Radioactive and Hazardous Wastes: An Overview

"My anxiety was to gain real knowledge of the earth."

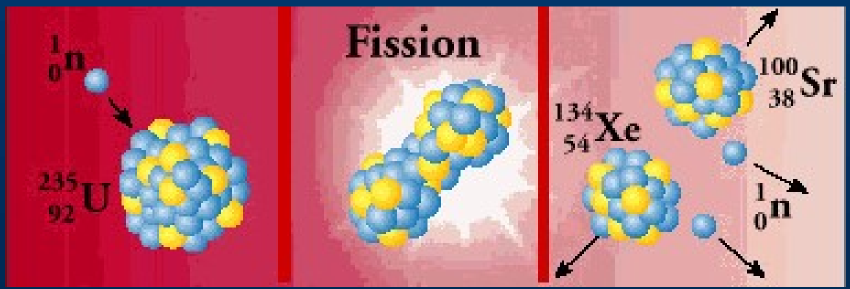
—Henry Lawson in "Journey to the Center of the Earth" by Jules Verne.

Wastes Types in the U.S.

Regulator/source	Waste category
U.S. Nuclear Regulatory Commission (U.S. NRC)	Used/spent nuclear fuel Low-Level Radioactive Waste
U.S. Department of Energy (U.S. DOE)	Legacy Wastes which can include: High-Level Radioactive Waste Transuranic Waste Low-Level Radioactive Waste
U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.	Exempt Source Material Special Nuclear Material Mixed Waste (Mixed Radiological and Hazardous Waste) Low-Activity Radioactive Waste

Used Nuclear Fuel

During the fission of UO_2, ^{235}U is reduced from about 3% to 1%. ^{238}U from 97 to 94%. About a third of the fuel must be replaced with fresh fuel every 18 to 24 months. The spent or used fuel must then be disposed. Fission products include zinc through the lanthanides.



Used Nuclear Fuel: fission products

$$^{235}U_{92} + {}^{1}\eta_{0} \rightarrow {}^{236}U_{92} \rightarrow$$

$$^{A}X_{Z} + \eta_{0} + Q$$

where X can be about 35+ different elements from zinc (Z = 30) to terbium (Z = 65), A (mass) can range from 95 to 140 amu.

Q is about 200 MeV (megaelectron-volts) per fission.

Formation of Pu-239

$^{238}U_{92} + {}^{1}\eta_{0} \rightarrow {}^{239}U_{92}$

$^{239}U_{92} \rightarrow {}^{239}Np_{93} + \beta^{-}$ (a neutron becomes a proton)

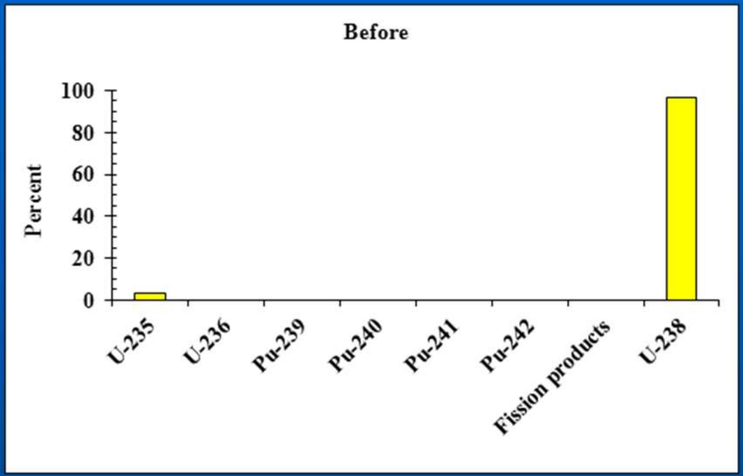
Half-life of 23.5 minutes.

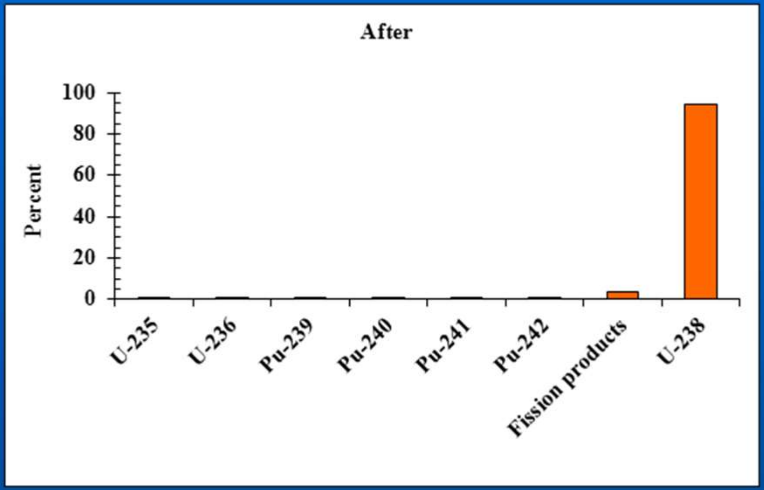
$^{239}Np_{93} \rightarrow {}^{239}Pu_{94} + \beta^{-}$

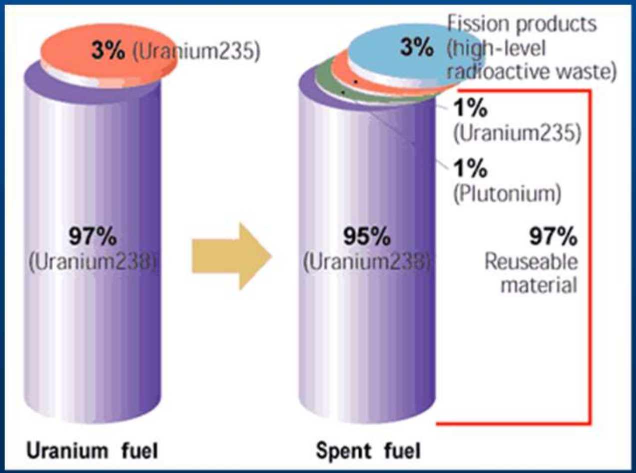
Half-life of 2.36 days.

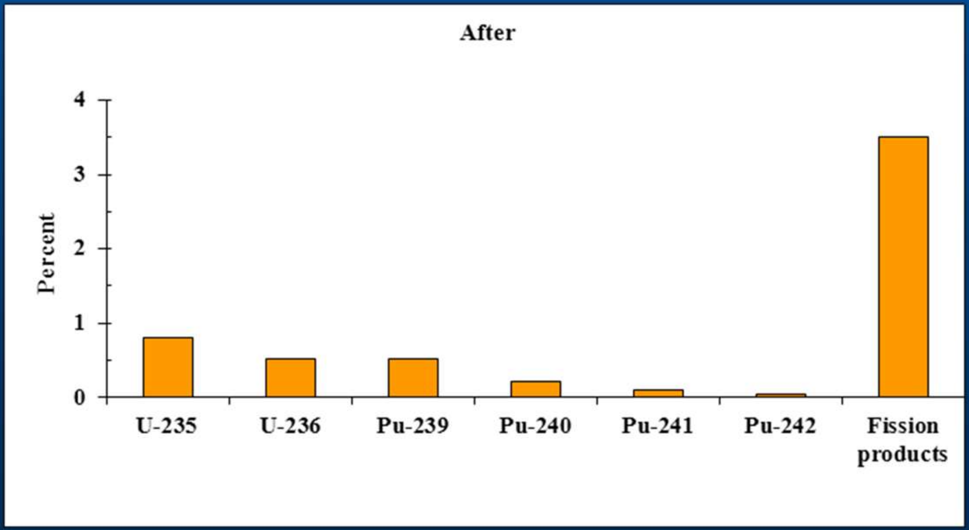
Then $^{239}Pu_{94}$ has a half-life of 24,110 years (24.1 Ka).

Composition of fresh and UNF









U.S. NRC Waste Classification

Low-Level Radioactive Wastes (LLRW or LLW)

A broad category of solids, liquids and gases that can contain mixtures of radionuclides that are by-products from several sources.

Wastes from nuclear plant operations and maintenance, industrial sources, medical applications, agriculture, environmental, pharmaceutical, and from site remediation and decommissioning projects.

Liquids	**Chemical waste solutions, decontamination fluids, liquid-scintillation fluids, and contaminated oil.**	
Wet solids	**Evaporator residues, spent ion-exchange media, spent filters.**	
Solids (dry active wastes)		
Compactible	**Non-compactible**	
Plastics: Coveralls, protective suits, gloves, hats, bags, bottles. Paper: Adsorbent paper, cartons. Absorbents: Vermiculite, bentonite. Cloth: Coveralls, laboratory coats, rags, gloves. Rubber: Boots, hoses, gloves. Wood: Construction lumber, plywood packing. Metals: Paint cans, aerosol cans. Glass: Bottles, laboratory glassware, faceplates. Filters: Air filters, respiratory canisters.	**Metals: Small tools, filter frames. Wood: Construction lumber, plywood packing. Conduit: Tubing, cable, wire, electrical fittings, pipes, valves. Concrete debris. Floor sweepings, contaminated soil. Glass: Lab glassware, instrument tubing. Lead: Shielding material.**	

Low-Level Radioactive Wastes

Radionuclides in LLRW

Neutron activation products.

Stable elements in reactor components, cooling water, non-reactor components that are made radioactive by absorbing neutrons.

