中興工程顧問股份有限公司
SINOTECH ENGINEERING CONSULTANTS, LTD

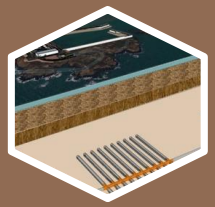
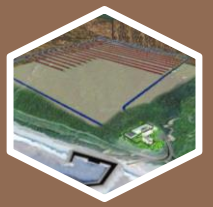
# Development of Near Surface Disposal in Taiwan

Ying-Chieh Lin

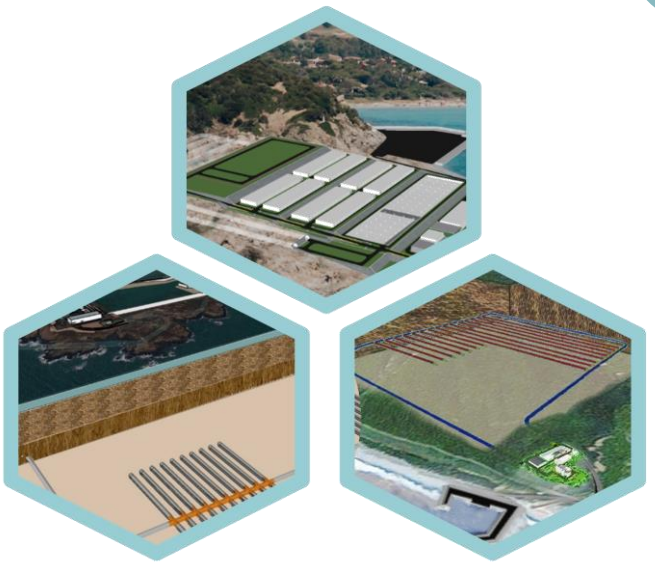
21 Oct. 2024

# Outline

1. Planning for Near-Surface Disposal Implementation
2. Design Concept for Near-Surface Disposal
3. Safety Assessment
4. Conclusions and Recommendations

# 1. Planning for Near-Surface Disposal Implementation



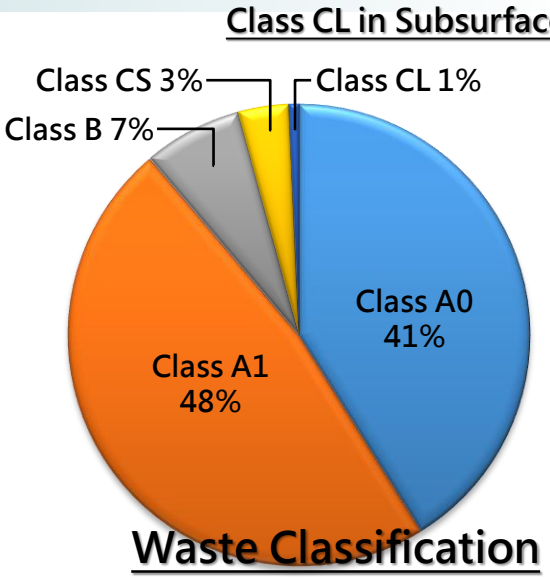
# Current Status of Near-Surface Disposal Implementation

## Why Promote Near-Surface Disposal?

- ✓ Difficulties in site selection, maybe require re-selection
- ✓ Class A waste accounts for 90%, and the cost of near-surface disposal is relatively low

## Conditions for Promotion

- ✓ The government abandons the current site selection results and chooses a suitable new location




## How to Promote

- ✓ Site Selection Condition Planning: The current two recommended candidate sites are not suitable for near-surface disposal, so additional site selection conditions are needed.
- ✓ Disposal Technology Establishment: Includes safety strategy, site characteristic conceptual model, design of disposal barrier system and facility, safety assessment.

## Current Goals

- ✓ Evaluate the type of disposal system
- ✓ Analyze additional site selection conditions and identify potential sites
- ✓ Assess whether existing technology is sufficient enough

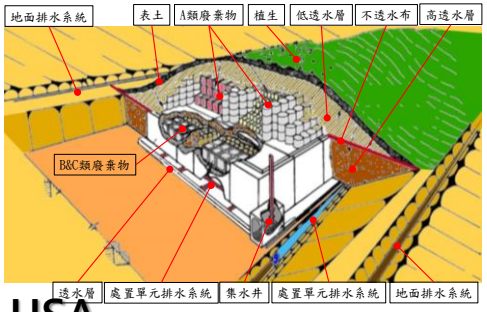
# Selection of Near-Surface Disposal System Type

## Disposal System Types

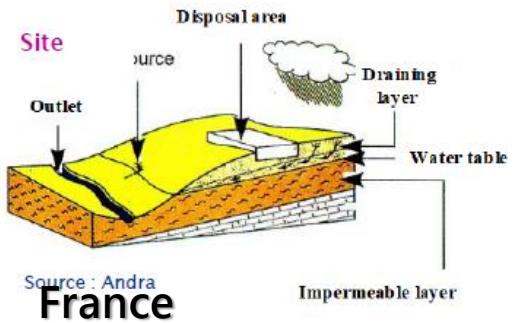
- **Drainage Type**: Remove most infiltrating water to reduce the possibility of water contacting the waste.
- **Water Resistant Type**: Blocks most infiltrating water to reduce the total amount of water that contacts the waste.

## Considerations

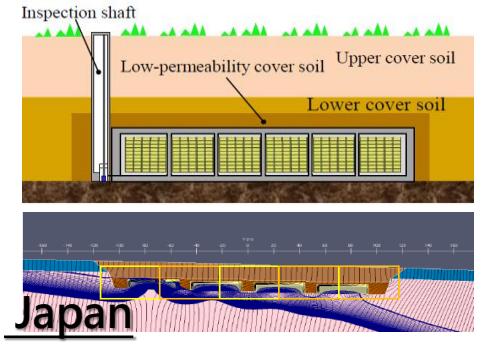
- Compliance with Taiwanese regulatory standards.
- Benefits in maintaining containment and isolation safety functions after facility closure.
  - Containment Function: Reducing water infiltration, drainage capability, structural stability, and closure stability.
  - Isolation Conditions: The security system against inadvertent human intrusion during the operation and active institutional period.
- Sufficient engineering technology support for facility promotion, construction costs, operation, and maintenance.



USA



France



Japan

**Prefer Drainage Type Disposal System**

# Site Selection Conditions

## Existing Site Selection Conditions

Low-level waste site selection regulations → Other regulations

| Guidelines for Restriction Areas |
|---|
| • Geology and strata<br>• Geochemical conditions<br>• Population density<br>• Surface water and groundwater |
| **Other Regulations (Environmentally Sensitive Areas)** |
| • Water sources, water quality, water conservation, cultural assets, wildlife protection, national parks, military, hot springs, etc..... |

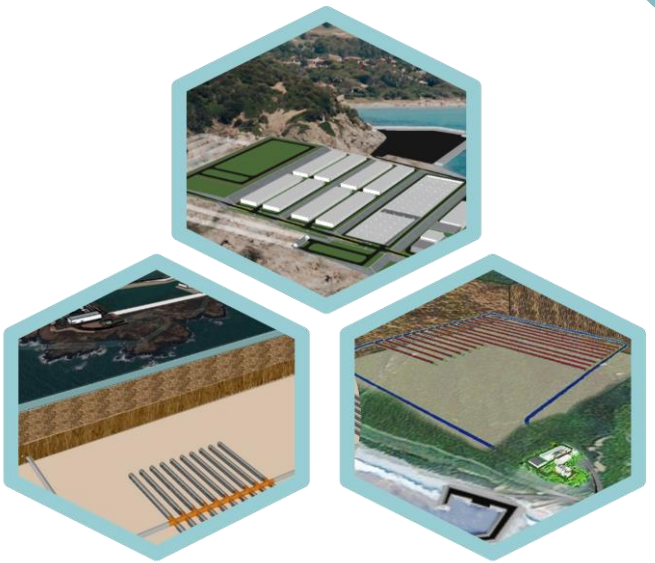
## Near-Surface Disposal - Additional Site Selection Conditions

