Overview of Waste Classification and Disposal Routes

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Outline

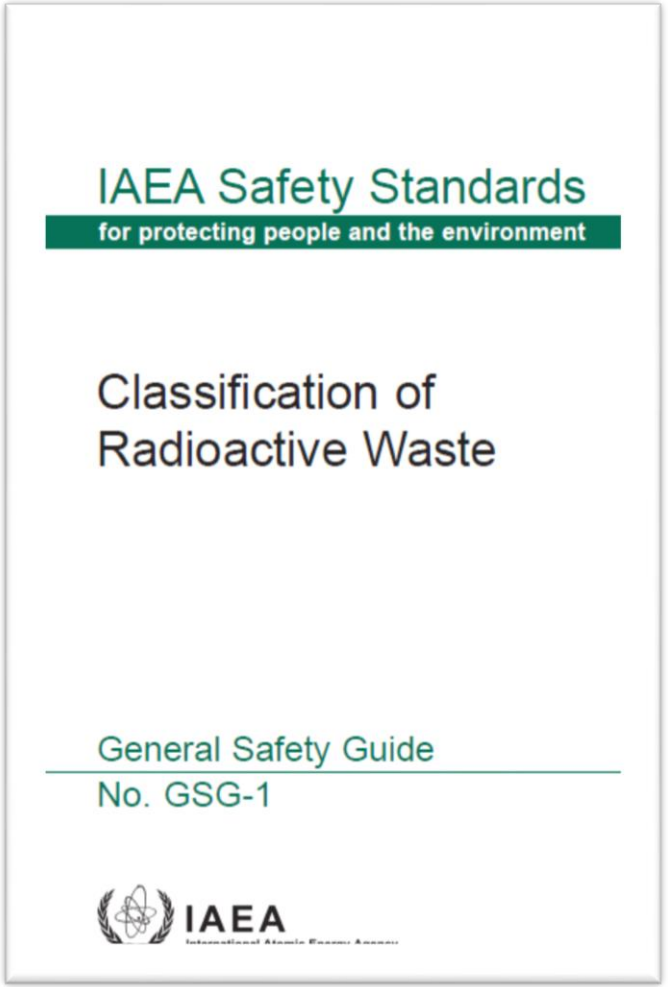
- Background
- IAEA GSG-1 waste classes
- National waste classes
- Possible disposal routes
- EGIRM disposal route arrangement

Background

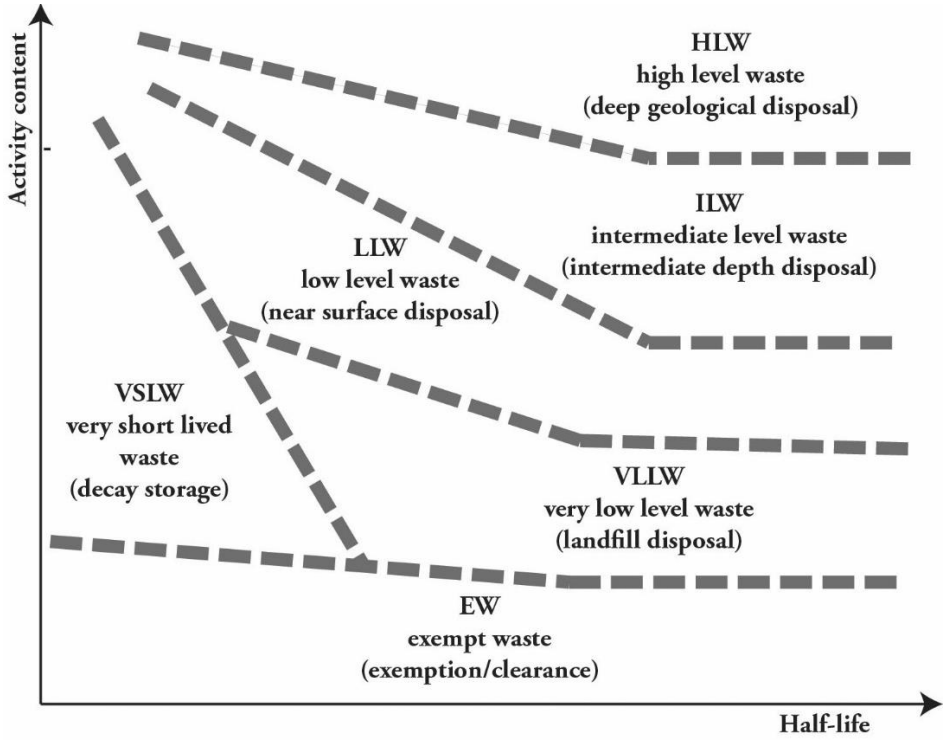
- Radioactive waste can be divided into different categories or “classes” according to its radiological or other properties
  - This matches the waste to its preferred or optimal management and disposal method according to a national policy and/or available infrastructure
- Different countries may have different classifications for similar wastes, depending on their policies and needs
  - This makes comparison between countries difficult
- Therefore, a common framework is essential for international comparisons or benchmarking