Examples of activation products:

cobalt-60 $^{60}Co_{27} \rightarrow {}^{60}Ni_{28} + e^{-} + \gamma$ **(5.3 years)**

iron-55 $^{55}Fe_{26} + e^{-} \rightarrow {}^{55}Mn_{25} + \gamma$ **(2.7 years)**

Radionuclides in LLRW

carbon-14 ($^{14}C_6$) $^{14}C_6 \rightarrow {}^{14}Na_7 + e^-$ (5,700 years) [5.7 ka]

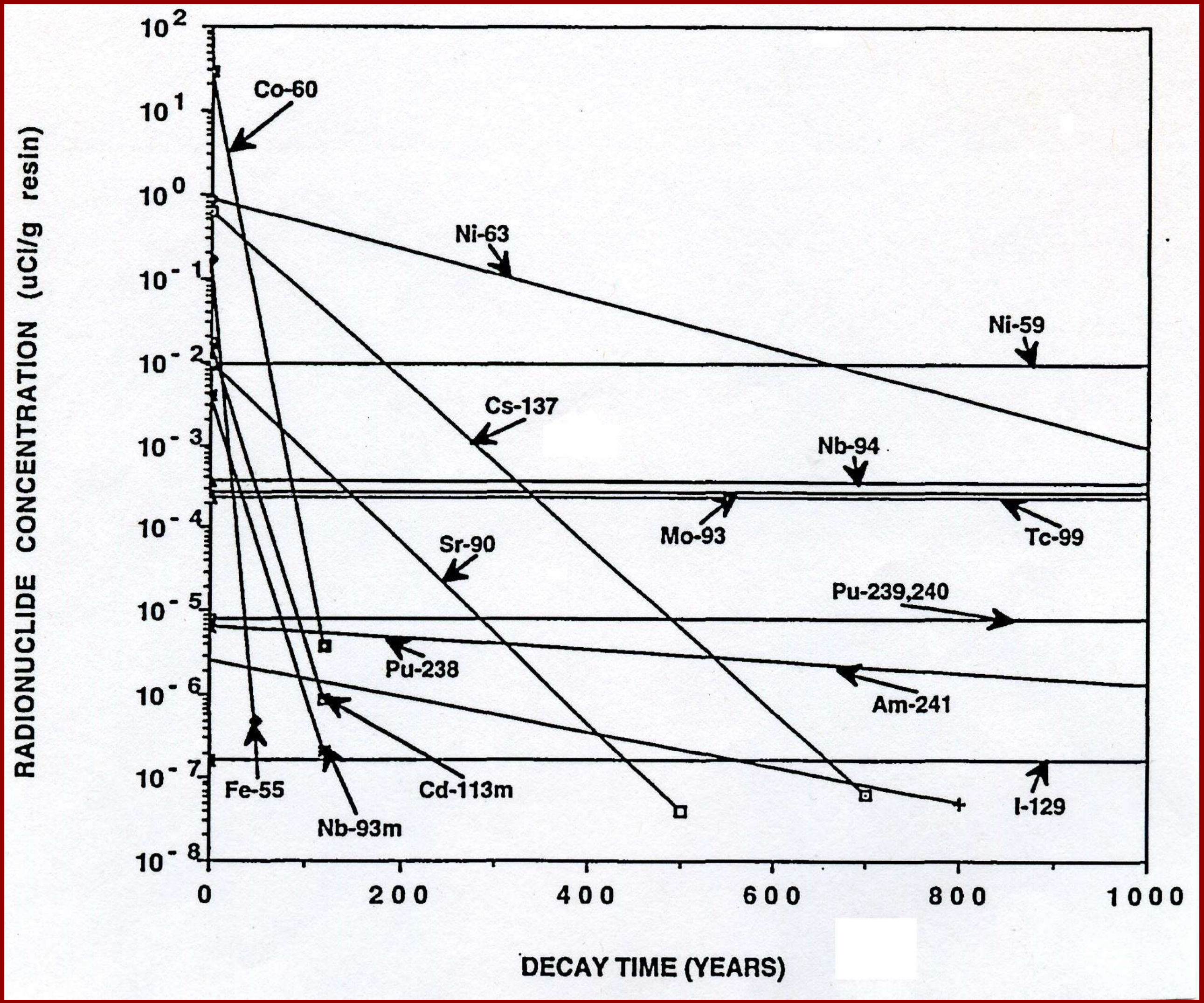
lead-205 ($^{205}Pb_{82}$) $^{205}Pb_{82}$ + e- $\rightarrow$ $^{205}Tl_{81}$ (thallium) (1.7 x 10^7 years) [17 Ma]

tritium ($^3H_1$) from boron in the cooling water via neutron capture:

$$^{10}B_5 + \eta \rightarrow [^{11}B_5] \rightarrow {}^3H_1 + 2(^4He_2)$$

$$t_{1/2} = 12.32 \text{ years} \quad t_{bio\ 1/2} = 10 \text{ days}$$

Spent ion exchange resin. "Reactor water clean up" from the Clinton Power Plant



Medical LLRW

Wastes from nuclear medicine.

Radionuclides used in medicine have relatively short half-lives. Decay-in-storage (DIS) used to manage.

Technetium-99m used in imaging. Half life = 6 hours by gamma decay.

$$^{99m}Tc_{93} \rightarrow 99Tc_{93} + \gamma$$

Medical LLRW

Radioactive pellets containing ^{125}I and ^{89}Sr mixed with tumor disposed as a biological waste.

$$^{89}Sr_{38} \rightarrow {}^{89}Y_{39} + e^- \quad (50.6 \text{ days})$$

$$^{125}I_{53} + e^- \rightarrow {}^{125}Te_{52} \text{ (tellurium)} + \gamma \quad (60.1 \text{ days})$$

Low-Level Radioactive Wastes

Radioactive wastes from research projects and instruments.

Carcasses of animals treated with radioactive materials used in medical or pharmaceutical research.

Wastes from the University of Illinois: Division of Research Safety (DRS), Radiation Safety.

LLRW pick up at UIUC

DRS will pick up radioactive wastes after a form is filled out on-line and approved.

Wastes can include solids, liquids, carcasses, and sharps (vials, glassware, plastic containers).

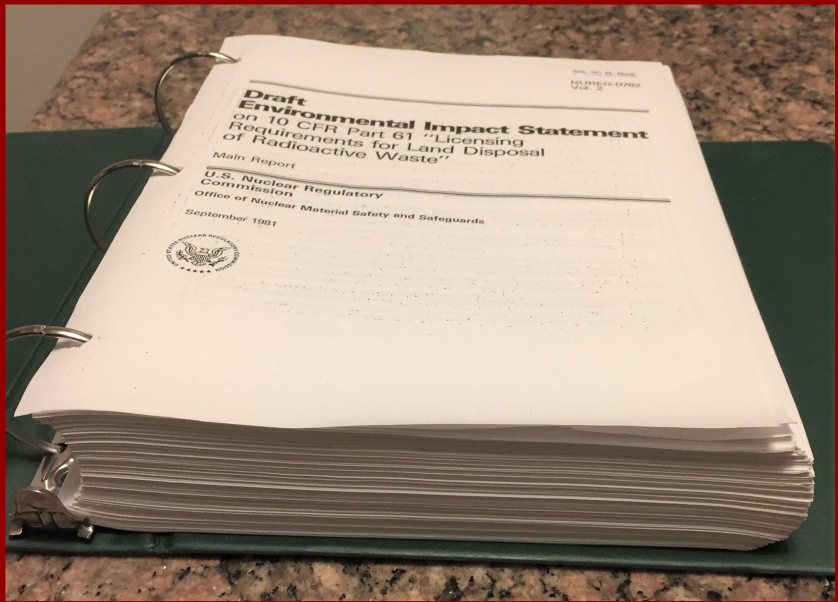
DRS uses a waste broker, Chase Environmental in Knoxville, TN. Chase transports and handles the final disposal (more later).

LLRW Classification

The U.S. Nuclear Regulatory Commission conducted a study to derive LLRW classification criteria from 1978 to 1982.

Published in 1982, the rule is "10 Code of Federal Regulations (CFR) part 61 Licensing Requirements for Land Disposal of Radioactive Waste."

Part 61 for short.



Part 61

Based on the operations and field data from the commercial LLRW sites of that era: Maxey Flats (Kentucky) and West Valley (New York) (more about these later).

