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Characteristics and Classification of Radioactive Materials and Wastes

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Very Broad Differences in Properties

- **Activities:**
  - < 1 mCi (10^{-3}) to
  - > 1 KCi (10^{3})
- **Radiation:**
  - Alpha
  - Beta
  - Gamma radiation
  - Neutrons
- **Form**
  - Solid metal (cobalt-60)
  - Dispersible and water soluble (cesium-137, radium-226)

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Very Broad Differences in Hazard

- Almost harmless consumer products to
- Very powerful sources of ionizing radiation
- Very mildly contaminated soil
- Liquid waste with Cs-137, Sr-90
- Activated metal

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Harmless

Low-activity check source

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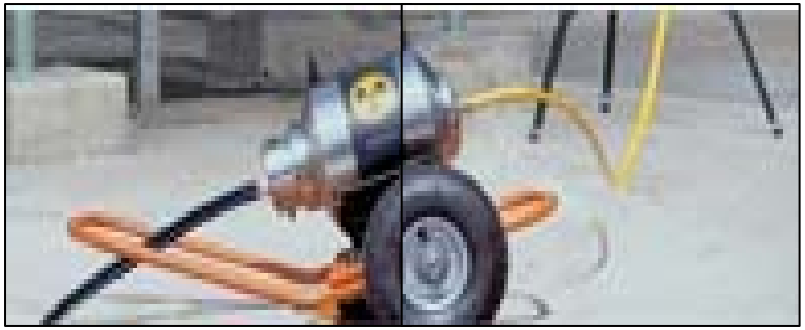
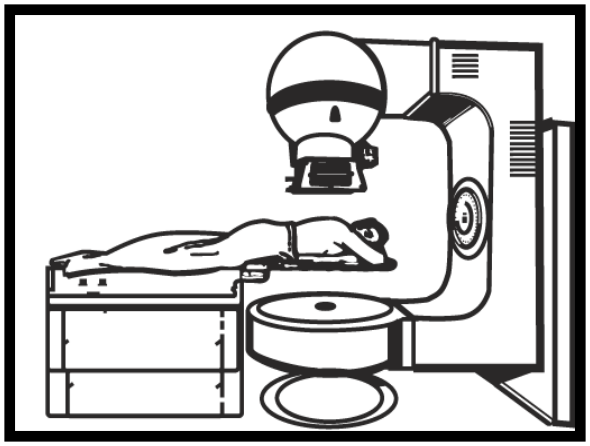
Powerful and In Use



~ 30 Ci Ir-192

Very Powerful and In Use



~ 1 KCi Co-60 or
Cs-137 Teletherapy

14 KCi Co-60
Irradiator “Pencil”

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Needed: Systems of Categorization

- Worker and public safety measures
- Security measures
- Waste storage and disposal

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Safety and Security Categorization

- **Safety classification ~ = security classification**
- **Categorization system allows graded approach where level of control is easily matched to the hazard**

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Disposal Categorization

- Categorization system allows graded approach to waste storage
- Categorization system allows graded approach to waste disposal
- Allows planning for storage and disposal facilities
- Allows design of storage and disposal systems

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Describe 3 Categorization Systems

- Safety & Security Measures - IAEA TECDOC 1344
- Waste Storage and Disposal - U.S. NRC 10 CFR 61
- Waste Storage and Disposal - IAEA DSG 390

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IAEA-TECDOC-1344

Categorization of radioactive sources

Revision of IAEA-TECDOC-1191, Categorization of radiation sources

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

July 2003

IAEA Approach to Categorization for Worker Safety and Security TECDOC-1344

- **Only two factors:**
  - **How dangerous is the material (D)**
  - **How much material is there (A)**
- **D-value was developed based on health consequences from two scenarios:**
  - **Unshielded source carried in pocket or stored in room**
  - **Dispersal by fire or explosion**
- **A-value is the activity**

IAEA Approach to Categorization

- Categorization depends on A/D
- Five Categories
- Category 1 SRS will cause death after exposure of only a few minutes to unshielded SRS
- Category 5 SRS not hazardous
- For example:

