Radioactive Waste Classification; Source Categorization Waste Inventory

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Workshop on "Radioactive waste management – solutions for countries without nuclear power programme"
2 – 6 November 2015, ICTP, Miramare – Trieste, Italy

IAEA
Atoms for Peace: The First Half Century
1957–2007

Contents

- Understand the IAEA approaches to classification and categorization and know the difference between them
- Apply waste classification to some simple examples
- Describe the contents of a national register of sources and national waste inventory

Source Categorization

CATEGORIZATION OF SEALED SOURCES

- Current categorization system recommended by TECDOC1344 (2003) and this forms basis of safety guide RS-G-1.9 (2005)
  - Based on source's potential for causing deterministic health effects
  - Aims to inform risk-based decision making
  - Safety and security - allows for accidents, malicious use, orphan sources –eg emergency planning
  - Focus on sources used in industry, medicine, agriculture etc

APPROACH TO CATEGORIZATION

- Based on calculation of a “D” value – an activity value specific to a radionuclide, above which a source is determined to be ‘dangerous’ (TECDOC-953)
- Five dose calculations are performed; these include both internal and external exposure; the categorization uses whichever is most restrictive

DOSE CRITERIA FOR D VALUES

1. 1 Gy to bone marrow or 6 Gy to lung from low LET radiation received by the organ in 2 days (dose level at which intervention is always justified to prevent early deaths according to BSS)
2. 25 Gy to the lung from inhaled LET radiation in 1 year (dose that kills beagle dogs in <1.5 years)
3. 5 Gy to the thyroid received in 2 days (dose that justifies intervention according to BSS)
4. Source in contact with the body a dose of >25 Gy at a depth of (a) 2 cm for most parts of the body (eg in a pocket for 10 hours) or (b) 1 cm for the hand for one hour
5. For a source that is too big to carry, 1 Gy to the bone marrow in 100 hours from a source at 1 m.

DOSE CRITERIA FOR D VALUES

- 4th criterion
- For a source in contact with the body, a dose of >25 Gy at a depth of (a) 2 cm for most parts of the body (eg in a pocket for 10 hours) or (b) 1 cm for the hand for one hour
- This the external dose for death of tissue – it can normally be treated without significant loss of facility at depths cited but would affect subsequent quality of life
  - This criterion is the most limiting for Ra-226 and gives a D value of 1 Ci. Note that the gamma radiation does not come from the radium but from one of its daughters

SOME D VALUES

	TBq	Ci	
Co-60	3 E-02	0.8	gamma 1.3 MeV
Ra-226	4 E-02	1	gamma 0.6-3.3 MeV
Am-241	6 E-02	2	alpha
Cs-137	1E-01	3	gamma 0.66 MeV
Tc-99m	7 E-01	20	beta 0.29 MeV
I-129	?	?	beta 0.15 MeV
Ni-63	6 E+01	2000	beta 0.07 MeV

CATEGORIES

1. Activity / D >= 1000
2. 1000 > A/D >= 10
3. 10 > A/D >= 1

Code of Conduct applies

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4. 1 > A/D >= 0.01
5. 0.01 > A/D >= Exempt / D

Typical sources

Category 1

- Radioisotope thermoelectric generators (RTGs)
- Fixed, multi-beam teletherapy (gamma knife)
- Fatal if exposed for more than a few minutes

Category 2

- Industrial gamma radiography
- High/medium dose rate brachytherapy
- Possibly fatal for contact over hours to days

Categorization and disposal

For disposal we need to consider the hazards in four main phases

Storage

Operation

Categorization is a useful means of summarizing the hazards

Transport — **Ditto but has its own set of regs**

Post closure — **Longevity (1/2 life) and mobility are more useful**

Waste Classification

Purposes of a classification system

Provides essential input for national WM policy & strategy	**“how much waste do we have and what kind and size of waste management facilities do we need?”**
Well understood terminology aids communication	**“this is classed as LLW so the contact dose rate should be no more than …”**
Gives a broad indication of the potential hazards so that appropriate decisions to be made at each step of lifecycle management	**“can we to handle this waste manually or do we need to employ remote techniques?”**
Provides a systematic foundation for waste segregation and management programmes	**“we can keep all the LLW in storage facility “A” but some ILW will need more radiation shielding that “A” can provide”**
Indicates the disposal route for this waste	**“which disposal facility can accept this waste?”**
Efficient management system for operators	**“having a waste categorization system that covers all waste types means we don’t need to do things in an *ad hoc* or case by case way”**

Waste classification - System

Ideal classification system should:

- ***Cover all RW types***
- ***Address all stages of RW management***
- ***Relate RW classes to potential hazard***
- ***Be flexible***
- ***Not change accepted terminology***
- ***Be simple, easy to understand***
- ***Be universally applicable***

No such system exists!