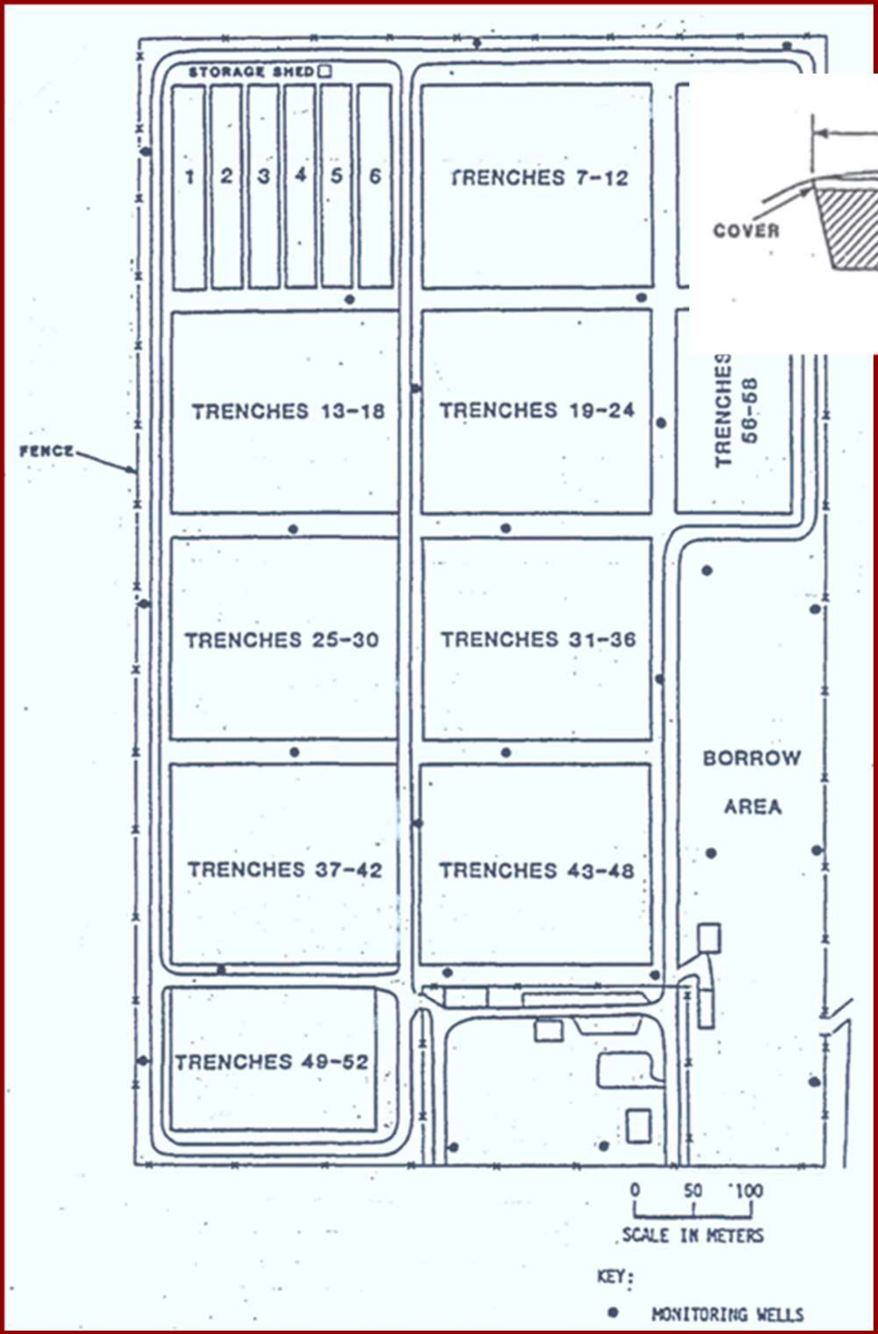
Also based on laboratory studies, risk assessment, worst-case assumptions and professional judgment.

Intent: provide protection during routine operations and passive, long-term protection.

Part 61

U.S. NRC conducted numerous analyses with different disposal site characteristics, exposed populations, time frames, radionuclide-specific leaching and transport behavior, wastes packaging, climates, costs, and engineered barriers.

A reference facility was created for the analyses.


STORAGE SHED
1
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TRENCHES 7-12
TRENCHES 13-18
TRENCHES 19-24
TRENCHES 56-58
FENCE
TRENCHES 25-30
TRENCHES 31-36
BORROW AREA
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SCALE IN METERS
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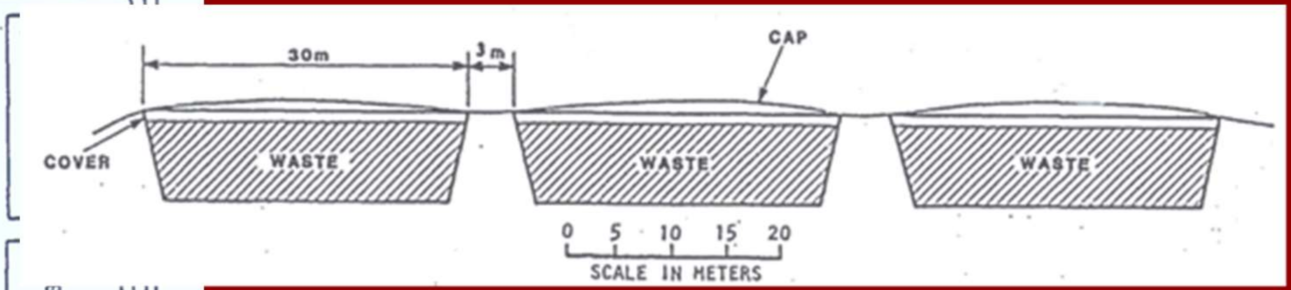
MONITORING WELLS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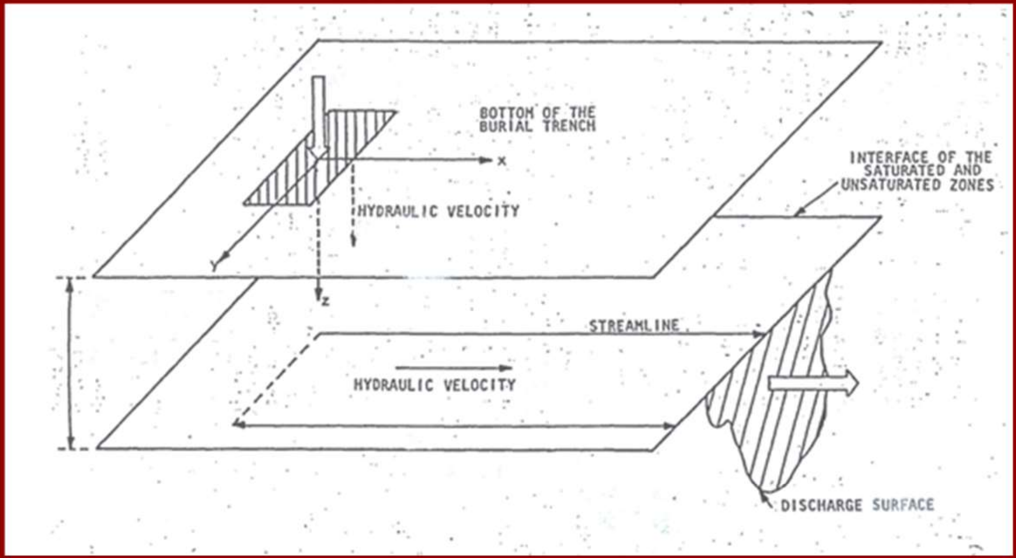
BOTTOM OF THE BURIAL TRENCH
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INTERFACE OF THE SATURATED AND UNSATURATED ZONES
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DISCHARGE SURFACE

Time frame

Construction and active disposal operations for 20 to 40 years.

Next 100 years of Institutional Control with site security, maintenance and monitoring.

After 100 years, worst case scenario: all information about the site is lost. Future generations do not know about the buried LLRW.

Three exposure scenarios considered

Direct Contact: an inadvertent intruder who knows nothing about the site.

Intruder-construction. Builds a house directly above the LLRW.

Intruder-agriculture. Builds a homestead and farms the land above the LLRW.

Intruder-discovery. Digs a hole into the site, removes and opens a waste container.

Exposure to contaminated groundwater

Radionuclides are assumed to leach from the wastes into shallow groundwater.

Consumption of radionuclide-contaminated groundwater from the site in each scenario:

1. A drinking water well in the disposal site used by the inadvertent intruder following the 100-year institutional control period.