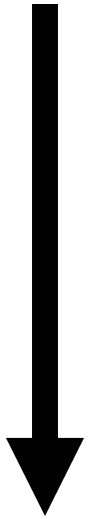
  1 < A/D < 10, then Category 3

Categorization Summary

TABLE 1. Categorization table

Category	Categorization of common practices[a]	Activity ratio[b] (A/D)
1	Radioisotope thermoelectric generators (RTGs) Irradiators Teletherapy Fixed, multi-beam teletherapy (gamma knife)	$A/D \geq 1000$
2	Industrial gamma radiography High/medium dose rate brachytherapy	$1000 > A/D \geq 10$
3	Fixed industrial gauges -level gauges -dredger gauges -conveyor gauges containing high activity sources -spinning pipe gauges Well logging gauges	$10 > A/D \geq 1$
4	Low dose rate brachytherapy (except eye plaques and permanent implant sources) Thickness/fill-level gauges Portable gauges (e.g. moisture/density gauges) Bone densitometers Static eliminators	$1 > A/D \geq 0.01$
5	Low dose rate brachytherapy eye plaques and permanent implant sources X ray fluorescence devices Electron capture devices Mossbauer spectrometry Positron Emission Tomography (PET) checking	$0.01 > A/D \geq Exempt^{c}/D$

MOST HAZARDOUS



LEAST HAZARDOUS

Example: Category 2 sealed sources

Individual sources are considered *personally very dangerous*.

- Could cause permanent injury (in minutes to hours) or death (in hours to days) if not safely managed.

Industrial Gamma Radiography

Brachytherapy
(High and Medium Dose Rate)

Example: Category 5 Sealed Sources

Individual sources are *not dangerous*.

- No one could be permanently injured by this material.

Lightning Preventers

Low dose brachytherapy eye plaques and permanent implant sources

X-Ray fluorescence devices

Tritium lights in wrist watches

U.S. Categorization of Radioactive Waste

- **Below is an over simplification**
- **“Commercial Waste” regulated by US Nuclear Regulatory Commission (NRC) and US Environmental Protection Agency.**
  - Spent Nuclear Fuel (SNF)
  - High-Level Radioactive Waste (HLW)
  - Low-level Radioactive Waste (LLW)
  - Uranium Mill Tailings
- **“Defense Waste” regulated by US Dept of Energy**
  - LLW
  - Transuranic Waste (TRU)
  - 11(e)2 Byproduct Material (similar to uranium mill tailings)

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U.S. 10 Code of Federal Regulations Part 61 (10 CFR 61)

Licensing Requirements For Land Disposal Of Radioactive Waste

Subpart A--General Provisions

§ 61.1 Purpose and scope.

(a) The regulations in this part establish, for land ***disposal of radioactive waste*****,** the procedures, criteria, and terms and conditions upon which the Commission issues licenses for the disposal of radioactive wastes containing byproduct, source and special nuclear material received from other persons.

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10 CFR 61 Regulatory Foundation For Licensing LLW Disposal Facilities

Three Performance Objectives to insure long-term protection of human health:

1) **Protection of the member of the general public from LLWs that may migrate from the LLW disposal system**
2) **Protection of individuals that may inadvertent intrude into buried LLWs or occupies the site after active controls are removed**
3) **Stability of the site after closure without the need for ongoing active maintenance**

→ **A safe LLW disposal facility in America must be certified (licensed) to do these 3 things**