Suitable conditions for safety functions

| | |
|---|---|
| **Spatial Characteristics of Disposal Facilities** | • Facilities located away from groundwater table<br>• Area requirement approximately 1~2 $km^2$ |
| **Transportation Conditions** | • Avoidance of unsafe land transportation routes<br>• Land transport range within 10 km of the coastline |
| **Ecological and Socioeconomic Conditions** | • Avoidance of biological habitats<br>• Consistent with national policies and commitments |

**Multiple Potential Sites Confirmed**

# 2. Design Concept for Near-Surface Disposal



# The Consideration of Safety Functions

**National regulations**

- public health and radiation protection
- environmental characteristics
- safety management and functional requirements

**Acceptance criteria**

- Solidified waste
- Surface dose rate

**LLW disposal safety management in Taiwan**

**International LLW safety management**

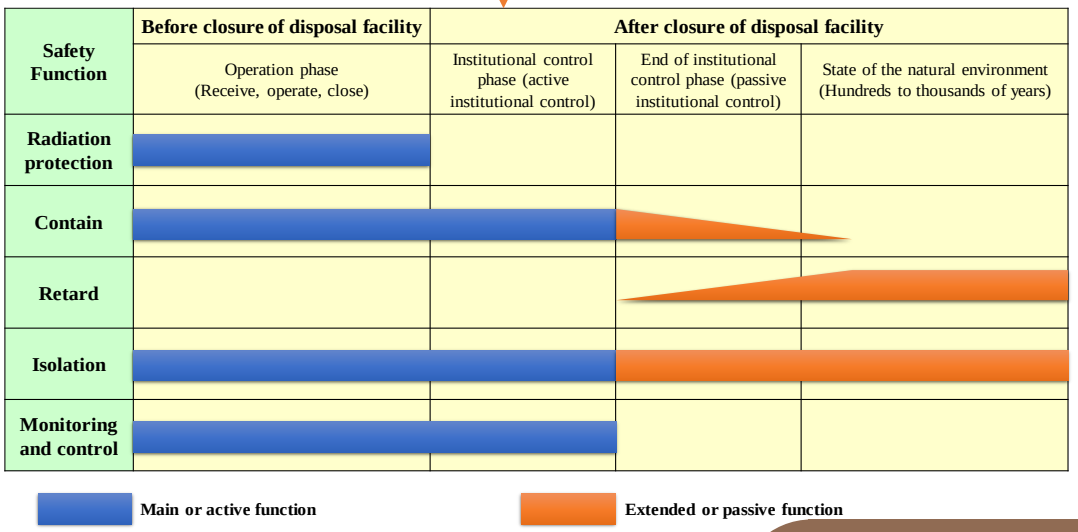
**IAEA**

- Fundamental Safety Principles
- Disposal Objectives and Facility Types
- Requirements of safety function (IAEA SSR-5): multi-safety, isolation, containment, monitoring and control of passive safety features
- Safety case

**Disposal System Design Concept**

## Functional objectives of disposal facility (10 CFR 61)

- Protection of the general public from the of radioactive hazards .
- Protection of inadvertent intruders.
- Protection of staff during operation.
- Ensure facility stability after closure.



# The Consideration of Design Concept

## Owner Requirements and Current Limitations

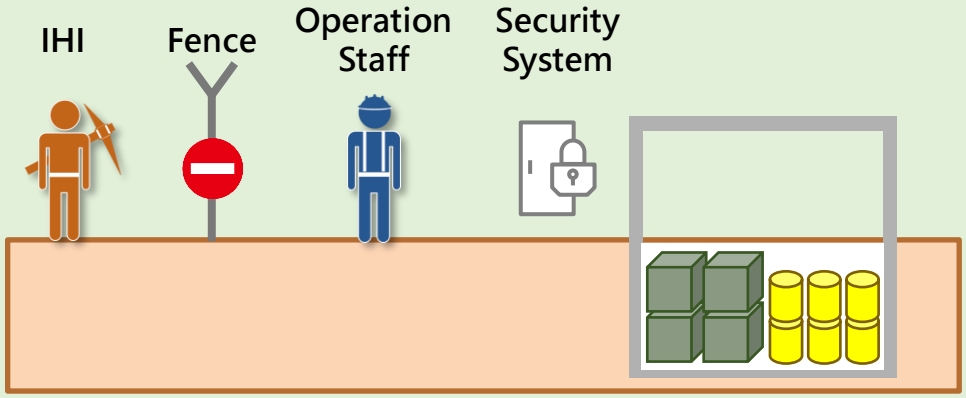
- Address public concerns regarding disposal safety
- Increase public acceptance of the disposal facility
- Both **storage and disposal** function for near-surface disposal facilities
- Slow progress in decommissioning plans (the uncertainty in sources and quantities)
- Continuous updates in container selection planning (operational equipment and disposal space)

(Belgium)

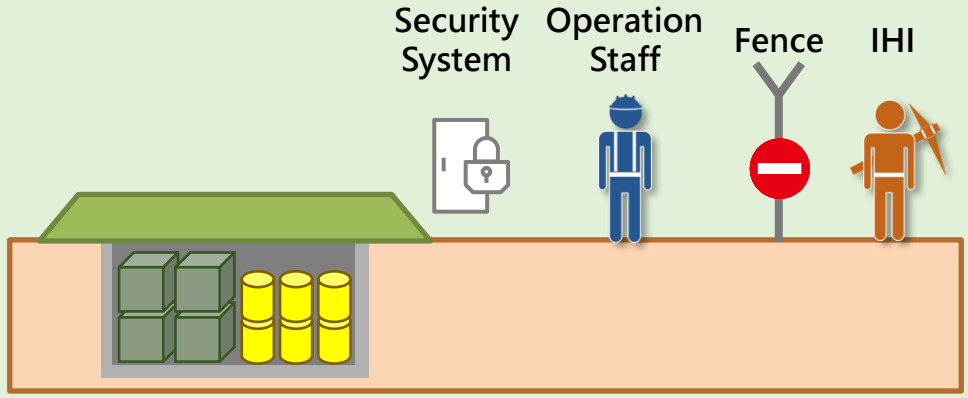
# Design Concept of Near-Surface Disposal System(1/2)

Rely on security system design and physical facilities to prevent the public from inadvertently entering the disposal facility

Inadvertent Intruder Protection Design – Operational Phase




Inadvertent Intruder Protection Design – institutional control Phase




During the transportation and disposal operations phase, it mainly relies on containers or disposal pits to provide the necessary radiation shielding for operation staff.

