Study of Radionuclide Migration Model for Concrete-Pit and Trench Disposal

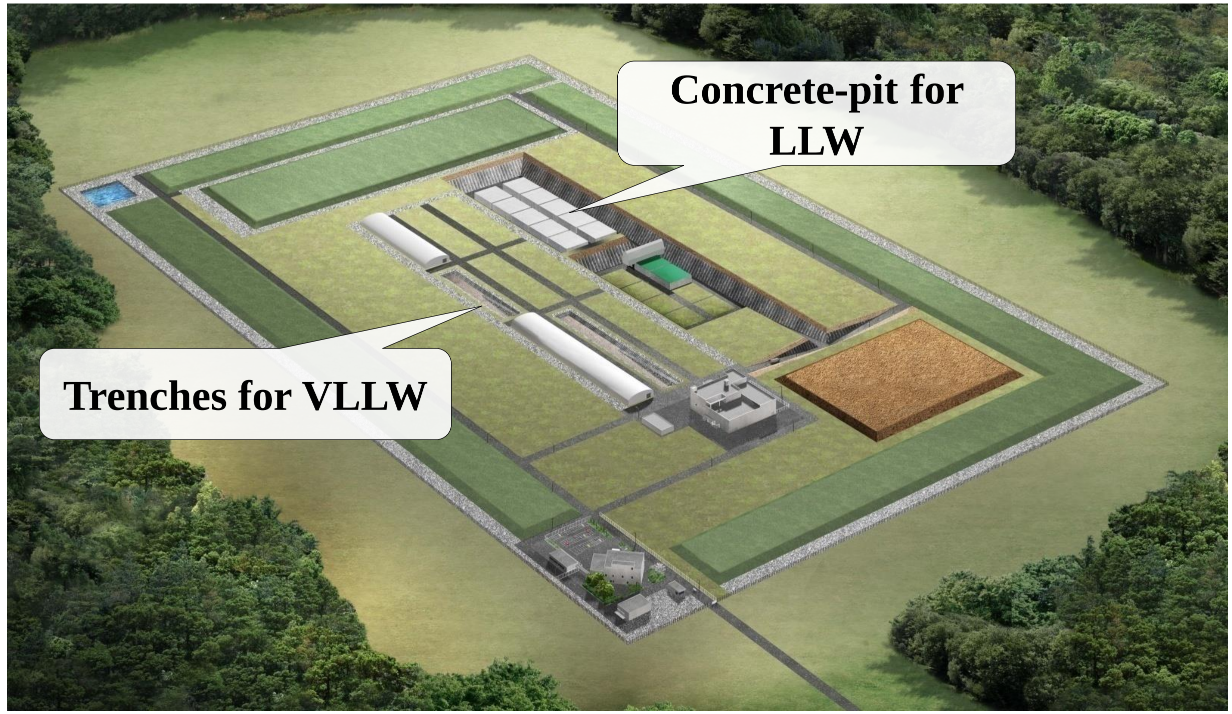
October 21, 2024

Akihiro Sakai
Japan Atomic Energy Agency

Outline of the JAEA Disposal Project

- JAEA is advancing its near surface disposal project of low-level radioactive waste generated from research facilities and other sources.

- Types of disposal facilities
  - Concrete vault disposal "referred to as **Concrete-pit disposal** in **Japan**"
  - **Trench disposal** (landfill)



- Amount of radioactive waste* to be disposed of by JAEA (Waste expected to be by 2048 f.y.)

  Total : approx. 134,000 m^3
  (including approx. 97,000m^3 of JAEA)

* Investigation at 2024

- Waste Disposal Capacity

Total	: 150,000 m^3 (=750,000 drums (200-liter))
Concrete-pit disposal	: 44,000m^3 (=220,000 drums (200-liter))
Trench disposal	: 106,000m^3 (=530,000 drums (200-liter)

Objective

- The JAEA disposal project has the following characteristics.

1. **Installation of Concrete-pit and Trench disposal facilities at the same site**.
   - Installing disposal facilities with different radioactivity levels, ground conditions, and structures
   - Considering overlapping evaluated doses from both disposal facilities.
2. **Disposal of waste generated from various facilities**
   - From research reactors, RI-use facilities, SF-reprocessing facilities, and uranium-handling facilities

- **Today's topic**: Characteristics of radionuclide migration analysis for concrete-pit and trench disposal based on the installation environment

Features of the Disposal Facilities

Trench disposal

- Disposal of Very Low-level Waste
- Position in the ground:
  Cover soil with 2.5m thickness.
  （depending site conditions, etc.)
- Components of the facility:
  Trench,
  Low-permeability Soil, etc.
- Institutional control period:
  approx. 50 years

Radioactive concentration limits of nuclides in radioactive waste

Nuclides	Upper limit (Bq/t)
Co-60	1×10^{10}
Sr-90	1×10^{7}
Cs-137	1×10^{8}

(stipulated in the rule).

Concrete-pit disposal

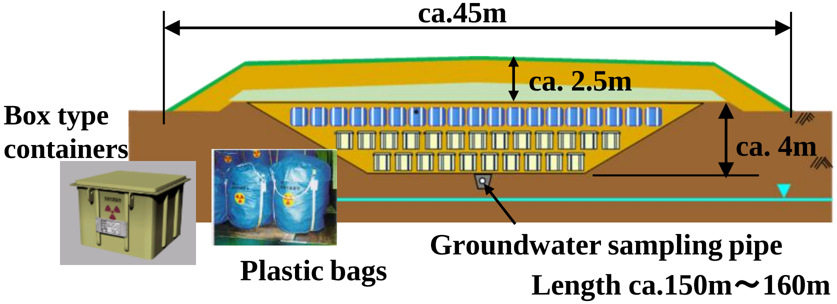
- Disposal for Low-level Waste
- Position in the ground:
  Several meters to a few tenths of a meter deep.（depending on site conditions, etc.)
- Components of the facility:
  Concrete-pit
  Bentonite mixed soil, etc.
- Institutional control period:
  300 ～400 years

Radioactive concentration limits of nuclides in radioactive waste

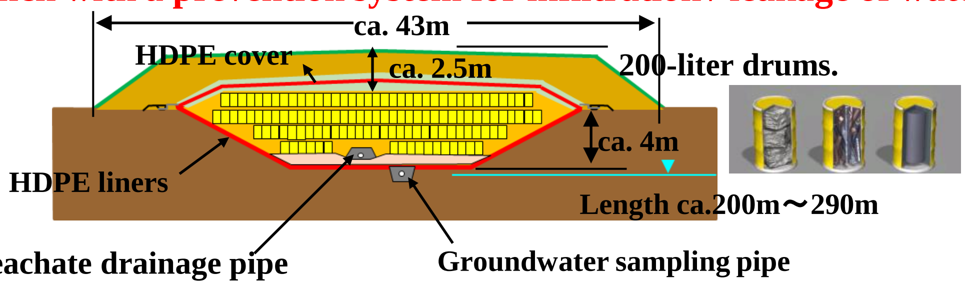
Nuclides	Upper limit (Bq/t)
C-14	1×10^{11}
Co-60	1×10^{15}
Ni-63	1×10^{13}
Sr-90	1×10^{13}
Tc-99	1×10^{9}
Cs-137	1×10^{14}
Alpha emitters	1×10^{10}

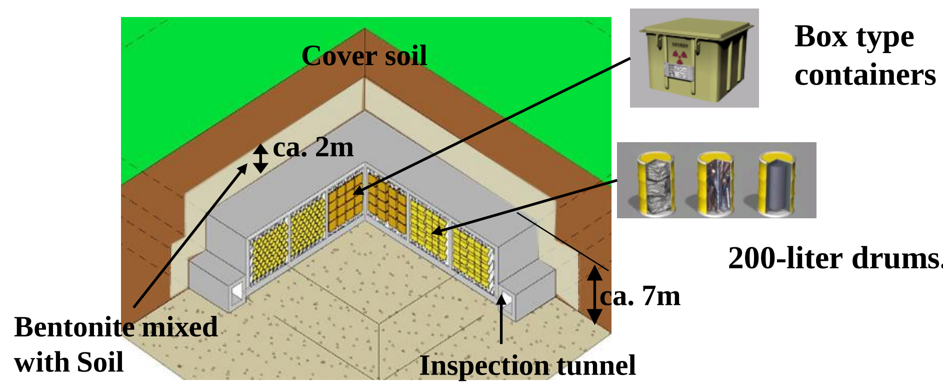
(stipulated in the rule).

Trench disposal facility: Disposal of concrete, metal waste, etc.



