NORM & Natural
Radiation Management
North America

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Houston, Texas

"Cradle to Grave"

NORM Management Workshop

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Emergency exits and fire extinguishers

Site-specific information

Cell phone usage

Breaks and lunch

Introductions

- Your Name, Your Company & Your Role
- Specialty/Value or Problem/Solution you have in the NORM Industry
- What are you looking to gain from the workshop?

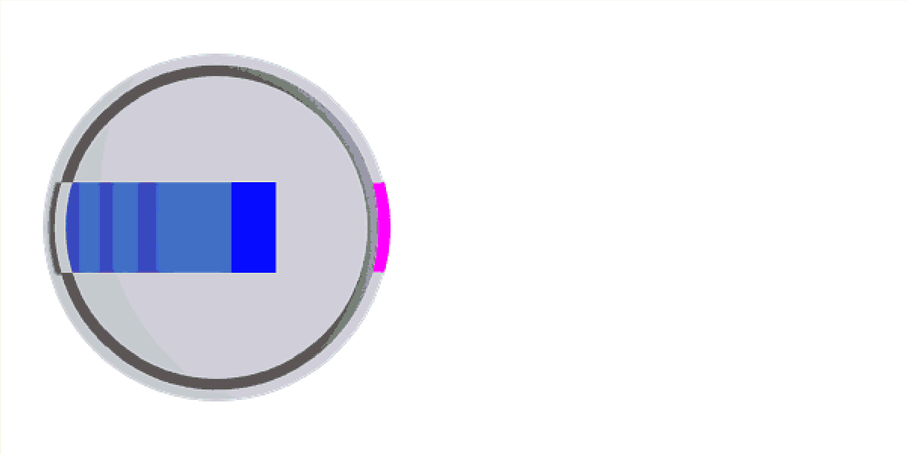
Workshop Objectives

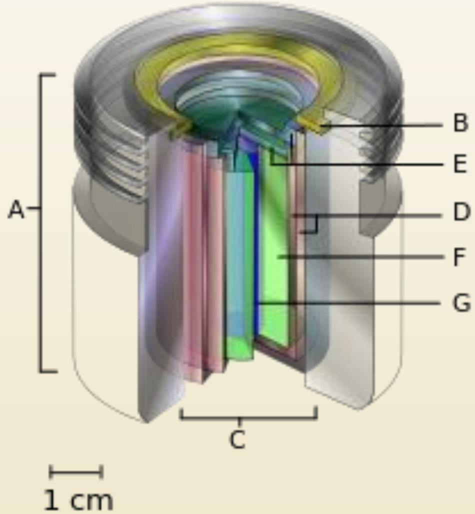
1. Designed to educate and inform decision makers about the "**Big Picture**" of NORM Management.
2. This **Universal Approach** provides a framework to ensure NORM management decisions are regulatorily, economically, and environmentally sound.
3. The workshop is a **Discussion** and an **Exchange of Ideas** with the colleagues in the room.

Course Outline

- Nuclear Science/Accumulation of NORM
- NORM Survey & Characterization
  - ✓ Morning Refreshments
- Processing Decisions & Options
  - ✓ Lunch
- Worker Protection, Health Physics & Compliance
  - ✓ Afternoon Refreshments
- Packaging/Transport/Disposal Options
- Discussion/Summary

Goiania Cesium Bomb





- 1987 – Brazil – Cs-137 Radiotherapy machine
- Scavengers looking for material removed the machine from abandoned business and sold the machine to a scrap yard.
- Scrap Yard broke open the Cesium capsule inside the machine

Distribution

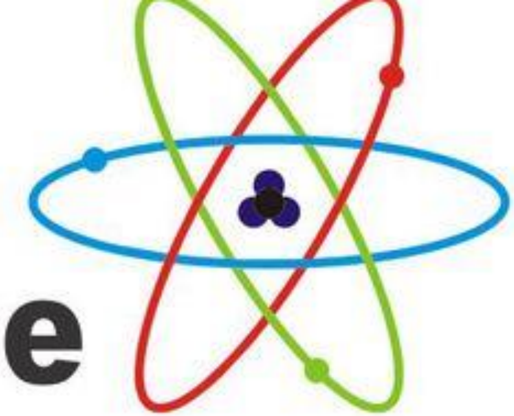
- Glowing blue stone distributed to friends
- Over 112,000 quarantined for monitoring in a soccer stadium
- 120 Contaminated (20 Hospitalized) 28 w/ radiation burns
- 4 people died - Including 1 – 6yr old girl who smeared the glowing blue material over her body and ingested Cesium.

Goiania Waste Generated

From 93 grams of Cs-137 (1400 Ci)

- 4500 drums
- 1400 metal boxes
- 10 shipping containers
- 6 sets of concrete packaging