Radiation Protection Safety Design - Transportation Operations


Radiation Protection Safety Design - Disposal Operations

# Design Concept of Near-Surface Disposal System(2/2)

## Long-term safety functions- After closure of the disposal system

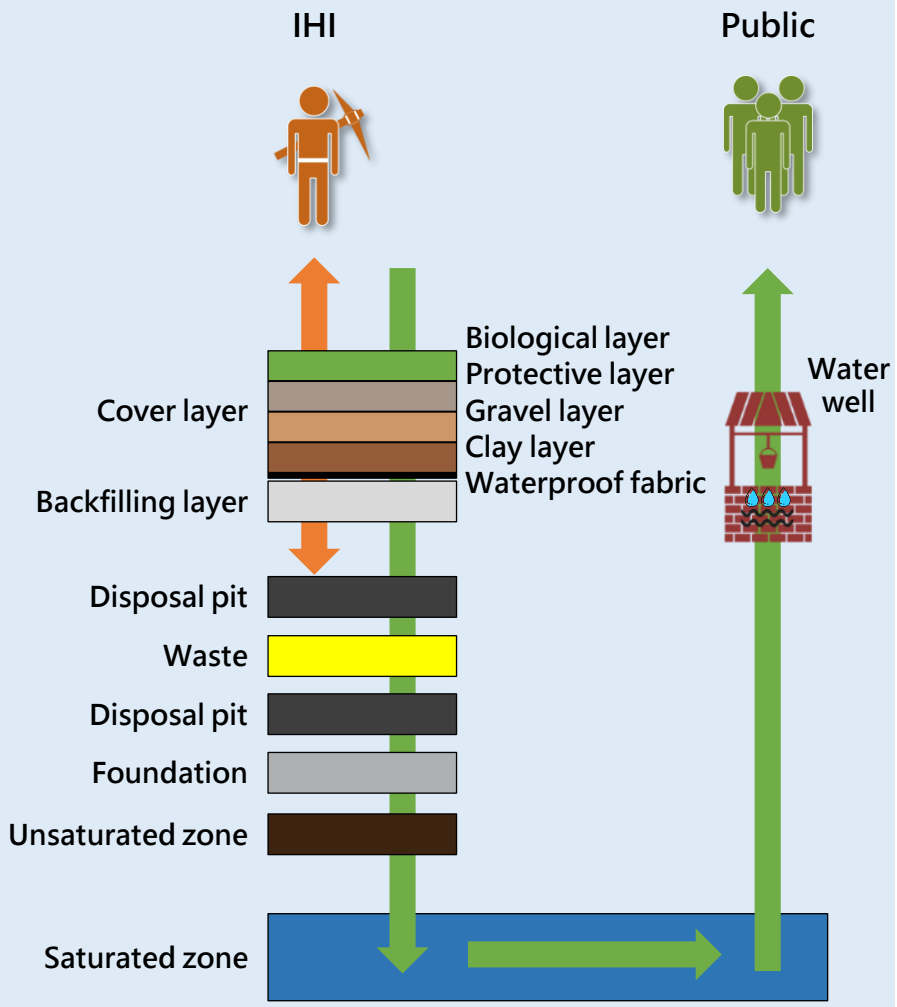
### Long-term safety function design concepts

- Adjust the composition and safety function design of EBS based on different low-level waste classification characteristics.
- Extend the isolation and containment functions of the disposal facility as much as possible.
- EBS above disposal pits is used to reduce water infiltration and prevent the failure of the disposal system due to environmental erosion and wind erosion after facility closure.

## Inadvertent Intruder Protection Design – End of institutional control

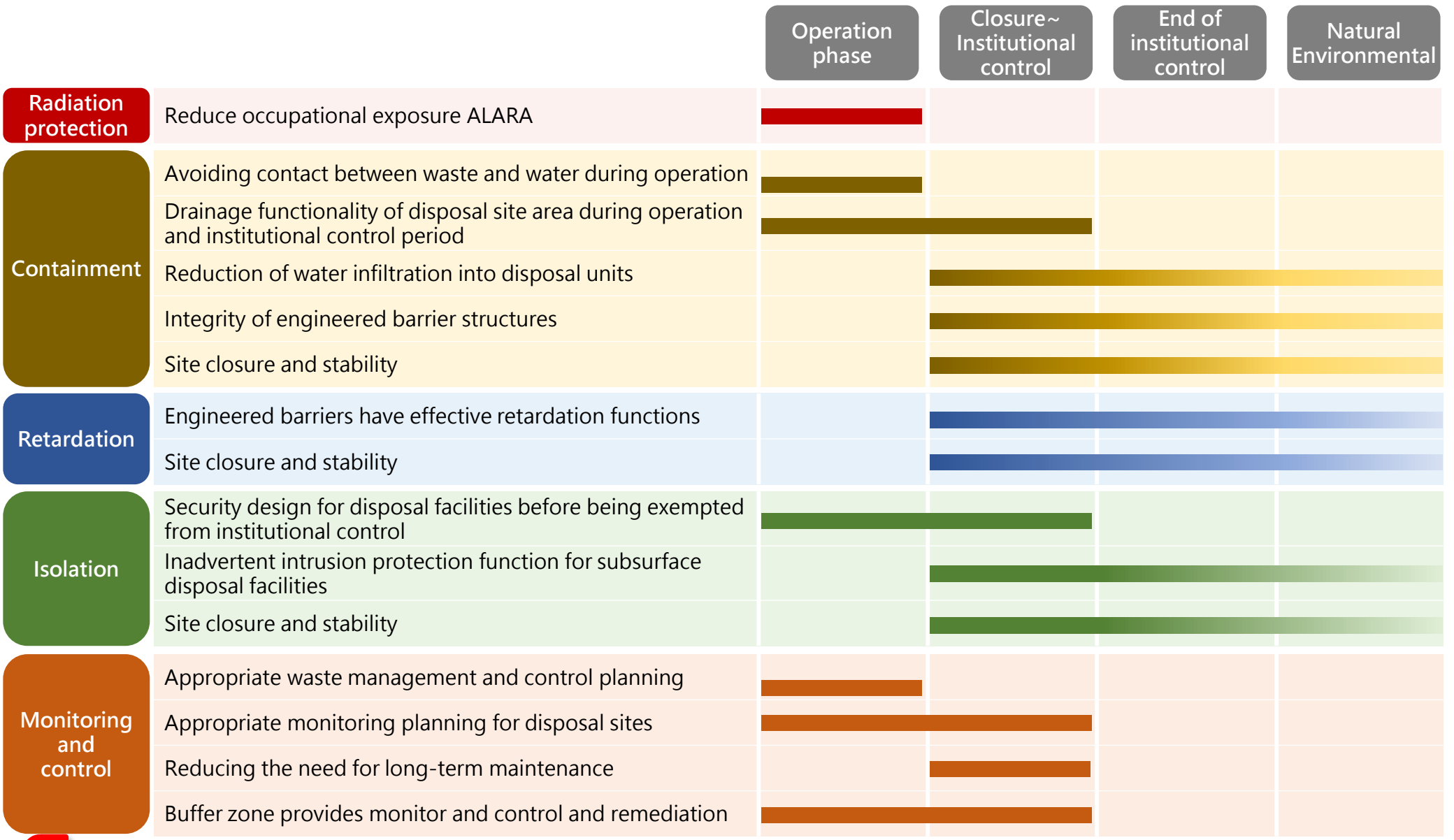
### End of institutional control

- Appropriate active institutional control period.
- Implement appropriate passive institutional control measures.
- The top plate thickness of class C waste disposal pits must reach 1 m to provide a passive barrier function for inadvertent intruder.