Trench with a prevention system for infiltration / leakage of water





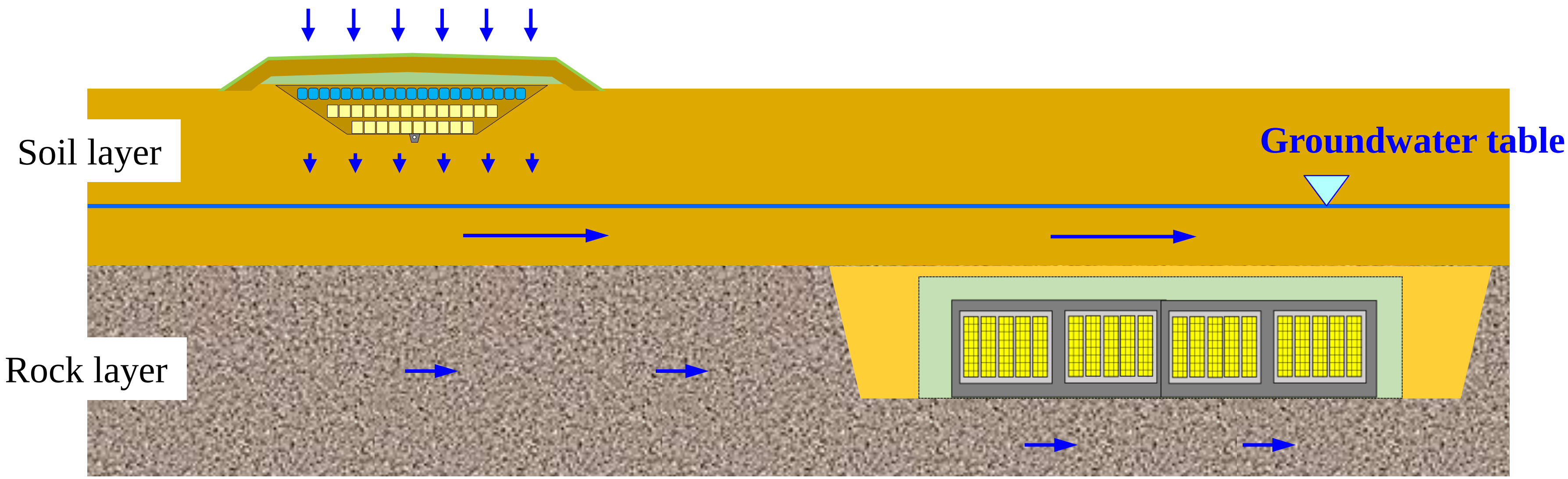
Considerations the Installation of Disposal Facilities

Trench disposal facility

- Placing above groundwater table:
  The depth of groundwater table is crucial
- Ground condition:
  To ensure bearing capacity and prevent liquefaction
- Evaluation of infiltration:
  Assess amount of water infiltration into the waste layer

Concrete-pit disposal facility

- Installation on ground with an N value greater than 50
  The depth of foundation rock is crucial
- The facility will be placed below the groundwater table
- Seepage flow analysis:
  Conduct seepage flow analysis using models that include multiple strata with different hydraulic conductivities.



Steps for Calculating Doses Resulting from the Disposal Facilities

1. Calculation of the amount of water infiltrating into and flowing out of the waste layer

- In trench disposal, the amount of water infiltrating into the waste layer is calculated using a two-dimensional FEM Code or HELP (Hydrologic Evaluation of Landfill Performance) Code
- In Concrete-pit disposal
  - ➢ A conceptual model of concrete-pits, surrounding barrier, cover soil and surrounding strata is created.
  - ➢ The amount of water percolating through the waste layer is calculated using 2-dimensional FEM Code.

↓

2. Analysis of radionuclide migration using one-dimensional calculation code

- In trench disposal, the flow rate of water flowing out of the waste layer is used as an input for computation of radionuclide migration using one-dimensional calculation code.
- In Concrete-pit disposal,
  - ➢ Several pathways for radionuclide migration are assumed.
  - ➢ The flow rate of water along each pathway, obtained from seepage flow analysis, is used as an input one-dimensional calculation code.

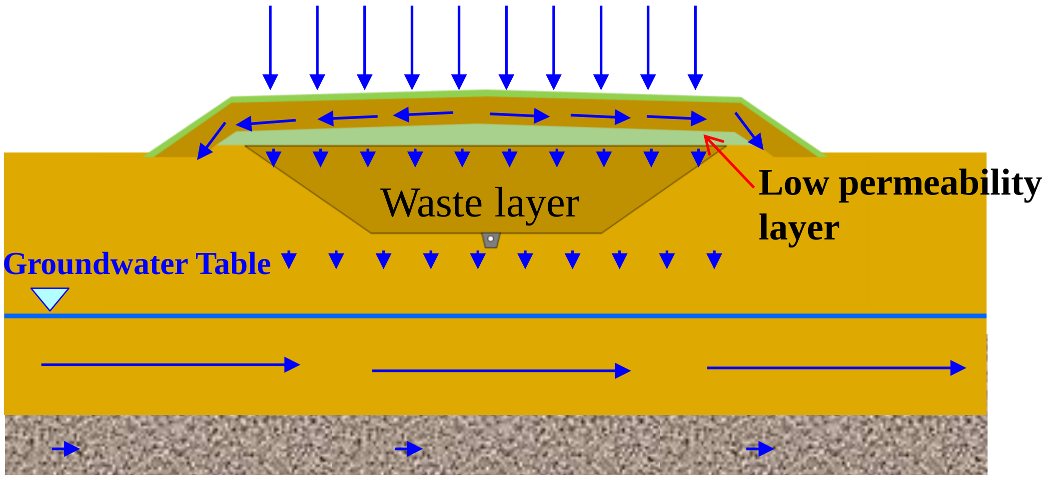
↓

Today's Topics

- **Development of seepage flow analysis through the waste layer**
- **Contribution of the infiltrated water to dose evaluation**

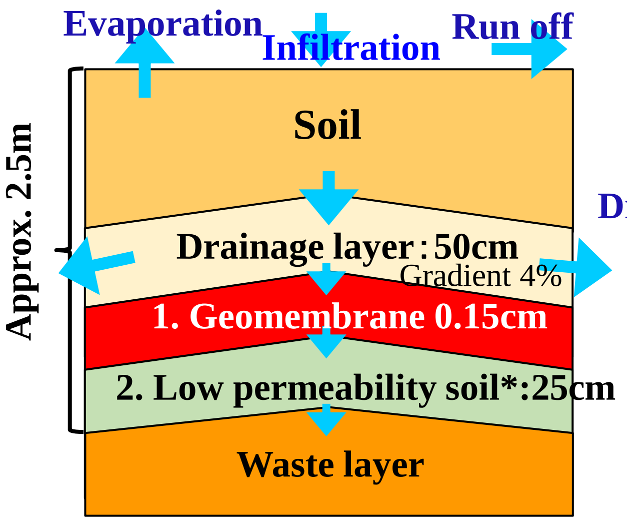
Calculation of Seepage Flow and Radionuclide Migration for Trench Disposal

Calculation of the Amount of Water Infiltrated into Trench

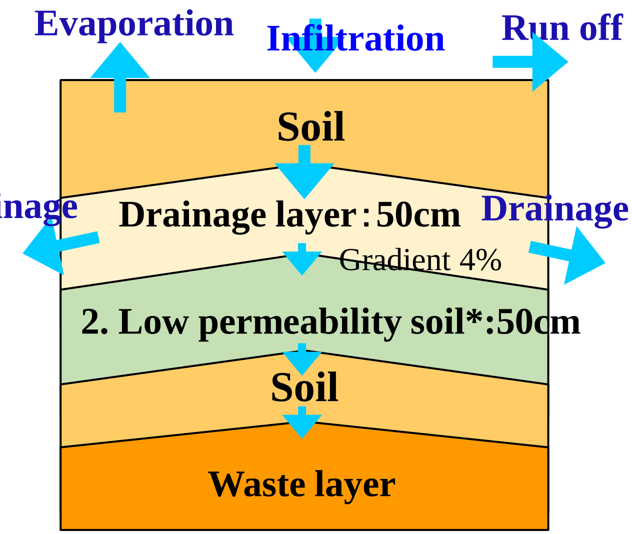


- Evaluation of water infiltration into the waste layer of the trench
- Reduction of inflow into the waste layer by combining low permeability soil, a drainage layer, and a geomembrane
- Analysis of the effect of the low permeability layer including the geomembrane, using the HELP code developed by the EPA

Model 1
(with the geomembrane)



Model 2
(without the geomembrane)



Parameter Study

1. Conditions for contact between **geomembrane** and **low permeability soil,** pinholes, defect density
2. Hydraulic conductivity(**HC**) of **low permeability soil; 10^{-5}m/s(sand) –10^{-9} m/s(cray)**