IAEA GSG-1

- IAEA General Safety Guide GSG-1 groups waste by half-life and radioactivity level
- The GSG-1 groupings are based primarily on considerations of long term safety, and thus, by implication, disposal of the waste
- GSG-1 does not include quantitative boundaries between waste classes
  - The boundaries are left up to countries to define based on their needs



IAEA GSG-1 (2)



- GSG-1 groupings are based on generic disposal routes which are considered to be the minimum appropriate method for a type of waste
- The higher the activity and/or longer the half life, the greater the disposal requirements
  - Does not exclude applying higher requirements to lower classes of waste
- Not all countries recognize all waste classes

IAEA GSG-1 (3)

- **Exempt waste** (EW): Waste that meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes (once such waste has been cleared from regulatory control, it is not considered radioactive waste)
- **Very short lived waste** (VSLW): Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared from regulatory control (primarily radionuclides with very short half-lives often used for research and medical purposes)
- **Very low level waste** (VLLW): Waste that does not necessarily meet the criteria of EW, but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities with limited regulatory control (concentrations of longer lived radionuclides in VLLW are generally very limited)

IAEA GSG-1 (4)

- **Low level waste (LLW):** Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near-surface facilities. This class covers a very broad range of waste. LLW may include short-lived radionuclides at higher levels of activity concentration, and also long-lived radionuclides, but only at relatively low levels of activity concentration.
- **Intermediate level waste (ILW):** Waste that, because of its content, particularly of long-lived radionuclides, requires a greater degree of containment and isolation than that provided by near-surface disposal. However, ILW needs no provision, or only limited provision, for heat dissipation during its storage and disposal.
- **High level waste (HLW):** Waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognized option for disposal of HLW. *(includes spent fuel when it is considered to be waste)*

National Waste Classes

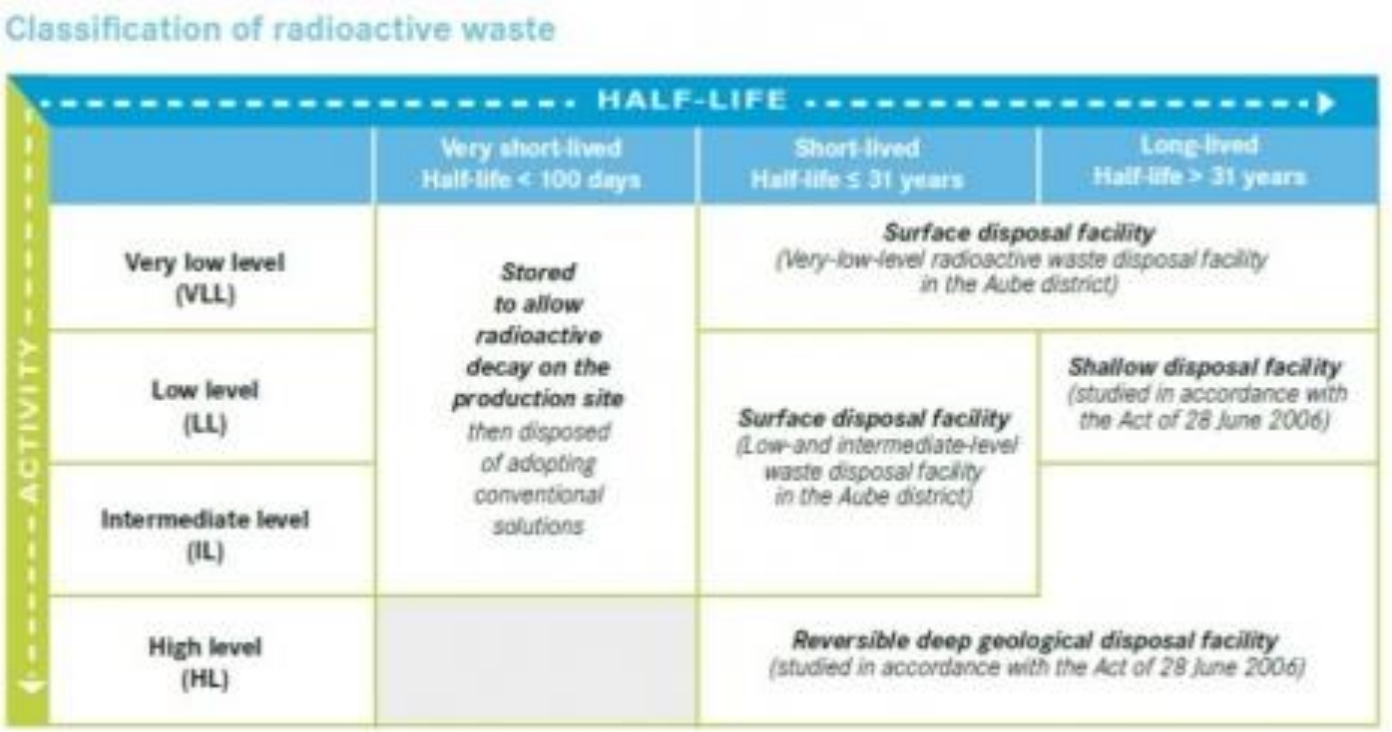
- Many countries adopt classifications similar to GSG-1, but include numerical boundaries that match their policies and infrastructure
  - Boundaries between classes are normally based on the safety case for the disposal facilities
- Classes and boundaries can be defined in primary legislation, regulations, national standards and/or guidance material (e.g. from regulatory bodies)
- Some countries with a single planned disposal route for all waste classes may have a simpler system (e.g. Germany, where all LLW and ILW is considered together as “waste with negligible heat generation” for disposal in a deep repository)
- Other countries have a complex system based on waste origin, radioactivity level, specific nuclides and other properties (e.g. USA with separate classifications for government vs non-government wastes)
- In order to allow comparison, national systems must be normalized to a common basis

