Joint ICTP-IAEA Workshop on Radioactive Waste Management - Solutions for Countries without Nuclear Power Programme, 2 November - 6 November 2015, Trieste, Italy

Disposal options for LILW and IAEA technical documents for radioactive waste disposal

P. ORMAI

IAEA, Waste Technology Section

The Abdus Salam International Centre for Theoretical Physics

- How many of you
  - are having radioactive waste disposal facility of any sort?
  - have ever visited a radioactive waste repository?
  - difficulties to imagine it how a radioactive waste disposal facility may look like?
  - can advise to your government concerning the type of radioactive waste disposal facility needed for the country?

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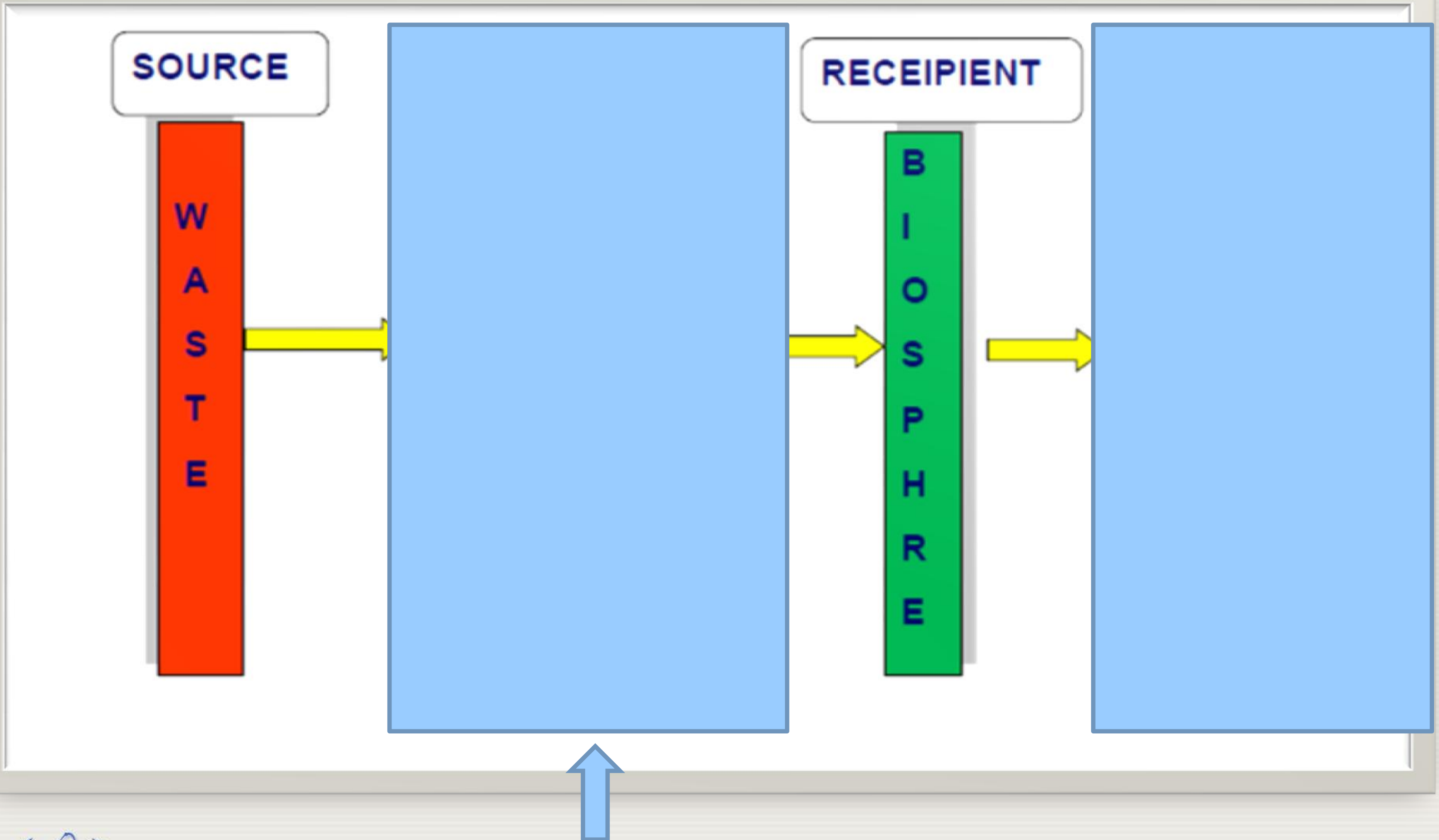
Presentation aims

The aim of this presentation is to:

- give an overview of alternative **disposal concepts**
- present a **criteria for selecting** a LILW repository design focussing on aspects relevant to countries without nuclear power programme
- recommend **IAEA technical documents** on radioactive waste disposal

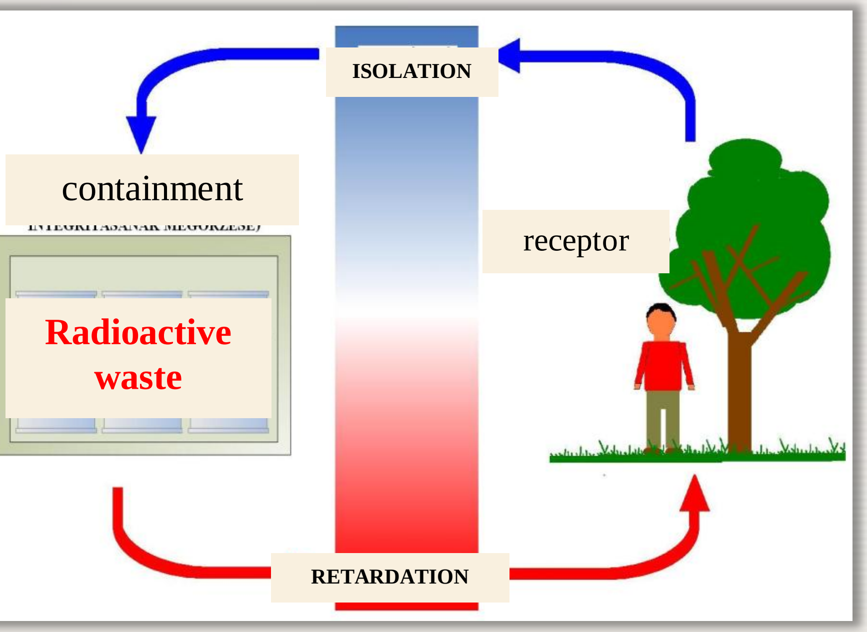



What is the issue?



Disposal system: site, engineering, control

The term ‘disposal’ refers to the emplacement of radioactive waste into a facility or a location **with no intention of retrieving** the waste.



Isolation:

- means design to **keep the waste and its associated hazard apart from the accessible biosphere**.
- It also means design to **minimize the influence of factors** that **could reduce the integrity** of the disposal facility.

Containment:

- implies designing the disposal facility to a**void or minimize the release of radionuclides**.

Why disposal?

- Long time scales for decay
- Ethics / sustainability / security
  - *polluter pays (this generation pays)*
  - *future generations may lack resources*
  - *societal breakdown*
  - *put beyond use*

Common drivers:

- *offer final solution*
- *increase safety / security*
- *save money*

Only disposal can provide an end-point to RWM !

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Disposal design aim

- All disposal designs aim to **prevent or reduce interaction between water and waste**.
- There are many ways of doing this:
  - ***choice of site*** *(arid region, unsaturated, mountainous site, etc.),*
  - ***choice of depth*** *(near surface above/ below grade, intermediate depth, deep geological),*
  - ***water resistant cap*** *(runoff drainage layer, clay barrier)*
  - ***long-lived containment*** *(BDC).*

- A primary issue **also** is **protection of inadvertent human intruder**
  - *detemine the degree to which a combination of depth of disposal, institutional controls, and engineered barriers can be relied upon to prevent or minimize this exposure scenario*.