*** Assuming bentonite-mixed soil**

HC values; Soil $1*10^{-4}$(m/s), Drainage Layer $1*10^{-3}$(m/s), Geomembrane $1*10^{-11}$(m/s)

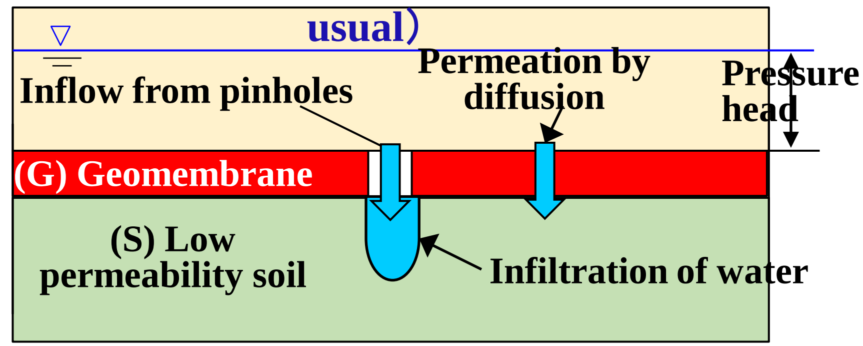
Geomembrane Liner Leakage Model

- Two types of model for water leakage from geomembrane are defined.
  1 Permeation at intact sections;
  Vapor diffusion through Intact geomembranes
  2 permeation from sections with pinholes or installation defects;
  Water permeates through gaps between the geomembrane and the lower layer and then percolates into the lower layer
- The number of pinholes and installation defects of geomembrane are set to 25 per 10^4 m^2, respectively. (as recommended in the HELP Code Commentary based on U.S. data).

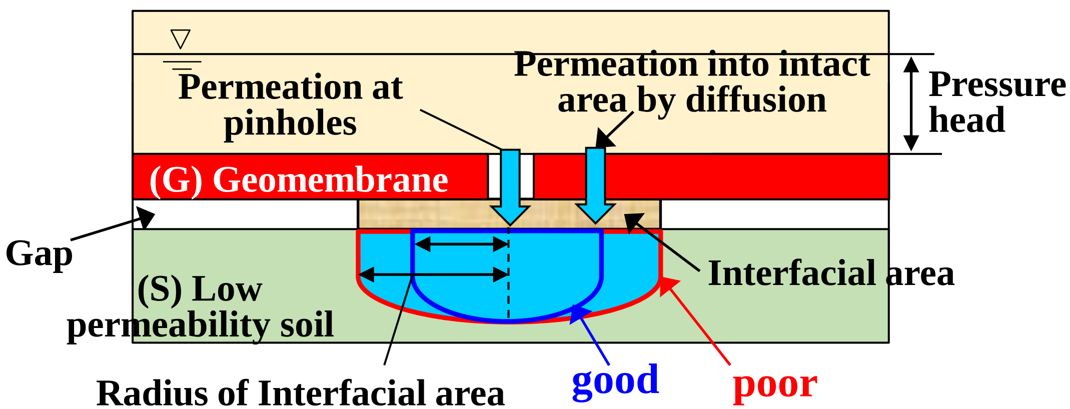
Installation Conditions for the Geomembrane (G) and soil (S)

1. Perfect : no gap, sprayed-on seal between G and S
2. Good : a few gaps between G and S
3. poor : a certain degree of gaps between G and S
4. worst : no impermeable function owing to the deterioration of G