IHI: Inadvertent Human Intrusion

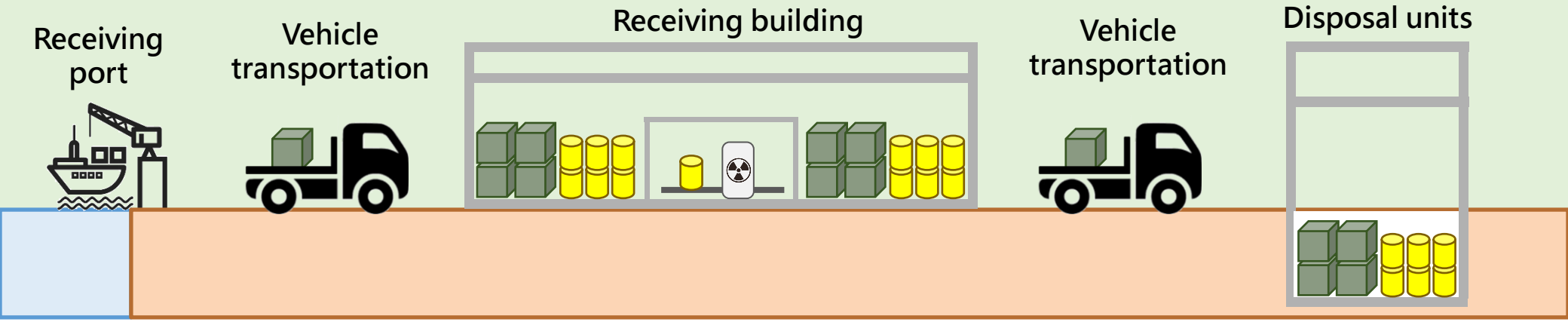
# Safety Functions and Design Features



# Design Features of the Containment Function

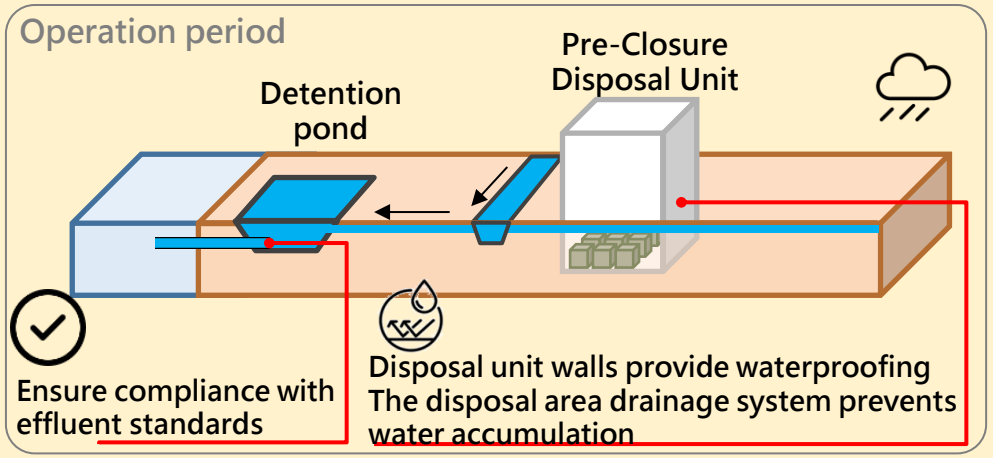
## Avoiding contact between waste and water during operation

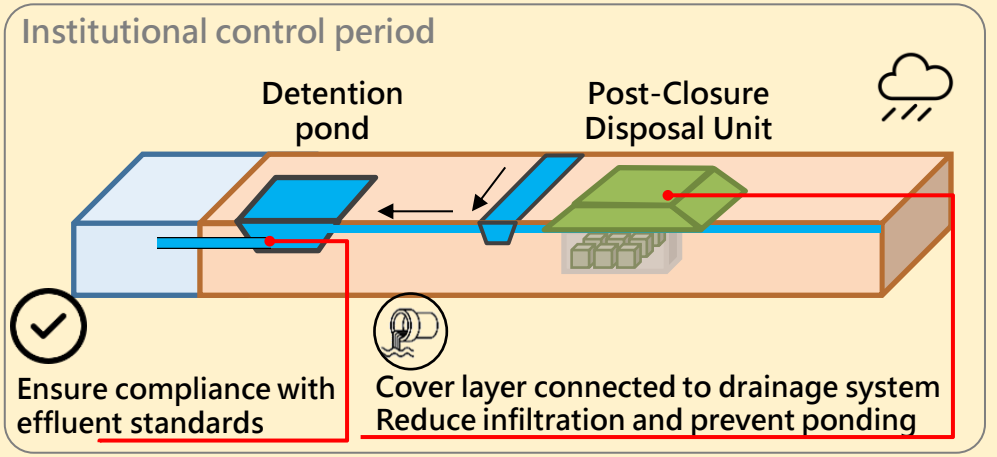
- The building's concrete walls to prevent rainwater or groundwater infiltrate to the building.




## Drainage functionality of disposal site area during operation and institutional control period

- Exclude surface runoff to prevent flooding of disposal units
- For long-term maintenance requirements, the gravity drainage system is designed

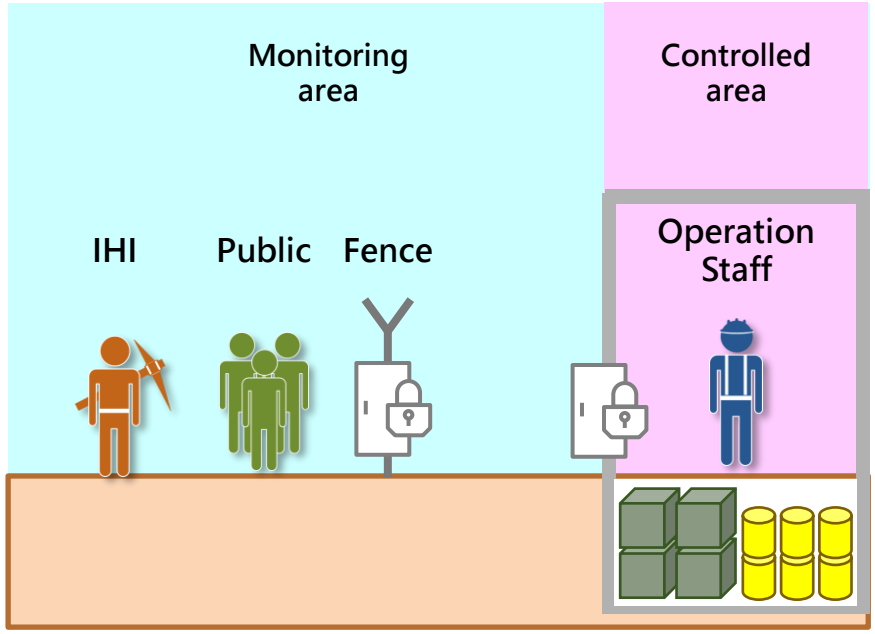


# Design Features of the Radiation Protection and Isolation Functions

## Operational area design concept

- Different operational areas based on container stacking operational requirements.
- Include both unloading and stacking areas.
- Walls provide radiation shielding and security functions, adopting a minimalist architectural design.
- Underground design enhances radiation shielding capabilities.
- Seismic resistance function for waste stacking and disposal areas.
- Disposal areas require buffer zones.