Example National Classes - Canada

- Defined in a national standard (CSA N292.0)
  - Numerical boundaries can be set by individual waste owners in consultation with national regulator, due to differing needs and infrastructure available to waste owners
- Basic classes follow IAEA GSG-1 scheme and terminology (VLLW, LLW, ILW, HLW)
- HLW is waste with > 2kw/m^3 of heat generation
  - Spent nuclear fuel is considered to be HLW
- Uranium mining & milling waste (UMM) is an additional class related to a specific type of large volume, low activity radioactive waste generated during the mining and milling of uranium ore and the production of uranium concentrate
- Individual waste owners decide on and build disposal route
  - Implemented disposal routes include surface mounds for UMM and some LLW,
  - Future planned disposal includes near surface disposal for some LLW, deep geologic disposal for some LLW and for ILW and deep geologic disposal for SF (HLW)

Example National Classes - France

- Defined in the “law for the national inventory” (Ministerial Order of 9 October 2008)
- Based on activity level and half-life
- Specific disposal routes for each class



Example National Classes – France (2)

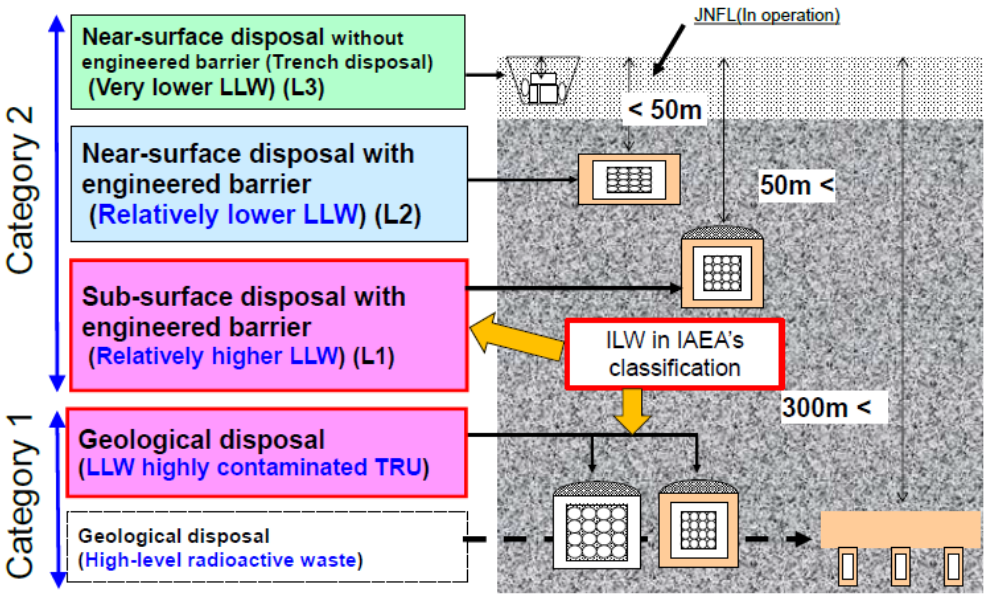
- **Very-low-level waste** (TFA) has activity level generally lower than 100 Bq/g. It is mostly due to the operation, maintenance and dismantling of NPPs, fuel cycle facilities and research establishments.
- **Low-level and intermediate-level short-lived** (FA/MA-VC) waste results mainly from the operation and dismantling of nuclear power plants, fuel-cycle facilities and research establishments. It has activity levels between TFA and FA-VLL/MA-VLL.
- **Low-level long-lived** (FA-VLL) waste consists mainly of graphite and radium-bearing waste. The activity of graphite waste ranges between 10,000 Bq/g and a few hundreds of thousands of Bq/g. Its long-term activity lies essentially with long-lived beta-emitting radionuclides. Radium-bearing waste contains long-lived alpha-emitting radionuclides and their activity lies between a few tens to a few thousands of Bq/g.
- **Intermediate-level long-lived** (MA-VLL) waste has activity ranging between 1 million and 1 billion Bq/g. There is either no or negligible heat generation. It originates mostly from the reprocessing of spent fuel.
- **High-level** (HA) waste consists mainly of vitrified-waste packages in the form of stainless-steel containers, which contain the vast majority of radionuclides from reprocessing of spent nuclear fuel, whether in the form of fission products or minor actinides. The activity level of vitrified waste lies in the order of several billions of Bq/g and it generates significant heat.