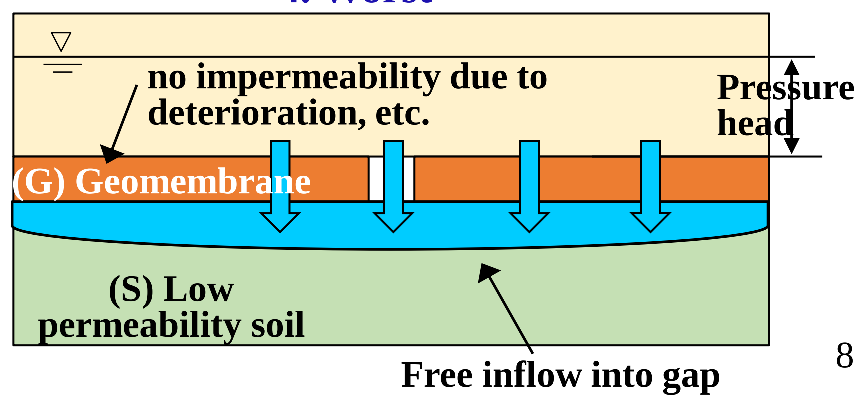
1. Perfect（not usual）



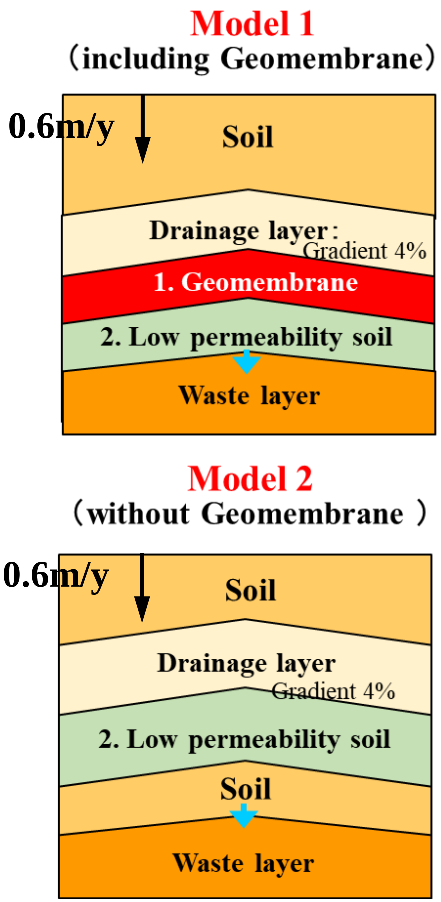
2. Good, 3. Poor



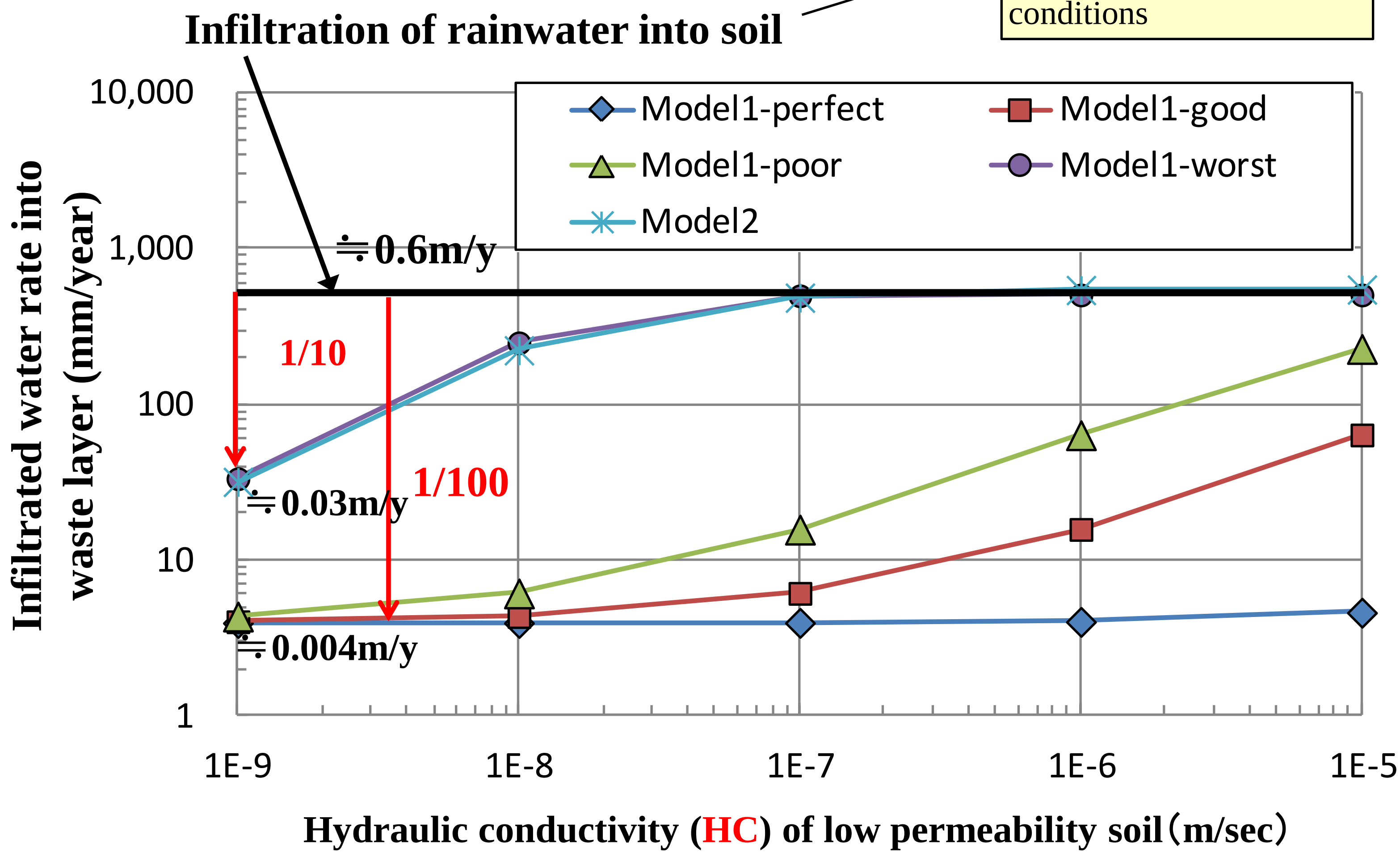
4. Worst



Calculation of the Amount of Water infiltrated into the Waste Layer

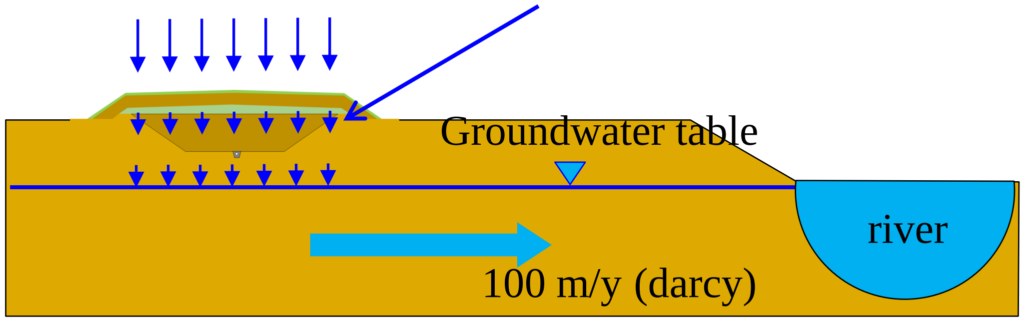


The value was calculated using soil condition and hypothetical weather conditions



Dose Calculation for the Trench Disposal Facility

The infiltrated water rates: 0.6、0.06、0.006 m/y



Ratio of Radioactivity

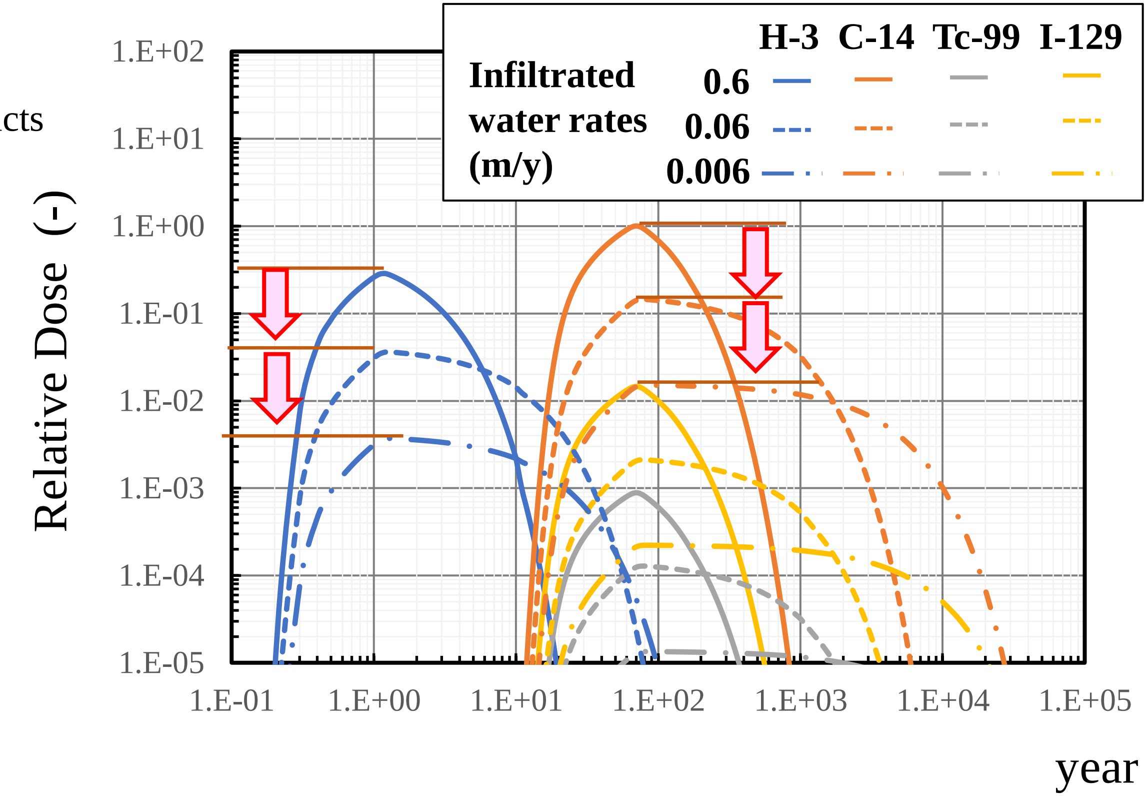
H-3	1.4E+01
C-14	1.0
Tc-99	1.0E-01
I-129	9.2E-03

Distribution coefficient Kd (m^3/kg)

	Waste	Soil
H-3	0.E+00	0.E+00
C-14	5.E-03	1.E-02
Tc-99	5.E-03	1.E-02
I-129	5.E-03	1.E-02

Exposure pathways

- Drinking river water
- Ingestion of livestock products
- Ingestion of river fish



As the infiltrated water rate decreases, the following changes are observed:

- **Exposure doses decrease**
- **Dose distributions broaden**
- **However, the time required to reach the peak dose remains unchanged**

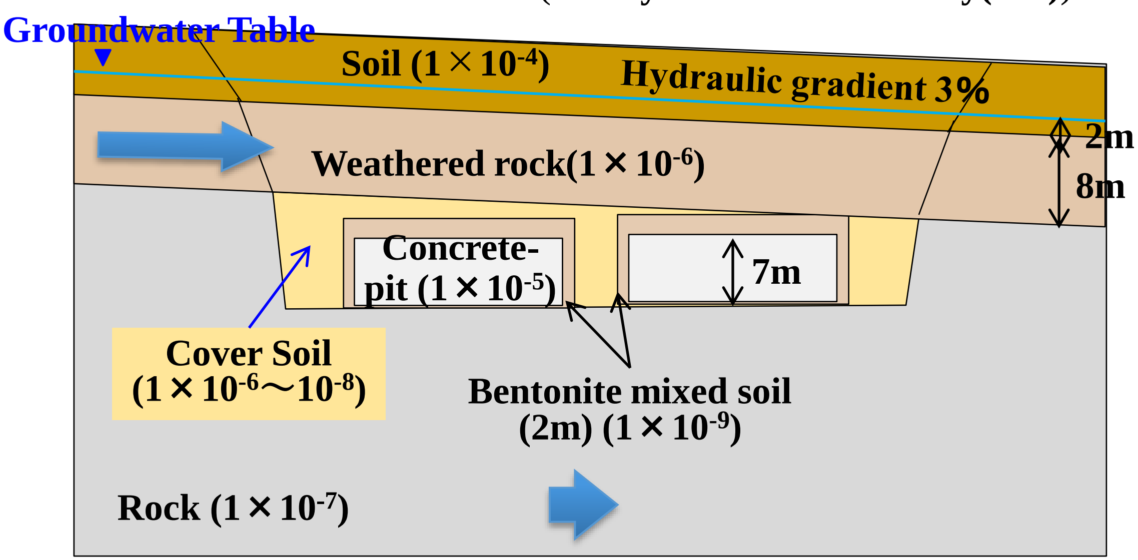
Calculation of Seepage Flow and Radionuclide Migration for Concrete-Pit Disposal

Outline of Seepage Water Analysis for the Concrete-Pit Disposal Facility

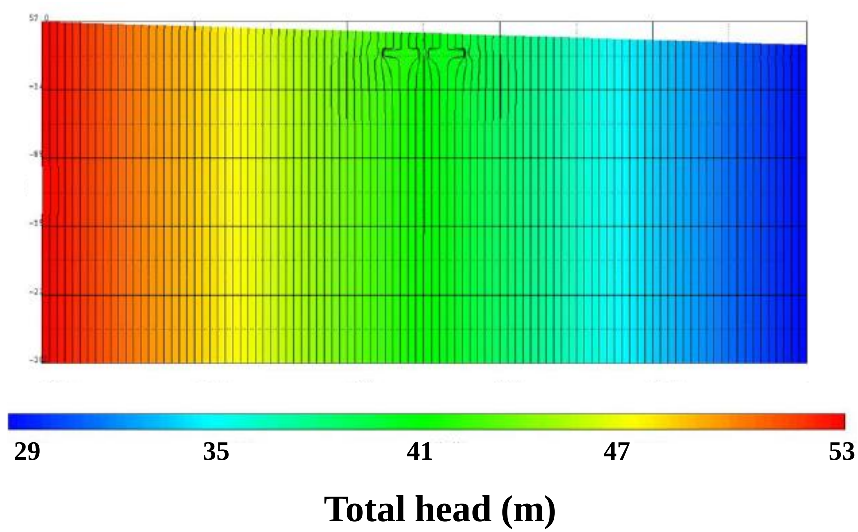
- Groundwater flowing through concrete-pits is a key carrier of radionuclides migrating into the geological environment surrounding the site.
- A general geological model was established, and the groundwater flow rate and direction in the model were computed using two-dimensional FEM calculation (calculation code: MIG-2DF developed by JAEA).

