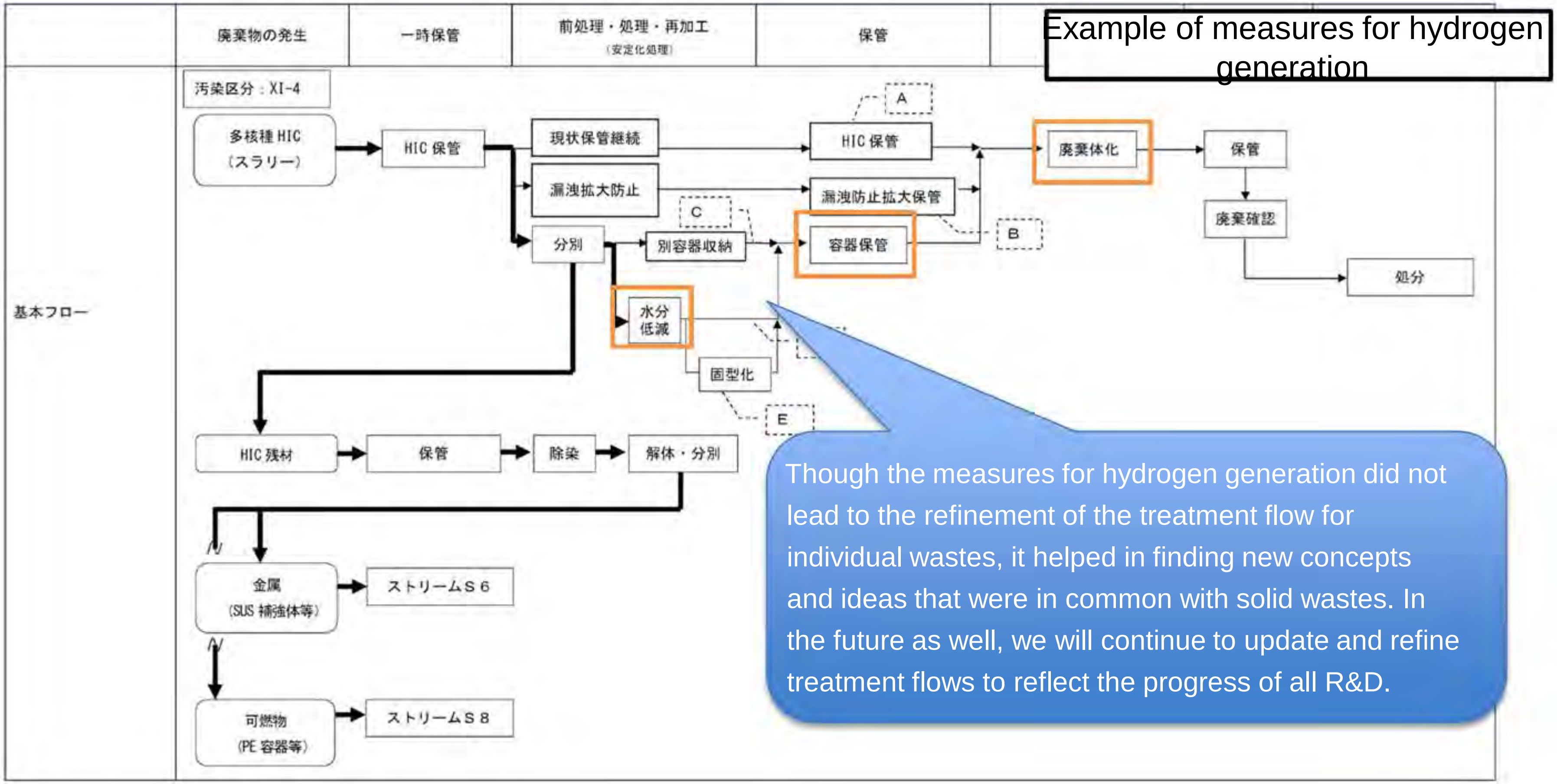
(1) Integration of R&D Results (Establishment of Waste Stream)

-Action Items for FY2018-

Study on the background and purpose of R&D (6/6)

(Research on characterization of “Stream S10 Slurry from multi-nuclide removal system” and example of measures for hydrogen generation)

The treatment flow will be updated and refined as necessary in accordance with the progress of R&D.



Example of measures for hydrogen generation

Though the measures for hydrogen generation did not lead to the refinement of the treatment flow for individual wastes, it helped in finding new concepts and ideas that were in common with solid wastes. In the future as well, we will continue to update and refine treatment flows to reflect the progress of all R&D.

(The measures for hydrogen generation consolidate the common concepts and the treatment flow was not updated in FY2018. The specific details of management method of individual waste will be established in the future.)

(1) Integration of R&D Results (Establishment of Waste Stream)

-Action Items for FY2018-

Study of the concept of input information management sheet (1/2)