Possible ways to classify

Waste can be classified by:

- **Origin**

  Nuclear fuel cycle, isotope production,..

- **Physical state**

  Solid, liquid, gaseous

- **Activity concentration**

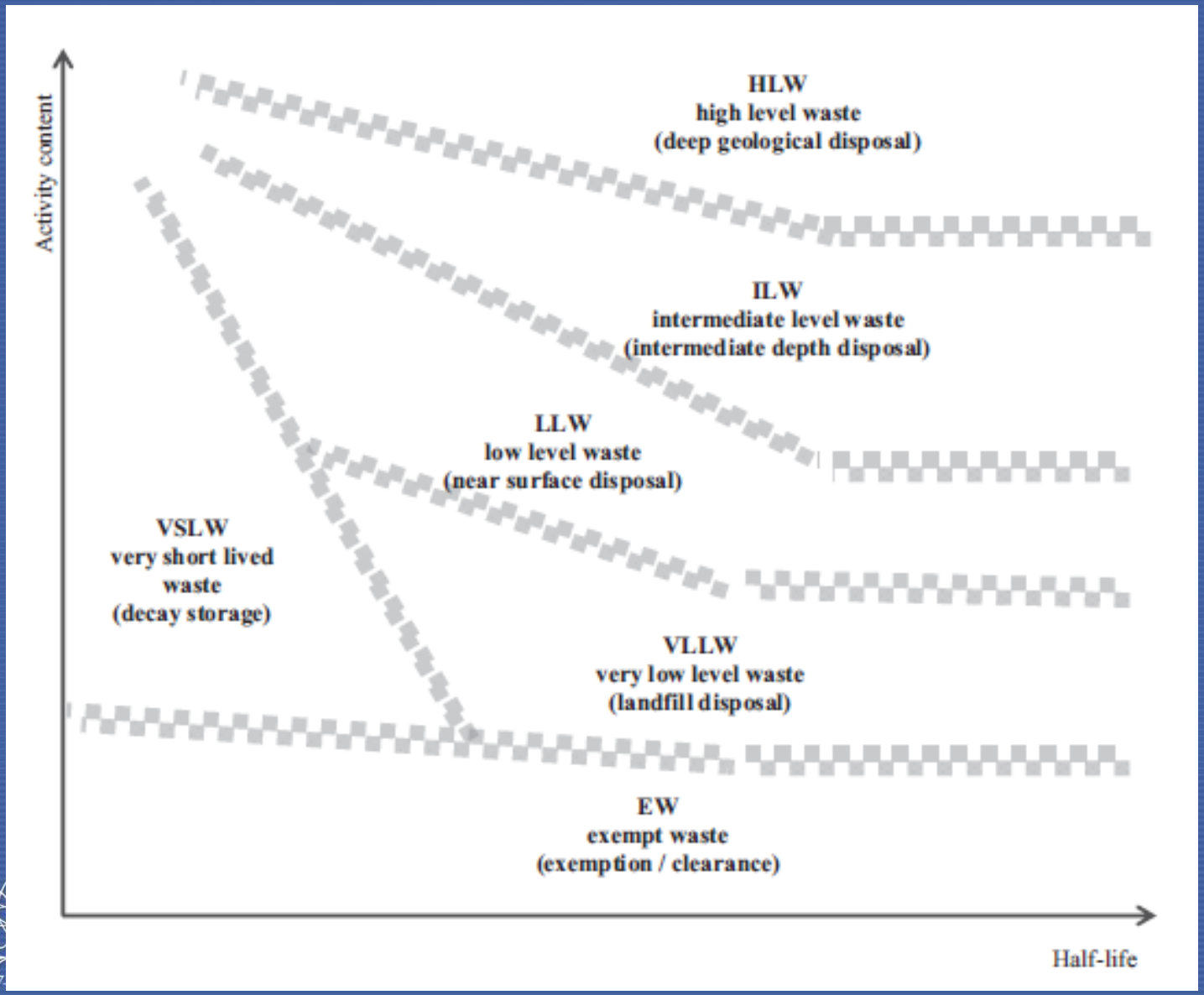
  Low Level Waste (LLW), Intermediate Level Waste (ILW), High level Waste (HLW)