Nuclear Science



The UNIVERSE

is made of

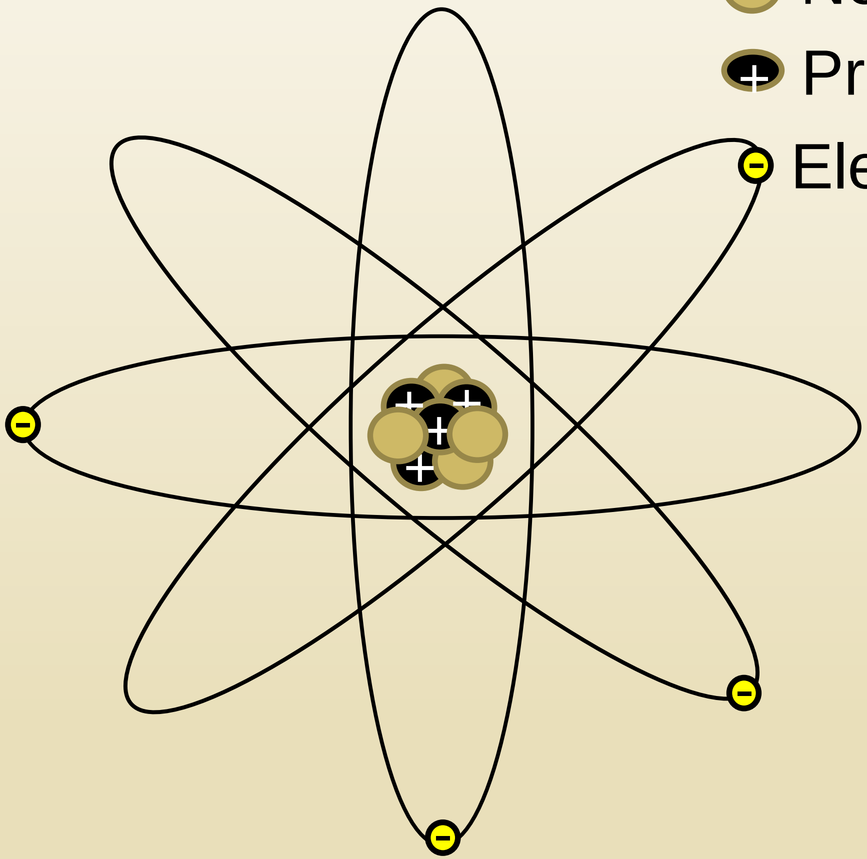
protons,

neutrons,

electrons &

morons

Basic Atom Structure



Neutron – no electrical charge

Proton – positive electrical charge

Electron – negative electrical charge

The # of Protons in the nucleus determines what type of element it is.

Periodic Table of Elements

Atm. # Pauling Valence
Symbol
Name
Atomic Weight

C Solid
Hg Liquid
H Gas
Rf Unknown

Metals: Alkali metals, Alkaline earth metals, Lanthanoids, Actinoids, Transition metals, Post-transition metals
Metalloids
Nonmetals: Other nonmetals, Halogens, Noble gases

Diatomic Compounds
Radioactive Elements

	IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIIIB 8	VIIIB 9	VIIIB 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
1	1 H Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050											13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57–71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89–103	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (270)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (293)	117 Uus Ununseptium	118 Uuo Ununoctium (294)

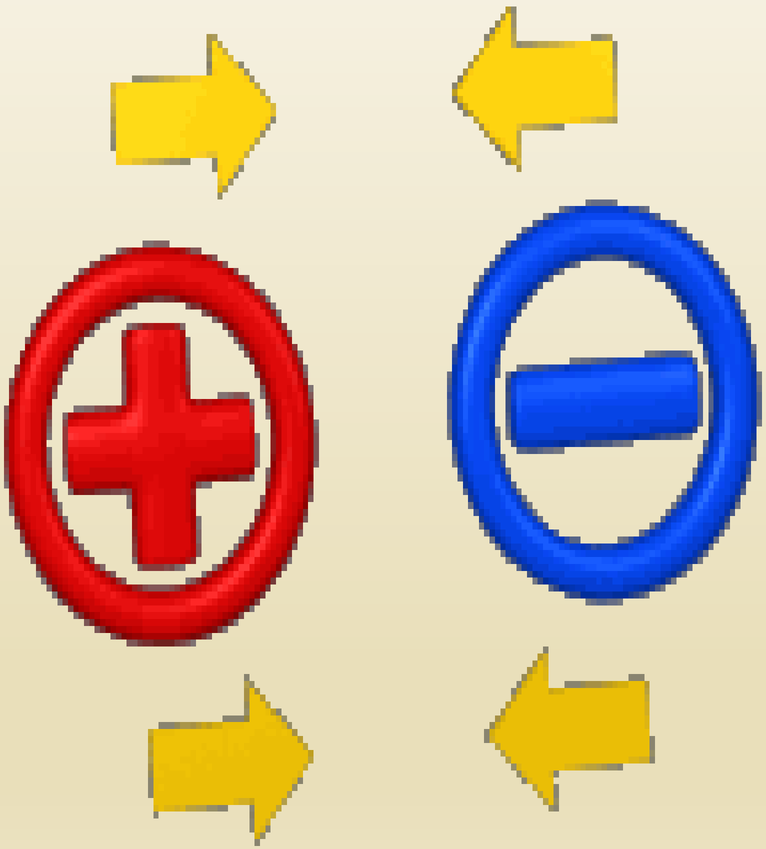
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