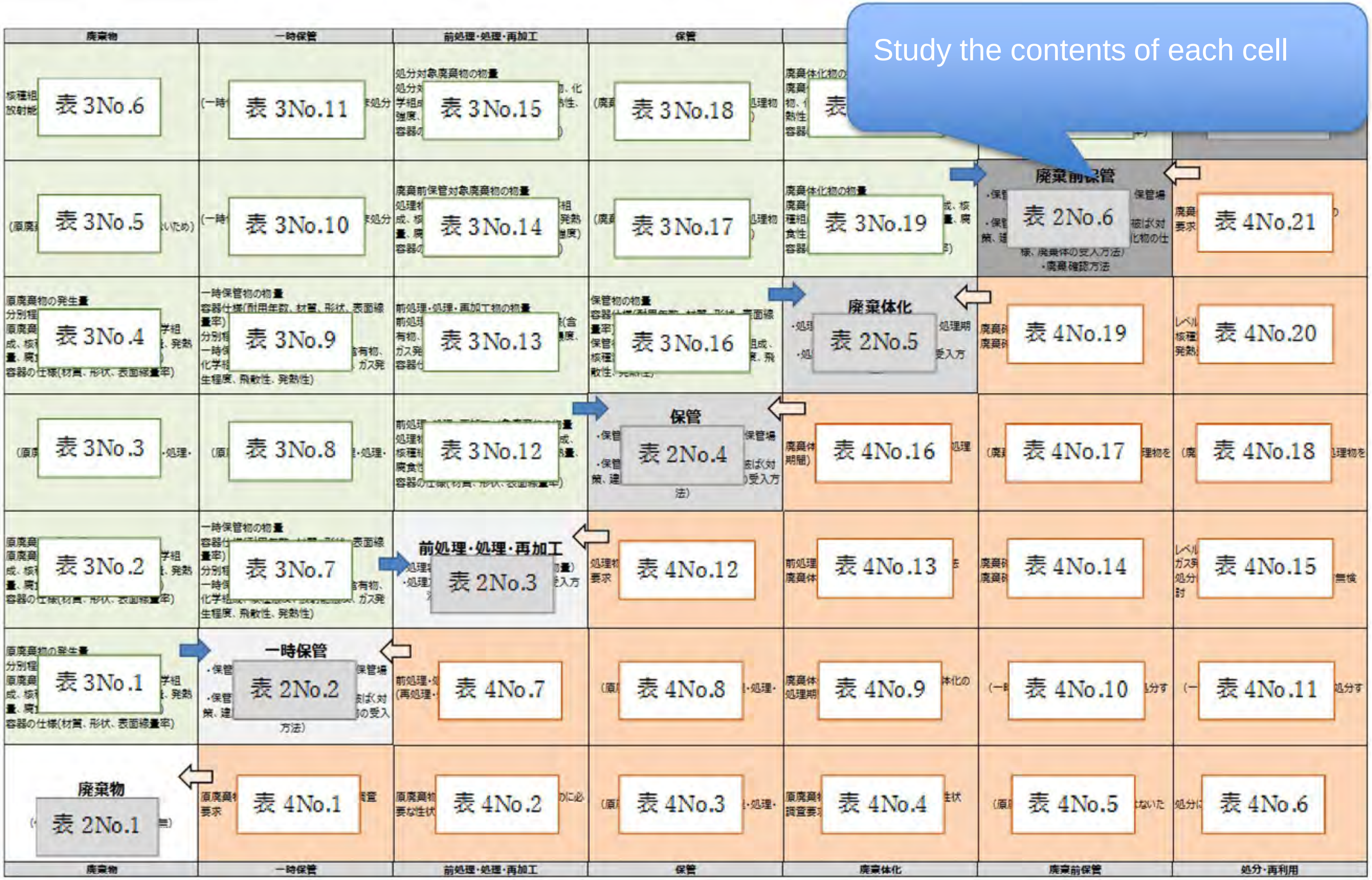
Clearly specify the operation details and target to be treated for each step.

	Waste	Temporary storage	Pre-treatment, treatment and reprocessing	Storage	Waste conditioning	Storage before disposal	Disposal / Reuse
Important operations	• Generation of sources of waste • Checking the characteristics of sources of waste	• Temporary storage of sources of waste until pre-treatment, treatment and reprocessing	• Treatment and processing for stable storage during a relatively long duration • Treated into a disposable form in some cases	• Storage until waste conditioning	• Treated into an underground disposable form	• Storage of waste until disposal • Confirmation of disposal (especially embedded radioactivity)	• Underground disposal of waste (or reuse)
Target to be handled	• Source of waste	• Source of waste	• Source of waste	• Treated matter	• Source waste • Treated matter	• Treated matter (in some cases) • Waste	• Treated matter (in some cases) • Waste

(1) Integration of R&D Results (Establishment of Waste Stream)

-Action Items for FY2018-

Study of the concept of input information management sheet (2/2)