Example National Classes - Germany

- Defined in the German Radiation Protection Ordinance (StrlSchV)
- All radioactive wastes in Germany are destined for deep geological disposal
  - No need to classify based on half-life
- The German waste classification system is based on heat generating capacity of the waste:
  - **Non-heat-generating** radioactive wastes are radioactive waste with negligible heat generation, i.e. average heat output of less than about 200 W/m^3 of waste (corresponding to a 3 degree K increase in temperature at the wall of the disposal chamber caused by decay heat from the radionuclides contained in the waste packages)
  - **Heat-generating** radioactive wastes are characterized by high activity concentrations and therefore by high decay heat output. This category includes reprocessing residues and spent nuclear fuel.
- Separate facilities are planned for the two waste classes

Example National Classes - Japan

- Defined in regulations of the Nuclear Safety Commission of Japan
- Two basic waste categories:
  - Category 1: (High-level waste (HLW)): Wastes requiring geologic disposal, e.g. vitrified waste that contains fission product separated from spent fuel during reprocessing.
  - Category 2: (Low-level Waste (LLW)): all other radioactive waste, subdivided into several categories based on origin and type.
- Specific nuclide concentration limits for each class & sub-class



Example National Classes – Japan (2)

- Category 2 is subdivided into several categories based on origin and type:
  - Long-lived low-heat radioactive waste from reprocessing and MOX fabrication (TRU waste)
  - Waste from power reactors - further subdivided as:
    - Relatively higher activity waste - e.g. irradiated core components
    - Relatively lower activity waste - e.g. routine solid wastes generated at NPPs
  - Very low-level radioactive waste (VLLW) - e.g. bulk concrete & other low activity materials
  - Uranium waste - Waste generated from uranium enrichment and uranium fuel fabrication facilities
  - Waste from research facilities - Waste generated from research, medical and industrial facilities using or producing radioisotopes
- Spent nuclear fuel is not considered to be a waste in Japan

Example National Classes - Sweden

- There is no legally defined waste classification system in Sweden for radioactive waste. There are, however, established waste acceptance criteria for different disposal routes of radioactive waste.
- Current disposal routes are:
  - **Shallow land burial** (equivalent to Very Low Level Waste): the main criterion is that the releases of radionuclides from the facilities shall not contribute significantly to the releases from the already existing nuclear facilities at the site. Therefore, the total activity content is limited to 100–1100 GBq per facility, of which a maximum of 10 GBq may consist of alpha-active substances.
  - **SFR (for short-lived L&ILW):**
    - Silo: Short lived L&ILW, max dose rate 500 mSv/h
    - BMA vault: Short lived L&ILW, max dose rate 100 mSv/h
    - BTF vaults: Short lived L&ILW, max dose rate 10 mSv/h
    - BLA vault: Short lived L&ILW, max dose rate 2 mSv/h
- Spent nuclear fuel is considered to be a waste in Sweden.

Example National Classes - Switzerland

- Defined in the Nuclear Energy Ordinance of the Swiss Federal Council
- All radioactive wastes in Switzerland are destined for deep geological disposal
  - No need to classify based on half-life
- The Swiss waste classification system is based on radiotoxicity and heat generating capacity of the waste:
  - **High level waste (HAA):** Vitrified fission product waste from the reprocessing of spent fuel, or spent fuel if declared as waste.
  - **Alpha-toxic waste (ATA):** Waste with a concentration of alpha-emitters exceeding 20,000 Bq/g of conditioned waste.
  - **Low- and intermediate-level waste (SMA):** All other radioactive waste.
- Two disposal facilities are planned – SMA, and HAA + ATA
  - Both could be co-located on same site

Example National Classes - USA

- Waste classes are defined in federal regulations
- The USA has two waste classification systems: one for "civilian" (commercial) wastes and the other for DOE (defense related) wastes.
- For civilian/commercial wastes, the categories are based on suitability for near-surface disposal:
  - **Low Level Waste** (LLW) is defined in regulation based on suitability for near-surface disposal through consideration of concentrations of long-and short-lived radionuclides. See 10 CFR 61 for full definitions. It is subdivided into:
    - **Class A** low level waste is determined by characteristics listed in 10 CFR 61.55 and physical form requirements in 10 CFR 61.56. (The US does not have a minimum threshold for Class A waste).
    - **Class B** low level waste is waste that must meet more rigorous requirements on waste form than Class A waste to ensure stability.
    - **Class C** low level waste is waste that not only must meet more rigorous requirements on waste form than Class B waste to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion.
    - **Greater than Class C** waste (GTCC) is waste that exceeds the limits for Class C waste and is not generally acceptable for near-surface disposal.