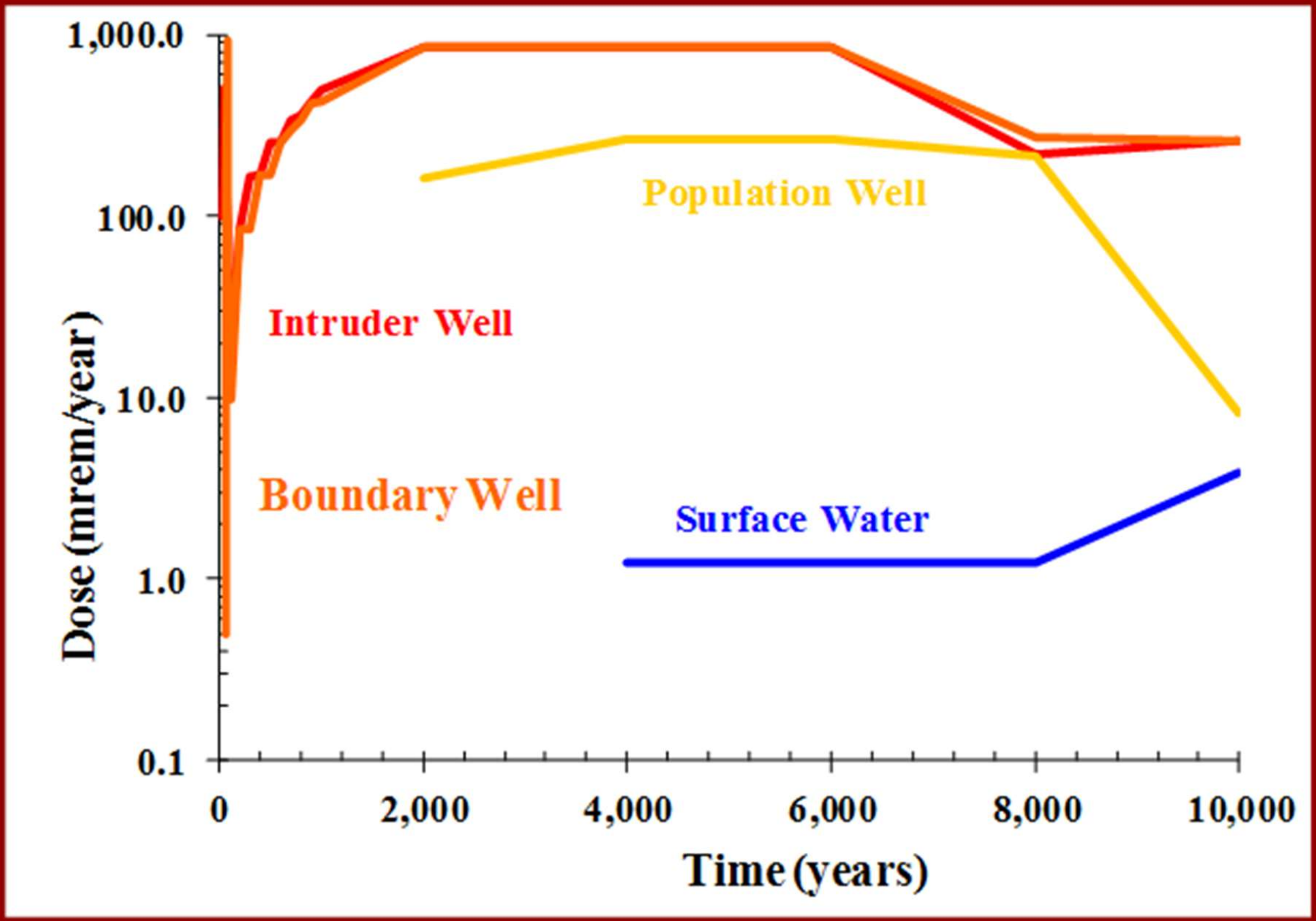
Exposure to contaminated groundwater

2. A drinking water well at the site boundary

3. A drinking water well 500 m down gradient from the disposal site.

4. A small stream 1 km away receiving shallow groundwater discharge used by 300 people as a source of drinking water.

Calculated thyroid gland dose as a function of time when evaluated at each biota access point (data from U.S. NRC, 1981). Shown as an example.



The ICRP's 500 mrem/year

Based on studies conducted by the International Commission on Radiological Protection, the U.S. NRC proposed a whole-body dose equivalent of 5 mSv/year (500 mrem/year) for the "critical group" which was the group of people who were most likely to receive the largest radiation dose during some of the given scenarios in Part 61.

Evolution of the waste classes

The U.S. NRC developed a classification system based on the physical stability of waste containers, the concentrations of the radionuclides, and accidental exposures caused by an **inadvertent human intruder** who is not aware of the presence of LLRW at the site. The classes of LLRW that are acceptable for shallow-land disposal are simply called Class A, B, and C.

Class A

Smallest level. Any substance containing any radionuclide is Class A. Specific activity: near background to 700 Ci/m^3 (25.9 TBq/m^3)

No special stability requirements such as solidification of waste packages. Cannot use cardboard boxes, however.

Not a threat to the inadvertent intruder beyond 100 years: exposure to the intruder is less than 500 mrem/year (5 mSv/year).

Class B

Middle level

Specific activity: 0.04 to 700 Ci/m^3 (1,480 MBq to 25.9 TBq)

The waste container must be designed to be stable for 300 years.

Not a threat to the inadvertent intruder beyond 100 years; exposure to the intruder is less than 500 mrem/year (5 mSv/year).

Must be segregated from Class A wastes at the site.

Class C

Largest level acceptable for shallow land disposal. Specific activity: 44 to 7,000 Ci/m^3 (1.63 to 259 TBq).

The waste container must be designed to be stable for 300 years. Requires some type of engineered barrier.

Will not endanger inadvertent intruder beyond 500 years; exposure to the intruder is less than 500 mrem/year (5 mSv/year).

Must be segregated from Class A wastes at the site.

Greater Than Class C (GTCC)

Not acceptable for shallow-land disposal.

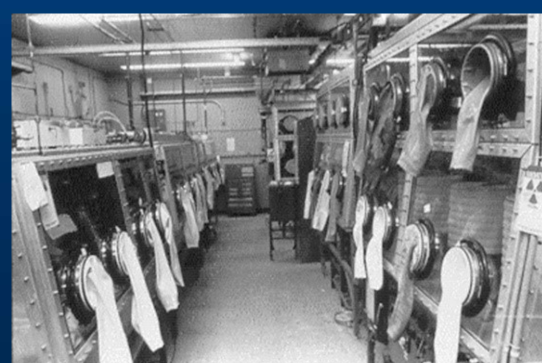
Poses a threat to the inadvertent intruder beyond 500 years.

Must be disposed in a geological repository or an alternative proposed by U.S. DOE and approved by U.S. NRC and EPA. Examples: sealed sources commonly ^{137}Cs and ^{241}Am, activated metals, decommissioning wastes.

Examples of GTCC wastes

Sealed sources commonly ^{137}Cs and ^{241}Am

Activated metals decommissioning wastes, ^{60}Co, ^{137}Cs, ^{241}Am



Low-Level Waste Classification

The selection of radionuclides used in waste classification was based on:

1. Present in wastes in significant concentrations.
2. Long half-lives (not less than hours).
3. Can be mobile in the environment after waste disposal.
4. Can pose significant exposures to ionizing radiation.

The U.S. low-level radioactive waste classification table for radionuclides with a half-life longer than 100 years.			
Radionuclide	**Ci/m^3**	**Class A**	**Class C**
C-14	8	≤ 0.8	> 0.8
C-14 (in Activated material (AM))	80	≤ 8.0	> 8.0
Ni-59 (Am)	220	≤ 2.20	> 2.20
Nb-94 (Am)	0.2	≤ 0.02	> 0.02
Tc-99	3	≤ 0.30	> 0.30
I-129	0.08	≤ 0.008	> 0.008
Alpha TRU, $t_{1/2}$ > 5 years	100 nCi/g	≤ 10 nCi/g	> 10 nCi/g
Pu-241	3,500 nCi/g	≤ 0.35 pCi/g	> 0.35 pCi/g
Cm-242	20,000 nCi/g	≤ 2 pCi/g	> 2 pCi/g

LLRW classification table for radionuclides with a half-life shorter than 100 years. All as Ci/m^3

Radionuclide	Class A	Class B	Class C
Sum with $t_{1/2}$ < 5 years	700	No limit	No limit
H-3	40	No limit	No limit
Co-60	700	No limit	No limit
Ni-63 (Am)	3.5	70	700
Sr-90	0.04	150	7,000
Cs-137	1	44	4,600

Mixtures of radionuclides

Most wastes are mixtures.

To classify a waste with more than one radionuclide, we add fractions.

For example,

Sr-90 (50 Ci/m^3) and Cs-137 (22 Ci/m^3). Both greater than Class A.

Divide concentration by the limit then add.

Mixtures of radionuclides

For ^{90}Sr, 50/150 = 0.33

For ^{137}Cs, 22/44 = 0.5

0.33 + 0.5 = 0.83

Because the result is < 1, it is Class B

Shortcomings with current NRC LLRW classification system

The U.S. NRC is currently considering revising Part 61.

Analyses and data are ~ 40 years old.

Emergence of potential LLRW streams that were not considered during the initial Part 61 rulemaking such as depleted uranium and blended (diluted) LLRW (Does A + C = B?)

Since Part 61. . .

U.S. DOE's increasing use of commercial facilities for the disposal of defense-related LLRW such as MTRU.

International experience gained in managing LLRW and intermediate-level radioactive wastes that did not exist when Part 61 was promulgated.

The process is on-going.

Non-Part 61 Radionuclides

Should new radionuclides be added?

Candidate 1

Chloride-36. Forms by neutron capture of ^{35}Cl. Forms from chloride impurities in stainless steel and coolant. Long half-life (3.10×10^5 years).

Decays as $^{36}Cl \rightarrow {}^{36}Ar + \beta^-$

Mobile in groundwater as an anion.

Geochemically non-reactive.

Non-Part 61 Radionuclides

Should new radionuclides be added?