- **Half-life**

  Short-lived waste, long-lived waste

IAEA classification

IAEA Conceptual Waste Classification System (2009)

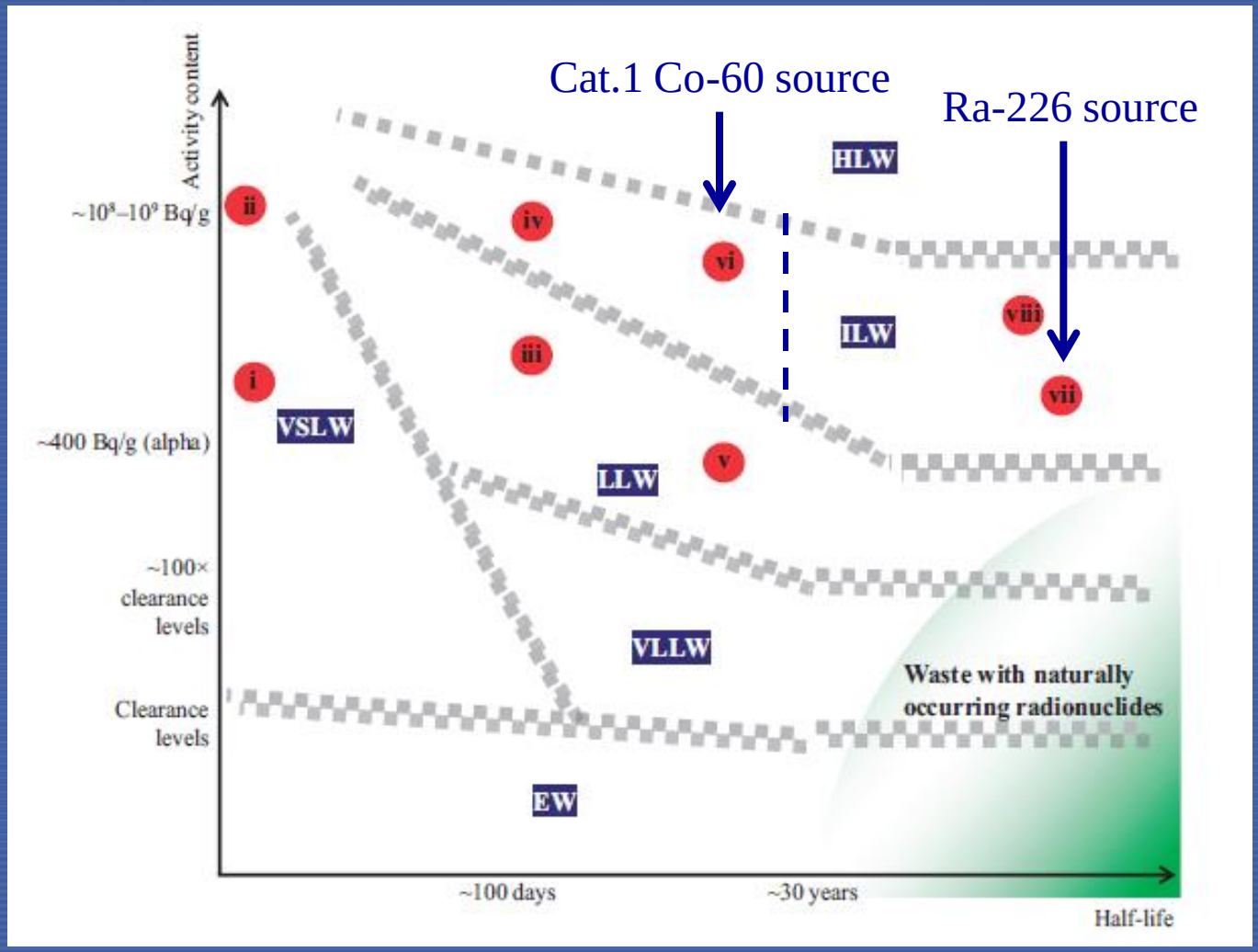


IAEA GSG-1 2009

Disused Sealed Sources

Example in Fig. III–1	Half-life	Activity	Volume	Example
i	<100 d	100 MBq	Small	Y-90, Au-198 (brachytherapy)
ii	<100 d	5 TBq	Small	Ir-192 (brachytherapy)
iii	<15 a	<10 MBq	Small	Co-60, H-3 (tritium targets), Kr-85
iv	<15 a	<100 TBq	Small	Co-60 (irradiators)
v	<30 a	<1 MBq	Small	Cs-137 (brachytherapy, moisture density detectors)
vi	<30 a	<1 PBq	Small	Cs-137 (irradiators) Sr-90 (thickness gauges, radioisotope thermoelectric generators (RTGs))
vii	>30 a	<40 MBq	Small, but may be large numbers of sources (up to tens of thousands)	Pu, Am, Ra (static eliminators)
viii	>30 a	<10 GBq		Am-241, Ra-226 (gauges)