Example National Classes – USA (2)

- Civilian/commercial wastes (con't)
  - **High level waste** (HLW): The highly radioactive material resulting from reprocessing of spent fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste containing fission products in sufficient concentrations and other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation.
  - **Spent fuel** (SF) is fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. For civilian applications, this is considered to be a waste.
  - **Byproduct material** (uranium mill tailings), tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. (Also referred to as AEA 11(e)2 waste.)

Example National Classes – USA (3)

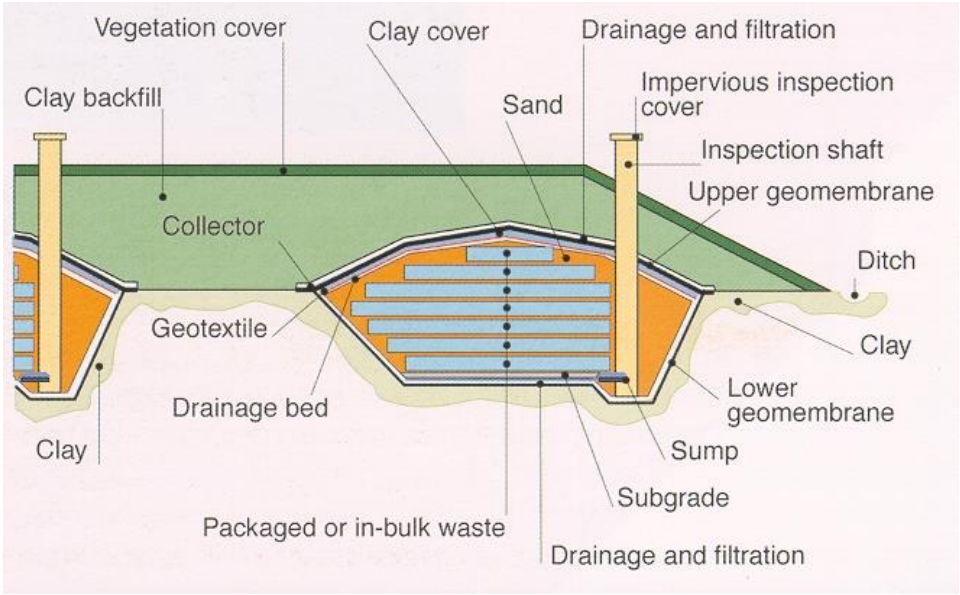
- The DOE classifies wastes as:
  - **Low level waste (LLW):** radioactive waste other than HLW, TRU and by-product material.
  - **High level waste (HLW):** (similar to civilian definition).
  - **Transuranic waste (TRU):** US DOE owned waste (mostly defense related) contaminated with man-made radioisotopes beyond or "heavier" than uranium on the periodic table of the elements (long-lived alpha-emitting waste with concentrations greater than 3700 Bq/g [100 nCi/g]). Subdivided into:
    - **Contact handled TRU (CH):** TRU waste with a surface dose rate of less than 200 millirem per hour
    - **Remote handled TRU (RH):** TRU waste with a surface dose rate of 200 millirem per hour or greater
  - **Byproduct material:** (similar to civilian definition).
  - **Spent fuel:** The DOE does not consider spent nuclear fuel to be a waste.

Possible Disposal Routes

- There are many different disposal system designs and implementations
  - There is no ‘best’ design for a disposal facility; the design should reflect the respective circumstances and the level of hazard or risk
  - Some designs are adaptable to different locations, while others are highly location specific
- Unlike most civil engineering structures, disposal facilities must be designed to last for a very long time – hundreds to hundreds of thousands of years or more
- Most designs rely on multiple, overlapping engineered and natural barriers – defence in depth
  - The role assigned to each barrier and the reliance on different barriers will vary depending on national requirements and waste types, e.g. reliance on a highly engineered waste package vs a highly engineered facility

Possible Disposal Routes (2)

- **Landfill** – basic surface or shallow-ground facilities, used for very low level wastes. Generally purpose-built when used for radioactive waste, but similar technology is also commonly used for chemically hazardous and municipal wastes.
- Examples include:
  - VLLW disposal at NPPs, Sweden
  - CSTFA, Morvilliers, France
  - El Cabril, Spain
  - JPDR, Tokai, Japan
  - Harwell HVLA, UK