Without the Need for Active Maintenance

3. Stability of the site after closure without the need for ongoing active maintenance

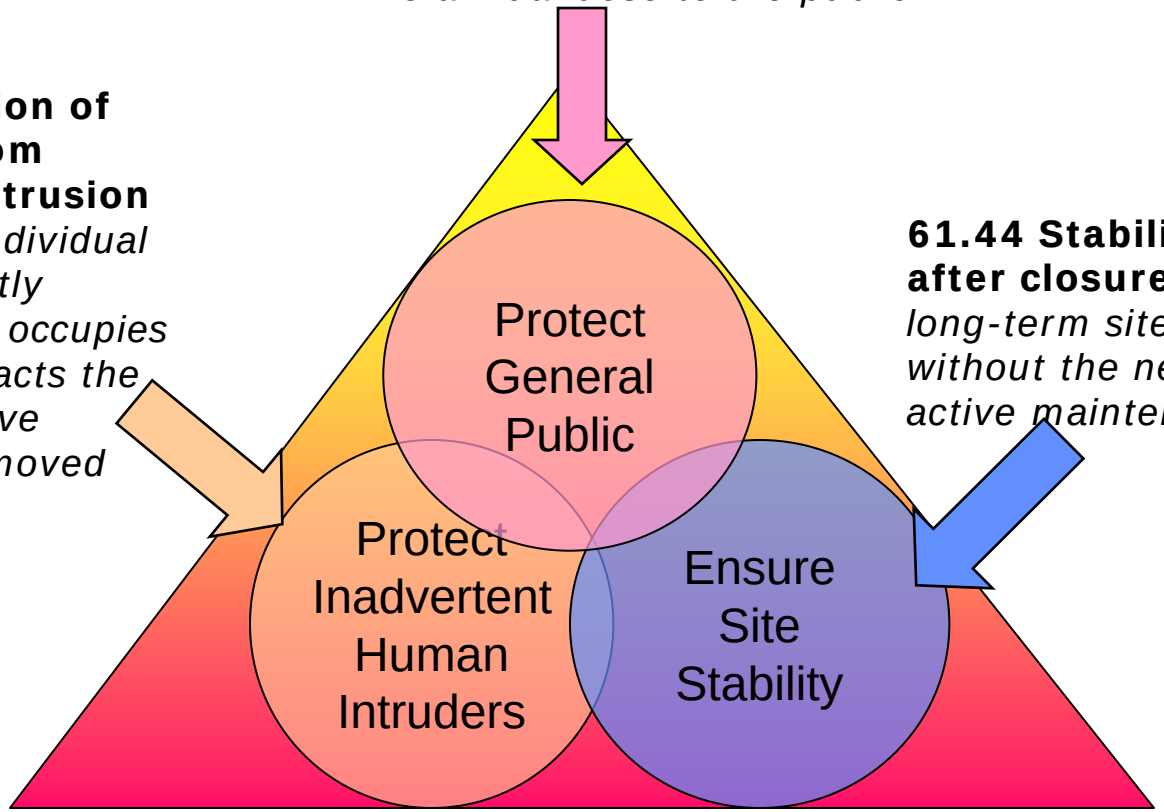
Some designs require active maintenance (e.g., trenches with impermeable liner requires monitoring and possible pumping) – the US NRC prefers designs that perform without ongoing maintenance

10 CFR 61 Post-closure Performance Objectives

61.41 Protection of the general population from radioactive releases – *Limits radioactivity releases to the general environment to minimize annual dose to the public*

61.42 Protection of individuals from inadvertent intrusion – *Protect any individual who inadvertently intrudes into or occupies the site or contacts the waste after active controls are removed*

61.44 Stability of the site after closure – *Achieve long-term site stability without the need for ongoing active maintenance*



Inadvertent Human Intruder

- **“A person who might occupy the disposal site after closure and engage in normal activities such as agriculture, dwelling construction, or other pursuits in which the person might be unknowingly exposed to radiation from the waste”. (10 CFR 61.2)**

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Inadvertent Human Intruder Protected by Waste Classification System

- NRC decided to protect IHI by developing a generic set of waste classes
- Class A, B, C, and Greater-Than-Class-C
- Independent of site-specific characteristics
- Graded Approach
  - Low hazard = low cost requirements
  - High hazard = high cost strict requirements

Low-level Waste Classification System

NRC Category	Description	Disposal Method
Class A	**Least hazardous – short & long-lived waste that will not endanger inadvertent human intruder beyond 100 years**	**Near-Surface**
Class B	**More hazardous – short-lived wastes that will not endanger inadvertent intruder beyond 100 years**	**Near-Surface with 300 year waste stability**
Class C	**More hazardous – short and long-lived wastes that will not endanger inadvertent intruder beyond 500 years**	**Near-Surface with 300 year waste stability, and greater depth or 500 year intruder barrier**
Greater-Than-Class C	**Most hazardous of LLW - dangerous to intruder beyond 500 years. Not typically appropriate for near-surface disposal**	**To be determined by DOE** **Similar to ILW in IAEA's system**