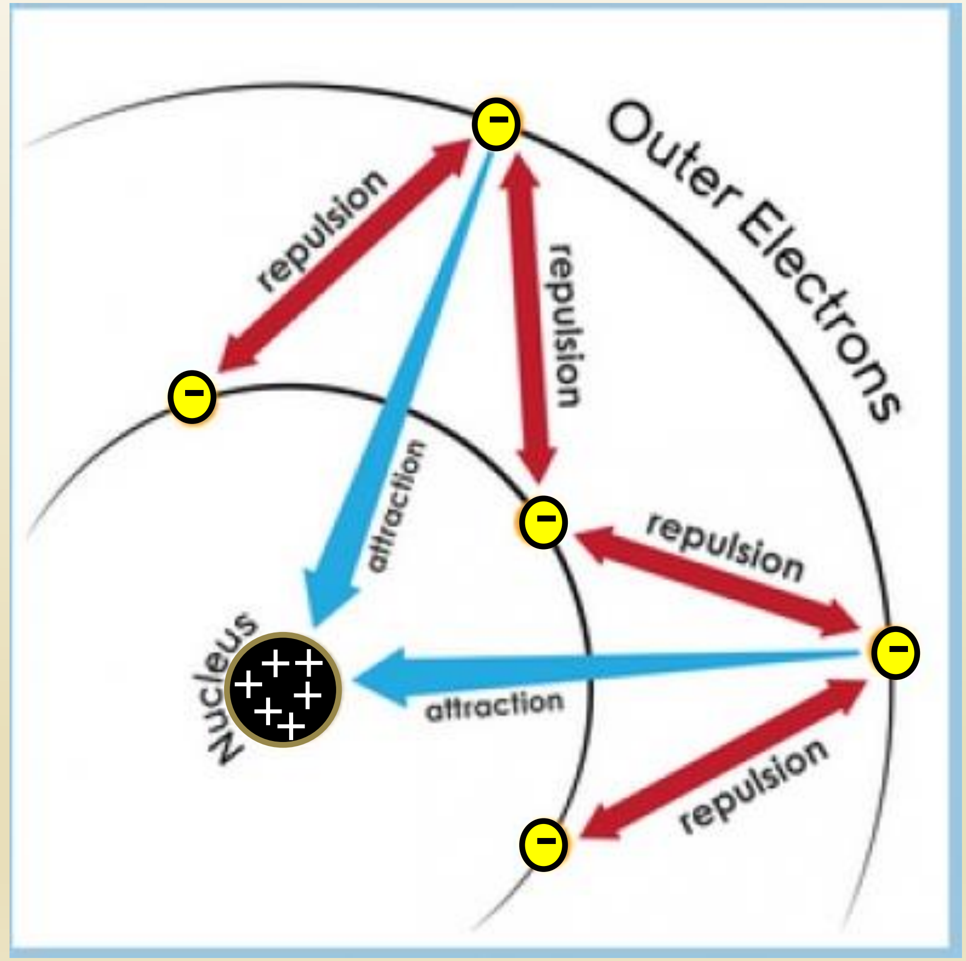
Ptable.com

Stable Atom Balance

Attractive Nuclear Force



Repulsive Coulombic Force

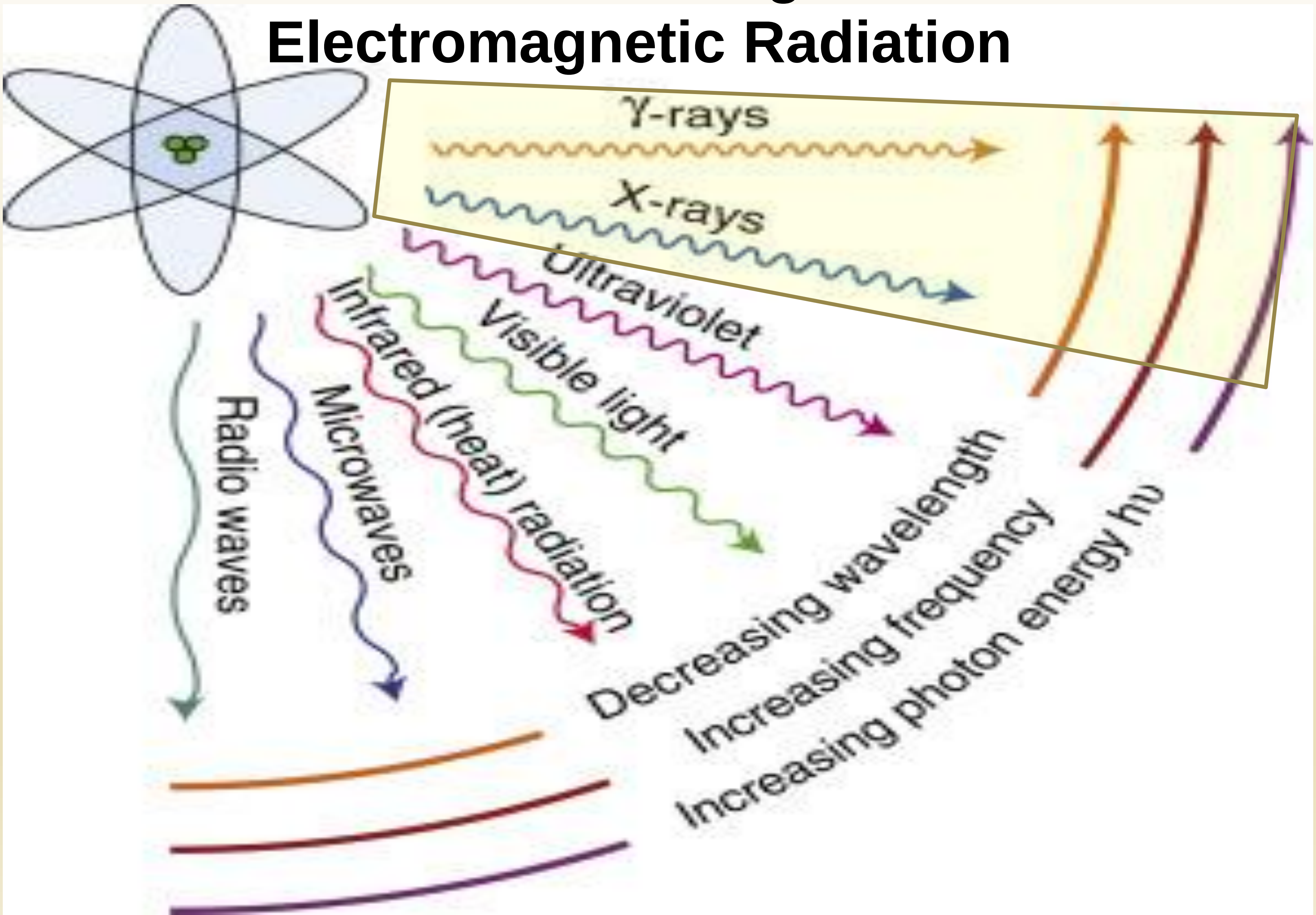


$1.33*10^{50}$ atoms in the world.