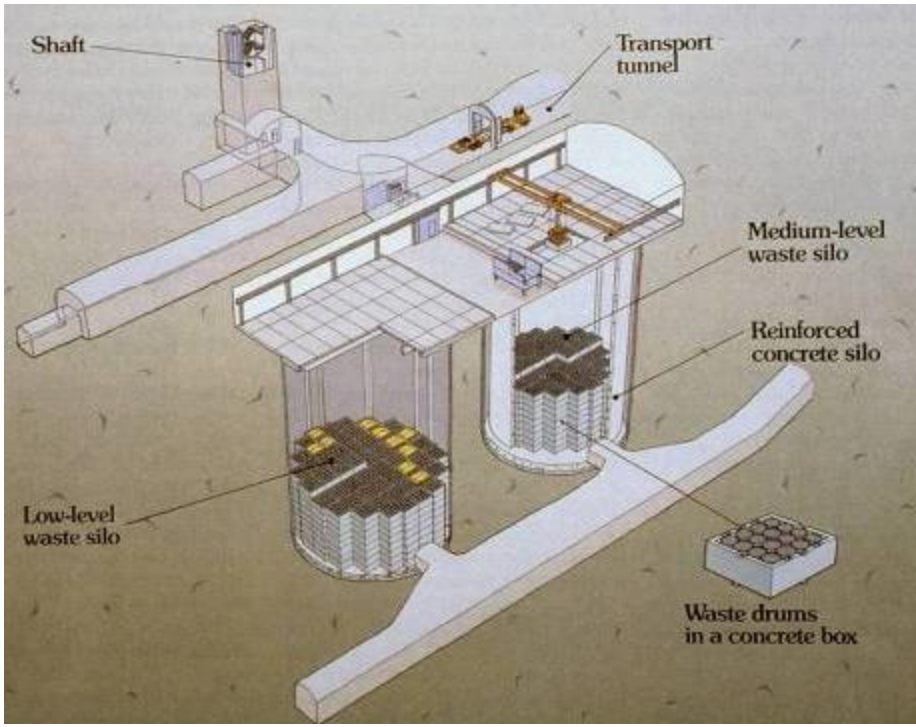


Possible Disposal Routes (3)

- **Engineered, near-surface disposal** – commonly used in many parts of the world for short-lived L&ILW disposal
- Can be vaults or trenches at or a few tens of metres below surface
- Examples include:
  - Dukovany, Czech Republic
  - CSFMA, Centre de l'Aube, France
  - El Cabril, Spain
  - Rokkasho, Japan
  - Saligny, Romania
  - Mochovce, Slovakia
  - Drigg, UK
  - WCS Texas, USA

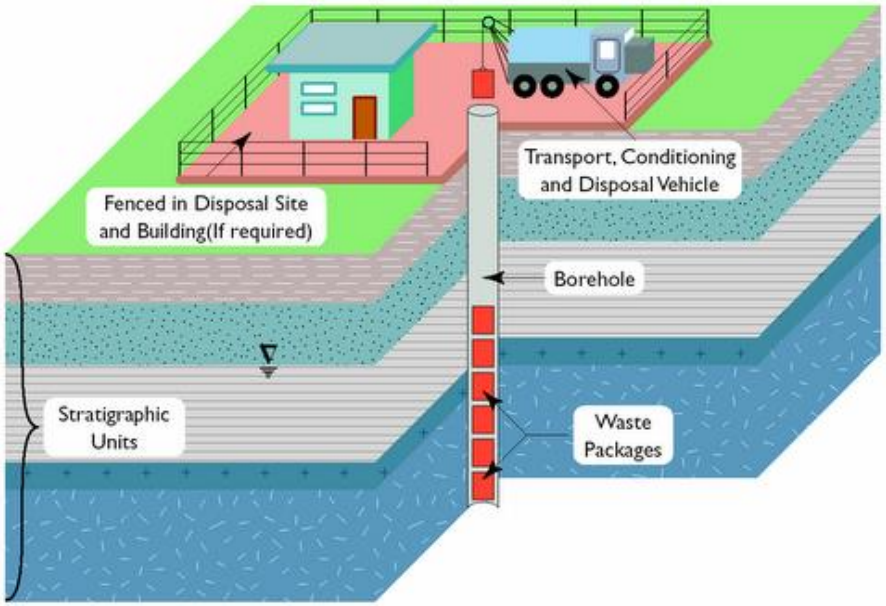
Possible Disposal Routes (4)