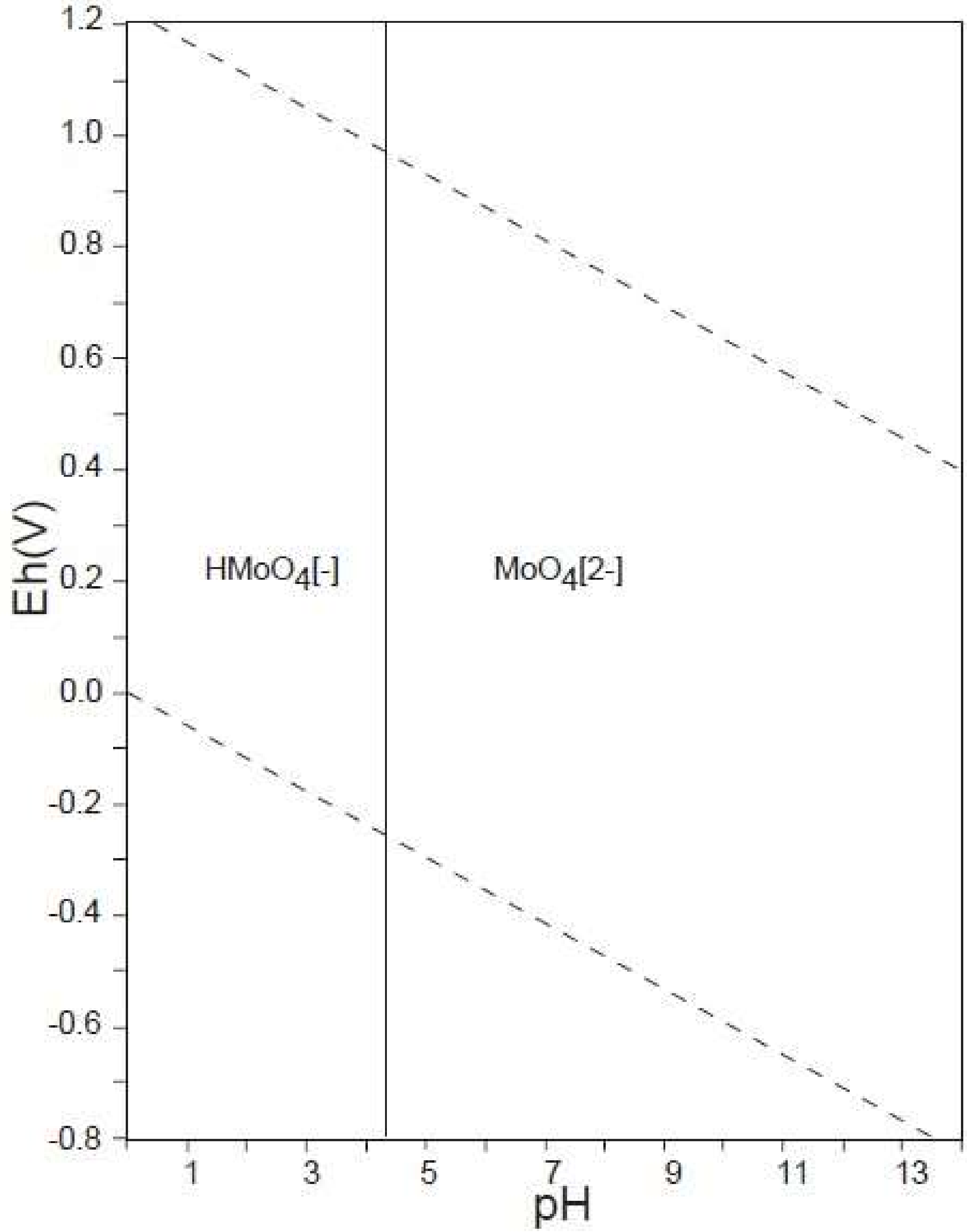
Candidate 2

Molybdenum-93. Forms by neutron capture of ^{92}Mo. Forms from molybdenum in stainless steel.

Long half-life (3,500 years).

Decays as $^{93}Mo + e^{-} \rightarrow {}^{93}Nb + \gamma$

Mobile in groundwater an anion.



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0.6
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0.0
-0.2
-0.4
-0.6
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Eh(V)
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MoO4[2-]
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3
5
7
9
11
13
pH

Non-Part 61 Radionuclides

Should new radionuclides be added?

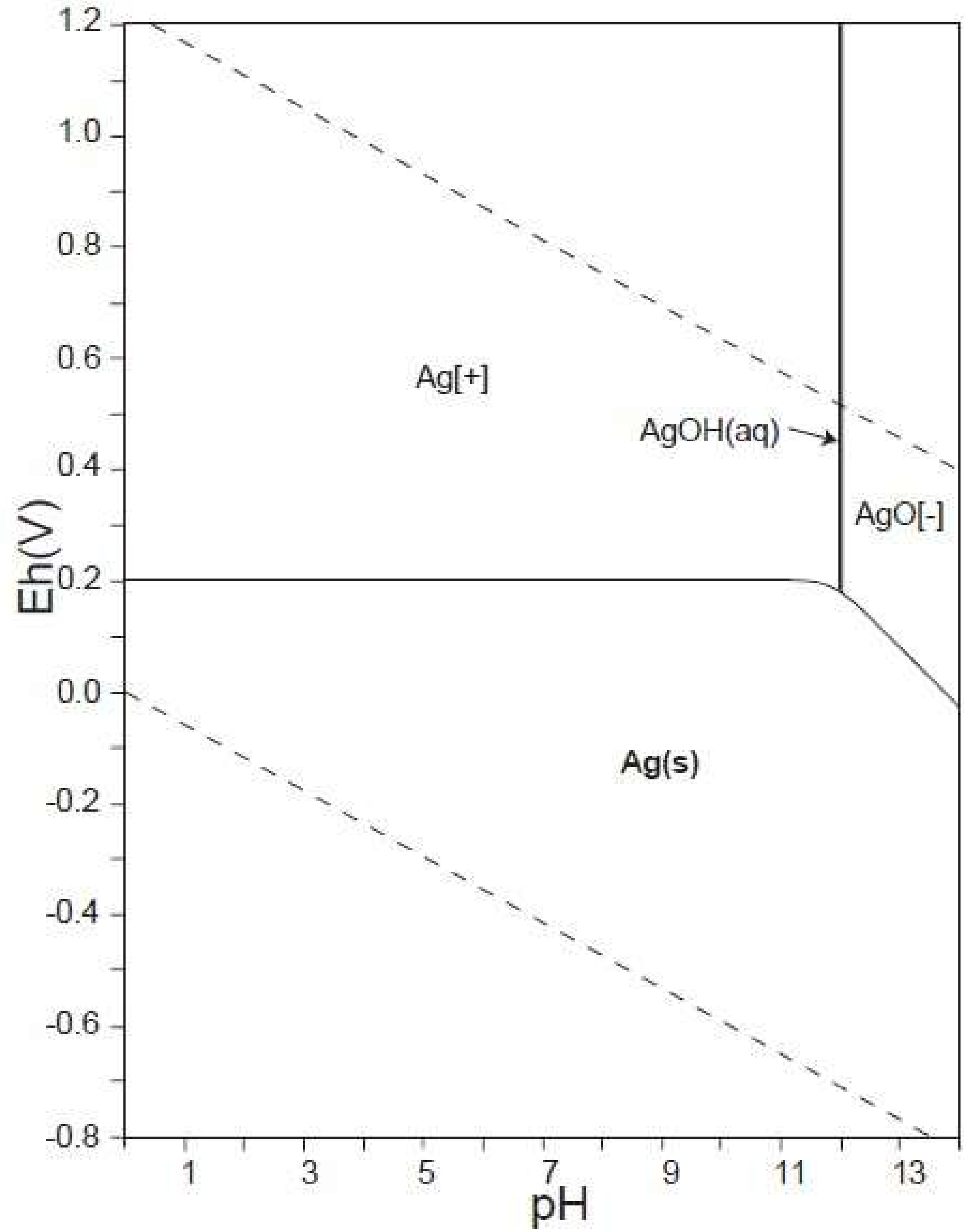
Candidate 3

Silver-108m. Forms by neutron capture of ^{107}Ag. Forms from Ag-Cd-In alloys used in some control rods.

Long half-life (429 years).

Decays as $^{108m}Ag \rightarrow {}^{108}Pd + \gamma$

Probably not mobile in groundwater.



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Eh(V)
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13
pH
Ag[+]
AgOH(aq)
AgO[-]
Ag(s)

Very Low-Level Radioactive Wastes

VLLW is an informal waste class that has been used by the NRC since 2000. NRC considers requests for VLLW disposal under CRF 20.0002. Specific criteria are lacking. NRC has stated " a few millirems per year." NRC described the wastes as "some residual activity . . . naturally occurring radionuclides . . . concrete and soil."

Very Low-Level Radioactive Wastes

March 2020. The NRC proposed to formalize the disposal of VLLW in municipal, county, and commercial landfills across the U.S.

NUCLEAR REGULATORY COMMISSION

10 CFR Chapter I

[NRC–2020–0065]

Transfer of Very Low-Level Waste to Exempt Persons for Disposal

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed interpretive rule; request for comments.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) is issuing a proposed interpretation of its low-level radioactive waste disposal regulations that would permit licensees to dispose of waste by transfer to persons who hold

Very Low-Level Radioactive Wastes

The public's response to NRC's idea was less than positive.

Advocates raise questions abo proposal to allow some nuclea waste to be disposed in landfil

In a statement on Thursday, Public Employees for Environmental Responsibility Pacific Director Jeff Ruch also criticized the proposal.

"NRC's action could transform most municipal dumps into radioactive repositories, with essentially no safeguards for workers, nearby residents, or adjoining water tables," he said.

NRC Considers Easing Low-Level Waste Regulations

- "Leave the waste out of our state and away from our children!!!"
- "This is an OUTRAGEOUS attempt to put us all in danger!"
- "Oh my god! No! No! You can't use the fear of a flu, to potentially give the world eternal cancer!"
- "I would like to tell the nuclear proponents to eat they're garbage (sic)"

Very Low-Level Radioactive Wastes

The public's response to NRC's idea was less than positive.