133,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000

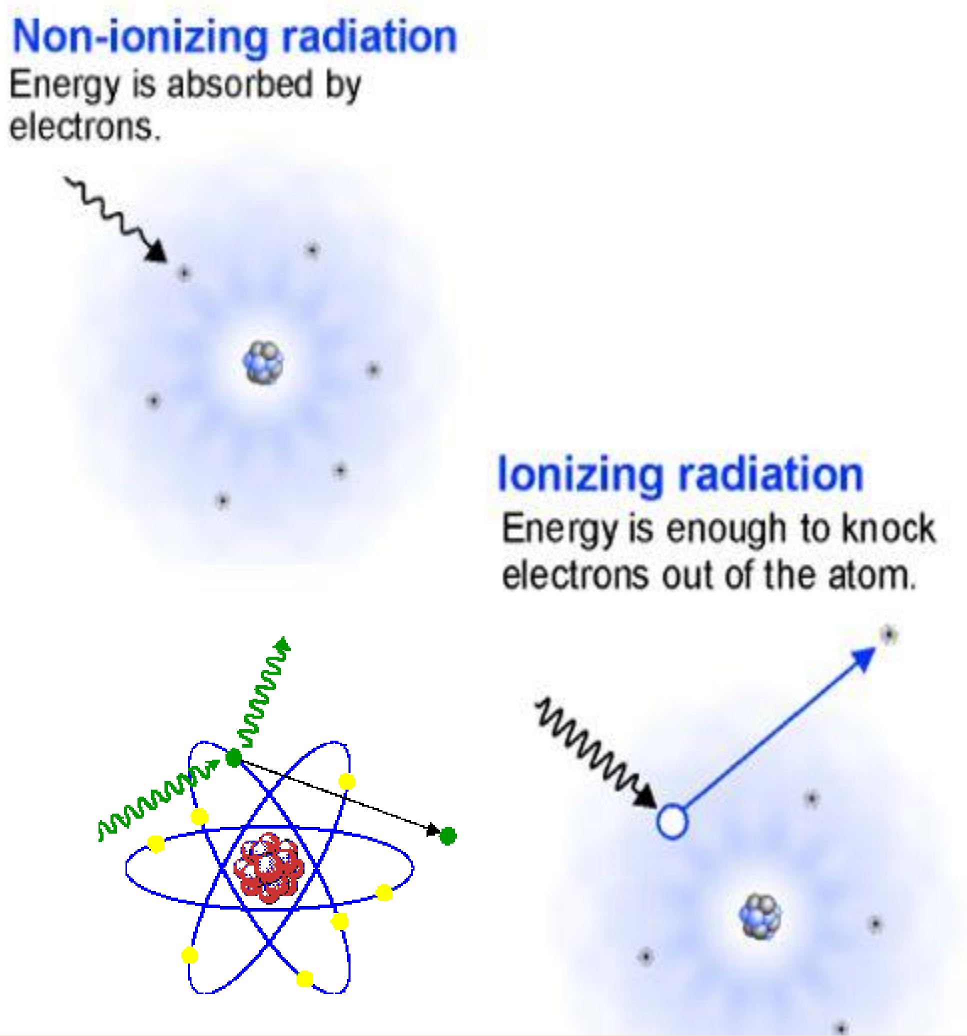
Only a small percentage are
"Unstable" (Radioactive)