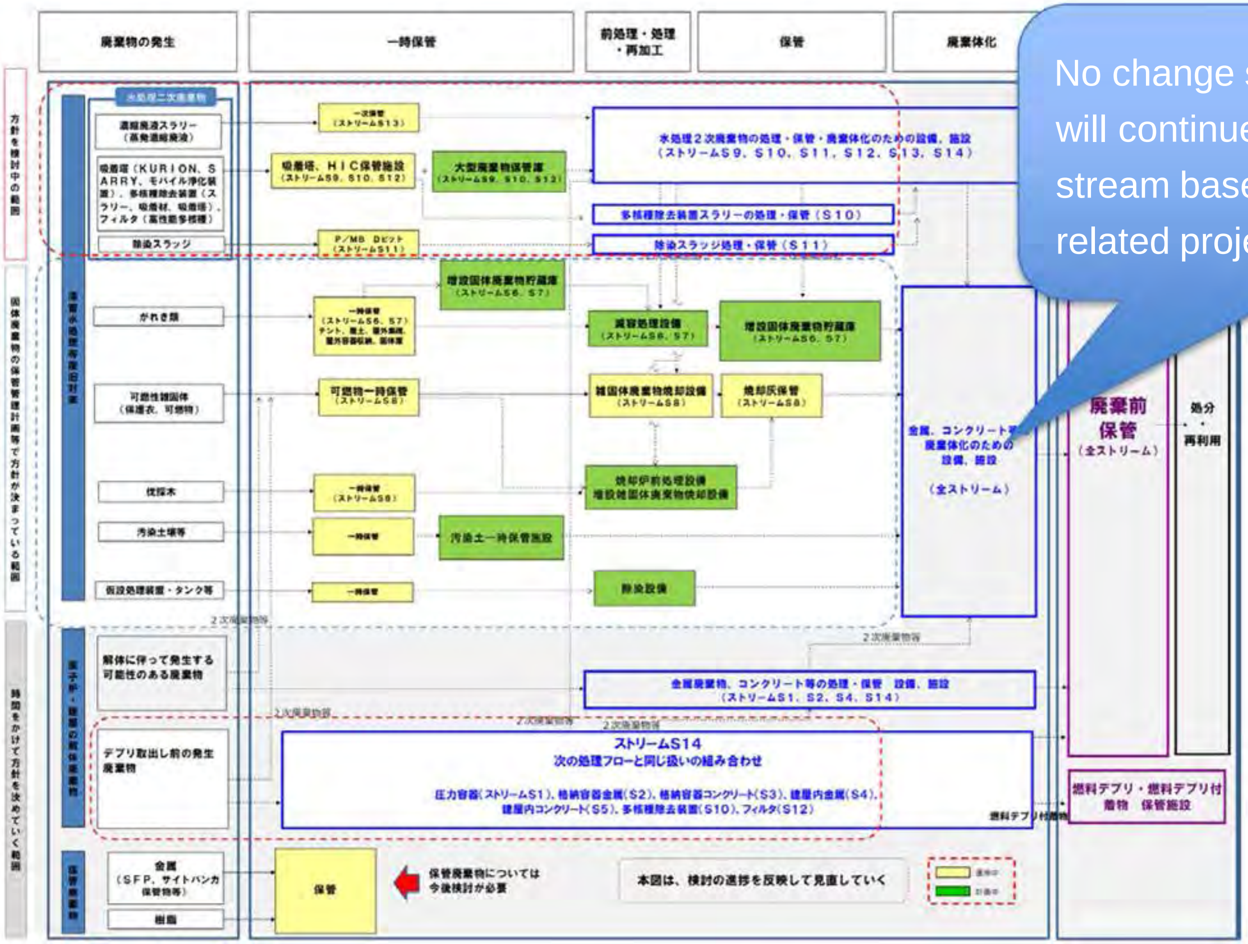
Study the contents of each cell

廃棄物	一時保管	前処理・処理・再加工	保管	廃棄体化		
表 3No.6	表 3No.11	表 3No.15	表 3No.18	表		
表 3No.5	表 3No.10	表 3No.14	表 3No.17	表 3No.19	廃棄前保管 表 2No.6	表 4No.21
表 3No.4	表 3No.9	表 3No.13	表 3No.16	廃棄体化 表 2No.5	表 4No.19	表 4No.20
表 3No.3	表 3No.8	表 3No.12	保管 表 2No.4	表 4No.16	表 4No.17	表 4No.18
表 3No.2	表 3No.7	前処理・処理・再加工 表 2No.3	表 4No.12	表 4No.13	表 4No.14	表 4No.15
表 3No.1	一時保管 表 2No.2	表 4No.7	表 4No.8	表 4No.9	表 4No.10	表 4No.11
廃棄物 表 2No.1	表 4No.1	表 4No.2	表 4No.3	表 4No.4	表 4No.5	表 4No.6
廃棄物	一時保管	前処理・処理・再加工	保管	廃棄体化	廃棄前保管	処分・再利用

(1) Integration of R&D Results (Establishment of Waste Stream)

-Integration into Waste Stream-

The refined treatment flow was integrated as a waste stream to verify the total image of waste management



No change since FY2017. We will continue to refine the waste stream based on the progress of related projects

(1) Integration of R&D Results (Establishment of Waste Stream)

-Summary-

1. A method for evaluating the integrated progress, consistency and issues of R&D was created using the input information management sheet, time schedule arrangement table, and waste stream.

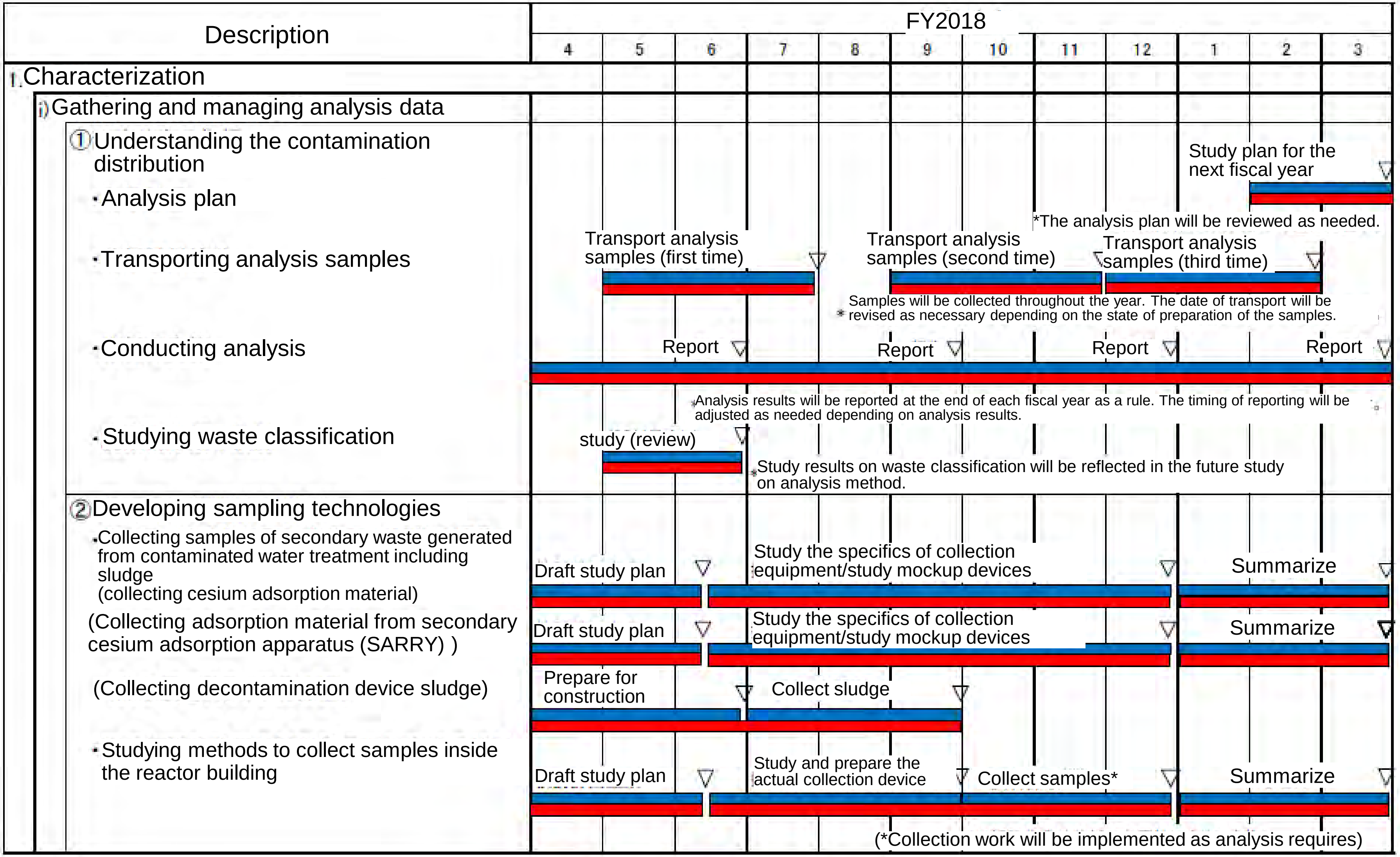
2. It was confirmed that the R&D for treatment and disposal of solid waste is being carried out with respect to waste that is currently being generated and waste, treatment and storage of which is planned to start soon.

3. The issue of insufficient inputs from downstream (disposal side) to upstream (waste side) in the R&D for treatment and disposal of solid waste was identified.

6. Schedule and Project Organization

Research and Development for Treatment and Disposal of Solid Radioactive Waste: FY2019 Study Schedule (1/6)

Legend
Blue: Plan
Red: Performance



Description

FY2018

4 5 6 7 8 9 10 11 12 1 2 3

1. Characterization

i) Gathering and managing analysis data

① Understanding the contamination distribution

- Analysis plan
  Study plan for the next fiscal year
  *The analysis plan will be reviewed as needed.
- Transporting analysis samples
  Transport analysis samples (first time)
  Transport analysis samples (second time)
  Transport analysis samples (third time)
  * Samples will be collected throughout the year. The date of transport will be revised as necessary depending on the state of preparation of the samples.
- Conducting analysis
  Report
  Report
  Report
  Report
  *Analysis results will be reported at the end of each fiscal year as a rule. The timing of reporting will be adjusted as needed depending on analysis results.
- Studying waste classification
  study (review)
  *Study results on waste classification will be reflected in the future study on analysis method.