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Selection of a disposal option

The selection of a disposal option depends on many factors, both **technical** and **administrative,** such as:

- waste characteristics and inventory
- radioactive waste management policy
- overall disposal strategy in the country (how many facilities)
- national legislative and regulatory requirements
- political decisions
- social acceptance
- the conditions of the country such as climatic conditions and site characteristics, availability of suitable host media.

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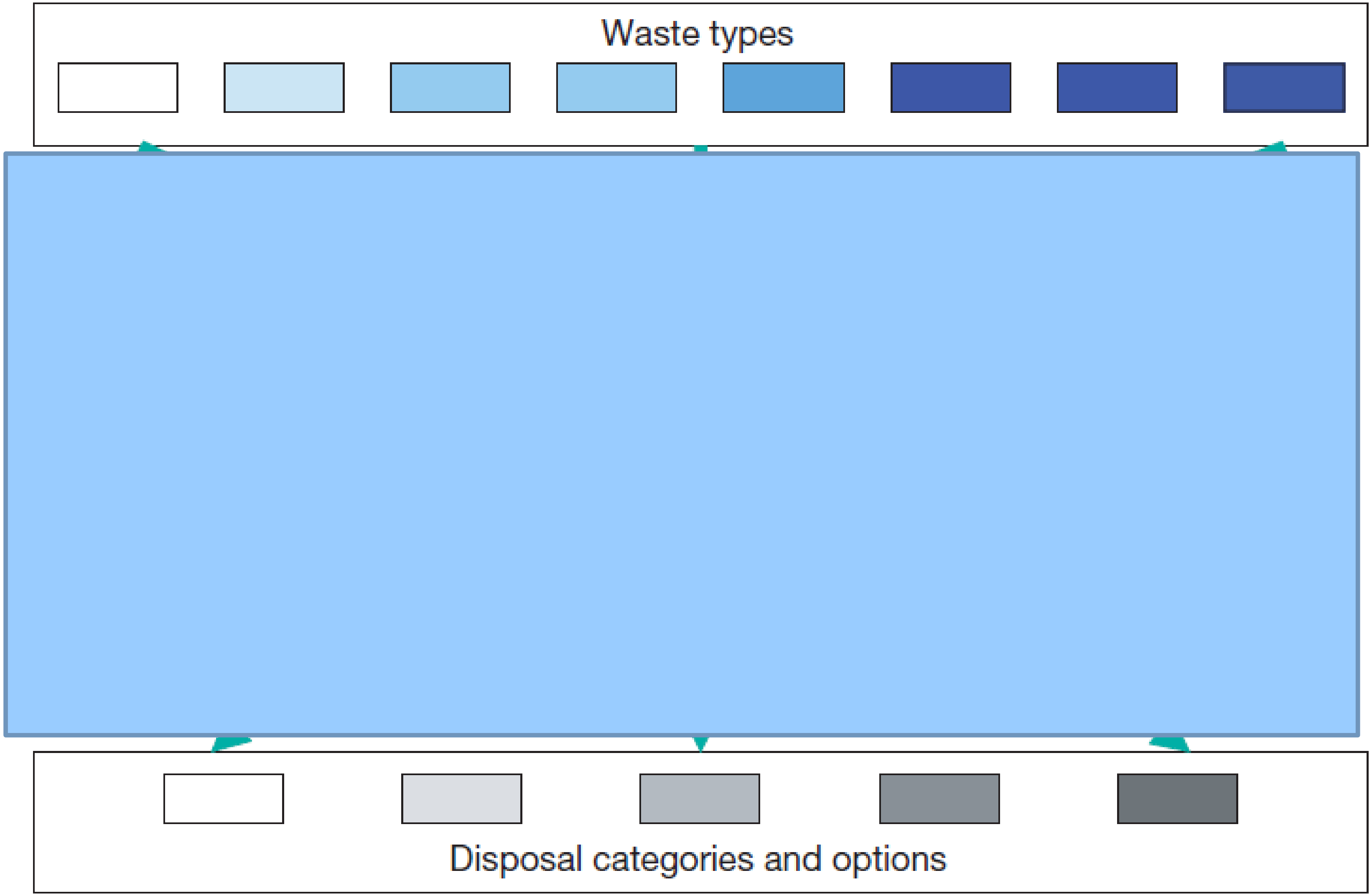
Disposal solution for different waste types



Repository types

There are **two** fundamental categories of repository; a **Near-Surface repositor**y and a **Geological repository**.

7 variant types of repository, many **disposal concepts** depending on the **safety functions** attributed to the various EB and NBs associated with a specific concept.

NEAR SURFACE REPOSITORIES (Situated from above ground level to a max. of 30m distance from ground surface)

i. Surface – Engineered structures or simple landfill

ii. Near Surface – Trench. Excavated trenches with only minor civil engineering attributes

iii. Near-Surface – Engineered. Facilities in which there is extensive use of e.g. concrete walls to partition cells, construction of drainage channels and other civil engineering structures, etc.

iv. Near Surface – Mined or natural cavity (sub-surface)

v. Near Surface – Shafts/Borehole

GEOLOGICAL REPOSITORIES (intermediate depth 30m to 300m depth; and deep >300m)

vi. Geological - Mined

vii. Geological - Borehole

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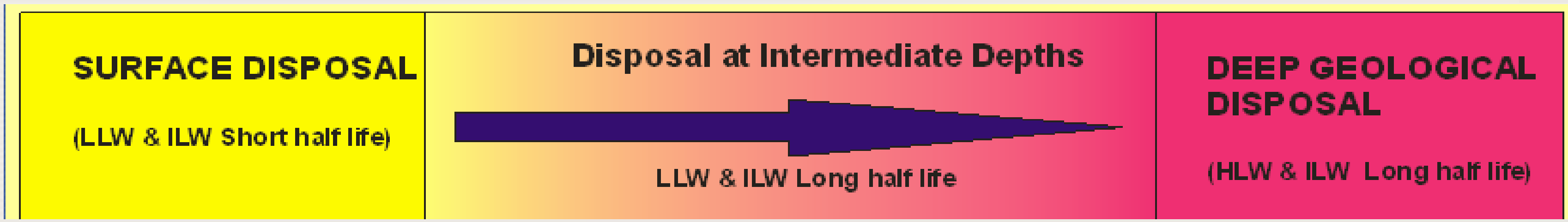

- **High reliance on ENGINEERED BARRIERS, supported by natural site characteristics**
- Long term institutional control may continue after repository closure to ensure safety

- **High reliance on NATURAL BARRIERS, supported by engineered and chemical barriers**
- Possible post-closure monitoring, but concept rely on passive safety

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Selection of disposal option/concept

- The task is to adapt the possible disposal solutions to the particular waste streams.
- Make a quick screening by using a simple matrix.
- Based on the IAEA Waste classification scheme VSLW, VLLW, LLW, ILW, HLW can be differentiated (special consideration should be given to **DSRS, NORM**/TENORM **Uranium M&M waste**).
- When assessing the disposal options, consideration should also be given to the **volume of waste** to be disposed of.