Low-level Waste Classification System

- **Above these boundaries, typically inappropriate for near surface disposal (called GTCC LLW, 10 CFR Part 61.55)**

Nuclide (half-life)	>Concentration
Table 1 Long-lived Radionuclides	
	(curies/m^3)
Carbon-14 (5,730yrs)	8
Carbon-14 in activated metal (5,730 yrs)	80
Nickel-59 in activated metal (75,000 yrs)	220
Niobium-94 in activated metal (20,000 yrs)	0.2
Technetium-99 (214,000 yrs)	3
Iodine-129 (16,000,000 yrs)	0.08
	(nanocuries/gram)
Alpha-emitting transuranics (half-life greater than 5 yrs)	100
Plutonium-241 (14 yrs)	3,500
Curium-242 (162.8 days)	20,000
Table 2 Short-lived Radionuclides	
	(curies/m^3)
Nickel-63 (100 yrs)	700
Nickel-63 in activated metal (100 yrs)	7,000
Strontium-90 (29 yrs)	7,000
Cesium-137 (30 yrs)	4,600

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"Near-Surface" Disposal

- **When the 3 performance objectives are met, Class A, B and C wastes are appropriate for *near-surface* disposal**
- **Greater than Class C is similar to IAEA's ILW and not typically appropriate for near surface disposal**
- **The NRC defines near surface disposal as disposal within 30 m of the lands surface**

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DS390
2006-07-03

IAEA SAFETY STANDARDS SERIES

for protecting people and the environment

Status: For review by Member States
Comments due 30 November 2006

Classification of Radioactive Waste

DRAFT SAFETY GUIDE No. DS 390

IAEA
International Atomic Energy Agency

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IAEA's Waste Classification System Draft Safety Guide DS-390

- To help member states develop their own classification system
- Based on long-term safety
- How much isolation is needed, and for how long
- Standards for naturally occurring nuclides and mining wastes may be different from standards for wastes from nuclear facilities
- Not a substitute for a site-specific safety assessment

IAEA's Waste Classification System
Draft Safety Guide DS-390

- Activity and half-life are primary factors in classification, with other modifying factors
- < 30 year half-life is short-lived
- > 30 year half-life is long-lived
- Classification assumes 300 years of institutional controls
- To repeat: Not a substitute for a site-specific safety assessment

IAEA's Waste Classification System

1. Exempt from regulation
2. Decay in storage, VSLW (e.g., Ir-192)
3. Disposal in engineered landfill-like facilities, VLLW
4. Disposal in engineered near surface facilities such as trenches, LLW
5. Disposal in intermediate-depth facilities including boreholes, ILW
6. Disposal in deep, inert geologic formations, HLW

IAEA's Waste Classification System Boundaries between classes

1. **Exempt, < 10 μSv / year**
2. **VSLW, decays to exempt in 10's years**
3. **VLLW, < 10 x or < 100 x the exemption level**
4. **LLW, no shielding for normal handling, < 2 mSv/hr contact dose**
5. **ILW, > 2 mSv/hr contact dose (in some countries, >400 Bq/g long-lived alpha maybe ILW independent of contact dose)**

Notes on IAEA's Waste Class System Boundaries between classes

4. LLW, no shielding for normal handling, < 2 mSv/hr contact dose*
5. ILW, > 2 mSv/hr contact dose (in some countries, >400 Bq/g long-lived alpha maybe ILW independent of contact dose**)

*not consistent with U.S. practice, for example a few curies Co-60 would be ILW in IAEA's system, but is LLW in U.S. system

** consistent with US practice, which does give special consideration to long-lived alpha wastes

IAEA's DS390 Waste Classification System
Typical Disposal Options

1. **VLLW - disposal in engineered landfill-like facilities**
2. **LLW - disposal in engineered near surface facilities such as trenches (< 10 m deep)**
3. **ILW - disposal in intermediate-depth facilities including boreholes (10's to 100's m)**