Calculation model for seepage water analysis

(HC:hydraulic conductivity(m/s))

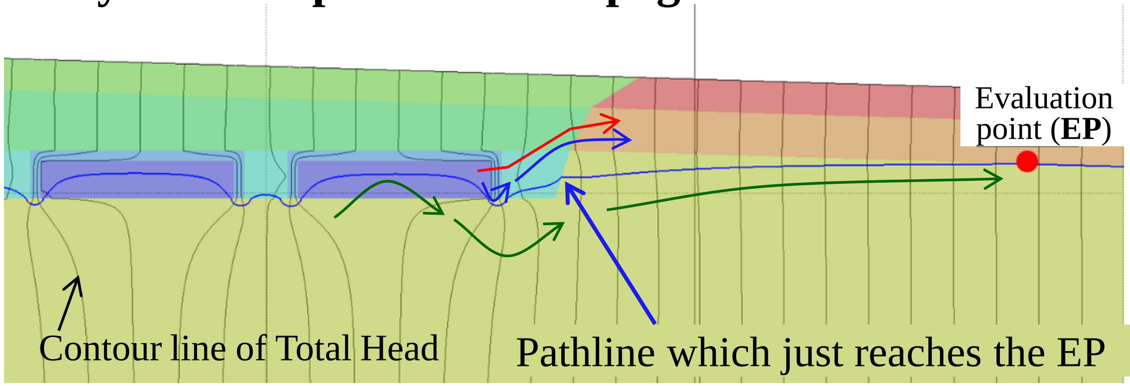


Example distribution of total head of groundwater



Study on Seepage Water Flowing out of the Concrete-Pit Disposal Facility

Analysis of the pathline of seepage water from concrete pit



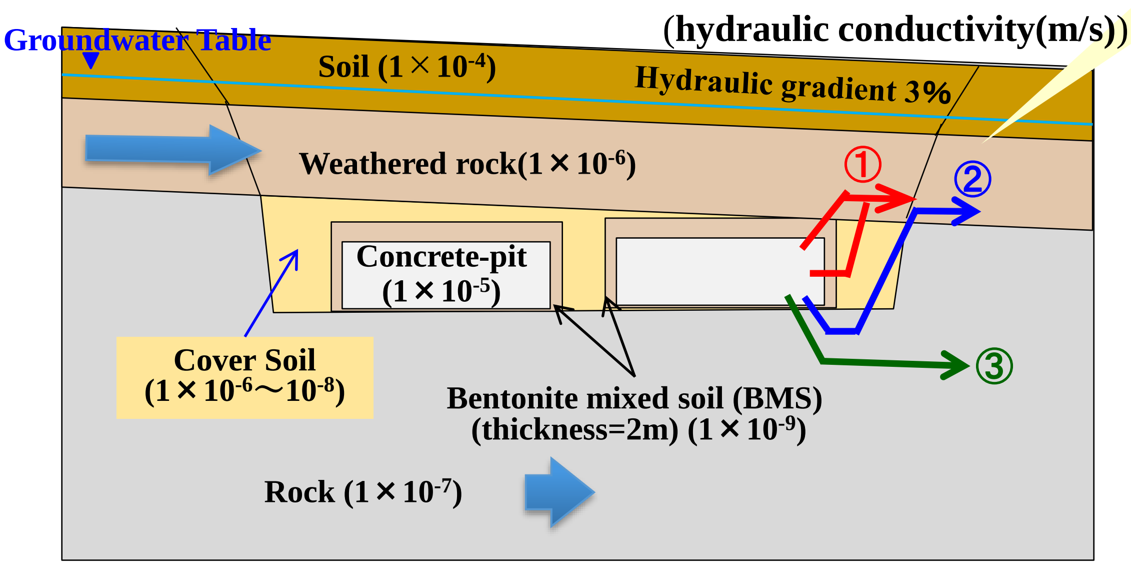
Migration pathways of leachate from the Concrete-pit

① : Leaching into weathered rock and soil thorough the BMS

② : Leaching into rock and then transferring to weathered rock and soil through the cover soil

③ : Leaching directly into rock

Conceptual model of leachate pathways



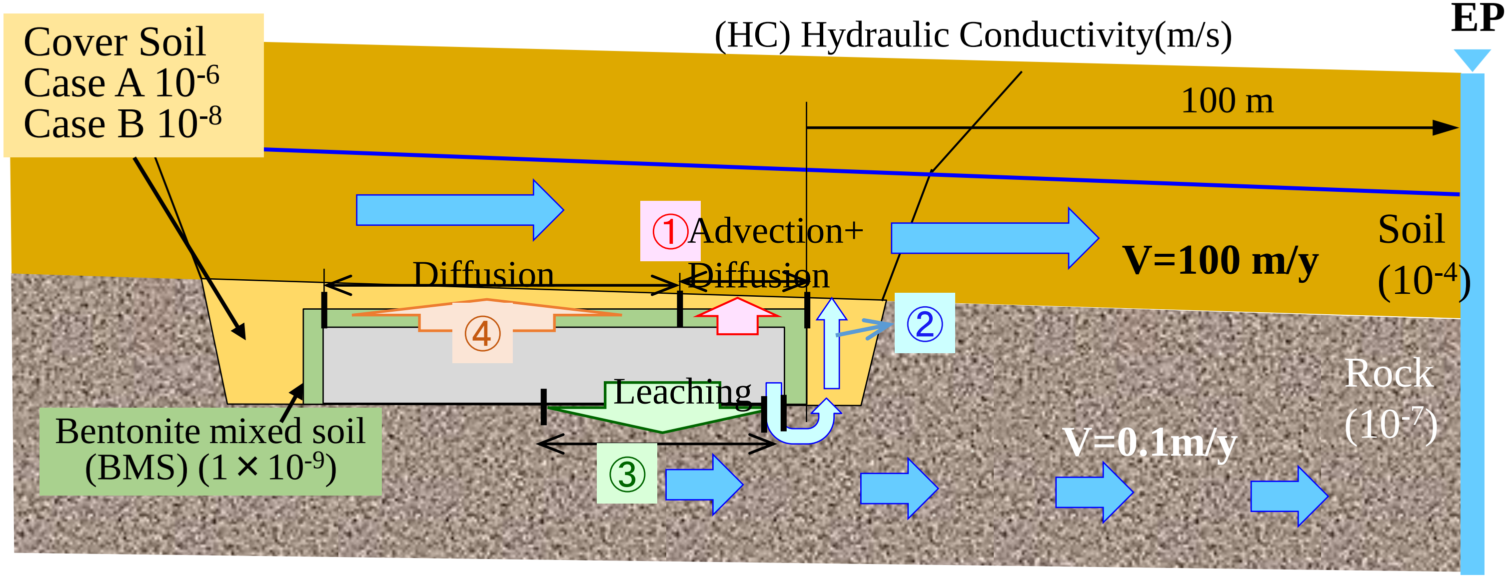
Flow rates of leachate out of concrete-pit (m^3/y)

HC of Cover Soil (m/s)	(A) 1×10^{-6}	(B) 1×10^{-7}	(C) 1×10^{-8}
Pathway ①	140	120	110
Pathway ②	150	30	3
Pathway ③	650	680	650
Total	940	830	760