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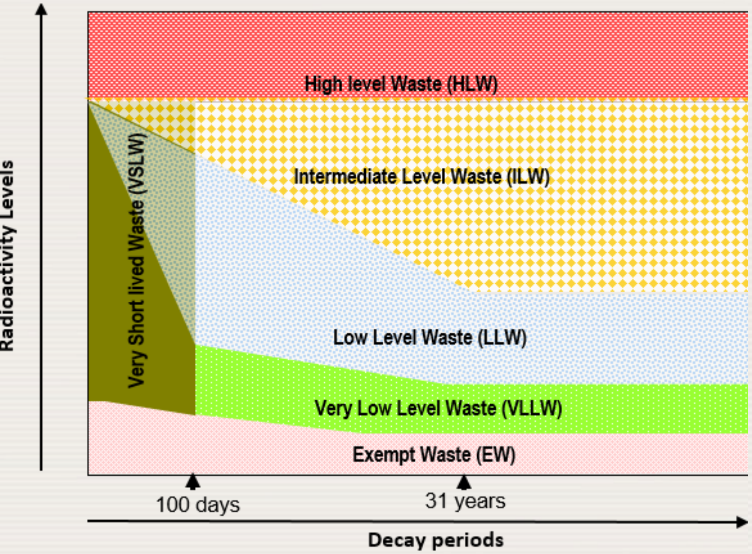
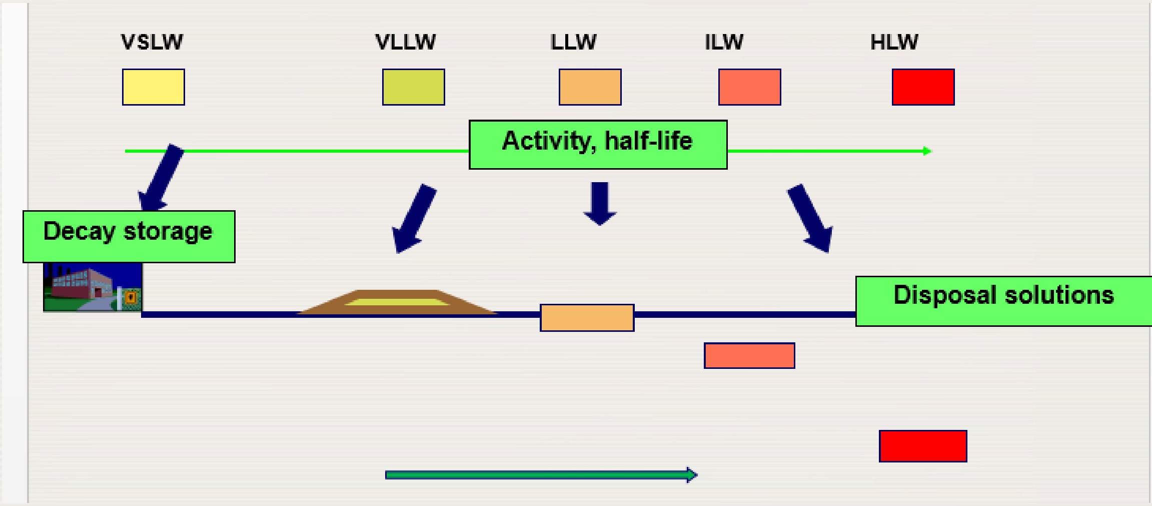
Selection of disposal option/concept
Stepwise approach (1)

The first reference should be the IAEA Waste classification scheme which provides a general system of classification accommodating various waste types and disposal solutions.





Disposal solutions with increasingly robust **isolation and containment**

This scheme offers a useful **initial consideration** despite it **identifies only boundaries & provides quantitative guidance** and does not prescribe specific disposal solution for certain waste types (as specific safety assessment for each disposal facility is required).

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Radioactive waste stream		[illegible]	Decay storage	Surface trench	Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC	Other
VSLW	low volume								
	large volume								
VLLW	low volume								
	large volume								
LLW	low volume								
	Large volume								
ILW	low volume								
	Large volume								
HLW									
DSRS	short-lived								
	long-lived								
	SHARS								
NORM	low volume								
	large volume								

Selection of disposal option

Stepwise approach (2)

- The next step is to **match the possible disposal solutions to the particular waste streams.**
- **Safety** is the fundamental objective of radioactive waste disposal. Several options can be ab ovo excluded from safety consideration point of view.
- Other options can be ruled out on the grounds of **technical reasons** (not feasible, difficult to implement, etc.).
- Based on the generic safety considerations, the characteristics and volume of waste **potentially acceptable** or **preferable options** can then be identified.
- There might be options which need to be more closely assessed from **technical** and **economic aspects**.

Not possible for safety reason	Not possible for technical reason	preferable	acceptable	Possible but needs to be assessed from technical or economic aspects

Radioactive waste stream		END POINT							
		[illegible]	Decay storage	Surface trench	Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC	Other
VSLW	low volume								
	large volume								
VLLW	low volume								
	large volume								
LLW	low volume								
	large volume								
ILW	low volume								
	large volume								
SNF/HLW									
DSRS	short-lived								
	long-lived								
	SHARS								
NORM	low volume								
	low volume								

Not possible for safety reason

Not possible for technical reason

preferable

acceptable

Possible but needs to be assessed from technical or economic aspects

Radioactive waste stream		Decay storage	Surface trench	Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC
		END POINT					
VSLW	Low volume						
	Large volume						
VLLW	Low volume						
	Large volume						
LLW	Low volume						
	Large volume						
ILW	Low volume						
	Large volume						
SNF/HLW							
DSRS	Short-lived						
	Long-lived						
	SHARS						
NORM	Low volume						
	Large volume						

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Disposal of VSLW and VLLW

preferable | acceptable | Possible but needs to be assessed from technical or economic aspects | Not possible for safety reason | Not possible for technical reason

Radioactive waste stream		END POINT					
		Decay storage	Surface trench	Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC
VSLW	Low volume						
	Large volume						
VLLW	Low volume						
	Large volume						

In some countries, VLLW is disposed of in **purpose-built** disposal facilities, in the form of earthen trenches with engineered covers.

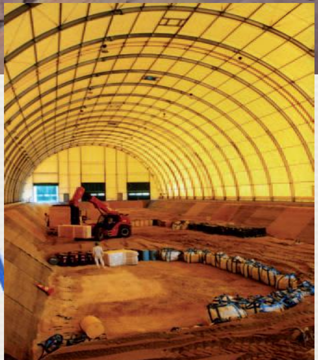
In other MS, it is **disposed of with other waste types**, e.g. LLW.

The decision on disposal method is usually made on **economic** and/or **regulatory** grounds.

- Above ground facility, non-permeable engineered bottom plate, leachate directed to external infiltration bed
- Water resistance cover.

Sweden

Morvilliers (France)



- From the decommissioning of nuclear facilities
- NORM waste
- Very low specific-activity levels - below a few hundreds of Bq/g
- Disposal requires no special processing or conditioning
- Some of the wastes are compacted into bales and wrapped in polyethylene

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Options for the disposal of LLW

Radioactive waste stream		END POINT						
		Decay storage	Surface trench		Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC
LLW	Low volume							
	Large volume							

A very wide range of specific activities **(~7 orders)**

Low amounts of long-lived radionuclides

The boundary between LLW and ILW is not precise

Limits on acceptable levels of long-lived (and other) nuclides will be depend on the design and location of the particular facility

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Near-surface disposal: facility types

Near-surface disposal facility types: **trenches, engineered vaults**, **mounds, silos**

An <u>engineered or earthen cap</u> is placed ove the waste containers to minimize wate infiltration**.**

Subsurface disposal facilities: Some countries prefer disposing of LLW in subsurface facilities or <u>co-locating LLW with ILW</u> in deeper facilities.

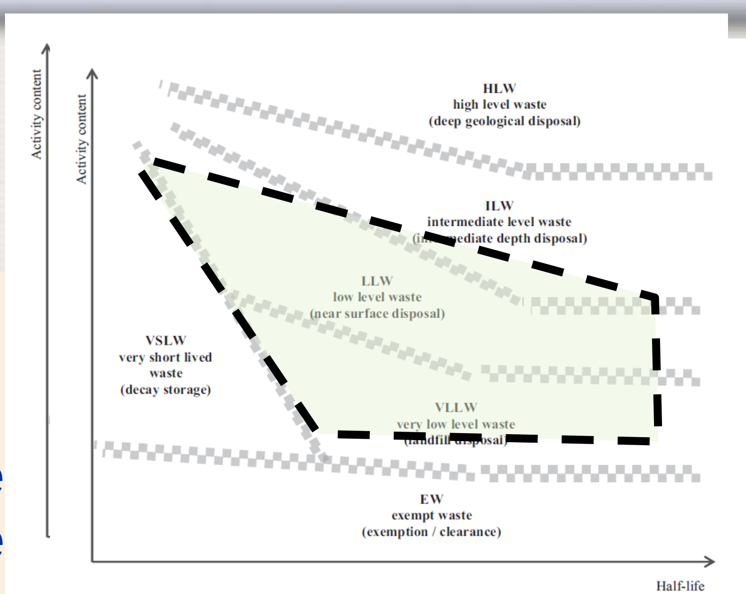
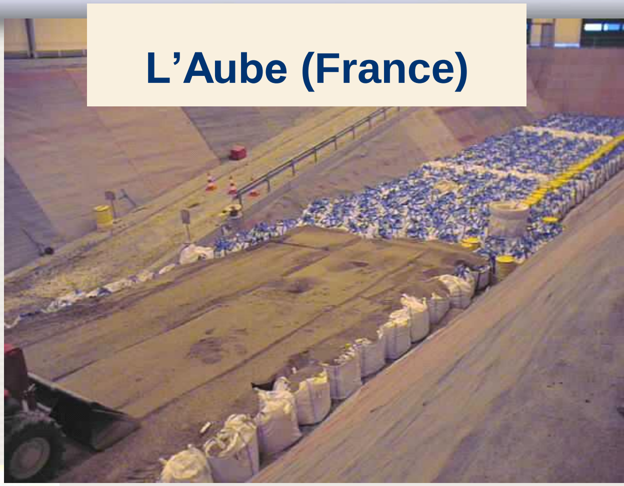


FIG. 1. Conceptual illustration of the waste classification scheme.