② Developing sampling technologies

- Collecting samples of secondary waste generated from contaminated water treatment including sludge
  (collecting cesium adsorption material)
  Draft study plan
  Study the specifics of collection equipment/study mockup devices
  Summarize

(Collecting adsorption material from secondary cesium adsorption apparatus (SARRY))
Draft study plan
Study the specifics of collection equipment/study mockup devices
Summarize

(Collecting decontamination device sludge)
Prepare for construction
Collect sludge

- Studying methods to collect samples inside the reactor building
  Draft study plan
  Study and prepare the actual collection device
  Collect samples*
  Summarize

(*Collection work will be implemented as analysis requires)

Legend
Blue: Plan
Red: Performance

Research and Development for Treatment and Disposal of Solid Radioactive Waste: FY2019 Study Schedule (2/6)

Description	FY2018											
	4	5	6	7	8	9	10	11	12	1	2	3
③Optimizing the analysis method ･Studying the contamination mechanism and representativeness of the data	Study the contamination mechanism (review)		▽	Study data representativeness (review)		▽	Study method to evaluate representativeness		▽	Summarize		▽
･Streamlining the analysis method	Study plan		▽	Study methods for streamlining					▽	Summarize		▽
④Managing analysis data ･Creating an analysis database	Study specifications		▽	Create a database (improve)					▽	Manage/summarize		▽
･Organizing and updating waste data	Draft study plan		▽	Study development and revision policies, disclose revised data					▽	Summarize		▽
ii) Increasing the accuracy of the analytical evaluation method •Analytical evaluation method	Study plan		▽	Study accuracy improvements/develop methods				Calculate inventory	▽	Organize procedures/Summarize		▽
•Gathering fundamental data	Study plan		▽	Collect fundamental data as an experiment					▽	Summarize		▽
iii) Summarizing the comprehensive inventory evaluation	Study plan		▽	Calculate/set inventory, build procedures					▽	Summarize		▽
iv) Measures for materials with impact on disposal ･Approach to setting allowable concentrations	Study plan		▽	Study approach to setting allowable concentrations					▽	Summarize		▽
･Study impact on disposal safety	Study plan		▽	Study quantitative evaluation methods					▽	Summarize		▽

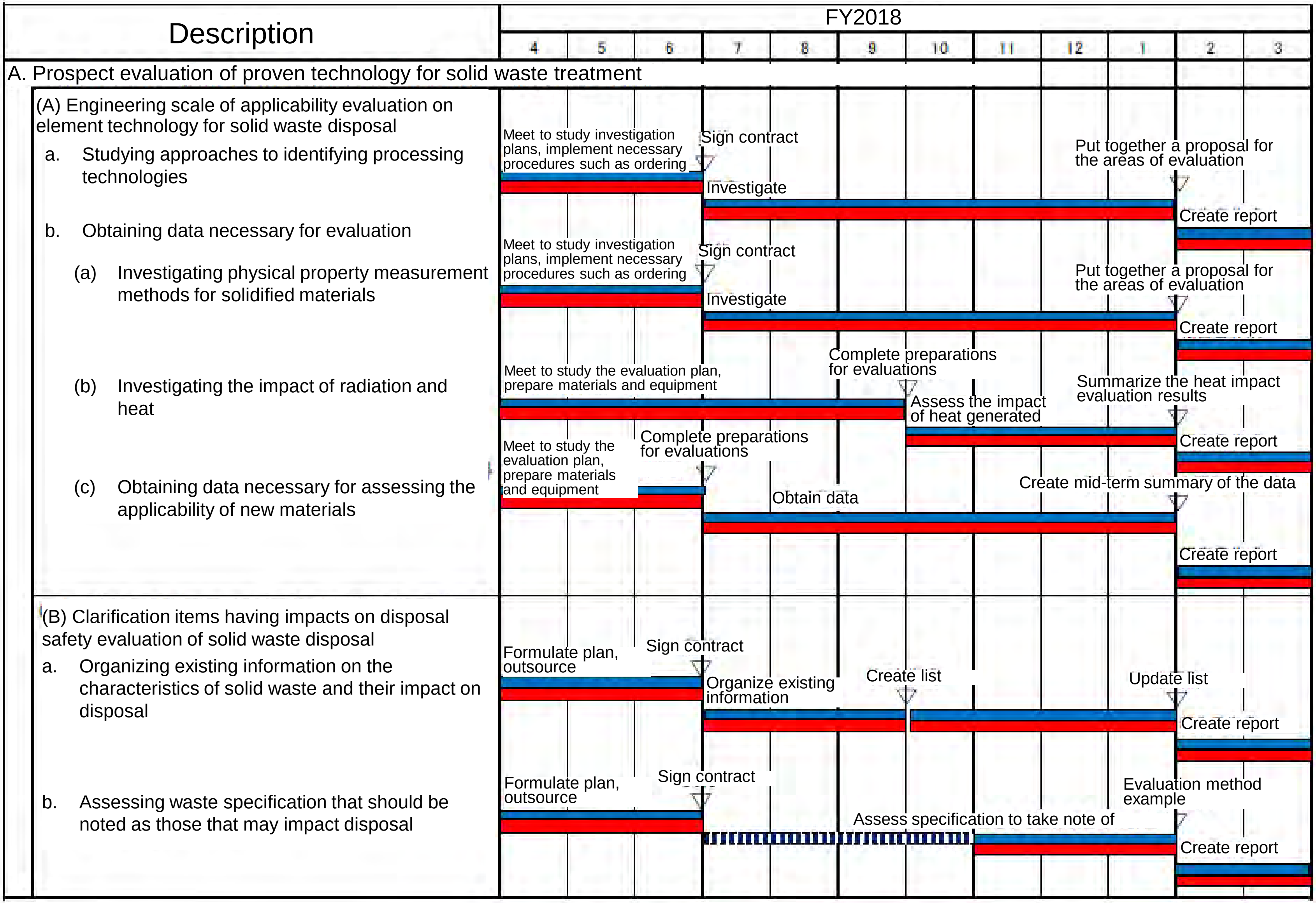
arch and Development for Treatment and Disposal of Solid Radioactive Waste: FY2019 Study Schedule