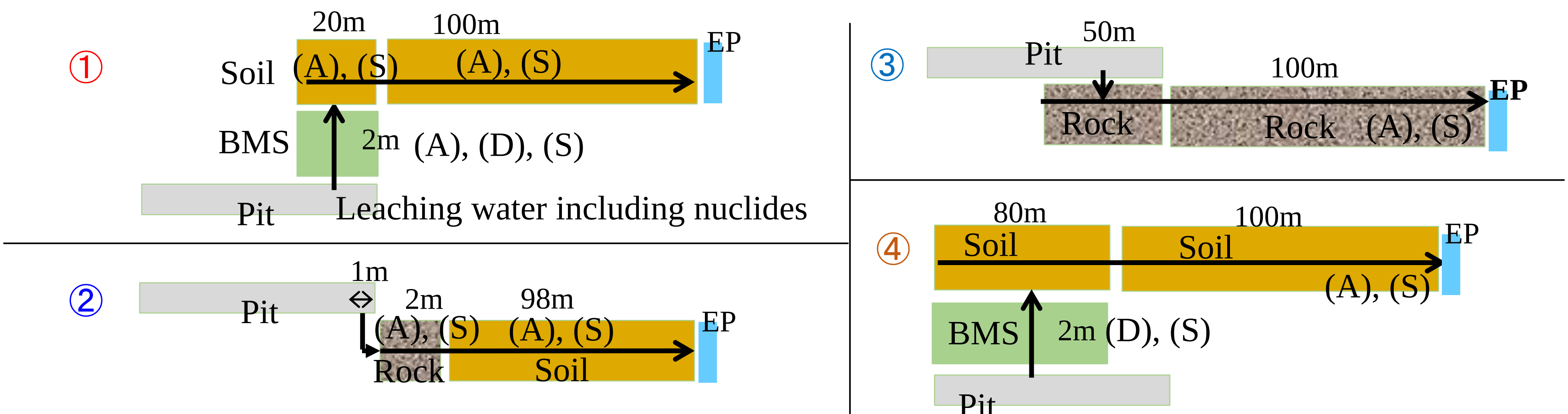
(HC) Hydraulic Conductivity

Dose Calculation Model for Concrete-Pit Disposal

Migration model of radioactive material for dose calculation

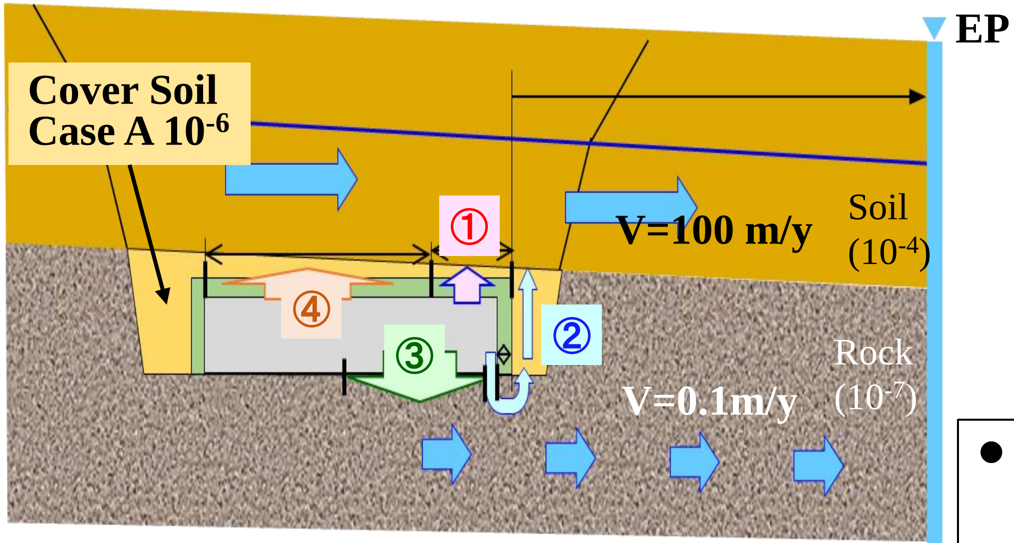


One-dimensional calculation model of nuclide migration through BMS, soil and rock



(A) Advection, (D) Diffusion, (S) Sorption

Dose Calculation for the Concrete-Pit Disposal Facility



Ratio of Radioactivity

H-3	8.4E+01
C-14	1.0
Tc-99	4.8E-03
I-129	8.4E-04

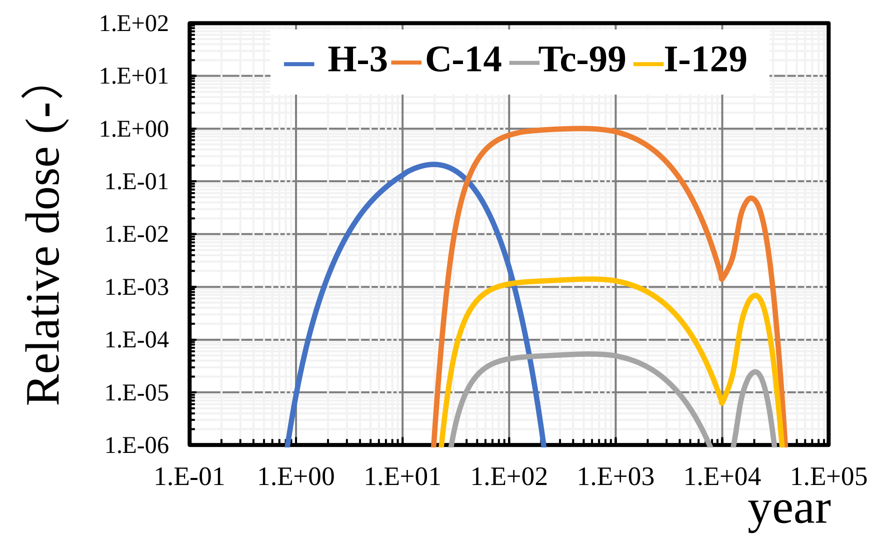
Distribution coefficient Kd (m^3/kg)

	Waste	BES	Soil and Rock
H-3	0.E+00	0.E+00	0.E+00
C-14	5.E-03	1.E-04	1.E-02
Tc-99	5.E-03	0.E+00	1.E-02
I-129	5.E-03	0.E+00	1.E-02

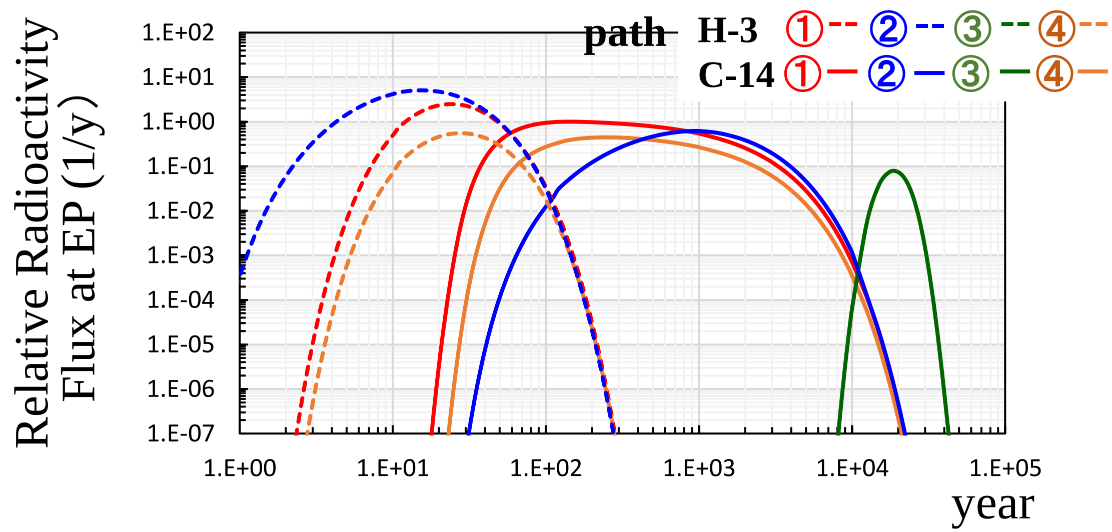
- Same exposure pathway as in the case of trench disposal

- Diffusion coefficient of BMS $3.0*10^{-10}$(m^2/s)