IHI: Inadvertent Human Intrusion

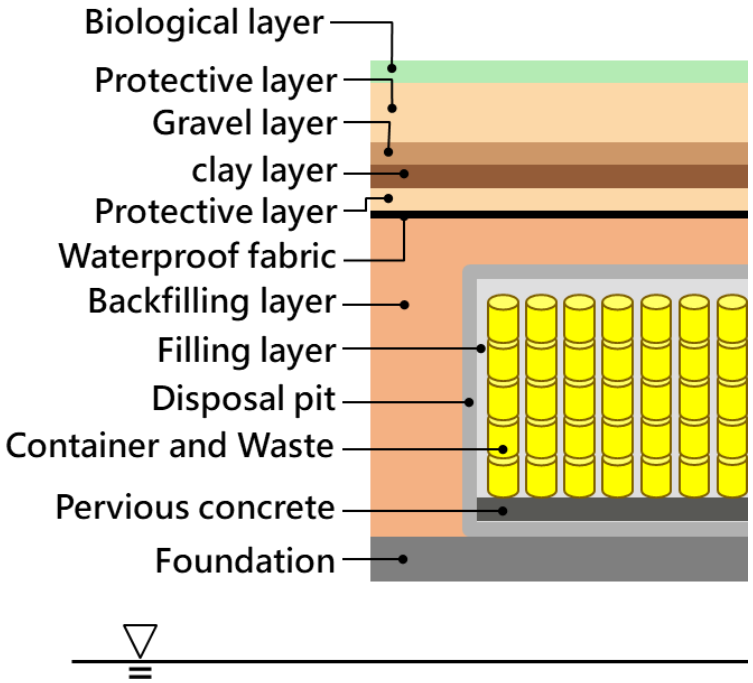
# Design Features of the Containment and Retardation Functions After Closure

**Design considerations for containment and retardation functions**

- **Reduction of water infiltration :** The cover layer system emphasizes drainage function, while the EBS focuses on water resistance function.
- **Structural integrity:** Considerations include container stacking, fill design, EBS stability, and durability to prevent failure of containment functions.
- **Stability of cover layer:** Consider the effects of wind and rainfall erosion, prevent nonuniform subsidence and slope collapse.

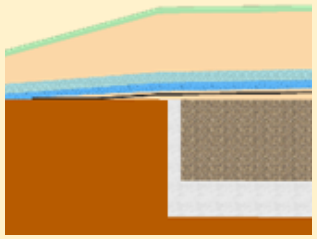
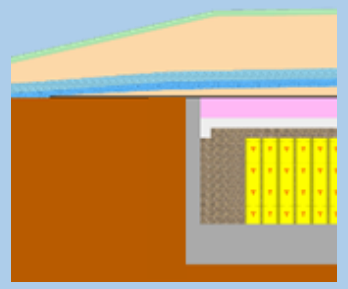
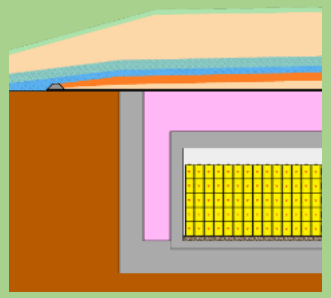
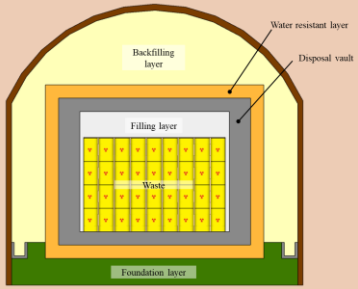
- **EBS system functional design consideration:**

| | |
|---|---|
| Cover layer | Drainage, Avoid maintenance |
| Backfilling layer | |
| Vault cap | Water Resistant |
| Filling layer, Container, Waste | Long-term Stability |
| Vault and foundation | |
| Avoid contact with groundwater | Water Resistant |



# The Disposal System and Wastes

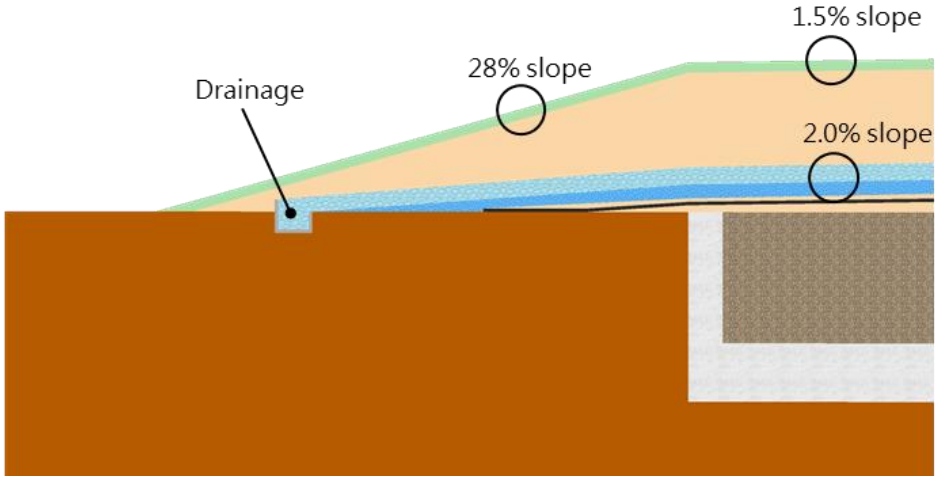
- Referring to IAEA classification and disposal type recommendations, the disposal system categorized into Trench type, Classic type, Concrete pit type, and high water resistance type.
- If the containers of class A1 and B waste provide sufficient safety functions, the "Classic type" is adopted.

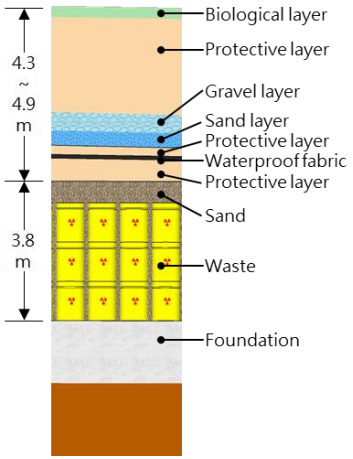
| **IAEA classification** | **VLLW Landfill disposal** | **LLW Near-surface disposal** | | | **ILW Subsurface disposal** |
|---|---|---|---|---|---|
| Taiwan Classification | A0 | A1 | B | CS | CL |
| Disposal type | Trench type | Classic type/Concrete pit type | | Concrete pit type | High water resistance type (subsurface) |
| 55 gallon drum |  |  | |  |  |
| HPCC | | | | | |
| T-Box | | | | | |

# Trench Type Disposal System

## Trench Type Features

- Disposal target: Class A0 waste packages, 55 gallon drum, HPCC, T Box
- Reduce contact between waste and water
  - ✓ Utilize solidified body or container function to provide containment function for ~100 years.
  - ✓ The cover layer thickness should be sufficient to resist wind and rainfall erosion for at least 100 years.
  - ✓ The vegetation on the surface is used to reduce the impact of the rainfall or wind erosion.
- Integrity of EBS
  - ✓ To prevent the nonuniform subsidence of the cover layer, the gap between packages should be filled with well-grading sand.