Legend
Blue: Plan
Red: Performance

Description	FY2018											
	4	5	6	7	8	9	10	11	12	1	2	3
ted to pre-disposal management												
ness evaluation according to the ics of solid waste	Study plan		▽	Study the applicability of existing technologies		▽	Challenges in applying such technologies to accident waste		▽	Summarize		▽
nd evaluating storage and management methods according to the characteristics of the solid waste												
ng storage measures for high dose waste												
res for hydrogen gas generation (investigation of cases abroad)	Study plan		▽	Assess/study 1F applicability of overseas knowledge including vent requirements/conditions					▽	Summarize		▽
ures for wastes generated by fuel debris retrieval	Study plan		▽	Study classification and storage of waste generated when retrieving fuel debris					▽	Summarize		▽
ing stabilization technology for secondary waste ted from contaminated water treatment ability evaluation of in-drum type glass cation technology	Draft test plan	▽	In-drum glass solidification engineering (scale-up) test						▽	Summarize		▽
ng stabilization of decontamination device	(Studies completed in FY2017 due to changes in plans)											
chnology related to reducing the amount of	Draft study plan		▽	Study/investigate methods to reduce and classify α contaminated waste					▽	Summarize		▽
osal concept and safety evaluation olid wastes	Draft study plan		▽	Investigate subject disposal site		▽	Investigate/assess disposal system		▽	Summarize		▽
research and development results (waste	Draft study plan		▽	Assess in an integrated manner, progress made, consistency of results, and challenges yet to be tackled					▽	Summarize		▽

Legend
Blue: Plan
Red: Performance

Research and Development for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods) FY2019 study Schedule (4/6)



Description

A. Prospect evaluation of proven technology for solid waste treatment

(A) Engineering scale of applicability evaluation on element technology for solid waste disposal

a. Studying approaches to identifying processing technologies

b. Obtaining data necessary for evaluation

(a) Investigating physical property measurement methods for solidified materials

(b) Investigating the impact of radiation and heat

(c) Obtaining data necessary for assessing the applicability of new materials

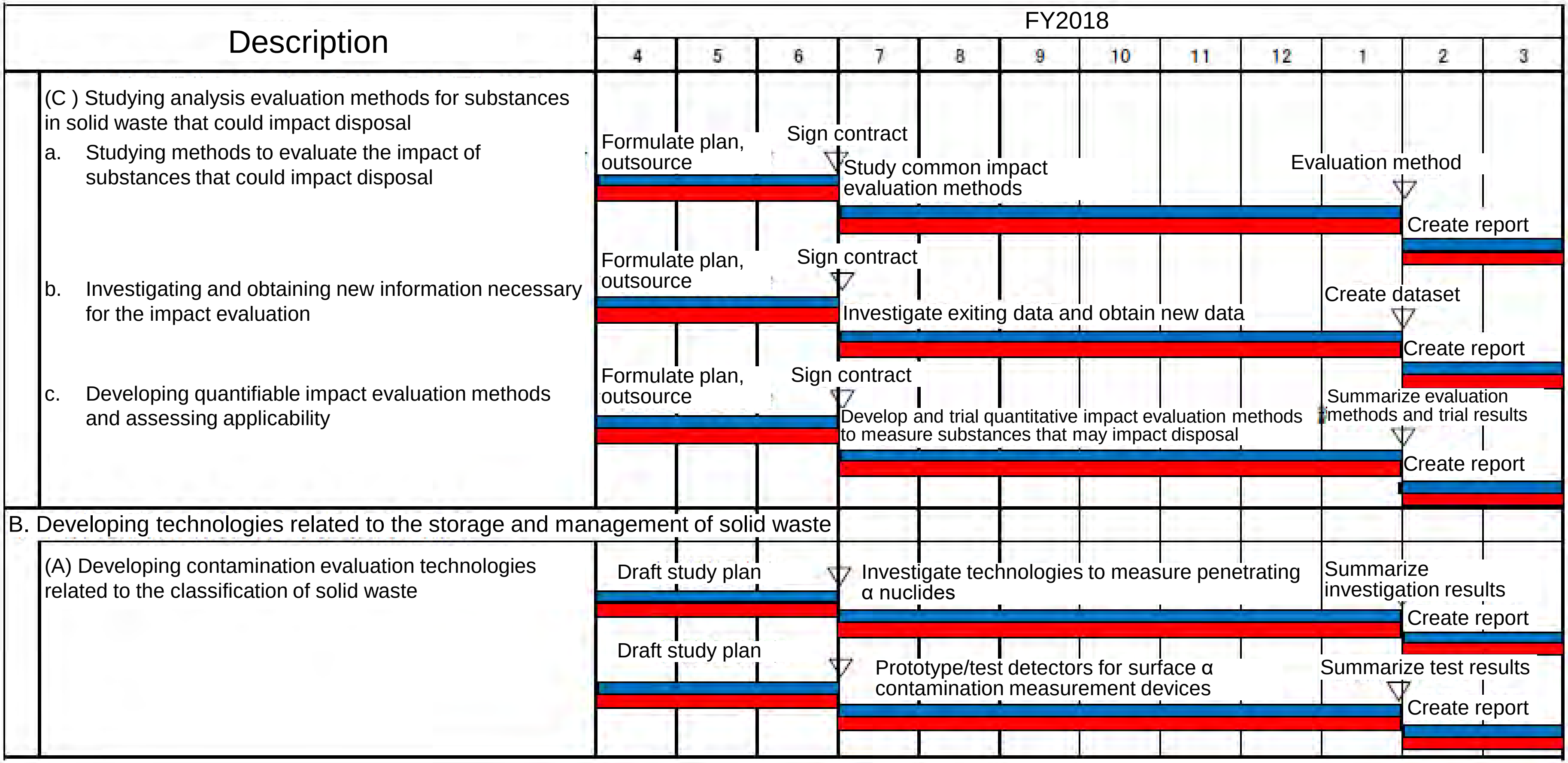
(B) Clarification items having impacts on disposal safety evaluation of solid waste disposal

a. Organizing existing information on the characteristics of solid waste and their impact on disposal

b. Assessing waste specification that should be noted as those that may impact disposal

Legend
Blue: Plan
Red: Performance

Research and Development for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods): FY2019 study Schedule (5/6)



Description

FY2018

4 5 6 7 8 9 10 11 12 1 2 3

(C) Studying analysis evaluation methods for substances in solid waste that could impact disposal

a. Studying methods to evaluate the impact of substances that could impact disposal

Formulate plan, outsource

Sign contract

Study common impact evaluation methods

Evaluation method

Create report

b. Investigating and obtaining new information necessary for the impact evaluation

Formulate plan, outsource

Sign contract

Investigate exiting data and obtain new data

Create dataset

Create report

c. Developing quantifiable impact evaluation methods and assessing applicability

Formulate plan, outsource

Sign contract

Develop and trial quantitative impact evaluation methods to measure substances that may impact disposal

Summarize evaluation methods and trial results

Create report

B. Developing technologies related to the storage and management of solid waste

(A) Developing contamination evaluation technologies related to the classification of solid waste