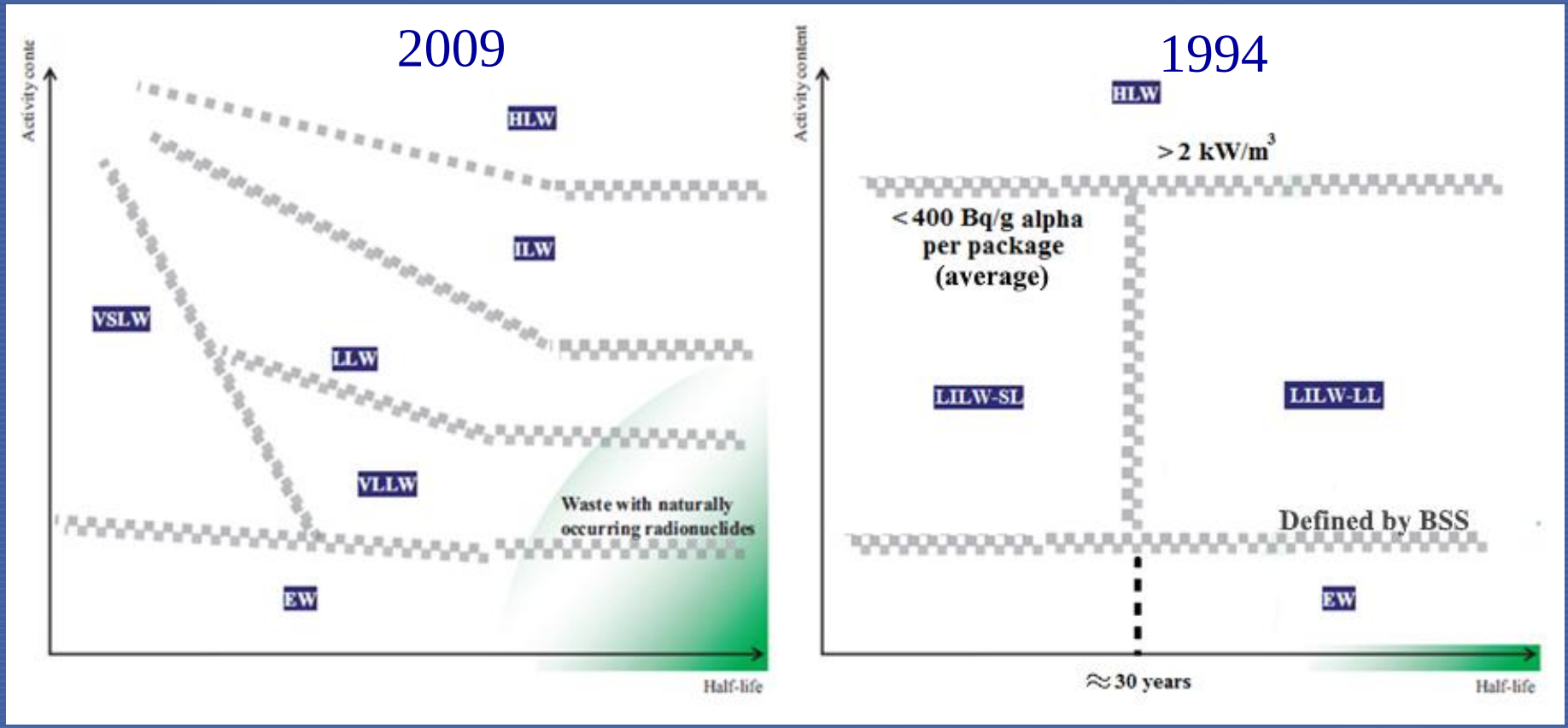
Disused Sealed Sources