Unstable Atoms give off Electromagnetic Radiation

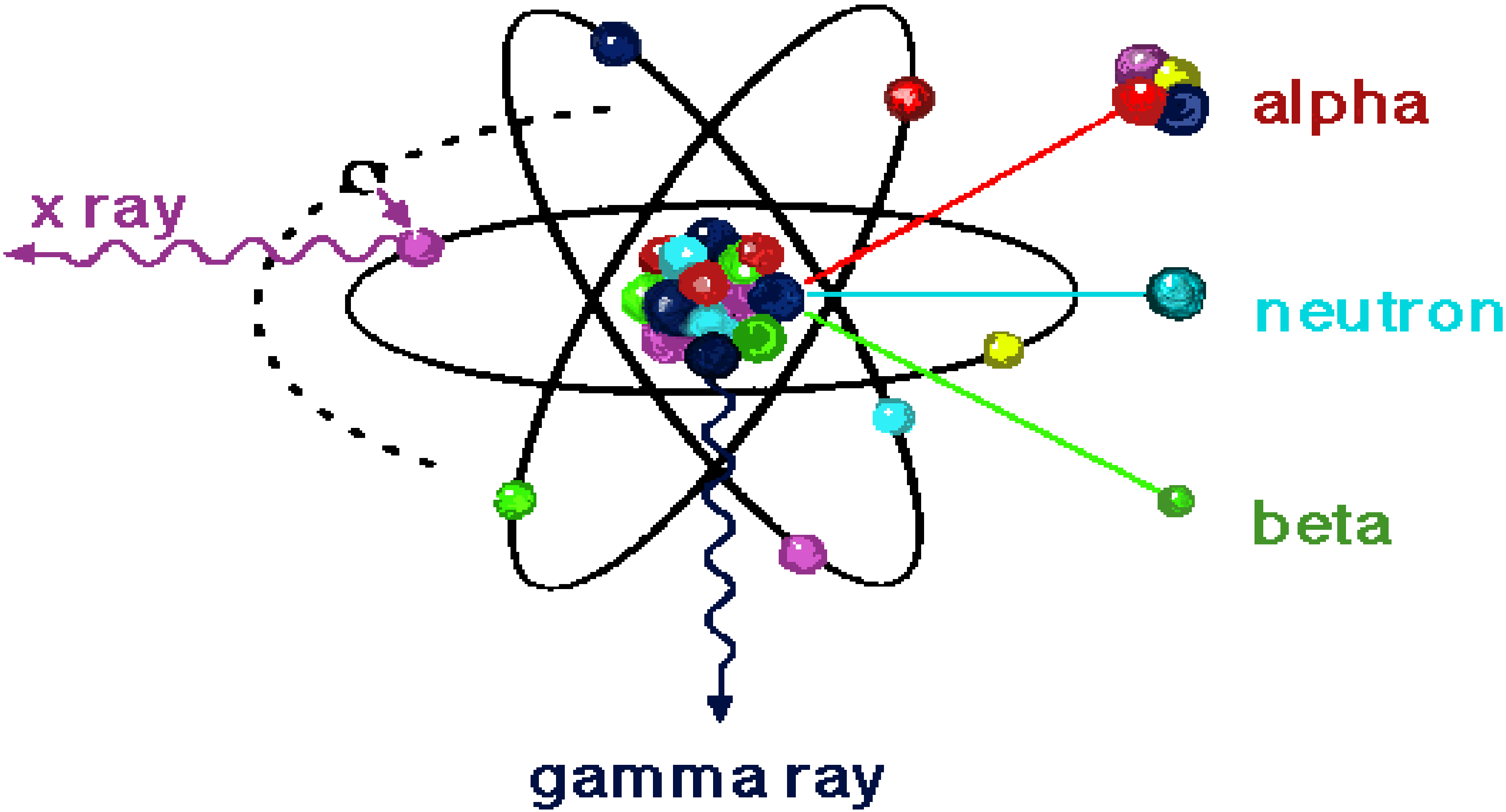


Effects of Radiation

- Radiation becomes harmful when it has enough energy to remove electrons from atoms
- The process of removing an electron from an atom is called ionization
- Visible light is an example of non-ionizing radiation



Ionizing Radiation



Unstable nuclei seeks most stable situation

Ionizing Radiation Fingerprint

All Ionizing radiations will have its own unique fingerprint that allows scientists to identify each individual “Isotope”

- **Type of Radiation: α, β, γ, x-ray, n**
- **Radiation Energy: eV**
- **Rate of Decay: Half-Life**