# Classic Type and Concrete Pit Type Disposal System

| Disposal System | Disposal target | | | | Containment function | Design considerations |
|---|---|---|---|---|---|---|
| | container | A1 | B | CS | | |
| Classic type | HPCC | ✓ | --- | --- | 300 years | • HPCC and T-Box provide sufficient safety functions. |
| | T-Box | ✓ | ✓ | --- | | |
| Concrete pit type | 55 gallon drum | ✓ | ✓ | --- | 300 years | • The concrete pit can provide sufficient safety function for wastes in 55-gallon drums |
| | HPCC | --- | ✓ | --- | | |
| | Various Containers | --- | --- | ✓ | 500 years | • Both drainage and water resistance design.<br>• Cap thickness is ~1 m |

## Metal Containers

Fill with concrete material

- Create a high alkaline environment to reduce metal corrosion effect
- Extend containment function of metal containers

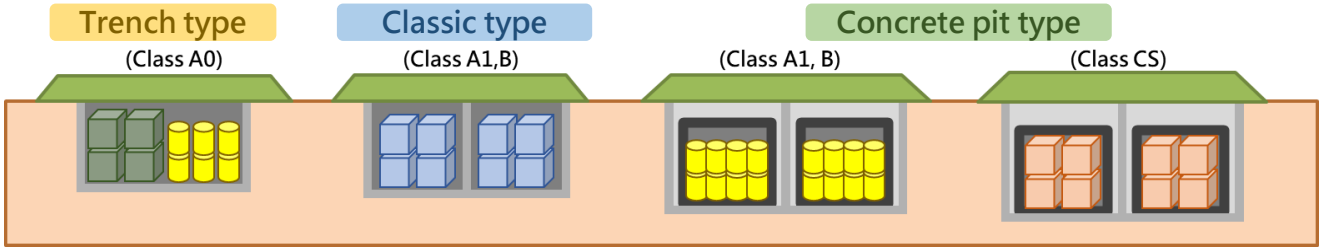
## Concrete Containers

Fill with fine aggregate

- Comparing with HPCC, the filling layer provide a higher permeability environment.
- suppressing the water infiltrate into HPCC.

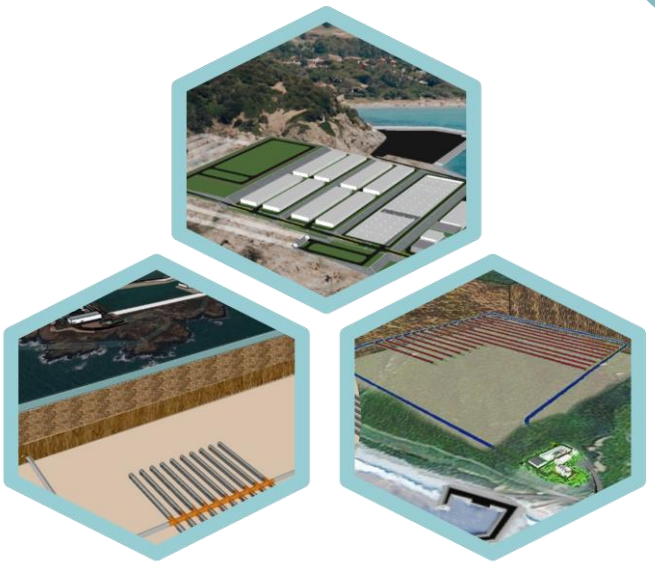
# The Years of Active Institutional Control Period

- **Establish inadvertent human intrusion scenarios with exposure doses below 0.25 mSv/yr (same as the regulatory limit for design scenarios).**
- **Inadvertent human intrusion scenarios: Develop scenarios based on site environmental considerations and passive institutional control measures.**
  - ✓ Drilling Scenario: Direct radiation from drilling cores, air immersion, inhalation, and ingestion of dust (similar to subsurface disposal).
  - ✓ Cover Layer Activity Scenario:

| **Cover Layer Activity Scenario**<br>Initial Year (2100) |  | | | |
|---|---|---|---|---|
| Use the dose rate at 1 m above the highest package surface as the initial condition (mSv/hr) | $3.04\times10^{-3}$ | $3.76\times10^{-2}$ | $3.17\times10^{-1}$ | $5.18\times10^{-2}$ |
| Cover Layer Activity Scenario Shielding | None | | Vault cap, filling layer | |
| Direct radiation exposure process | Leisure activities totaling 16 hours per week on the cover layer | | | |
| Analysis results | In 2150, the 'Classic type' radiation dose dropped to 0.24 mSv/yr. | | | |

- **The duration required for drilling scenario events with radiation doses below 1 mSv is longer than the cover layer activity scenario.**
- **The active institutional control is set at 90 years after closure (Class CL waste disposed in subsurface disposal systems).**

# 3. Safety Assessment



# Post-closure Safety Analysis Process

## safety analysis process

**Updating and screening of FEPs**

- IAEA-ISAM FEPs list
- Some FEPs add a fourth-level definition

**Climate evolution**

- Maintain climate warming scenario predictions
- Add predictions of entering ice age cycles after warming

**Scenario evolution**

- Predict environmental characteristics based on climate evolution
- Predict EBS degradation time and results
- Divide analysis time periods into 100 years, 300 years, 700 years, and 1000 years post-closure

**Reference scenario**

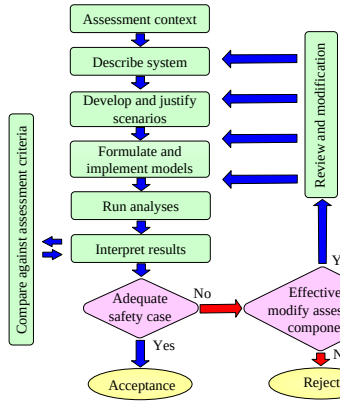
**Earthquake scenario**

**Scenario of a single engineered barrier unit failure**

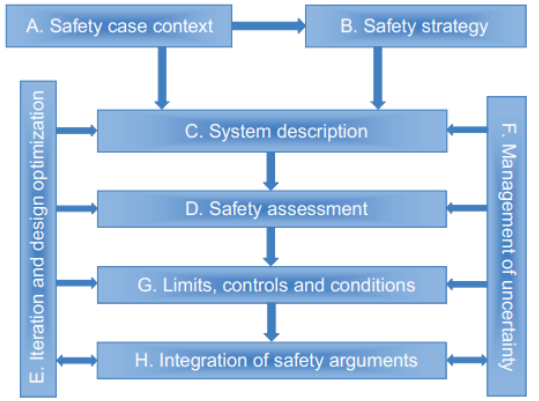
- Used to demonstrate the function of deep defense (Not relying on the function of a single barrier unit)