Trench type disposal concepts

NTS - Area 5 (USA)

Richland (USA)



L'Aube (France)

Peña Blanca (USA)

Ezeiza (Argentina)

El Cabril (Spain)

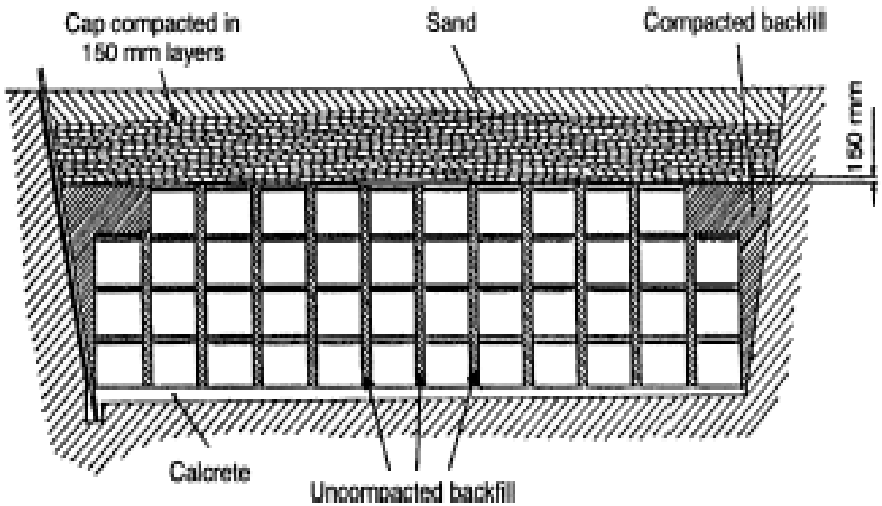
Vaalputs (South Africa)

Australia

US Ecology Richland, Hanford – USA

- Arid desert environment
- Large trenches
- Waste containers are placed up to 13.7 m deep in trenches
- LLW, NORM and accelerator wastes
- Additional concrete engineered barriers for Ra bearing wastes

VAALPUTS – South Africa



- Arid environment
- Reliance on geological features
- Much less engineering
- Typically lower cost

Australia

- **non nuclear country**
- Dry environment
- Remote areas
- Little possibility of leaching or exposure
- Small to large trenches
- Low volumes of drummed wastes from mining and uranium ore processing
- Occasional disposals as and when wastes arise

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Engineered vaults

*Drigg – **UK***
*Rokkasho – **Japan***
*Mohovce – **Slovak**ia*
*Centre de l'Aube – **France***
*Vector – **Ukraine***
*Dukovany – **Czech Republic***
*Püspökszilágy – **Hungary***
*El Cabril – **Spain***
*Hanford – **USA***

All follow essentially the **same design**:

- *above or just below grade concrete-lined vaults*
- *split into separate compartments*
- *mobile weatherproof roof during operation*
- *multilayer cap*
- *drainage systems (above and below waste)*
- *cement encapsulation and backfill*

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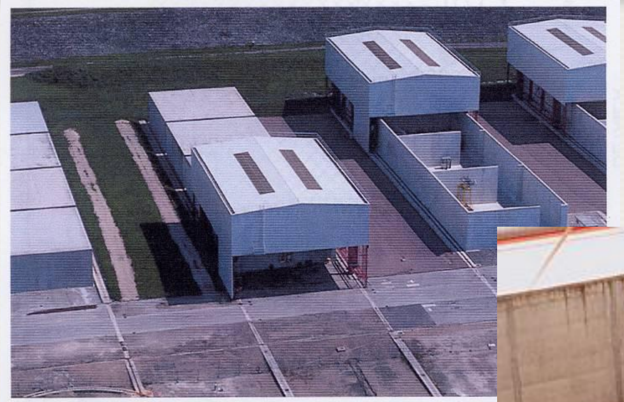
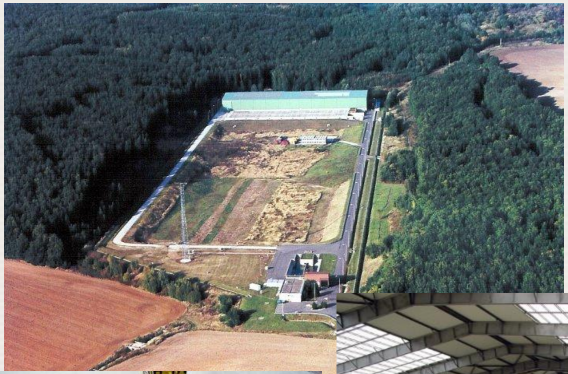
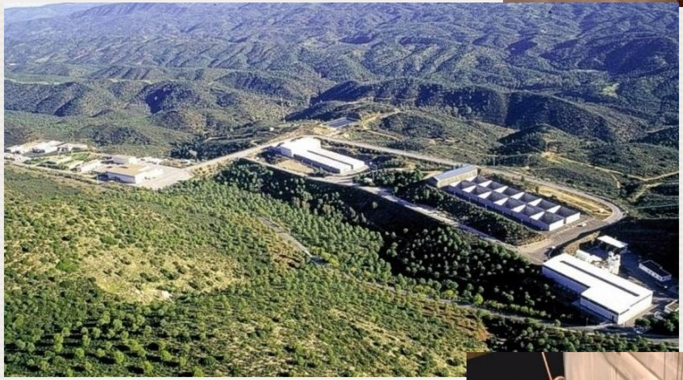


Centre de l’Aube (France)



MOCHOVCE - Slovakia



EL-CABRIL – Spain

ROKKASHO – Japan

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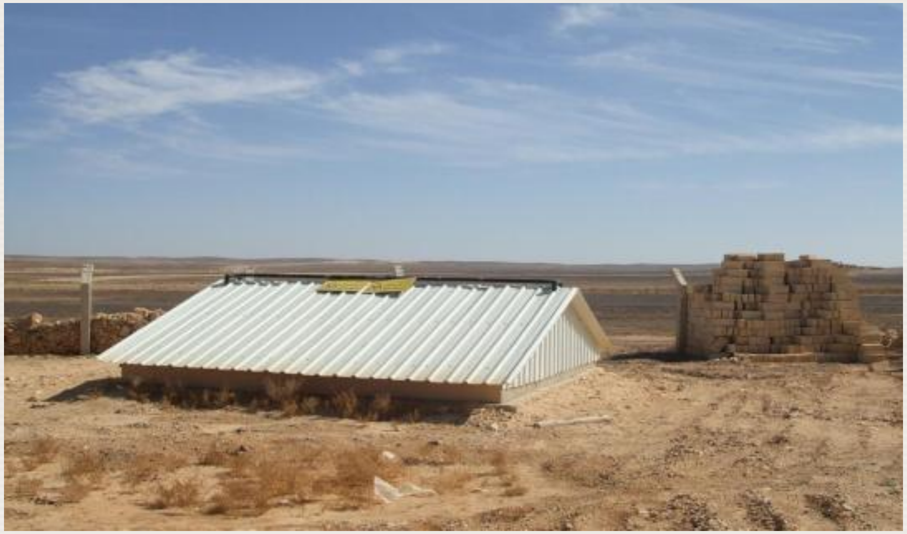
Not one size-fits-all case