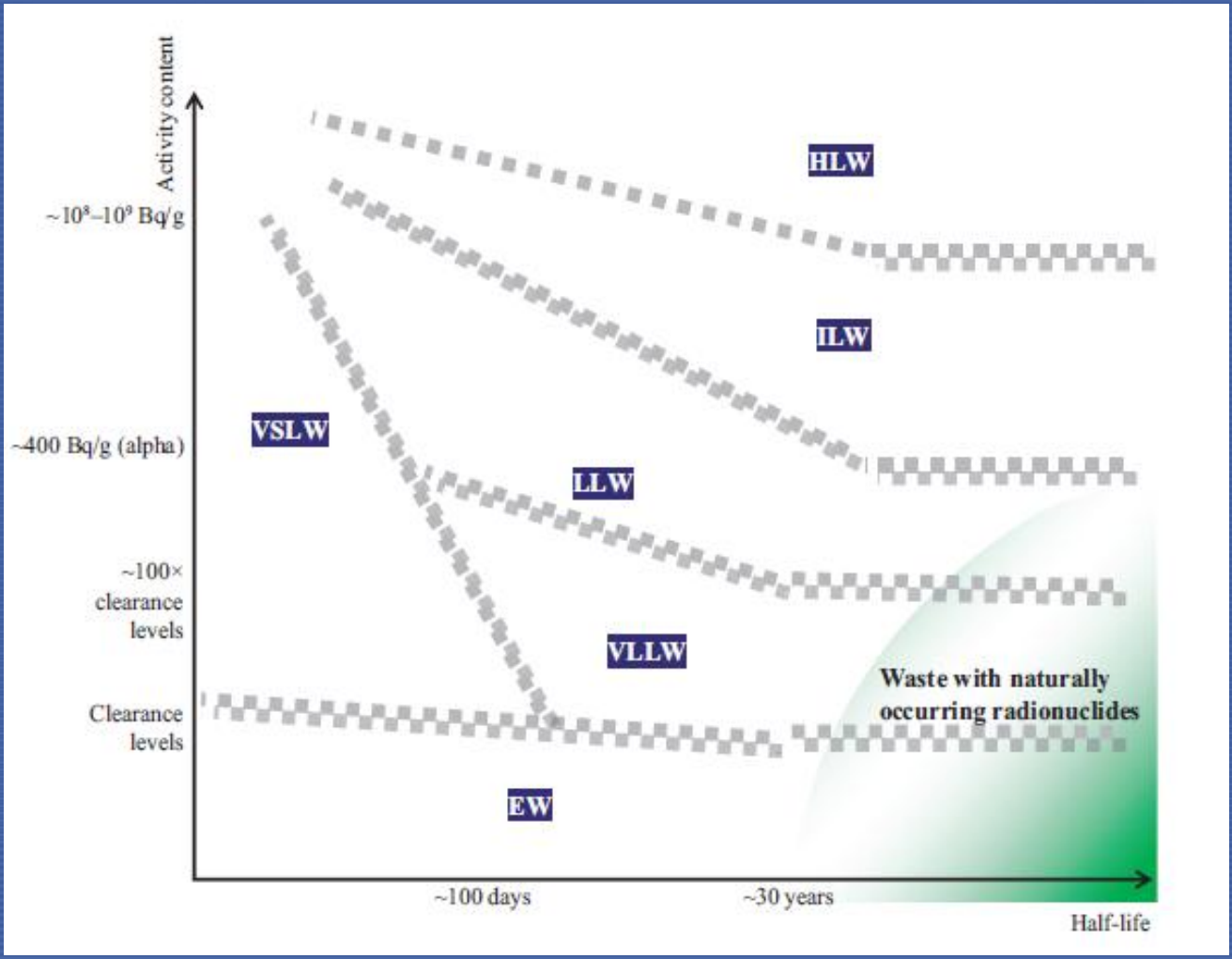
IAEA Waste Classification System (1994)