**Inadvertent human intrusion scenario**

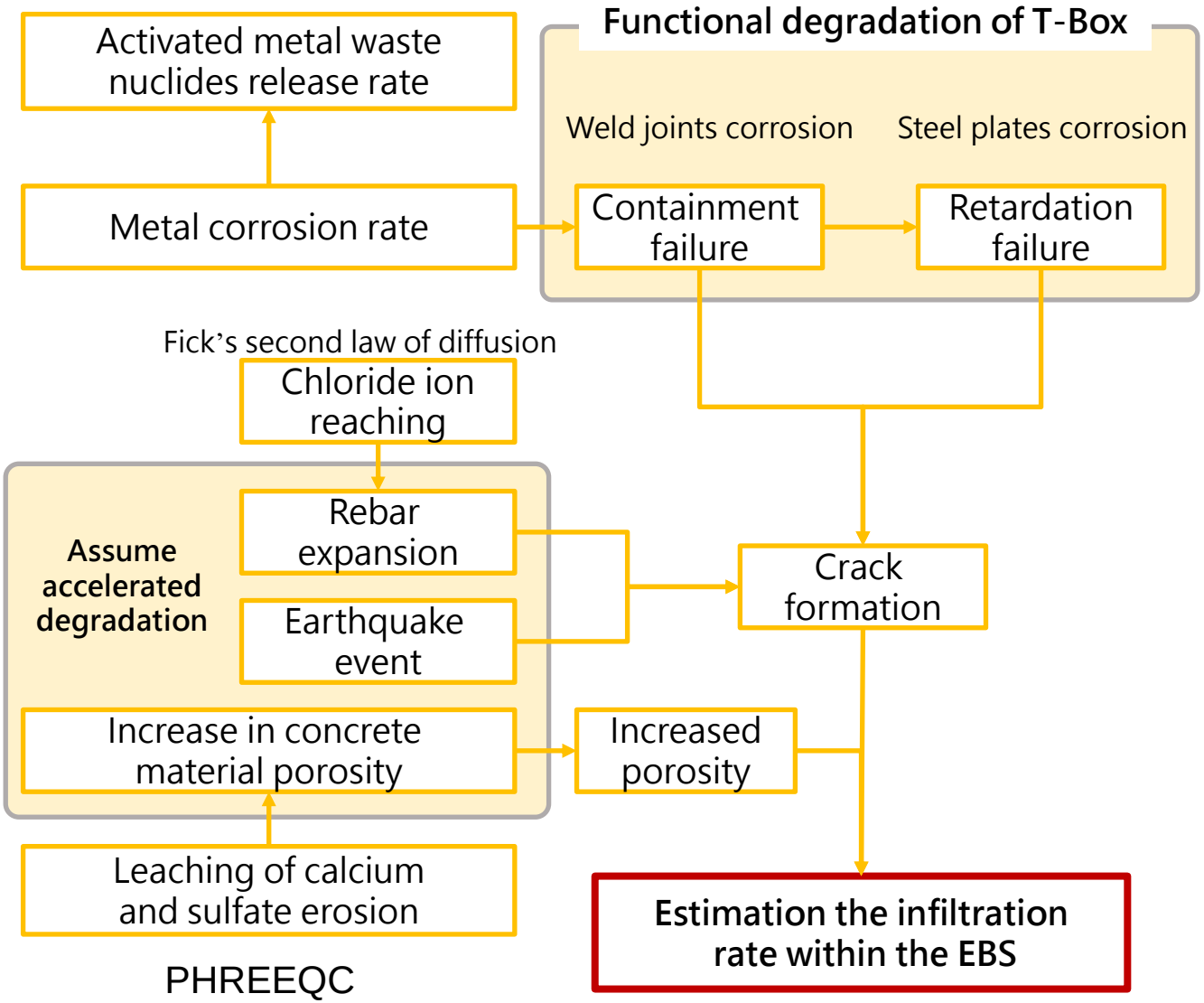
### IAEA-ISAM

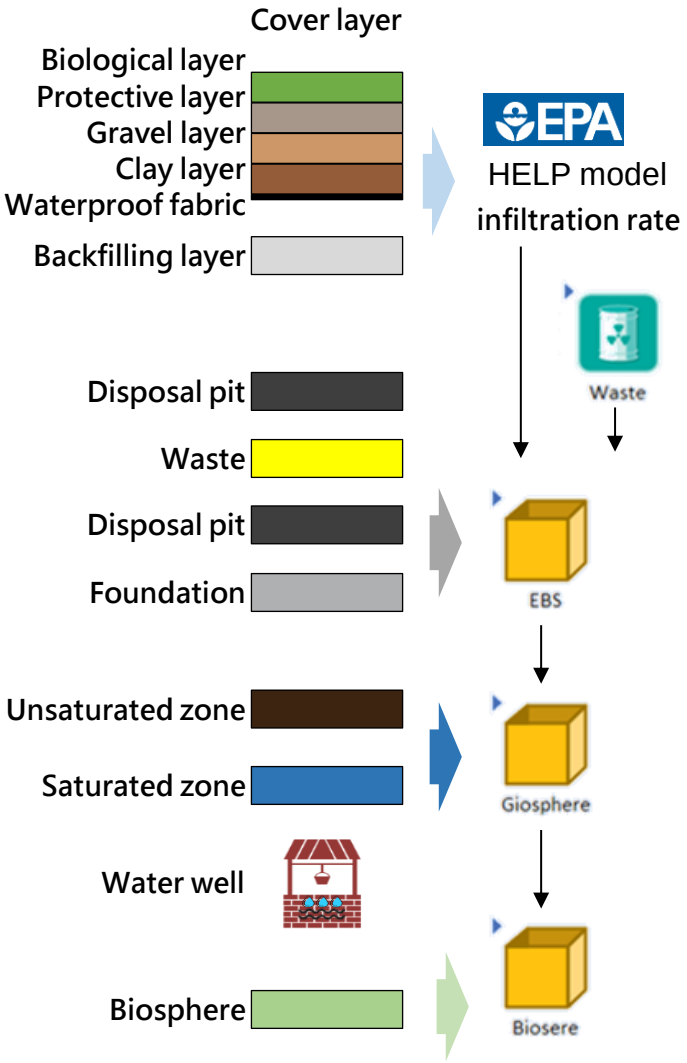



### Safety-Case



# Framework for Radionuclide Transport Analysis



# Analysis of Assessment Results

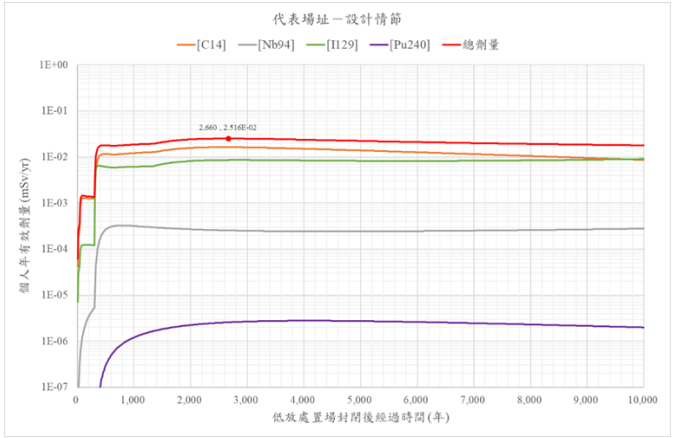
## Release dose characteristics

- After post-closure, the doses exhibit a bimodal pattern, with release trends stabilizing around 600 years.
- First peak:
  - ✓ Initial release: 55 gallon drum and HPCC
  - ✓ Containment failure of T5 begins at 180 years
- Second peak:
  - ✓ Complete failure of T5 at 300 years
  - ✓ Failure of T2-T4 begins at 330 years

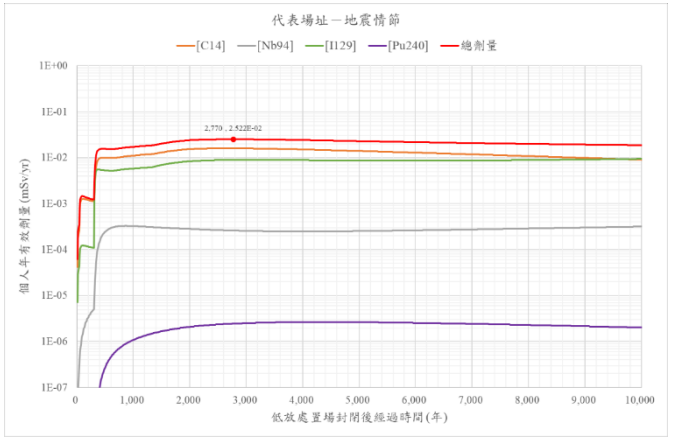
## Assessment results

- The retardation function of natural barriers is less significant.
- Conservative assumptions of EBS failure and degradation cause a significant impact on the dose rate.
- Assessment of infiltration rates in EBS is important.
- The infiltration ability of the cover layer significantly affects the dose rate.
- Subsurface disposal of class CL waste exhibits better EBS function and lower total activity, resulting in less noticeable impacts.