Reinforced concrete underground pit
(3.6 m x3.6 m with depth 3.1 m)
Capacity: 15 m^3

Capacity is 18 million tons and
covers appr. 45 hectares

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Mined disposal facilities or quarries

Sometimes mined disposal facilities were originally created for other purposes, for example to **exploit metal ores** or other resources, or to create **safe storage areas** for ammunition or other potentially hazardous materials

RICHARD - Czech Republic:
Former limestone mine subsequently enlarged to act as a munitions factory

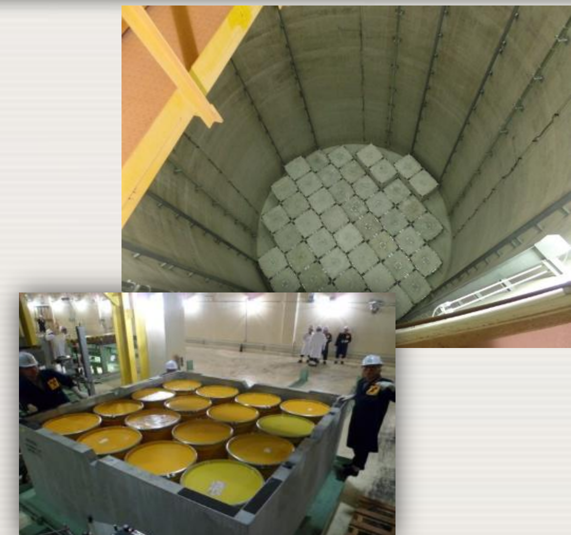
Purpose-built rock caverns

- HIMDALEN – Norway (not nuclear country)
- Disposal facility for institutional waste
- Storage for Pu-bearing waste (from research)

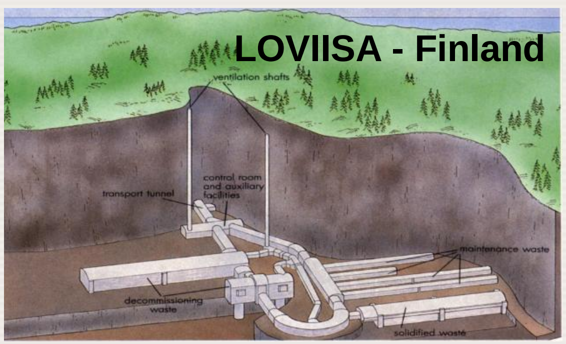
Subsurface, geological, deep geological repositories for LILW (SL)

SFR, Sweden

Bátaapáti, Hungary

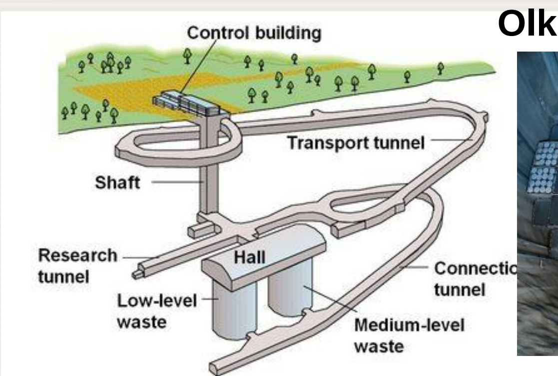


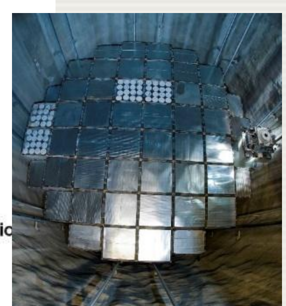
Wolsong, Korea



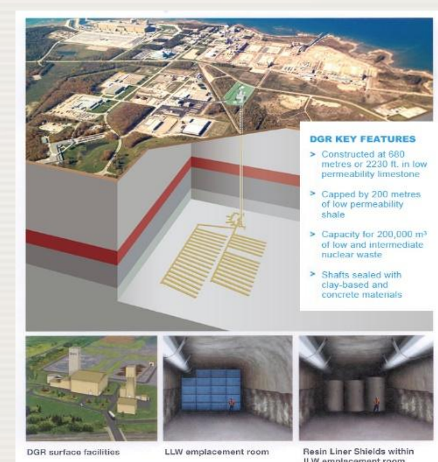
LOVIISA - Finland

Olkilouto - Finland





KONRAD - Germany



Kincardine - Canada

OPTIONS FOR THE DISPOSAL OF ILW

Radioactive waste stream		END POINT						
		Decay storage	Surface trench		Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC
ILW	Low volume							
	Large volume							

Disposal at depths of greater than **several tens of m** is generally considered to be the most appropriate option for ILW.

While repositories specifically for ILW exist in some countries, in others, **co-disposal with spent fuel and high level waste** is being considered.

Disposal of NORM waste

Radioactive waste stream		END POINT						
		Decay storage	Surface trench	Tailing dam	Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC
NORM	Low volume							
	Large volume							

Where is the NORM from:

- *Uranium mining and milling*
- *Uranium overburden and mine spoils*
- *Phosphate industry wastes (phosphate fertilizers and potash)*
- *Coal mines (coal ash)*
- *Oil and gas production scale and sludge*
- *Waste water treatment sludge*
- *Metal mining and processing waste (Zinc & lead mining, Al mines)*
- *Geothermal energy production waste.*
- *Scrap metal release and recycling*
- *Rare earth element mining (rarer earth element metallurgy)*

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Disused Sealed Radioactive Sources (DSRS)

What to do when a source becomes disused?

1. ***Return to manufacturer***
   - in line with IAEA Code of Practice (Jan 2004)
   - but many orphan sources
2. ***Decay storage***
   - OK if half-life less than, say, 5 years
3. ***Long-term storage***
   - not sustainable
4. ***Disposal***

Although the ultimate solution should be disposal, **currently long term storage is the general practice.**

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Disposal of DSRS

Radioactive waste stream		END POINT						
		Decay storage	Surface trench		Engineered surface facility	Geologic repository (intermediate depth)	Geologic repository (deep)	BDC
DSRS	short-lived							
	long-lived				WAC			
	SHARS							

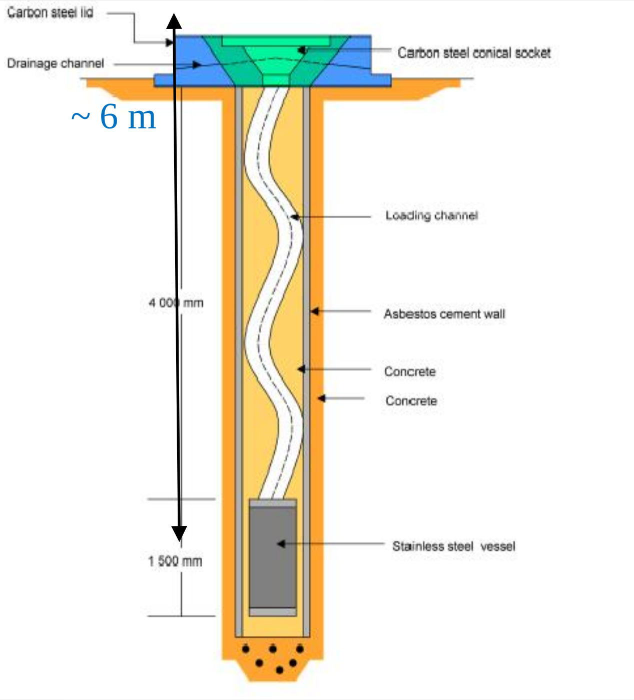
Disposal options for DSRS vary depending on the **activity levels** and **types of radionuclides** in the sources.