So you will have destroyed the commercial low-level radioactive waste facilities that have put their money into creating the monitoring and the other requirements. You will have destroyed the nation's low-level radioactive waste system. And at the same

This is perhaps the most anti-nuclear action I've ever heard, which is to make everybody who's living near a municipal landfill terrified that you are now going to be sending radioactive waste there without even telling them, without an

Very Low-Level Radioactive Wastes

The public's response to NRC's idea was less than positive.

I can't imagine that after the decades it took for those places to open up and to get licensed that they're willing to be comfortable with those who do not have to go through that process to try to prove that they're able to isolate the waste, that they

this health crisis is ended. We want the NRC to stand for Nuclear Regulatory Commission, not No One Really Cares.

Very Low-Level Radioactive Wastes

The NRC's awkward and ill-timed proposal was withdrawn. One voice said:

- Today we have sites such as the WCS Hazardous Waste facility where VLLW-like waste is disposed of as an option for the safe disposal of VLLW without needing the additional risk of potentially adding VLLW to publicly accessible landfills. The author also thinks that if the NRC wishes to move forward with a VLLW process, the formal adoption and creation of waste disposal criteria by means of a formal rulemaking for VLLW by the NRC would be a positive step forward.

Roy, W. R. 2020. Very Low-Level Waste Disposal in the US: NRC's Proposed Interpretation. *Journal of Nuclear Energy Science and Power Generation Technology*

Radioactive wastes in general

"Front-end Wastes"

U, Th, Rn and decay products

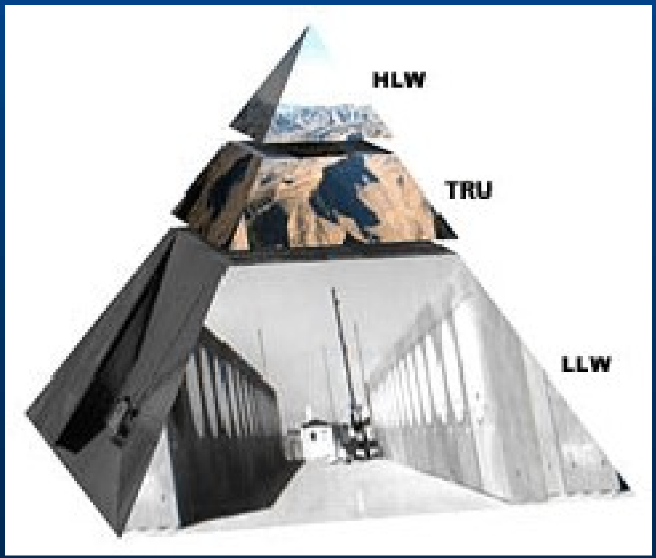
Larger volumes

"Back-end Wastes"

Fission products

Activation products

Smaller volumes



Comparison of waste types

MSW = municipal solid waste. Nonhazardous city trash and yard wastes per year.

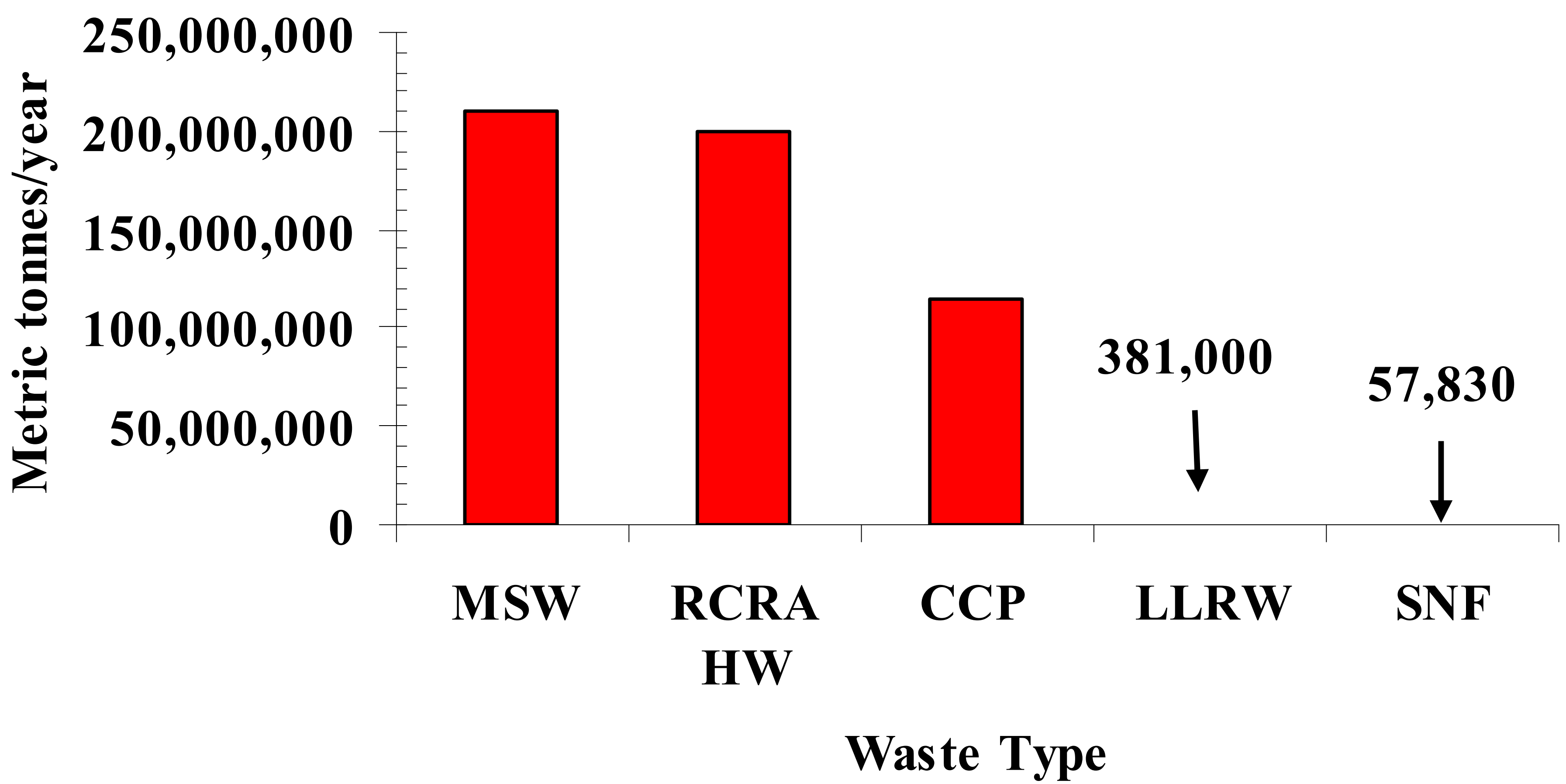
RCRA HW = Resource Conservation and Recovery Act Hazardous Wastes (spent organic solvents, acids, listed chemicals, radioactive wastes and more per year.

CCP = Coal combustion products (coal ash, flue-gas scrubber sludge per year.

LLRW = Low level wastes disposed at commercial facilities in 2019—99% Class A waste.

SNF = Spent nuclear fuel currently being stored—NOT the amount generated per year (as of 2019)

Comparison of waste types



U.S. DOE High-Level Waste

High-Level Waste (HLW). The by-products of fuel reprocessing. Acidic, liquid wastes that contain uranium, plutonium, and fission products.

U.S. DOE TRU Wastes

Transuranic Wastes (TRU)

Atomic number greater than 92 such as ^{239}Pu, ^{241}Am, or ^{237}Np

At present, almost all from U.S. DOE weapons, energy research, and site cleanup programs.

May include plutonium-contaminated clothing, tools, sludge, liquids.

U.S. DOE LLRW

Low-Level Radioactive Waste. The U.S. DOE does not differentiate low-level wastes. U.S. DOE simply defines low-level wastes as “that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material or naturally occurring radioactive material” Byproduct material is tailings or wastes produced by the extraction of uranium or thorium or any discrete source of radium-226.

U.S. DOE RRM

Residual Radioactive Material (RRM) is the U.S. DOE-U.S. NRC term for mill tailings resulting from the processing of ores for the extraction of uranium and other valuable constituents in the ores. The U.S. NRC does not consider mill tailings to be LLRW.

U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.

Exempt. Radioactive materials that are consumer products that do not contain a sufficient amount of a radionuclide(s) to pose a significant radiological risk to the public are defined as Exempt.

U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.

Exempt. Examples include electronic components that contain cesium-137, cobalt-60, radium-226, krypton-85 and others, gunsights containing tritium, incandescent gas mantles that contain thorium-232, and smoke detectors that contain americium-241.

U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.

Source Material. The U.S. NRC defines "source material" as material that contains thorium or uranium provided that the uranium has not been enriched with respect to uranium-235. Depleted uranium is also classified as a Source Material.

U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.

Special Nuclear Material. The U.S. NRC defines this material as plutonium, uranium-233, and any uranium that is enriched with ^{233}U or ^{235}U. This classification does not include Source Material.

U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.

Mixed Wastes. This type of waste is a mixture of radioactive material and hazardous components—hazardous as defined by the U.S. Resource Conservation and Recovery Act (RCRA).

Mixed Wastes

The U.S. NRC and the U.S. DOE regulate the radioactive portion of a mixed waste, and the U.S. EPA regulates the hazardous-waste portion under the authority of RCRA. Mixed Wastes are also known as Mixed Radiological and Hazardous Waste.

U.S. Environmental Protection Agency (U.S. EPA), U.S. NRC, and U.S. DOE.