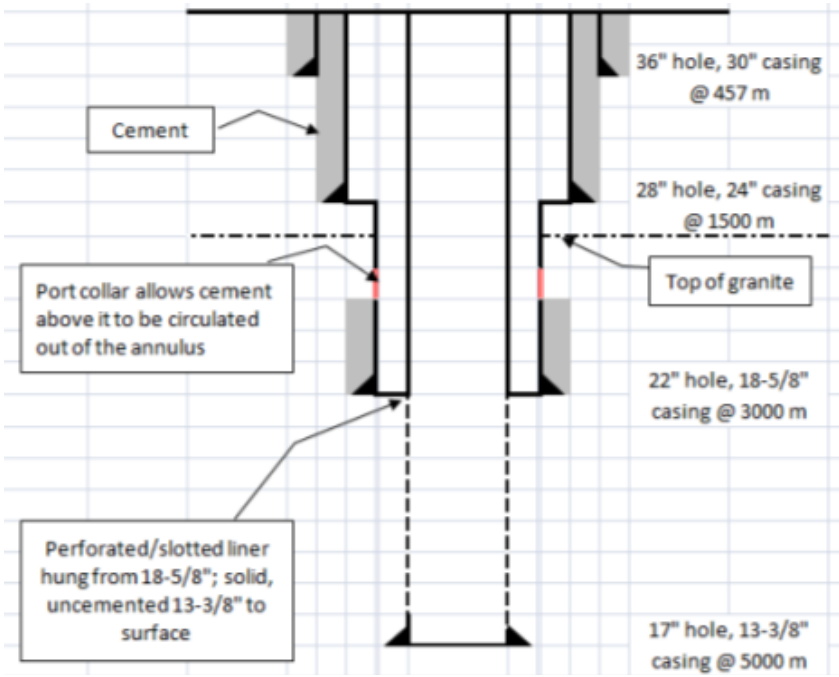
- **Rock caverns** can be built at various depths for various types of waste
- Can be purpose-built, or adapted from old mines
- Access from surface by shaft or ramp
- Existing examples include:
  - SFR, Sweden
  - Loviisa & Olkiluoto, Finland
  - Wolsung, Korea
  - Himdalen, Norway
  - WIPP, USA
  - Bátaapáti, Hungary
- Planned facilities include:
  - Konrad, Germany (LILW)
  - Kincardine, Canada (LILW)
  - Facilities in France, Sweden, Finland, Canada, etc of SF & HLW



Possible Disposal Routes (5)

- Borehole disposal can be developed for various depths and waste types
- Especially suited for low volume, high activity waste
- Examples include IAEA BOSS