Waste Class	Typical Characteristics	Disposal Options
1. Exempt Waste (EW)	Activity levels at or below clearance levels, which are based on an annual dose to members of the public of less than 0.01 mSv	No radiological restrictions
2. Low and Intermediate Level Waste (LILW)	Activity levels above clearance levels and heat output less than about 2 kW/m^3	
2.1. Short-lived Waste (LILW-SL)	Restricted long-lived radionuclide concentrations (limitation of long-lived alpha emitting radionuclides to 4,000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package)	Near surface or geological disposal
2.2. Long-lived Waste (LILW-LL)	Long-lived radionuclide concentrations exceeding those for short-lived waste	Geological disposal facility
3. High Level Waste	Thermal power above about $2kW/m^3$ and long-lived radionuclide concentrations exceeding the limitations for short-lived waste	Geological disposal facility

Comparison of IAEA 1994 and 2009 Schemes



IAEA Conceptual Scheme (2009) with Numbers



Classification as Practiced

- Many member states use their own system, customized to fit local needs.
- **Disposal endpoint is what is most commonly used to define waste classes (as recommended by IAEA system).**
- As part of Joint Convention, each country reports on national system of waste classification and reports a national inventory of radioactive waste.

Classification Systems versus Waste Acceptance Criteria

Difference between waste acceptance criteria (WAC) and a waste classification system?

- **WAC – are specific to a particular storage or disposal facility.**
- **Waste classification systems – provide a national system of classification for managing all types of radioactive waste. Do not specify criteria for individual facilities.**
- **WAC provide detailed specifications regarding waste properties (e.g. weight of a waste package) that waste must meet before it can be accepted at a particular storage or disposal facility.**

Disused Sealed Sources

- Disused sealed sources were not factored into the 1994 radwaste classification system but they are covered by the current (2009) system.
- RS-G-1.9 Categorization of Radioactive Sources Safety Guide (2005) provides an indicator of the immediate hazard (mostly the gamma field) posed by the source
- GSG-1 (Classification of RW) does help

Register of sources and waste inventory

Register of Sources

Normally kept and maintained by the regulatory body
Will certainly include sources of Cats 1-3, possibly Cats 4&5 also. Would expect it to specify

- **Name and address of owner**
- **Place where normally kept**
- **Contact person (RPO) and contact details**
- **Type of source, manufacturer/ vendor**
- **Activity at date, radionuclide**
- **Arrangements for return to vendor**
- **Date of return or handover to WMO**
- **etc**

Inventory of waste

Normally kept and maintained by the WMO. Subject to inspection by the regulatory body

Will usually specify inter alia

- **Name and address of owner**
- **Physical, chemical, biological & radiological properties**
- **Volume and mass**
- **Source of the waste**
- **Intended method of disposal**
- **Processing carried out to date**
- **Current storage arrangements**
- **Intended further processing before storage or disposal**
- **Expected volume and mass after further processing**
- **Package details (if packaged – standard packages only)**

Should include (under separate heading) committed waste

See *www.nda.gov.uk/ukinventory* and *www.andra.fr*

Examples of national classification schemes

National RW classification scheme - France

Category	Disposal
High level	Deep*
Intermediate level long-lived (>31 years half life)	Deep*
Low level, long lived (>31 years)	Intermediate depth *
Low level and intermediate level short lived (<31 years)	Near surface, engineered
Very low level	Near-surface, low engineered
Very short-lived (<100 days)	Decay storage

*Under investigation

Commercial RW classification - USA

Table B-1 U.S. Commercial Radioactive Waste Classification

Waste Class	Description
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.[23]
Class A LLW	Class A waste is determined by characteristics listed in 10 CFR 55(a)(2)(i) and physical form requirements in 10 CFR 61.56(a). (U.S. does not have a minimum threshold for Class A waste).
Class B LLW	Waste that must meet more rigorous requirements on waste form than class A waste to ensure stability.
Class C LLW	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.
GTCC LLW	LLW not generally acceptable for near-surface disposal.
AEA Section 11e.(2) Byproduct Material	Tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by such solution extraction operations do not constitute "byproduct material" within this definition.[24]