Calculation Result of Exposure Dose

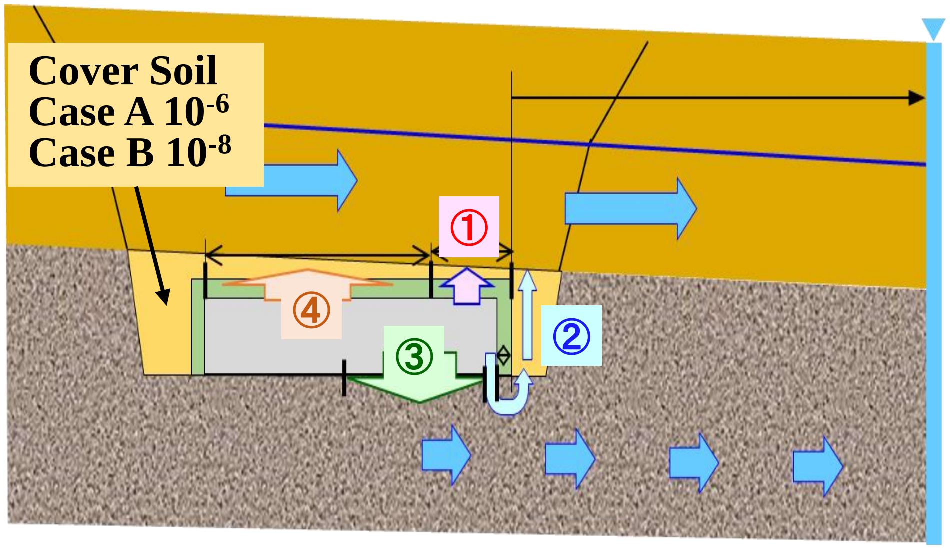


Radionuclides Discharge Flux at EP



Parameter Study: HC of Cover Soil

(HC) Hydraulic Conductivity(m/s)

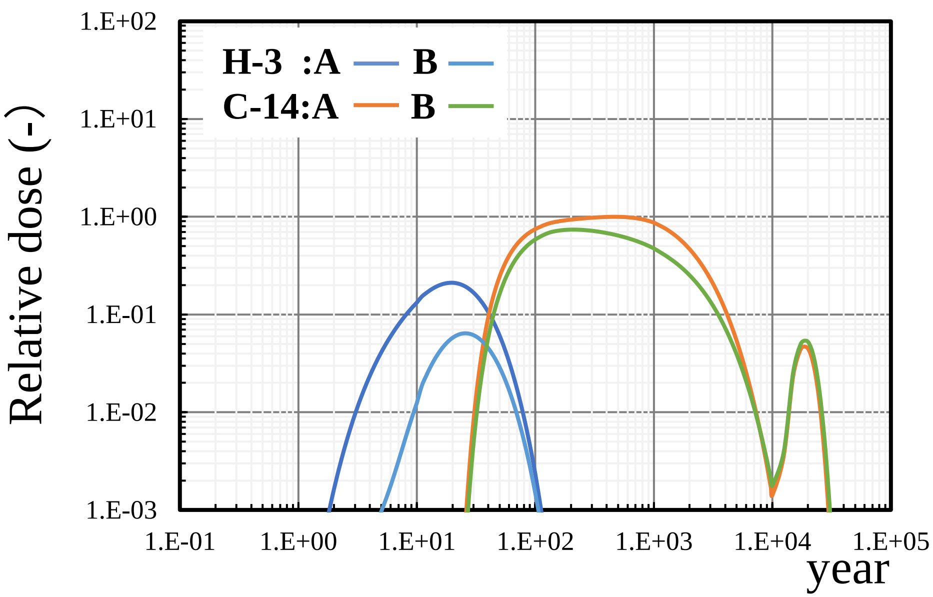


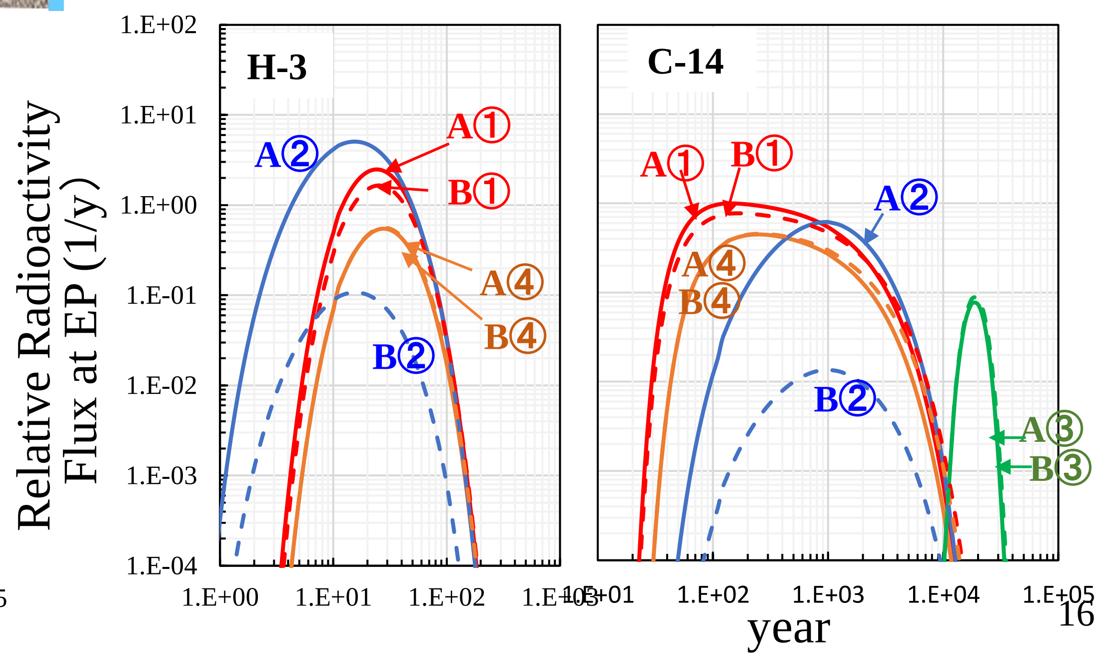
Flow rates of water out of the concrete-pit facility (m^3/y)

HC of Cover Soil (m/s)	(A) 1×10^{-6}	(B) 1×10^{-8}
Path ①	140	110
Path ②	150	3
Path ③	650	650
Path ④	0	0
Total	940	760

Distribution coefficient Kd (m^3/kg)

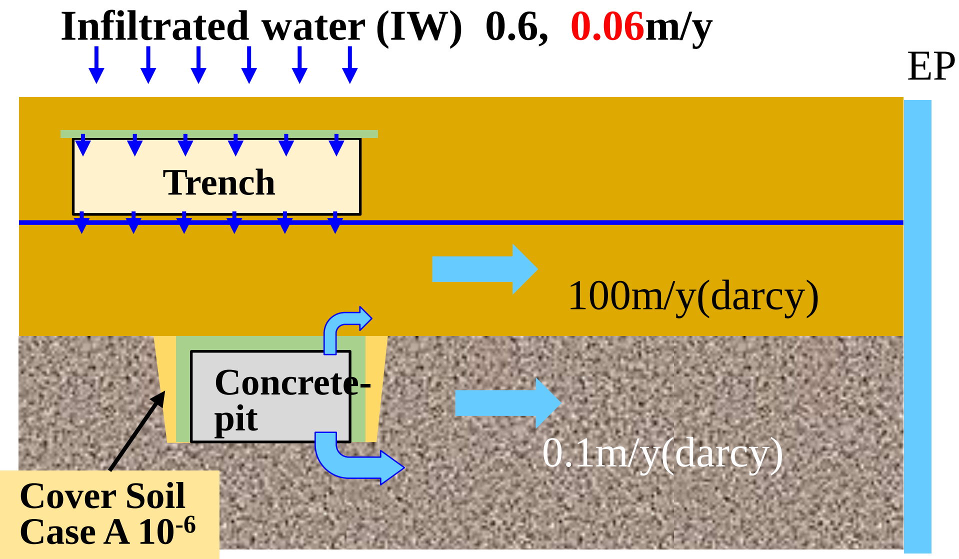
	H-3	C-14
Waste	0.E+00	5.E-03
BES	0.E+00	1.E-04
Soil and Rock	0.E+00	1.E-02