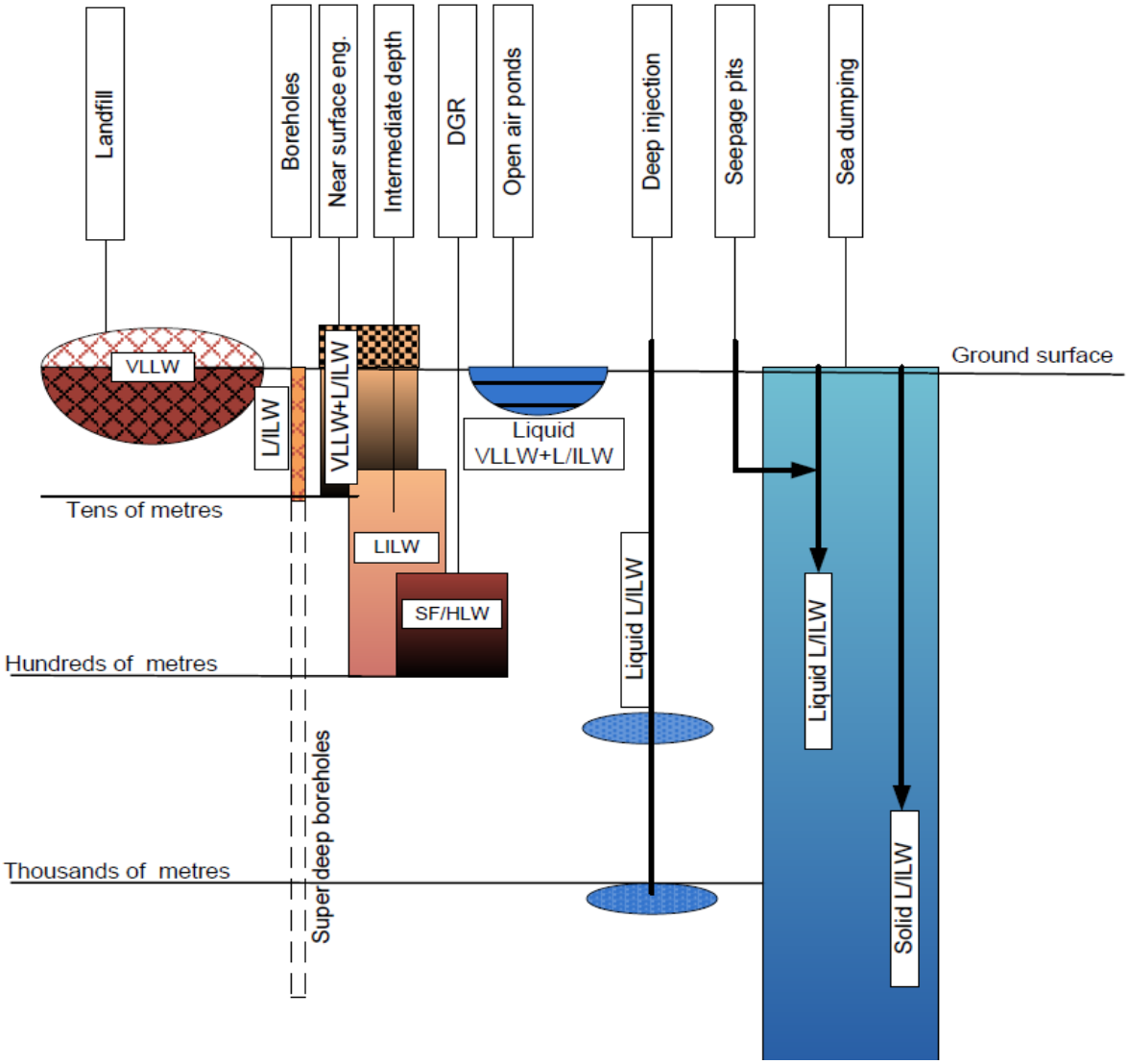




Possible Disposal Routes (6)

- Other types of disposal that have been used in the past or used locally include:
  - **Sea dumping** – practiced by a number of countries. Wastes were packaged and dropped into designated disposal zones in the Atlantic and Pacific oceans. Banned by international convention in 1975.
  - **Liquid injection** – practiced mainly by USA and Russia for radioactive liquids. Still in use in Russia for low and intermediate liquid radioactive wastes. Commonly used in US and elsewhere for non-nuclear wastes. Liquids are pumped under pressure into deep geological formations

Summary of Disposal Routes



EGIRM Disposal Route Arrangement

- All types of disposal facilities for SF and RW have several common features:
  - Position relative to the ground surface
  - Method of joining with the ground surface
  - Sophistication of engineered barriers
  - Whether heat generation needs to be considered
- These can be used to create a simplified classification scheme for disposal facilities, regardless of type of waste disposed
- Basis for scheme is documented in NEA report 7323 "*National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste - Methodology for Common Presentation of Data*"

EGIRM Disposal Route Arrangement (2)

Type of facility	Features	RW classes (in terms of GSG-1) that can be disposed	SSR-5 equivalent (1.14)
UF			
UF-1	- no direct, open connection with surface during construction or operation stage (i.e. ramp, shaft or borehole access); - intensive application of artificial barriers; - heat emission is considered in design; - package for SF/HLW/ILW – be sure.	SF; HLW; ILW; LLW; VLLW; (NORM; TENORM) – solid	Geological disposal
UF-2	- no direct, open connection with surface during construction or operation stage (i.e. ramp, shaft or borehole access); - rather wide application of artificial barriers; - heat emission is not considered in design; - package for ILW – be sure.	ILW; LLW; VLLW; (NORM; TENORM)	Disposal on intermediate depth + geological disposal + borehole disposal

EGIRM Disposal Route Arrangement (3)

Type of facility	Features	RW classes (in terms of GSG-1) that can be disposed of	SSR-5 equivalent (1.14)
NSF			
NSF-1	- open air at construction stage; sometimes also during operation; - rather wide application of artificial barriers; - heat emission is not considered in design;	ILW; LLW; VLLW; (NORM; TENORM)	Near-surface disposal + disposal on intermediate depth (particularly)
NSF - 2	- open air at construction stage; sometimes also during operation; - minimally reasonable application of artificial barriers; - heat emission is not considered in design; - Minimal packaging	LLW; VLW; (NORM; TENORM)	Near-surface disposal; Landfilling

EGIRM Disposal Route Arrangement (4)

Type of facility	Features	RW classes (in terms of GSG-1) that can be disposed of	SSR-5 equivalent (1.14)
NSF			
BH-1	- No direct, open connection with the surface during construction & operation stage; - No excavated underground space for RW emplacement; - Heat emission not considered in design; - Package for RW - possible	DSRS, ILW, LLW	Intermediate depth boreholes
BH-2	- No direct, open connection with the surface during construction & operation stage; - No excavated underground space for RW emplacement; - Heat emission is considered in design; - Package for RW - required	SF, HLW, DSRS (high activity)	Deep Boreholes
BH-3	- No direct, open connection with the surface during construction & operation stage; - Conditional application of artificial barriers (only around boreholes); - Heat emission is considered in design; - Package for RW – no package	Liquid ILW, LLW	No equivalent

EGIRM Disposal Route Arrangement (5)

Type of facility	Features	RW classes (in terms of GSG-1) that can be disposed of	SSR-5 equivalent (1.14)
NSF			
SDL	Past practice of disposal, now banned, performed as dumping of liquid RW into sea/ocean	Liquid LLW	Now banned
SDS	Past practice of disposal, now banned, performed as dumping of solid RW into sea/ocean	ILW, LLW	Now banned

Questions?