To repeat: Not a substitute for a site-specific safety assessment

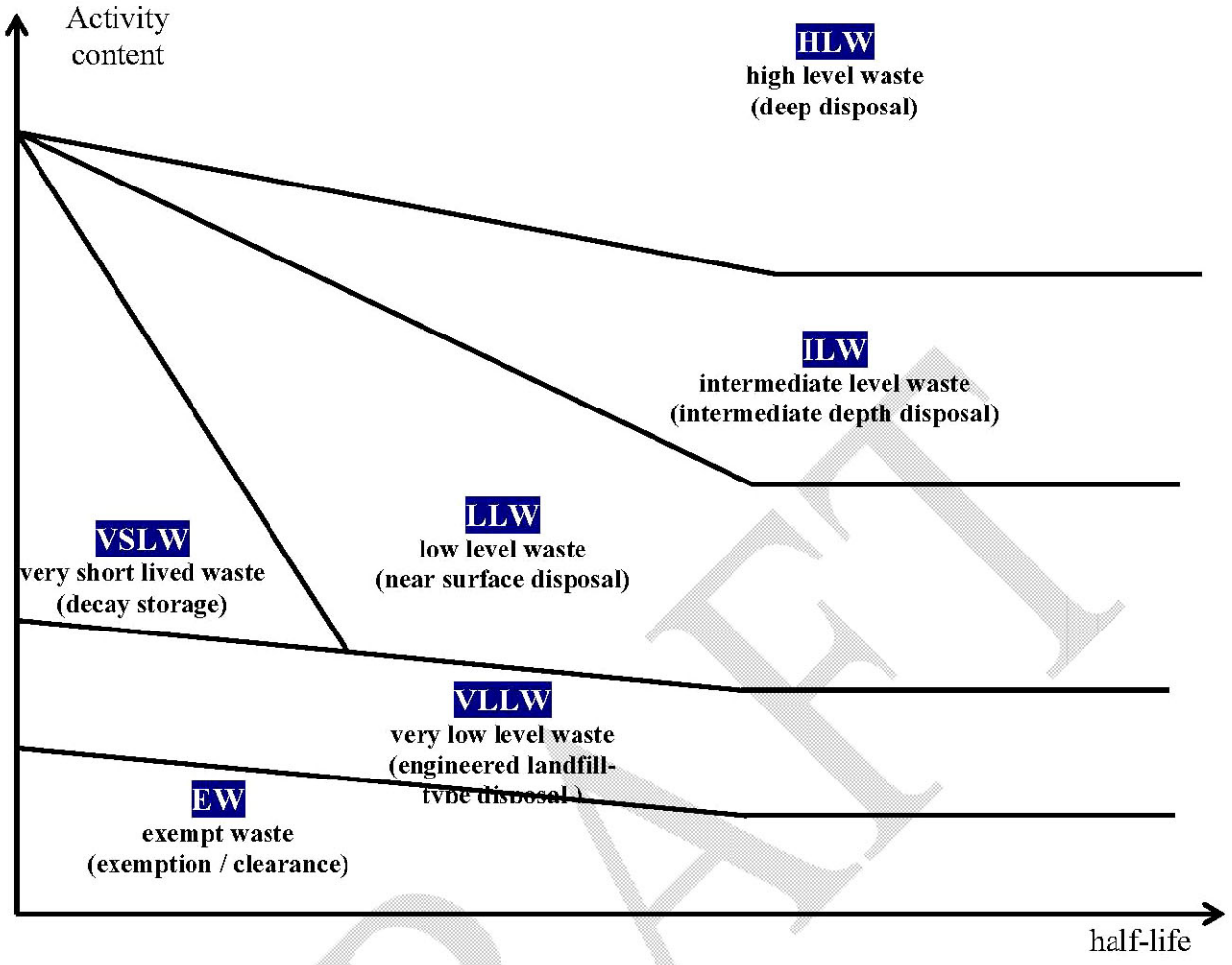

FIG. 1. Revised waste classification scheme.

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Summary

- **Radioactive materials and wastes vary greatly in activity, form and type of ionizing radiation and hazard**
- **Categorization allows graded approach for safety, security, and disposal**
- **Reviewed three categorization systems**
  - One for safety and security for materials in-use
  - Two systems for wastes