LILW short-lived ($T_{½} \leq 30$ y) waste packages may be disposed of in engineered **near-surface** repositories

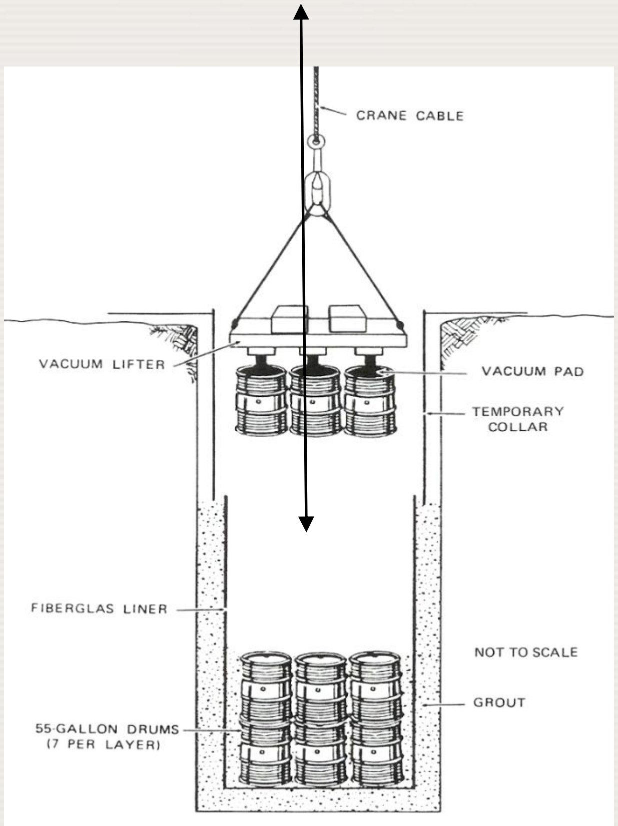
Expensive, not economical for DSRS only

Drilled or sunk shafts and boreholes

Disposal using shafts and boreholes at depths of up to 30 m are also classified as near-surface disposal facilities.



"RADON" Boreholes



"Greater Confinement"
The Nevada test site

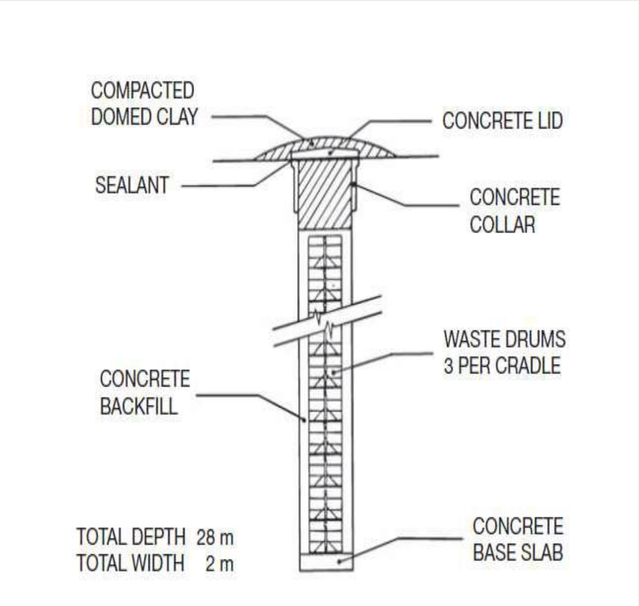


FIG. A-4. Borehole disposal at Mt Walton East, Australia [A-3].

Mount Walton East, Australia

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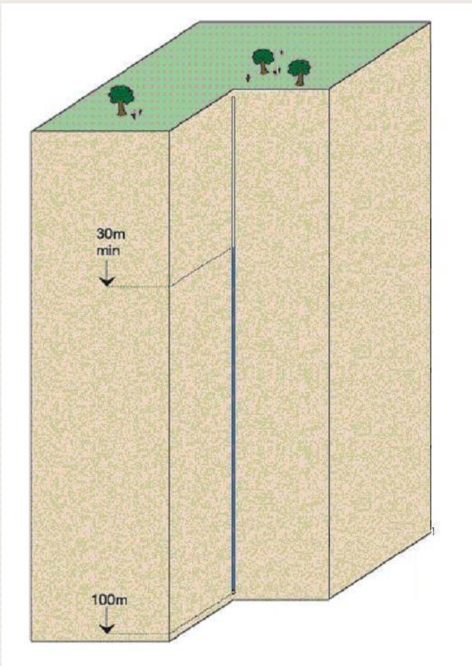
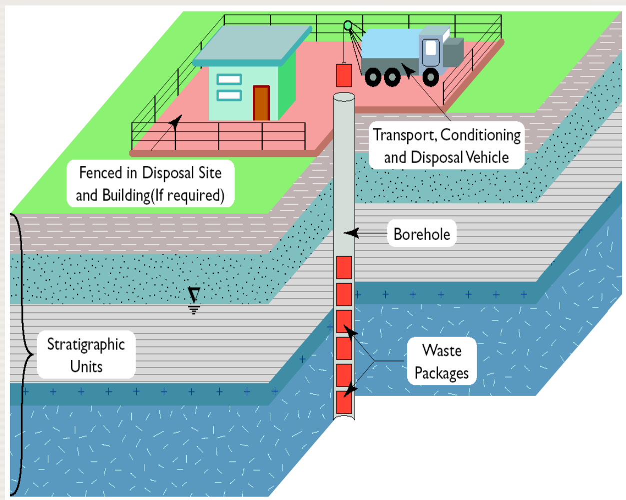
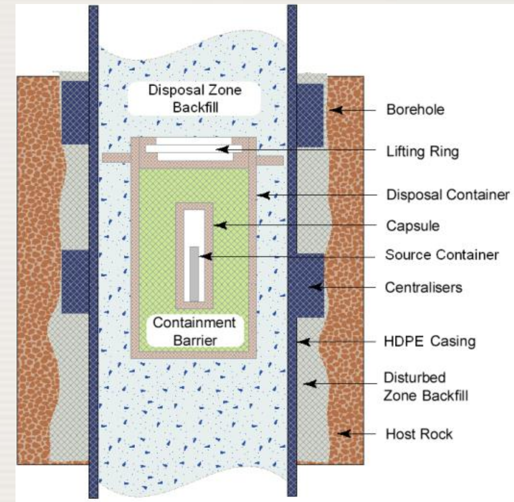
IAEA BDC: Borehole Disposal Concept

The intention is that disposal would always be at a depth of at least 30 m from the ground surface.







Depth : 30 to 100 m (and deeper)
Diameter : ~ 250 mm
Sources conditioned in capsu
and containers

- **Borehole facilities offer safe, simple, economic alternative for all DSRS**
- **No decrease in safety standards**
- **Small footprint**
- **Safe implementation with limited resources**
- **Broad range of suitable (safe) site properties**

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Conclusion

- There is a **great deal of experience** in disposal
- Repository type/design depends on:
  - *Overall disposal strategy in the country*
  - *Waste inventories*
  - *The nature of the site (host media) and its surroundings*
  - *Climate*
  - *Legislative restrictions*
  - *Political decisions*
  - *Social acceptance*
- **The notion of the best (‚optimal') disposal solution is elusive**
  - *Deciding what would be an optimal solution is complicated by many factors (e.g. policy constraints, and public sensitivities, siting constraints, the specific waste streams, resources available)*
- **Available technologies** must be **assessed**