Government (DOE) RW classification - USA

High level
TRU
LLW
U mine tailings
Residual materials (ex-military)

Spent nuclear fuel considered to be a resource, not a waste

National RW classification scheme - Belgium

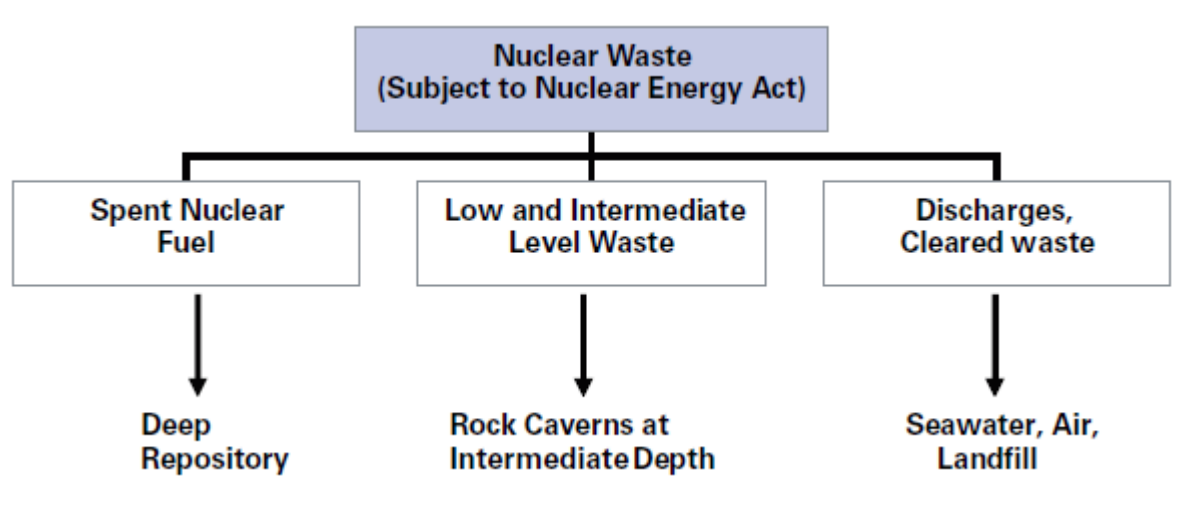
Three RW categories

- A RW suitable for surface disposal
- B RW unsuitable for surface disposal but not heat generating
- C Heat generating

Broad comparison with IAEA 2009

	Low-level activity	Medium-level activity	High-level activity
Short-lived waste	A	A	C
Long-lived waste	B	B	C

National RW classification scheme - Finland



Spent nuclear fuel = HLW

LILW divided into

- ILW requires special radiation protection (shielding) when handling
- LLW requires no special radiation protection measures