Draft study plan

Investigate technologies to measure penetrating α nuclides

Summarize investigation results

Create report

Draft study plan

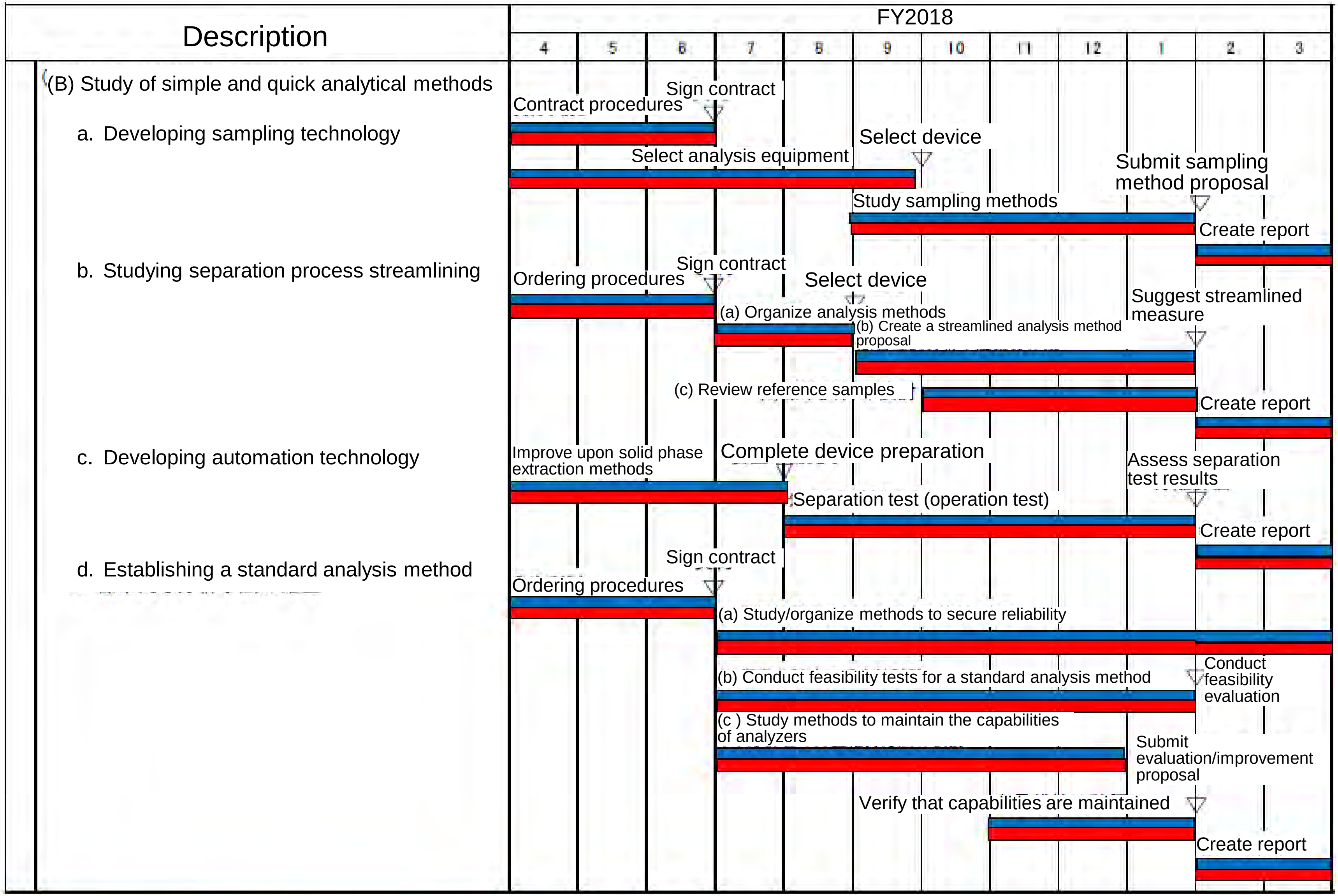
Prototype/test detectors for surface α contamination measurement devices

Summarize test results

Create report

Legend
Blue: Plan
Red: Performance

Research and Development for Treatment and Disposal of Solid Radioactive Waste (R&D on Preceding Processing Methods and Analytical Methods): FY2019 study Schedule (6/6)



Description

FY2018

4 5 6 7 8 9 10 11 12 1 2 3

(B) Study of simple and quick analytical methods

a. Developing sampling technology

Contract procedures

Sign contract

Select analysis equipment

Select device

Study sampling methods

Submit sampling method proposal

Create report

b. Studying separation process streamlining

Ordering procedures

Sign contract

Select device

(a) Organize analysis methods

(b) Create a streamlined analysis method proposal

Suggest streamlined measure

(c) Review reference samples

Create report

c. Developing automation technology

Improve upon solid phase extraction methods

Complete device preparation

Separation test (operation test)