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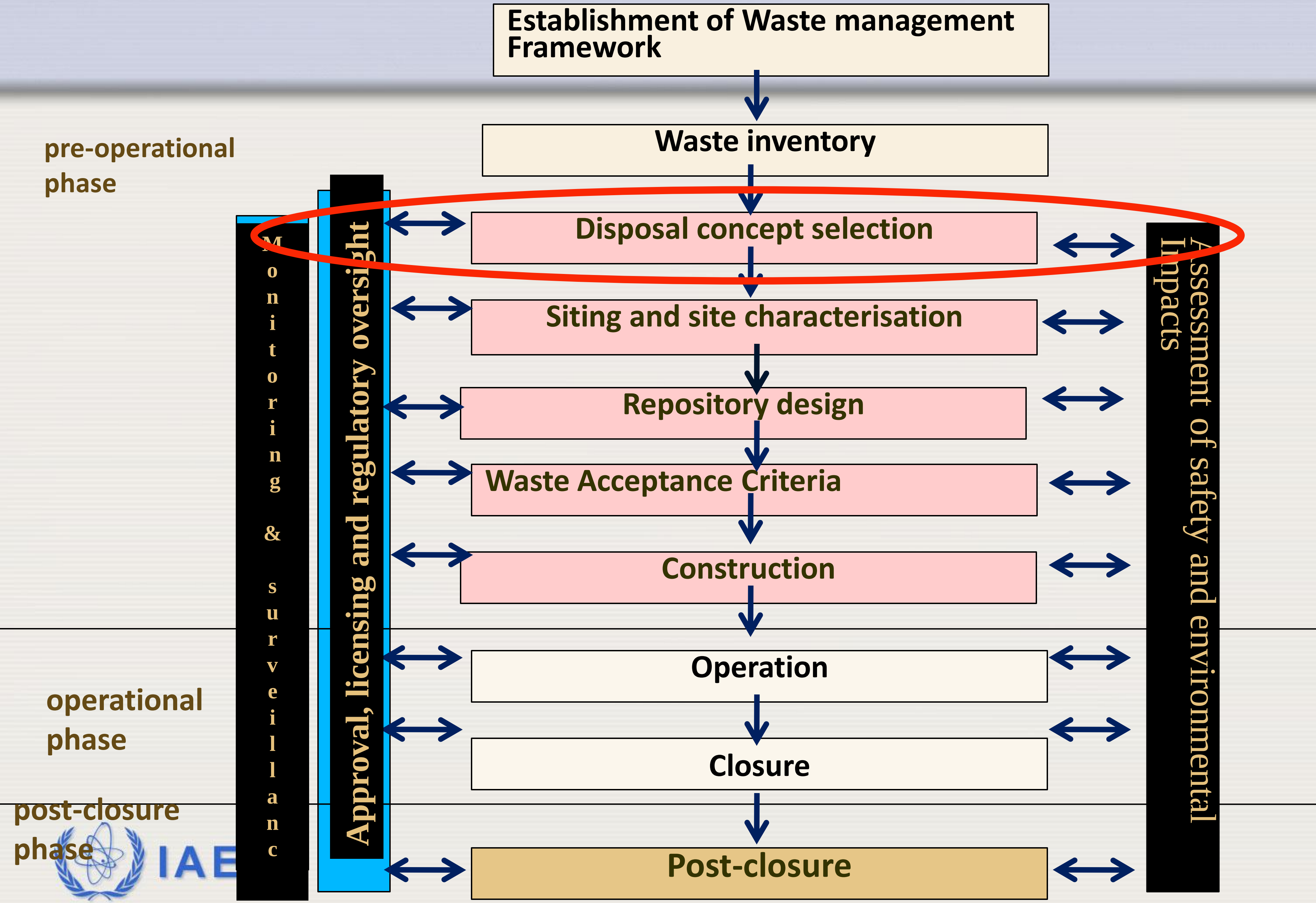
Establishment of Waste management Framework
Waste inventory
Disposal concept selection
Siting and site characterisation
Repository design
Waste Acceptance Criteria
Construction
Operation
Closure
Post-closure
pre-operational phase
operational phase
post-closure phase
Monitoring & surveillanc
Approval, licensing and regulatory oversight
Assessment of safety and environmental impacts

Not one size-fits-all case

- `Simple` case:
  - mostly SL-LLW
  - mostly homogeneous waste
  - small of moderate volume

- **political willingness**
- **resources**
- **social acceptance**

- More complex case:
  - LL LILW
  - heterogeneous waste
  - atypical waste streams
  - hazardous constituencies
  - large volume (NORM, post accident,
    remediation-related)
  - complex or controversial site

- **political inertia**
- **lack of resources**
- **lack of social acceptance**

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"Feasibility" is not only a technical issue

One of the greater challenges is gaining and maintaining societal acceptance

Sound governance must secure and maintain acceptance

Keeping in mind that "safe, secure, and feasible" remains its foundation.

Safety Standards Categories

Fundamental Safety Principles

Requirements – Legal, Technical, & Procedural Safety Imperatives

Guidance on Best Practice to Meet Requirements

Safety Standards - Disposal

- Site Aspects
- Design
- Construction
- Operation
- Closure
- Post Closure
- Safety Assessment
- Management System

IAEA Safety Standards
for protecting people and the environment
Fundamental Safety Principles
Jointly sponsored by Euratom FAO IAEA ILO IMO OECD/NEA PAHO UNEP WHO
Safety Fundamentals
No. SF-1
IAEA

IAEA Safety Standards
for protecting people and the environment
Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards
Jointly sponsored by EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP, WHO
General Safety Requirements Part 3
No. GSR Part 3
IAEA

IAEA Safety Standards
for protecting people and the environment
Disposal of Radioactive Waste
Specific Safety Requirements
No. SSR-5
IAEA

IAEA Safety Standards
for protecting people and the environment
Classification of Radioactive Waste
General Safety Guide
No. GSG-1
IAEA

IAEA Safety Standards
for protecting people and the environment
Near Surface Disposal Facilities for Radioactive Waste
Specific Safety Guide
No. SSG-29
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IAEA Safety Standards
for protecting people and the environment
Geological Disposal Facilities for Radioactive Waste
Specific Safety Guide
No. SSG-14
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IAEA Safety Standards
for protecting people and the environment
Borehole Disposal Facilities for Radioactive Waste
Specific Safety Guide
No. SSG-1
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IAEA Safety Standards
for protecting people and the environment
The Safety Case and Safety Assessment for the Disposal of Radioactive Waste
Specific Safety Guide
No. SSG-23
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IAEA Safety Standards
for protecting people and the environment
Monitoring and Surveillance of Radioactive Waste Disposal Facilities
Specific Safety Guide
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Safety Guide
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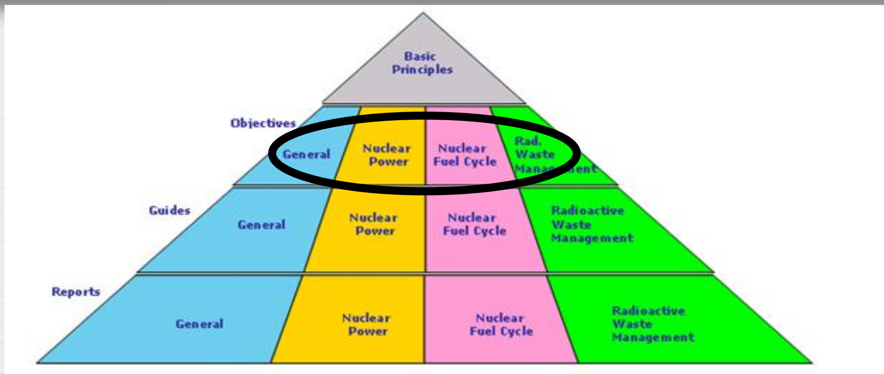
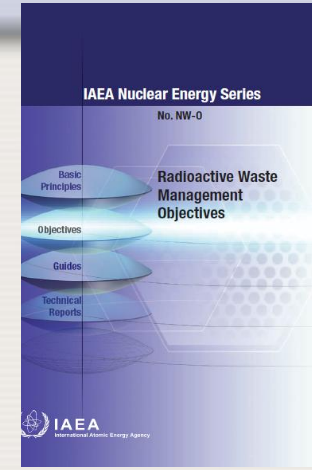
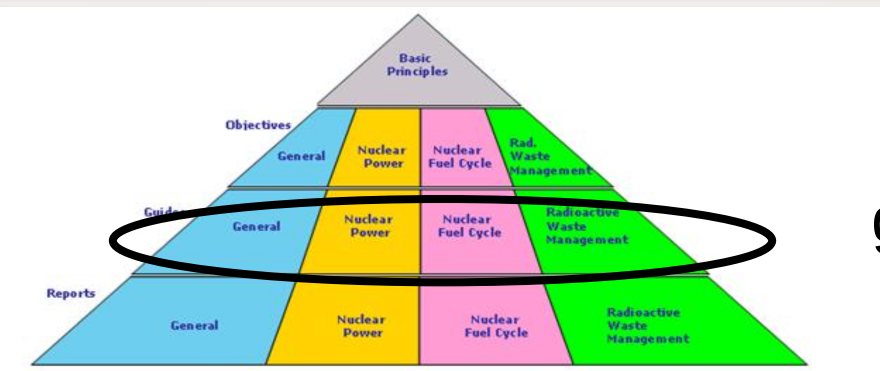
Nuclear Energy Series