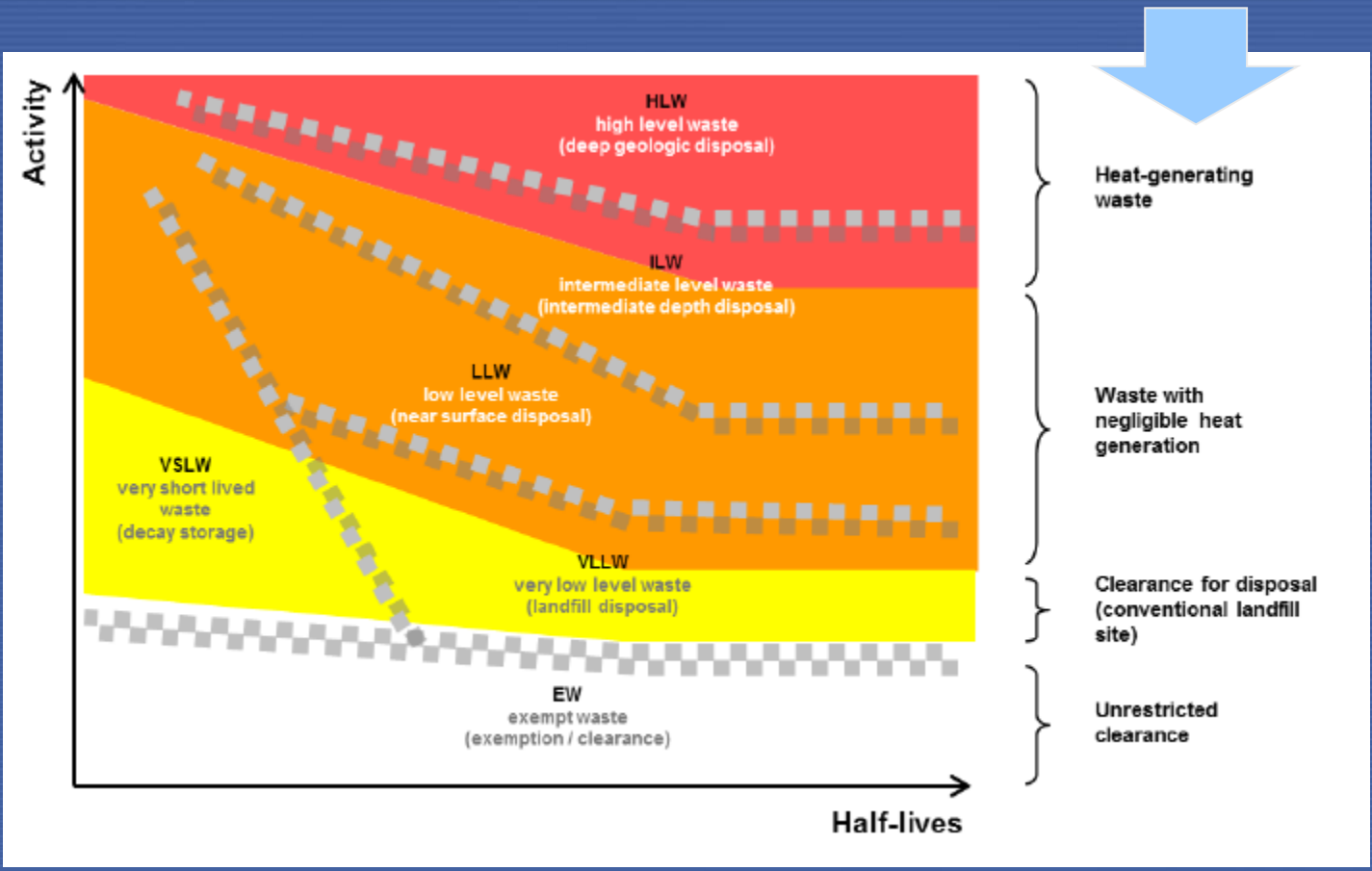
Further division of LILW into short- and long-lived based on calculated specific activity at 500 years

Clearance criteria established based on trivial dose

National RW classification scheme - Japan

Classification			Example
High Level Waste			Vitrified fission products
LLW	Waste from power reactors	Waste of core structure	Control rods, core structure
		LLW	Liquid waste, filters, used equipment etc
		VLLW	Concrete, metals
	Long-lived low heat (TRU)		Fuel element parts, filters etc
	Uranium waste		Expendables, Sludge etc
	Waste from research facilities		Liquids, concrete, plastics, filters etc
Below clearance level – treated as non-radioactive			

National RW classification scheme - Germany



Correspondence between German system of RW classification (arrowed) and IAEA 2009

Long-lived reprocessing wastes such as fuel element components

Country	Name
Belgium	Type B
Finland	Does not exist (no reprocessing)
France	ILW-LL
Germany	Non-heat generating waste
Japan	Long-lived, low-heat (TRU)
USA	LLW (Greater than Class C) or TRU if contaminated with alpha radionuclides

Conclusion

- Categorization relates to safety and security of radioactive sources. It is not intended to be applied to waste management
- Waste classification schemes are nationally- based.
- IAEA has a conceptual scheme, devised in 2009, that serves as a model. It is based on activity level and half life and is focussed on likely disposal routes. It provides no definitive numbers
- Some countries continue to base their classification scheme on the simpler 1994 IAEA scheme. This provides fewer waste categories
- The more recent scheme is more amenable to disposal of disused sealed sources
- Member states are expected to keep a register of sources in use and an inventory of waste