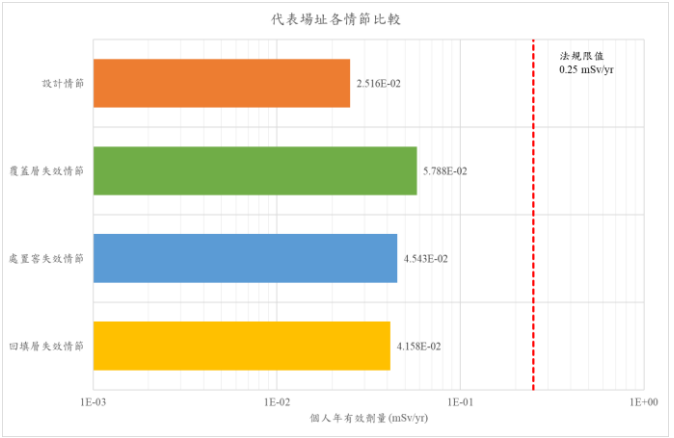
Reference scenario



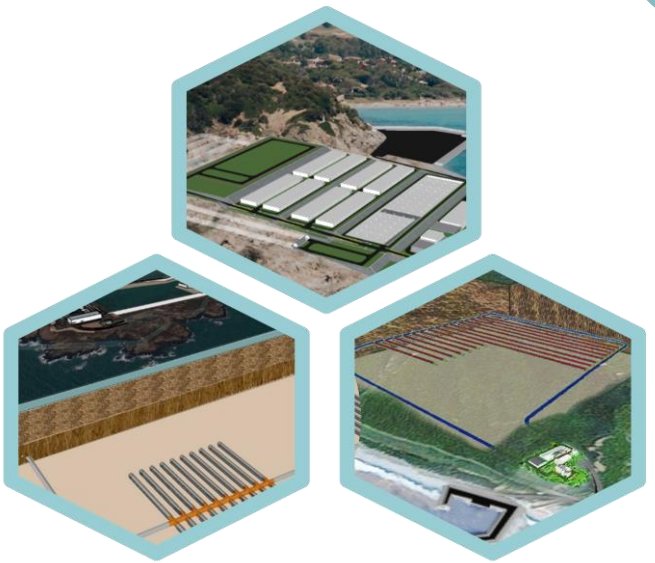

Earthquake scenario




Scenario of a single engineer barrier unit failure



# 4. Conclusions and Recommendations



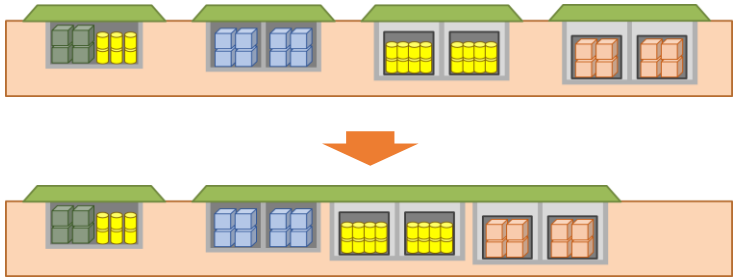
# Conclusions and Recommendations

## Conclusions

- Based on current assumptions, the procedures for the design of near-surface disposal facilities have been implemented.
- Comparing with subsurface disposal systems, the functions of EBS and cover layers have a more pronounced impact on dose rate.
- Then reduction of infiltration capabilities and effective time by the EBS and cover layers are important issues.

## Development Directions

- Ensure the durability of cover layer design.
- If the groundwater table is too high, the shallow depth design or water resistant type design can be adopted.
- Design optimization: Reduce the required area of the disposal area.



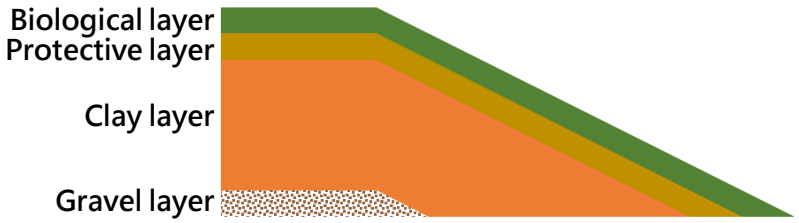
- Update design according to low-level disposal plan development.

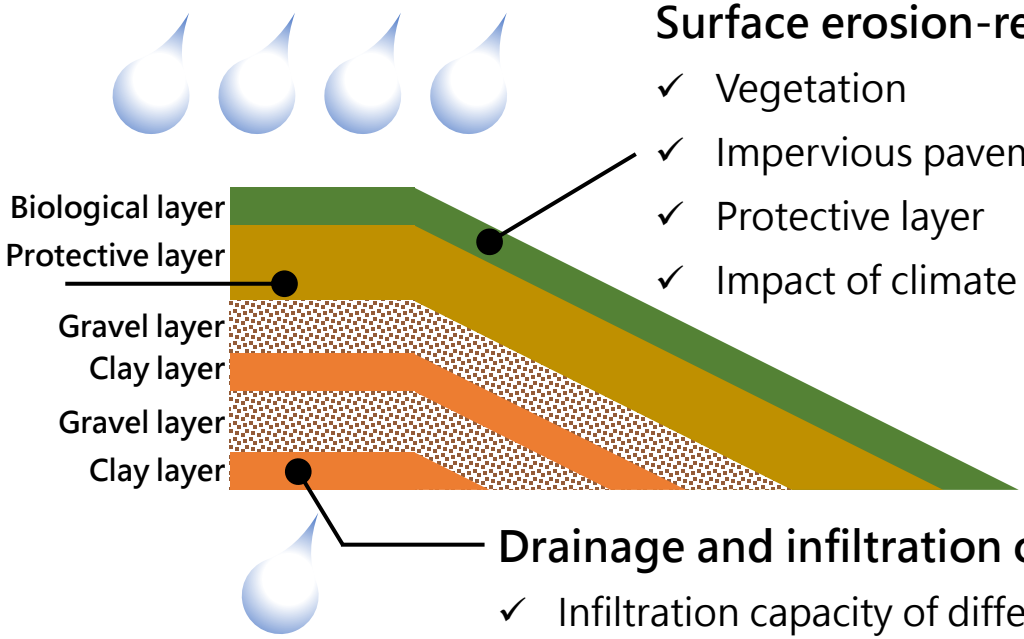
# Safety Assessment Technology Development

- **Simulation techniques for EBS degradation processes**
  - ✓ Characteristics of EBS degradation (disposal pits, T-Box, backfill, and filling)
  - ✓ Analysis techniques of infiltration in EBS
- **Review the design of cover layer (design a hydraulic model experiments for rainfall erosion behavior)**

**Cover layer drainage and durability design**

- ✓ Gravel and clay composite system
- ✓ Dual-system design
- ✓ Significantly increase the thickness of the clay layer to achieve waterproofing and water resistance




**Surface erosion-resistant design**

- ✓ Vegetation
- ✓ Impervious pavement
- ✓ Protective layer
- ✓ Impact of climate change

**Drainage and infiltration characteristics**

- ✓ Infiltration capacity of different designs
- ✓ Lateral drainage and slope stability

# *Thank you*

正派經營、品質保證

追求卓越、創新突破