Most commercially-generated mixed waste is classified as Low-Level Mixed Waste.

The U.S. DOE produces three types of mixed wastes:

Low-Level Mixed Waste (LLMW)

High-Level Mixed Waste (HLMW) which contain high-level radioactive wastes such as those from reprocessing spent nuclear fuel + hazardous waste.

Mixed Transuranic Waste (MTRU)

Regulatory background

Resource Conservation and Recovery Act of 1976 (RCRA) is intended to protect human health and the environment from unsafe waste-disposal practices. It empowered the U.S. EPA to develop waste disposal regulations, that included criteria for the classification of "hazardous wastes."

What are “hazardous wastes?”

The term “hazardous wastes” is often used by the news media informally. Not all chemicals released are hazardous. The U.S. EPA has defined specific criteria that are applied to solids, liquids, and gases to define the degree of hazard.

What are "hazardous wastes?"

The U.S. EPA created standardized-test protocols to measure ignitability, corrosivity, reactivity, and toxicity. The wastes might vary from unused chemicals that were abandoned to mixtures of spent (reacted) chemicals.

Hazardous Wastes Types

Because of the great diversity of potential chemical wastes coupled with limited resources to investigate all possible waste streams, the U.S. EPA created two approaches to managing hazardous wastes:

Hazardous Wastes Types

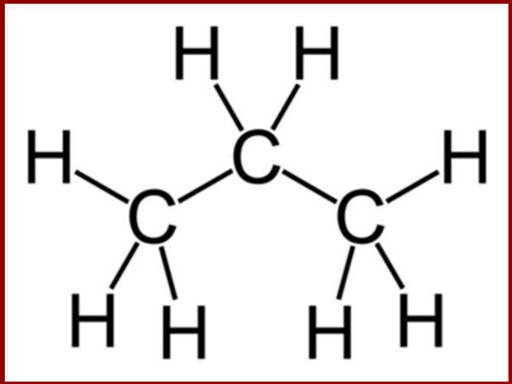
Listing and Waste Characteristics. Using the Listing approach, a waste can be classified as hazardous if it contains a chemical component that is on a list. The actual composition of the waste is not considered

Waste characteristic: Ignitability

A waste is classified as ignitable if (1) it is a liquid that has a flash point that is less than 140° F (60° C), (2) it is a flammable solid, (3) an ignitable compressed gas, or (4) an oxidizer as defined by the U.S. Department of Transportation. Solids like paper and wood are not subject to classification under (2).

Examples of ignitable wastes

Isobutyl chloride (C_4H_9Cl)
Acetone ($(CH_3)_2CO$)
Gasoline (petrol)
Benzene (C_6H_6)
Propane
Toluene (C_7H_8)



Waste characteristic: Corrosivity

A waste is corrosive if (1) it is a liquid with a pH equal to or less than 2, or equal to or greater than 12.5, or (2) it can corrode steel at a rate faster than 0.25 inch (0.62 cm) per year. Examples: strong acids and bases.

Sulfuric acid (H_2SO_4)

Sodium hydroxide (NaOH)

Waste characteristic: Reactivity

Reactive wastes can be defined in a number of ways. Such wastes are unstable under ambient conditions, and can be explosive, or react violently when mixed with water. Examples include lithium-sulfur batteries, explosives, metallic sodium, and ammonium perchlorate (NH_4ClO_4).

Listed Wastes

Hazardous Wastes: The F List

F-listed hazardous wastes consist of chemicals that were used for their intended purpose in industrial applications. The F-listings are descriptions of hazardous wastes from non-specific sources: these wastes may be generated in a wide range of different industries. Examples: spent organic solvents, wastes from metal treatment and finishing processes, and wood preservative wastes.

Listed Wastes

Hazardous Wastes: The K List

The K List of hazardous wastes contains wastes from specific sources. Like the F List, the wastes are manufacturing-process by-products. The chemical in the wastes have been used for their intended purposes. Examples: wastes generated by coal coking, inorganic paint manufacturing, and the production of pesticides.

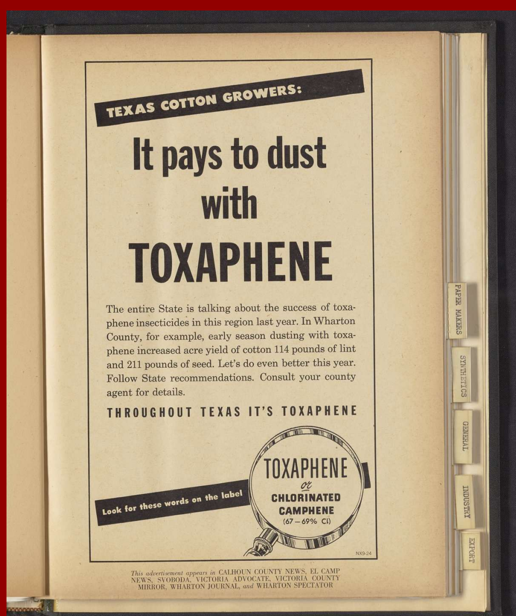
Listed Wastes

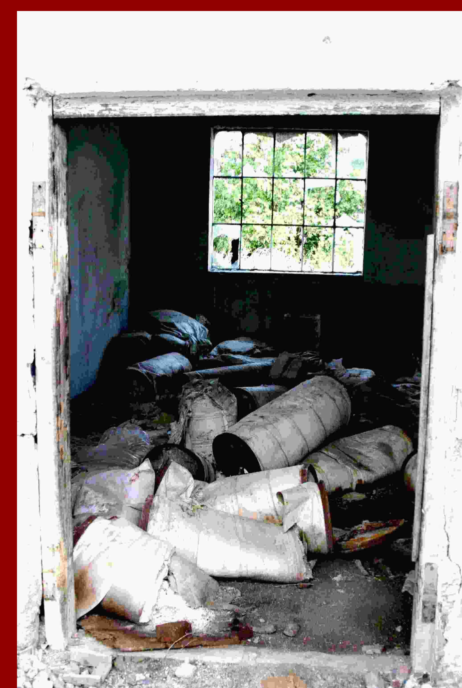
Hazardous Wastes: The U and P Lists

Pure commercial-grade and relatively concentrated forms of known toxic chemicals comprise the U and P Lists. Unlike the F and K Lists, these chemicals have not been used and could be surplus, discarded, or abandoned.

Listed Wastes

P wastes are regarded as more acutely toxic than U wastes. Example: an orphan container of pure toxaphene ($C_{10}H_8Cl_8$), a chlorinated hydrocarbon which is now a banned insecticide in the U.S.





Definition of hazardous waste

Wastes are defined as "hazardous" based on legal definitions that were derived from health-based studies, risk assessments, toxicity data, engineering designs for waste disposal and treatment, engineering safety factors, the cooperation of the regulated community, and the regulatory necessity to make enforceable, but *manageable* rules that are still protective of human health and environment.

Contaminated Media and Debris as Hazardous Wastes

If a hazardous chemical is spilled on soil, is the contaminated soil a "hazardous waste?"

Maybe. The U.S. EPA defines environmental media as soils, sediments, and groundwater. Debris can include broken concrete, decommissioned industrial equipment, and dismantled buildings.

Contaminated Media and Debris as Hazardous Wastes

Excavated media and decommissioning debris are major sources of wastes during site cleanup. If it can be demonstrated that the contaminated media and debris do not pose a significant threat to human health, the contaminated materials can be classified as nonhazardous.

Contaminated Media and Debris as Hazardous Wastes

The U.S. EPA concluded that flexibility in the interpretation of waste classification is needed to avoid regulating large volumes of materials with small amounts of listed chemical as hazardous. Without such a provision, a stricter interpretation of RCRA could discourage environmental cleanup efforts.

U.S. Environmental Protection Agency - LARW

Low-Activity Radioactive Waste (LARW). The U.S. EPA informally defines LARW as any radioactive material that contains relatively small amounts of radionuclides. "Low activity" is not equivalent to the U.S. NRC classification of "low level." LARW is regarded as a "concept" whereas LLRW is a regulatory definition.

U.S. Environmental Protection Agency - LARW

Radioactive wastes from several sources have the potential to be defined as low-activity wastes. These sources include Naturally Occurring and Accelerator-Produced Material (NARM) and Naturally Occurring Radioactive Material (NORM).

U.S. Environmental Protection Agency - LARW

When the radionuclides in NORM become concentrated by some anthropogenic activity or process, the resulting product is called TENORM—Technologically Enhanced Naturally Occurring Radioactive Material.

U.S. Environmental Protection Agency - LARW

The difference between a NORM and a TENORM is a subject of debate because both materials can result from the application of some type of technology that increases the risk of human exposure

U.S. Environmental Protection Agency - LARW

NORM

Naturally occurring radioactive materials.

Virtually anything (gas, solid, liquid) that contains radioactive elements that could expose people to radiation. Examples: radon. "NORM consists primarily of material containing potassium-40 and naturally occurring isotopes of [uranium and thorium]" (U.S. EPA). The major radionuclide of concern is radium-226.

Other low-level radioactive materials/wastes

TENORM

Technologically enhanced NORM.

When radionuclides in NORM become concentrated by some anthropogenic process, and waste products could be a source of radiation to people. Examples:

Coal ash

Coal contains uranium, thorium, and potassium-40. When the coal combusted, these non-volatile elements become concentrated in the ash.