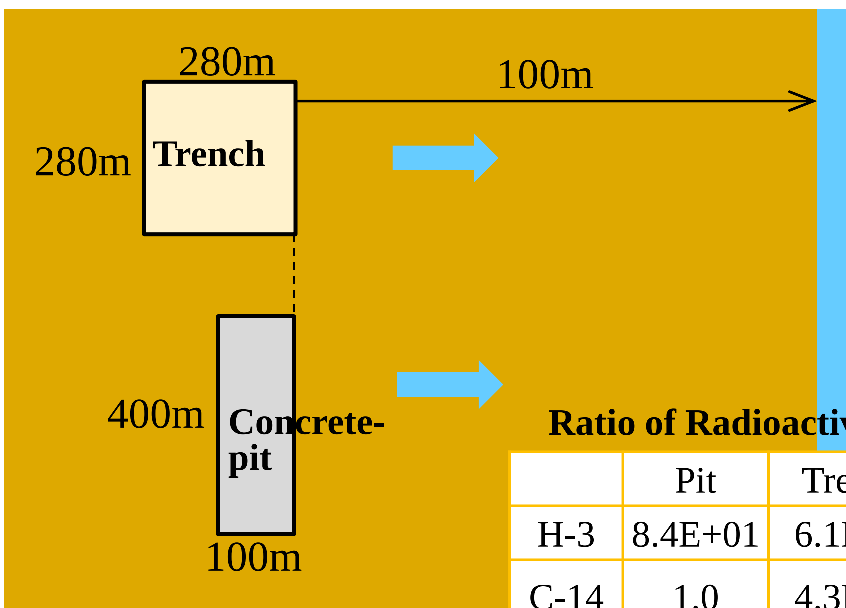




Case Study of Overlapping Dose from Trench and Concrete-Pit Disposal Facilities

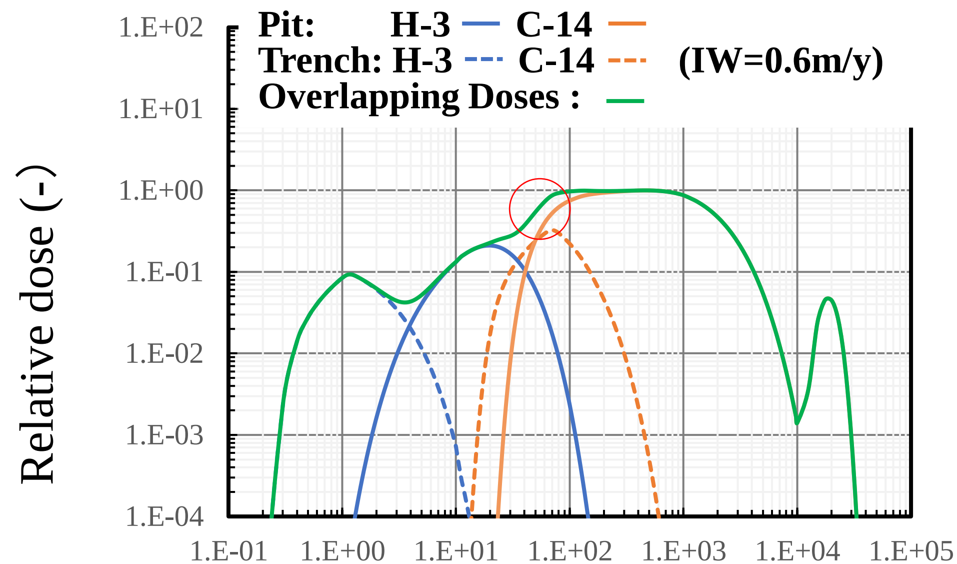
Overlapping Doses from Both Disposal Facilities

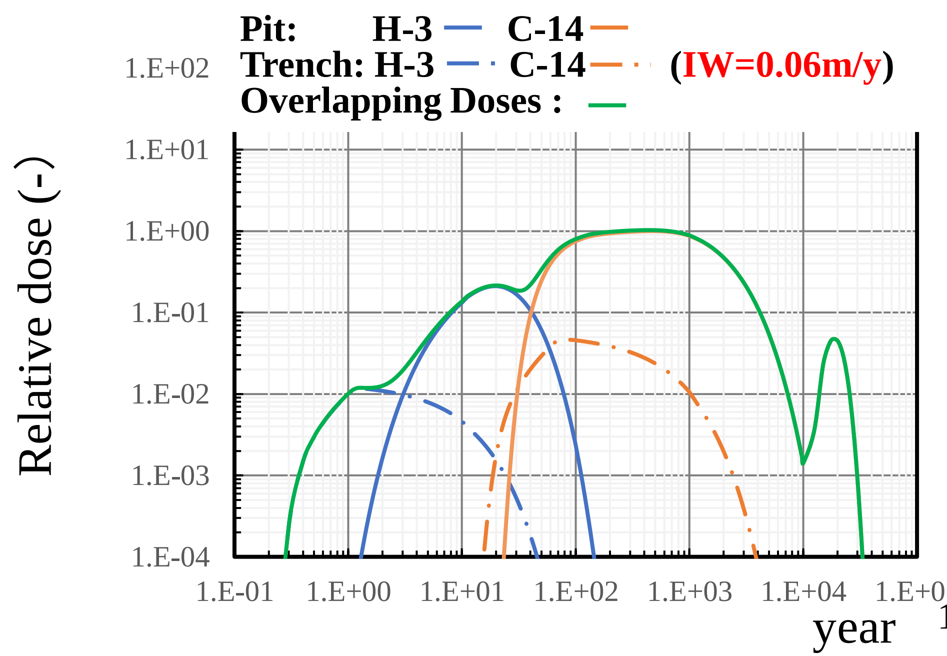




Ratio of Radioactivity

	Pit	Trench
H-3	8.4E+01	6.1E-02
C-14	1.0	4.3E-03

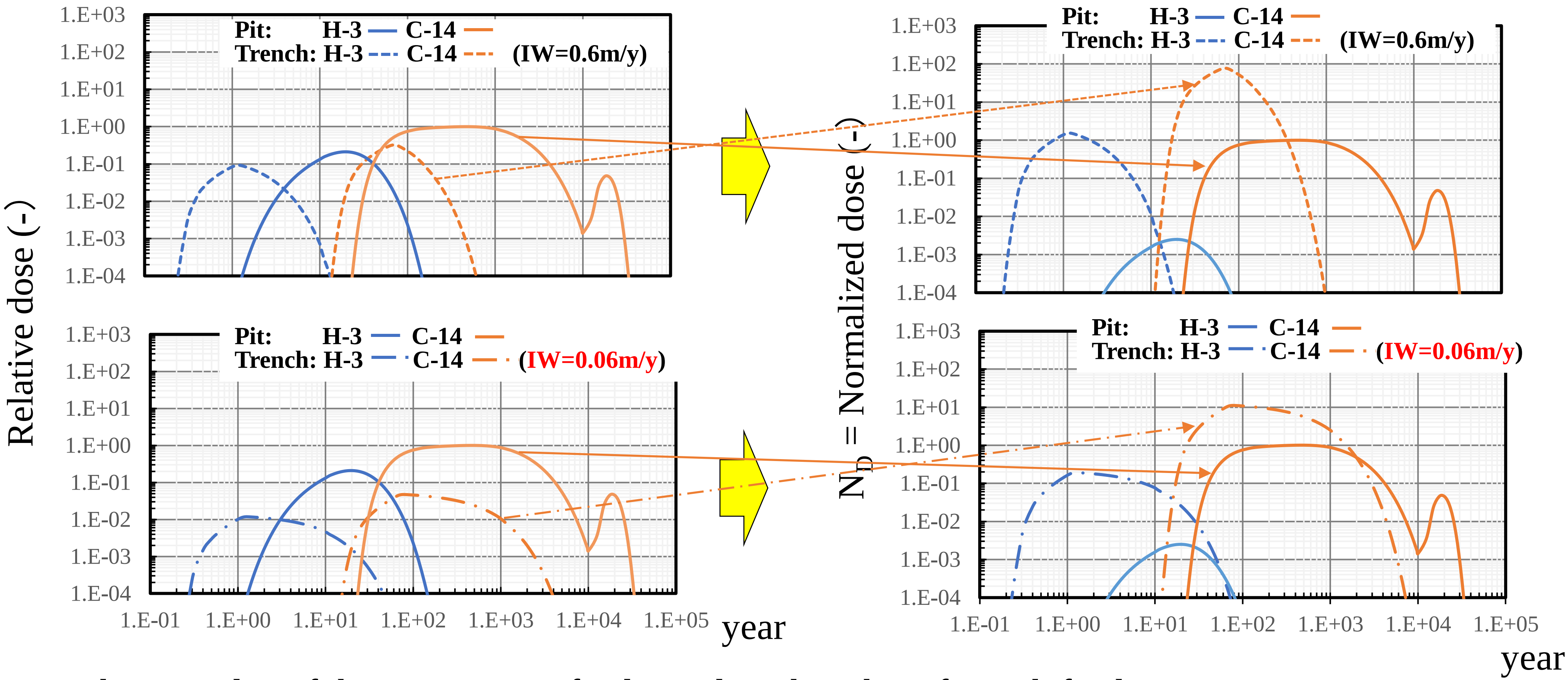




Comparison of Doses from Concrete-pit and Trench

- To compare the migration restriction effects of the design of each disposal facilities, the relative doses are normalized by dividing them with the ratio of radioactivity.

N_D = Relative Dose / Ratio of Radioactivity



- The N_D value of the concrete-pit facility is less than that of trench facility.
- When the amount of water permeating into the trench is reduced, N_D value of the trench facility will approach that of the concrete-pit facility

Summary

- JAEA intends to install concrete-pit and trench disposal facilities at the same site.
- JAEA has been developing appropriate barrier functions for the facility components based on the geological and natural environment of the disposal site.

Thank you for listening!

埋設事業センター
パンフレット

埋設事業センター　ホームページ
https://www.jaea.go.jp/04/maisetsu/