Assess separation test results

Create report

d. Establishing a standard analysis method

Ordering procedures

Sign contract

(a) Study/organize methods to secure reliability

(b) Conduct feasibility tests for a standard analysis method

Conduct feasibility evaluation

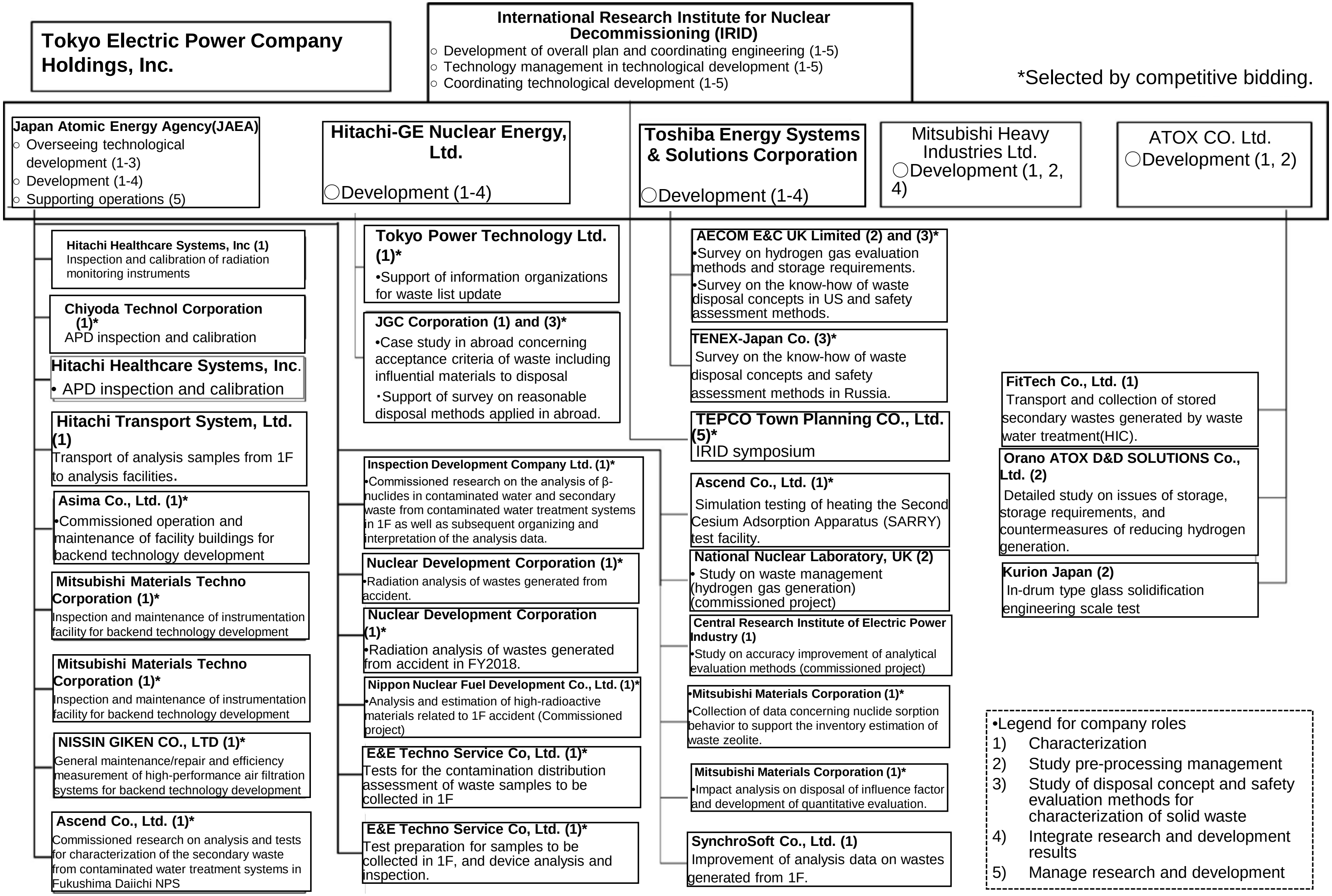
(c) Study methods to maintain the capabilities of analyzers

Submit evaluation/improvement proposal

Verify that capabilities are maintained

Create report

Structure for Research and Development related to the Treatment and Disposal of Solid Waste (FY2019)



Tokyo Electric Power Company Holdings, Inc.

International Research Institute for Nuclear Decommissioning (IRID)
○ Development of overall plan and coordinating engineering (1-5)
○ Technology management in technological development (1-5)
○ Coordinating technological development (1-5)

*Selected by competitive bidding.

Japan Atomic Energy Agency(JAEA)
○ Overseeing technological development (1-3)
○ Development (1-4)
○ Supporting operations (5)

Hitachi-GE Nuclear Energy, Ltd.
○Development (1-4)

Toshiba Energy Systems & Solutions Corporation
○Development (1-4)

Mitsubishi Heavy Industries Ltd.
○Development (1, 2, 4)

ATOX CO. Ltd.
○Development (1, 2)

Hitachi Healthcare Systems, Inc (1)
Inspection and calibration of radiation monitoring instruments

Chiyoda Technol Corporation (1)*
APD inspection and calibration

Hitachi Healthcare Systems, Inc.
- APD inspection and calibration

Hitachi Transport System, Ltd. (1)
Transport of analysis samples from 1F to analysis facilities.

Asima Co., Ltd. (1)*
•Commissioned operation and maintenance of facility buildings for backend technology development

Mitsubishi Materials Techno Corporation (1)*
Inspection and maintenance of instrumentation facility for backend technology development

Mitsubishi Materials Techno Corporation (1)*
Inspection and maintenance of instrumentation facility for backend technology development

NISSIN GIKEN CO., LTD (1)*
General maintenance/repair and efficiency measurement of high-performance air filtration systems for backend technology development

Ascend Co., Ltd. (1)*
Commissioned research on analysis and tests for characterization of the secondary waste from contaminated water treatment systems in Fukushima Daiichi NPS

Tokyo Power Technology Ltd. (1)*
•Support of information organizations for waste list update

JGC Corporation (1) and (3)*
•Case study in abroad concerning acceptance criteria of waste including influential materials to disposal
・Support of survey on reasonable disposal methods applied in abroad.

Inspection Development Company Ltd. (1)*
•Commissioned research on the analysis of β-nuclides in contaminated water and secondary waste from contaminated water treatment systems in 1F as well as subsequent organizing and interpretation of the analysis data.

Nuclear Development Corporation (1)*
•Radiation analysis of wastes generated from accident.

Nuclear Development Corporation (1)*
•Radiation analysis of wastes generated from accident in FY2018.

Nippon Nuclear Fuel Development Co., Ltd. (1)*
•Analysis and estimation of high-radioactive materials related to 1F accident (Commissioned project)

E&E Techno Service Co, Ltd. (1)*
Tests for the contamination distribution assessment of waste samples to be collected in 1F

E&E Techno Service Co, Ltd. (1)*
Test preparation for samples to be collected in 1F, and device analysis and inspection.

AECOM E&C UK Limited (2) and (3)*
•Survey on hydrogen gas evaluation methods and storage requirements.
•Survey on the know-how of waste disposal concepts in US and safety assessment methods.

TENEX-Japan Co. (3)*
Survey on the know-how of waste disposal concepts and safety assessment methods in Russia.

TEPCO Town Planning CO., Ltd. (5)*
IRID symposium

Ascend Co., Ltd. (1)*
Simulation testing of heating the Second Cesium Adsorption Apparatus (SARRY) test facility.

National Nuclear Laboratory, UK (2)
- Study on waste management (hydrogen gas generation) (commissioned project)

Central Research Institute of Electric Power Industry (1)
•Study on accuracy improvement of analytical evaluation methods (commissioned project)

•Mitsubishi Materials Corporation (1)*
•Collection of data concerning nuclide sorption behavior to support the inventory estimation of waste zeolite.

Mitsubishi Materials Corporation (1)*
•Impact analysis on disposal of influence factor and development of quantitative evaluation.

SynchroSoft Co., Ltd. (1)
Improvement of analysis data on wastes generated from 1F.