For Example: Radium-226

✓ **α/γ emitter**

✓ **α energy = 4.871 MeV**

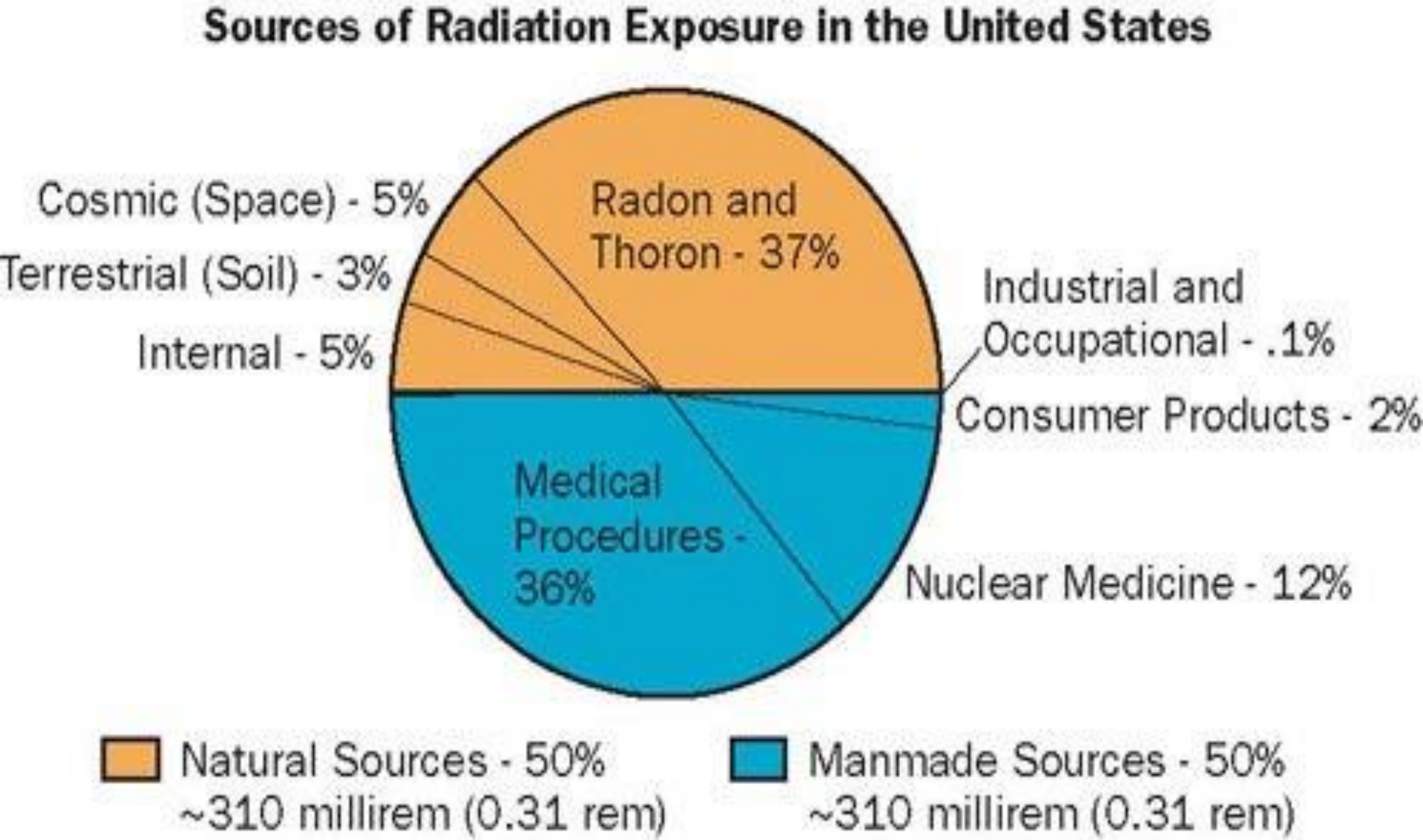
✓ **γ energy = 186 keV**

✓ **Half-Life = 1600 years**

$^{226}_{88}\mathbf{Ra}$