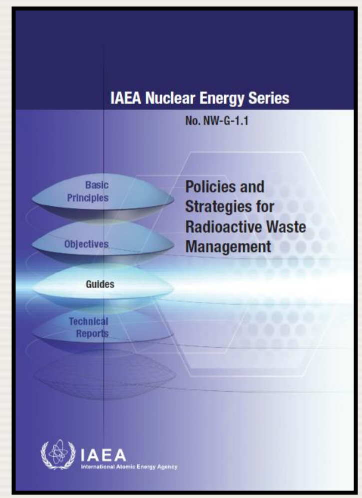


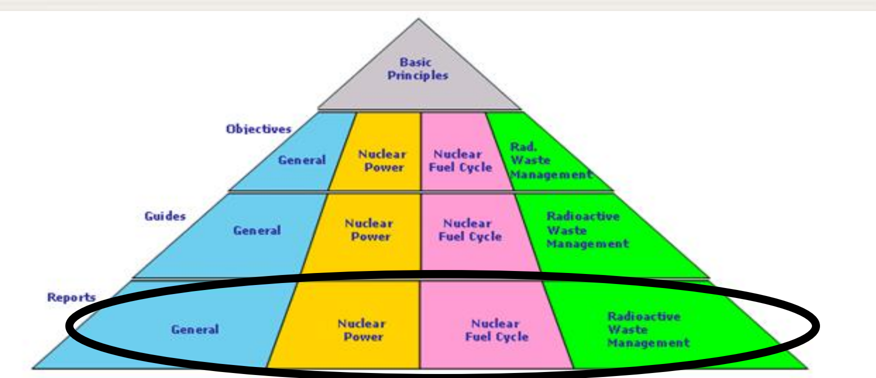
objectives

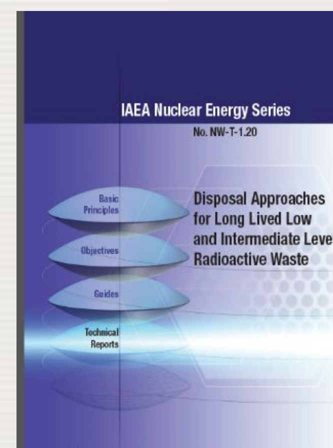




guides

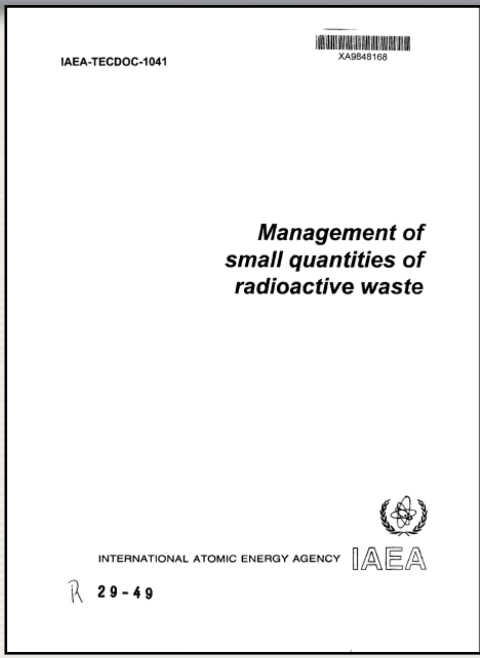


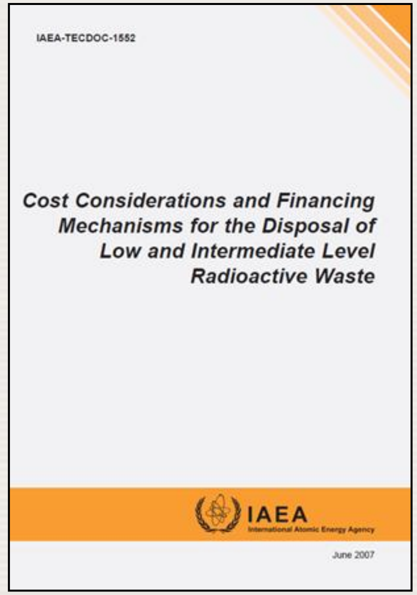


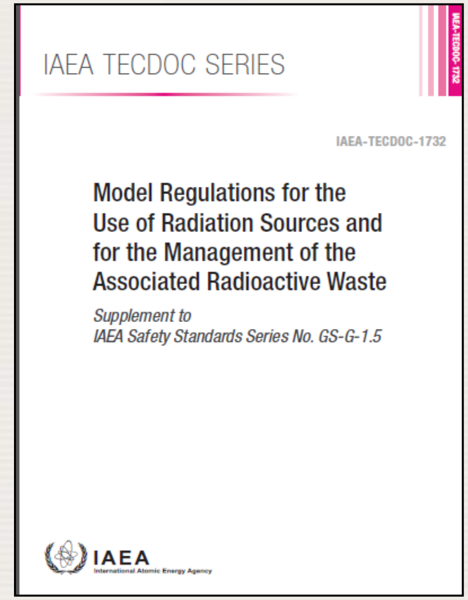


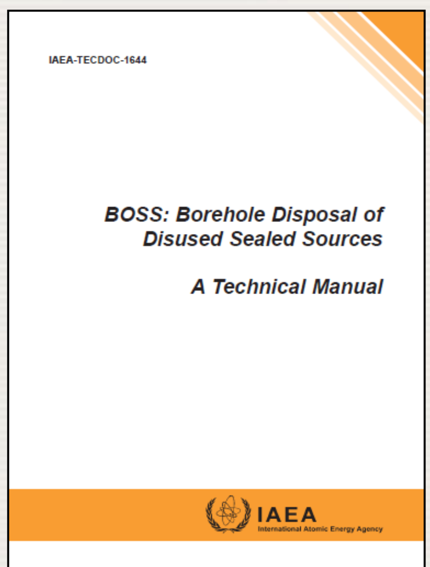
Technical reports

TECDOC


IAEA-TECDOC-1041
XA9848168
Management of
small quantities of
radioactive waste
INTERNATIONAL ATOMIC ENERGY AGENCY
IAEA
29-49


IAEA-TECDOC-1552
Cost Considerations and Financing
Mechanisms for the Disposal of
Low and Intermediate Level
Radioactive Waste
IAEA
International Atomic Energy Agency
June 2007


IAEA TECDOC SERIES
IAEA-TECDOC-1732
Model Regulations for the
Use of Radiation Sources and
for the Management of the
Associated Radioactive Waste
Supplement to
IAEA Safety Standards Series No. GS-G-1.5
IAEA
International Atomic Energy Agency


IAEA-TECDOC-1644
BOSS: Borehole Disposal of
Disused Sealed Sources
A Technical Manual
IAEA
International Atomic Energy Agency

IAEA

IAEA

Definitions

source: RWM Glossary 2003 and the IAEA Safety Glossary 2007

Radioactive waste repository:

- A nuclear facility where waste is emplaced for disposal

Near-Surface repository:

- A facility for disposal of radioactive waste located at or within a few tens of m from the earth's surface

Geological repository:

A facility for disposal of radioactive waste located underground (usually several hundred m or more below the surface) in a geological formation to provide long term isolation of radionuclides from the biosphere

Definitions (2)

New definition for **Near-surface repository**:

- A facility within which waste emplacement is designed to be undertaken at or within 30 m from the earth's surface. A near-surface repository is suitable for the disposal of VLLW and LLW, as defined in IAEA Safety Standard GSG-1.

New definition for **Geological repository**:

- A facility for the disposal of radioactive waste located underground in a stable geological formation at a distance greater than 30m from ground surface to provide containment and isolation of radionuclides from the biosphere. The depth of waste emplacement and the containment and isolation functions required of the engineered and natural barriers must be commensurate with the class of waste to be disposed.

IAEA