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Coal Ash Is More Radioactive than Nuclear Waste

By burning away all the pesky carbon and other impurities, coal power plants produce heaps of radiation

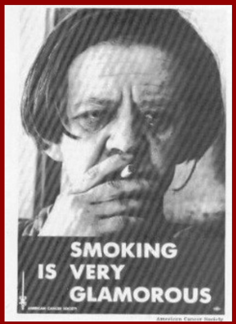
By Mara Hvistendahl | December 13, 2007 | 99

Other low-level radioactive materials/wastes

Water-treatment lime slurry

Calcium oxide is added to raw groundwater to increase pH and precipitate metals. The resulting waste is sometimes rich in radium-226.

Other TENORM materials/wastes



Tobacco (lead-210 and polonium-210)

Building materials: Common building products such as bricks, cement blocks, granite counter tops, and glazed tiles. Older glazes contain uranium.

Scrap metal recycling

Scale-filled water pipes that contain radium that accumulated with the scale (calcium carbonate).

Legacy Radioactive Wastes

Legacy wastes from WWII and the Cold War era.

Not to be confused with utility radioactive wastes.

Legacy Radioactive Wastes

Residual Radioactive Material

TRU wastes

Nuclear materials (uranium and plutonium)

U.S. DOE-defined low-level wastes.

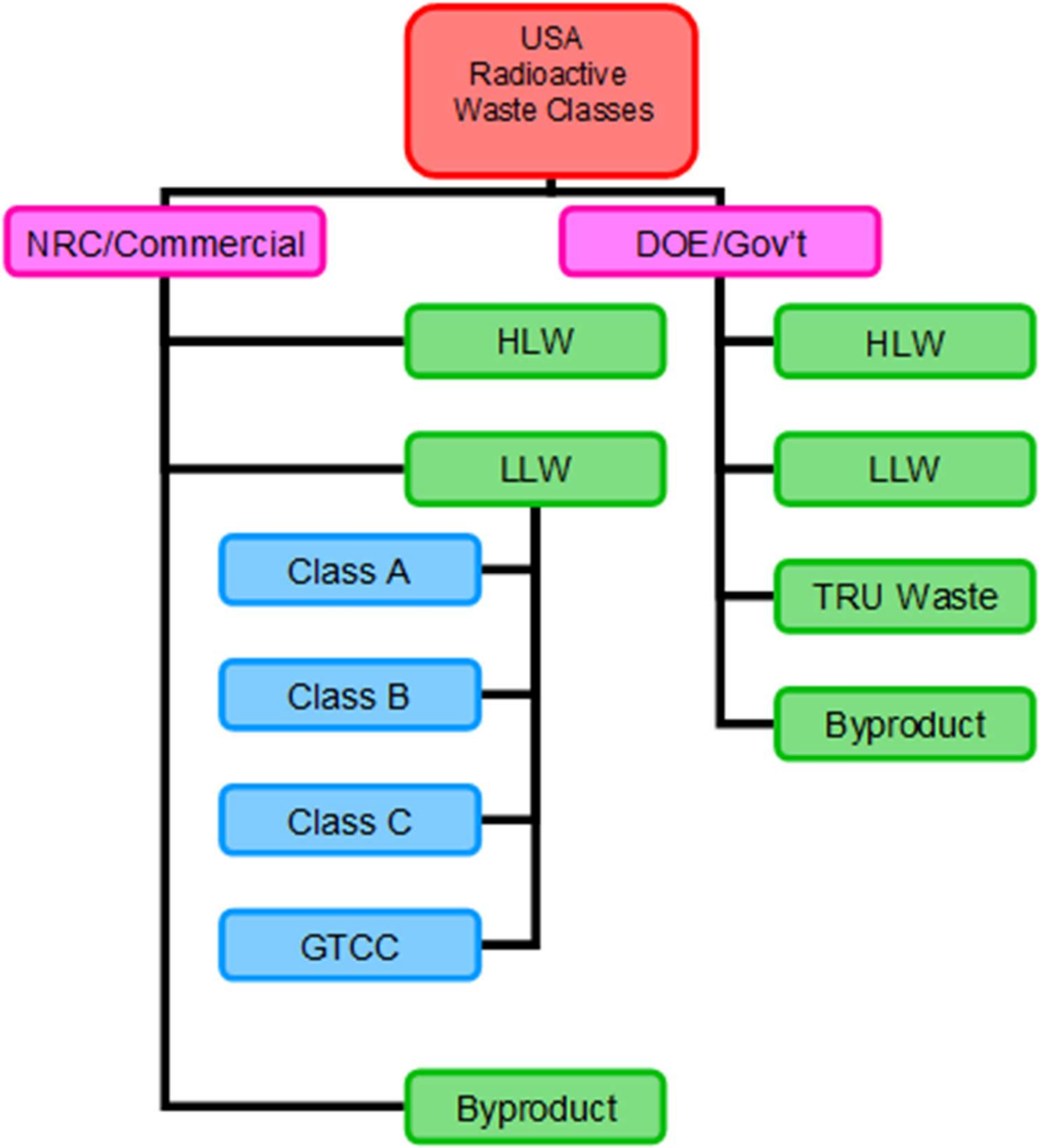
U.S. DOE-defined high-level wastes.

Contaminated soils.

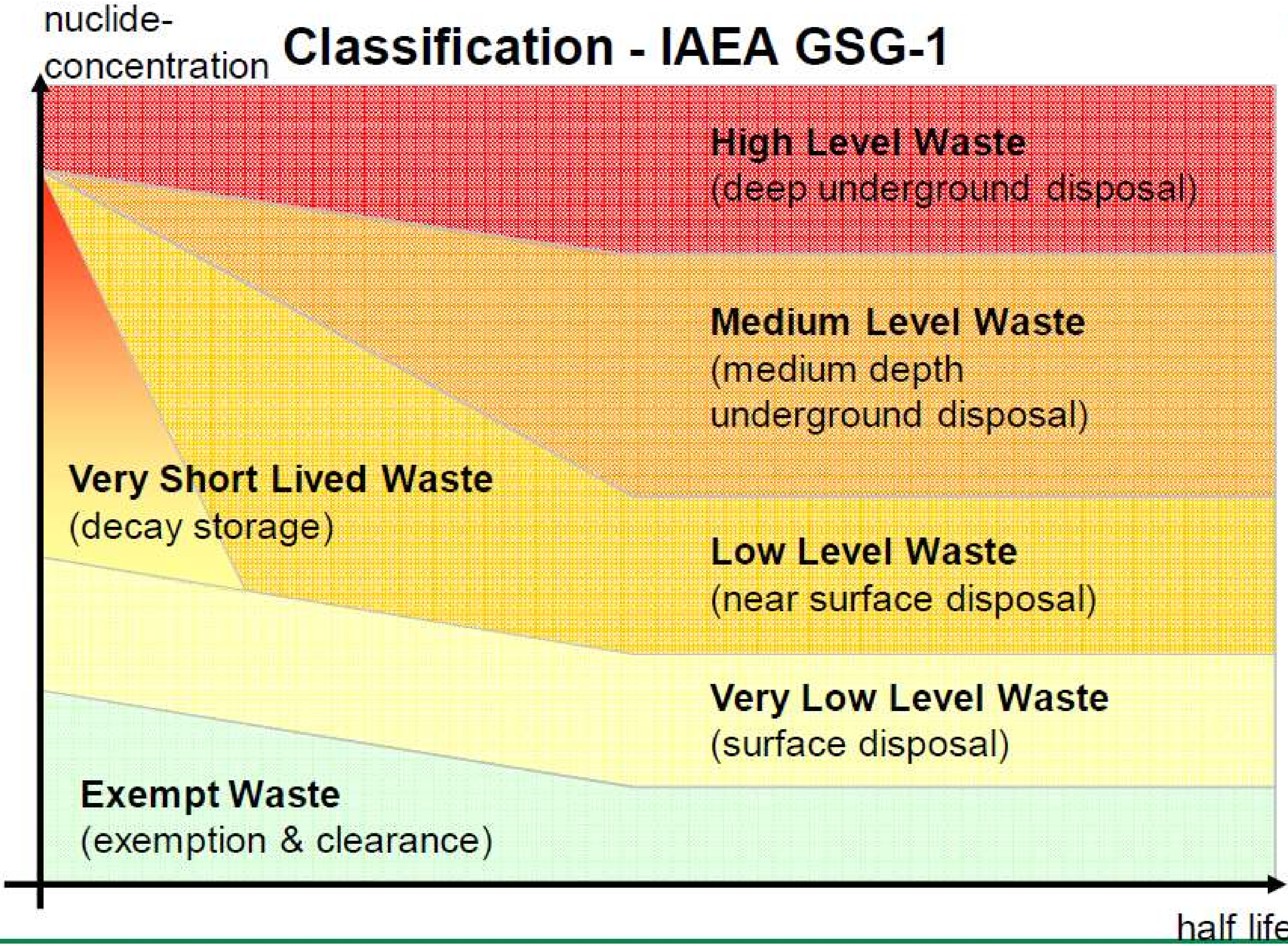
Demolition debris.

Surface-pit solids.

Contaminated groundwater.


USA
Radioactive
Waste Classes
NRC/Commercial
DOE/Gov't
HLW
LLW
Class A
Class B
Class C
GTCC
Byproduct
HLW
LLW
TRU Waste
Byproduct

Classification - IAEA GSG-1



Questions?