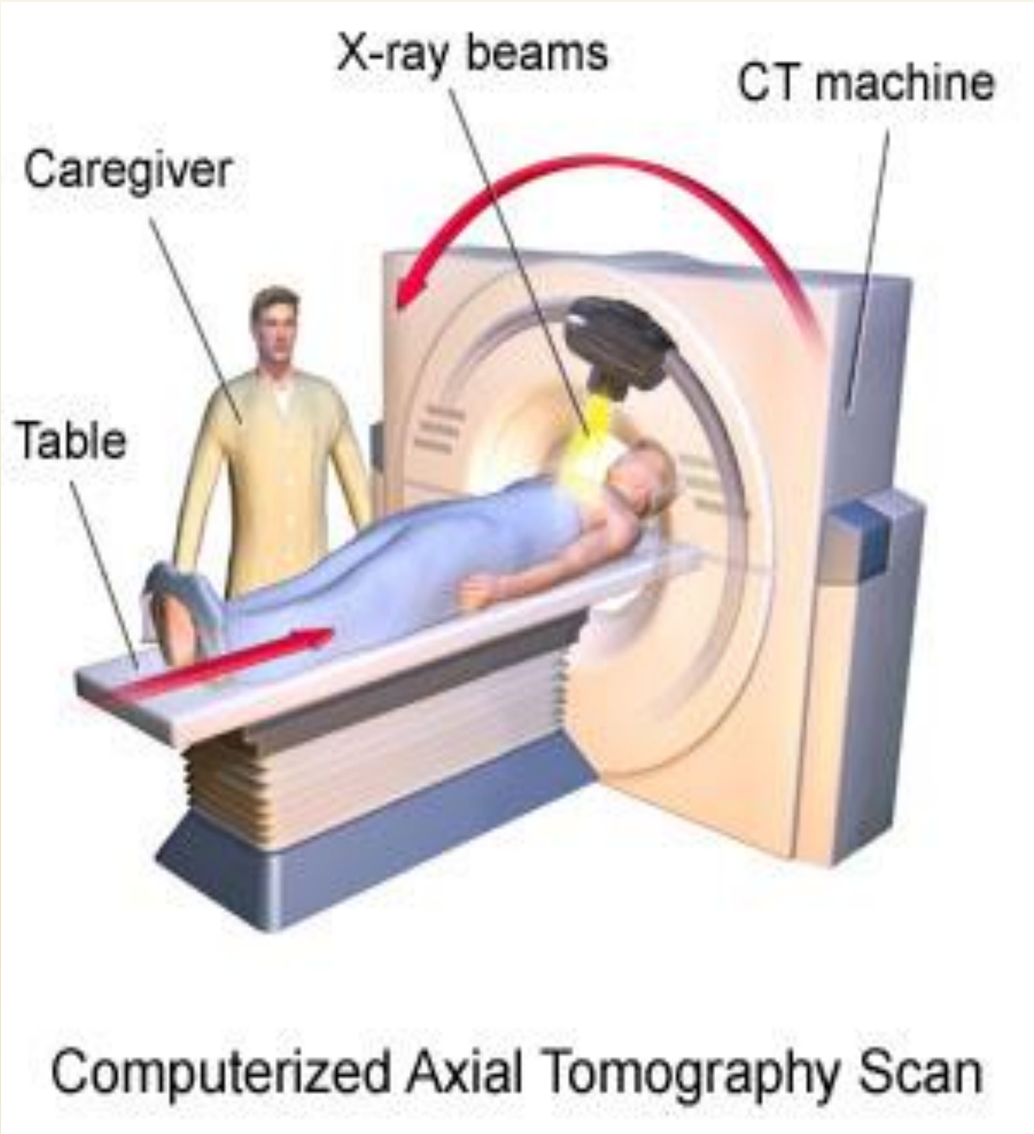
Background Radiation Exposure

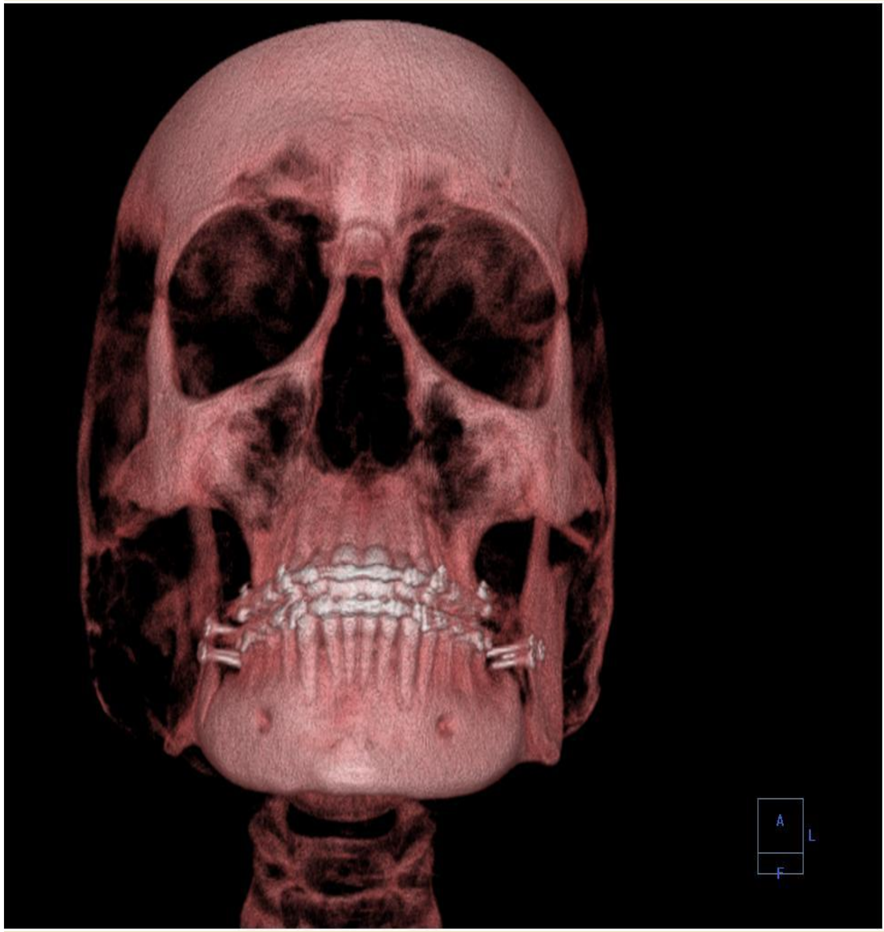
Annual Effective Dose/individual in the US = 620 mrem/yr.