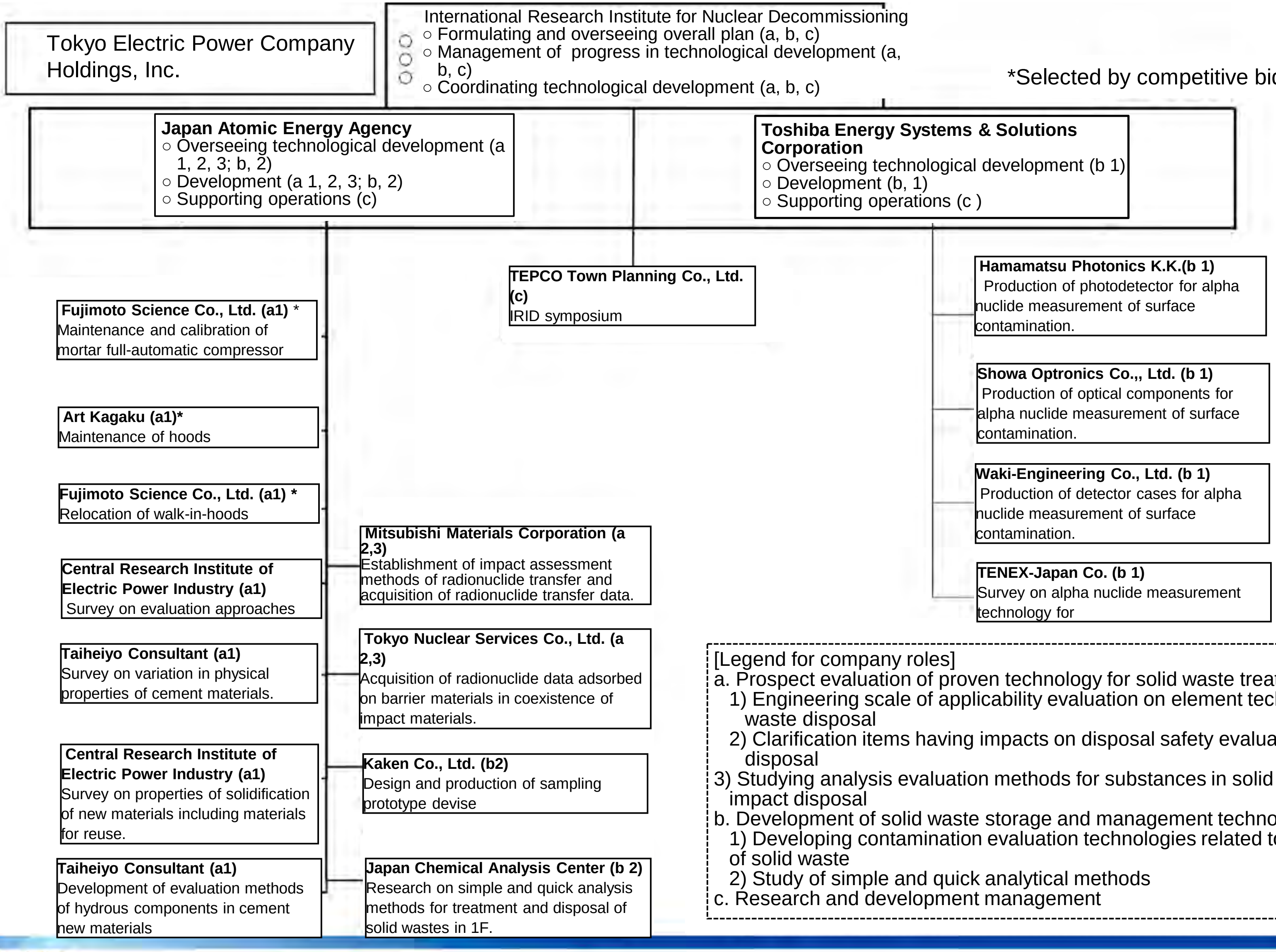
FitTech Co., Ltd. (1)
Transport and collection of stored secondary wastes generated by waste water treatment(HIC).

Orano ATOX D&D SOLUTIONS Co., Ltd. (2)
Detailed study on issues of storage, storage requirements, and countermeasures of reducing hydrogen generation.

Kurion Japan (2)
In-drum type glass solidification engineering scale test

•Legend for company roles
1) Characterization
2) Study pre-processing management
3) Study of disposal concept and safety evaluation methods for characterization of solid waste
4) Integrate research and development results
5) Manage research and development

Structure for Research and Development related to the Treatment and Disposal of Solid Waste (R&D on Preceding Processing Methods and Analytical Methods) (FY2019)



Tokyo Electric Power Company Holdings, Inc.

International Research Institute for Nuclear Decommissioning
- ○ Formulating and overseeing overall plan (a, b, c)
- ○ Management of progress in technological development (a, b, c)
- ○ Coordinating technological development (a, b, c)

*Selected by competitive bidding.

Japan Atomic Energy Agency
- ○ Overseeing technological development (a 1, 2, 3; b, 2)
- ○ Development (a 1, 2, 3; b, 2)
- ○ Supporting operations (c)

Toshiba Energy Systems & Solutions Corporation
- ○ Overseeing technological development (b 1)
- ○ Development (b, 1)
- ○ Supporting operations (c)

Fujimoto Science Co., Ltd. (a1) *
Maintenance and calibration of mortar full-automatic compressor

Art Kagaku (a1)*
Maintenance of hoods

Fujimoto Science Co., Ltd. (a1) *
Relocation of walk-in-hoods

Central Research Institute of Electric Power Industry (a1)
Survey on evaluation approaches

Taiheiyo Consultant (a1)
Survey on variation in physical properties of cement materials.

Central Research Institute of Electric Power Industry (a1)
Survey on properties of solidification of new materials including materials for reuse.

Taiheiyo Consultant (a1)
Development of evaluation methods of hydrous components in cement new materials

TEPCO Town Planning Co., Ltd. (c)
IRID symposium

Mitsubishi Materials Corporation (a 2,3)
Establishment of impact assessment methods of radionuclide transfer and acquisition of radionuclide transfer data.

Tokyo Nuclear Services Co., Ltd. (a 2,3)
Acquisition of radionuclide data adsorbed on barrier materials in coexistence of impact materials.

Kaken Co., Ltd. (b2)
Design and production of sampling prototype devise

Japan Chemical Analysis Center (b 2)
Research on simple and quick analysis methods for treatment and disposal of solid wastes in 1F.

Hamamatsu Photonics K.K.(b 1)
Production of photodetector for alpha nuclide measurement of surface contamination.

Showa Optronics Co.,, Ltd. (b 1)
Production of optical components for alpha nuclide measurement of surface contamination.

Waki-Engineering Co., Ltd. (b 1)
Production of detector cases for alpha nuclide measurement of surface contamination.

TENEX-Japan Co. (b 1)
Survey on alpha nuclide measurement technology for

[Legend for company roles]
a. Prospect evaluation of proven technology for solid waste treatment
  1) Engineering scale of applicability evaluation on element technology for solid waste disposal
  2) Clarification items having impacts on disposal safety evaluation of solid waste disposal
3) Studying analysis evaluation methods for substances in solid waste that could impact disposal
b. Development of solid waste storage and management technology
  1) Developing contamination evaluation technologies related to the classification of solid waste
  2) Study of simple and quick analytical methods
c. Research and development management