50% from Artificial Sources

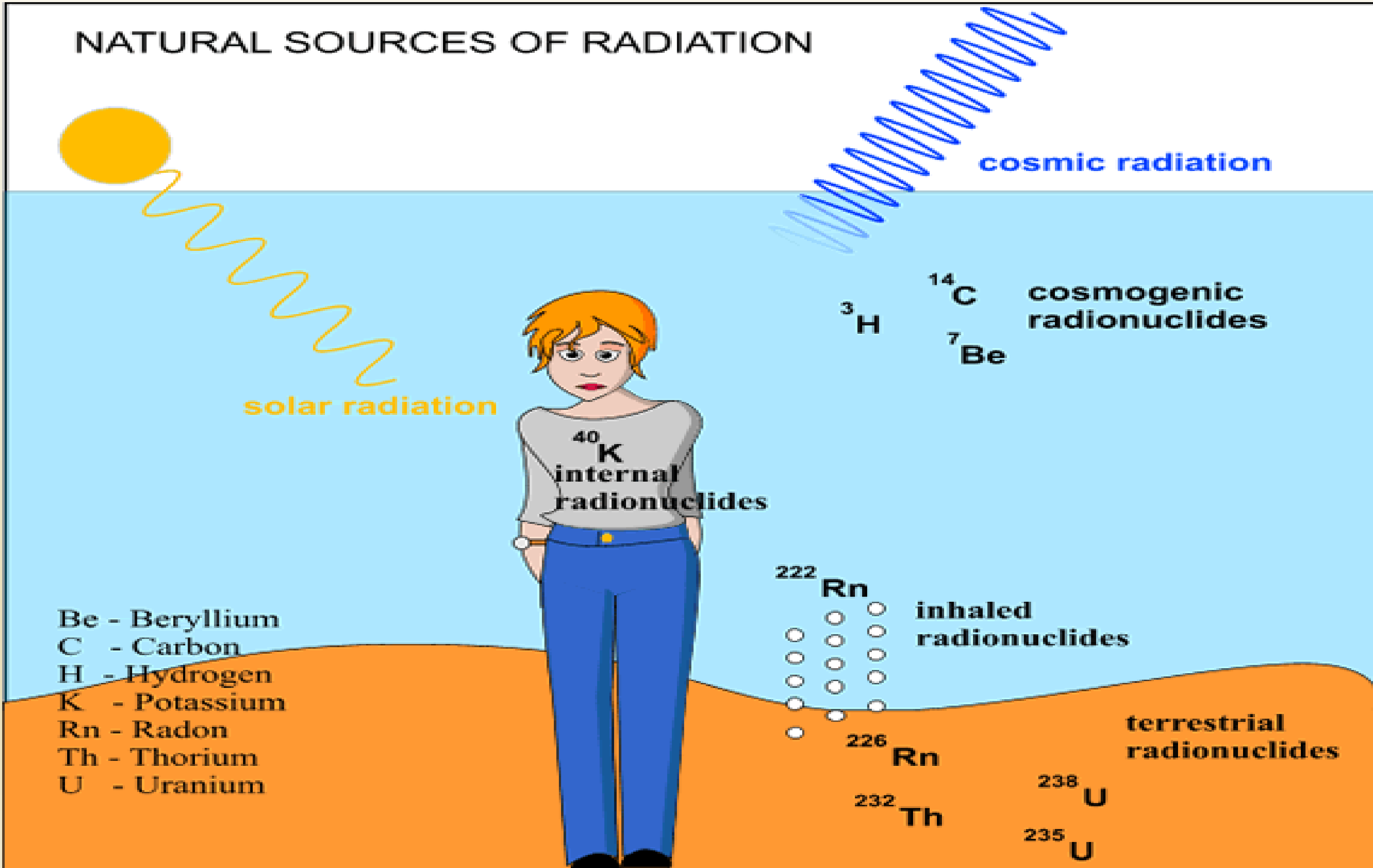
Biggest Dose from Medical



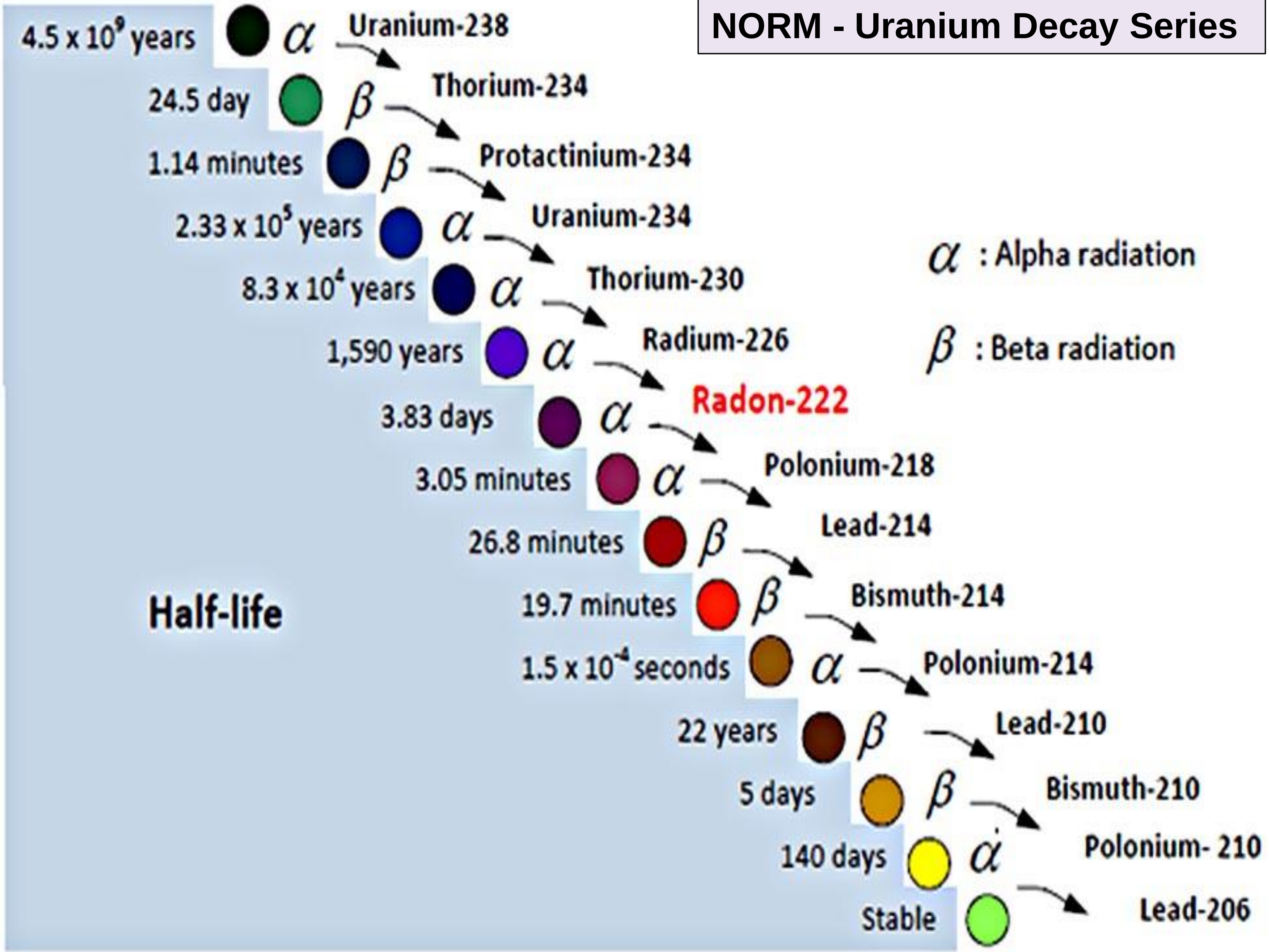


50% from Natural Sources

Biggest Dose from Radon



NORM - Uranium Decay Series

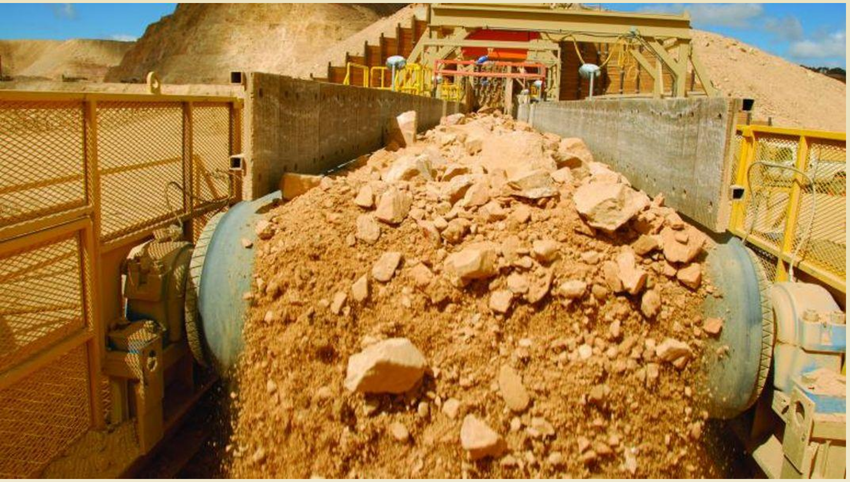


Industries Known to Generate NORM

- **Mining**
  - Hard Rock Metal Mining
  - Uranium Mining
  - Rare Earths Mining/Process
  - Mineral Mining/Processing
- **Energy production**
  - Oil and Gas Production, Transmission & Refinery Wastes
  - Coal Combustion Residuals
- **Water treatment**
  - Drinking Water Treatment
- **Consumer products**
  - Fertilizer Processing
  - Building Materials

Metal Mining

- Zircon
- Gold/Silver
- Titanium

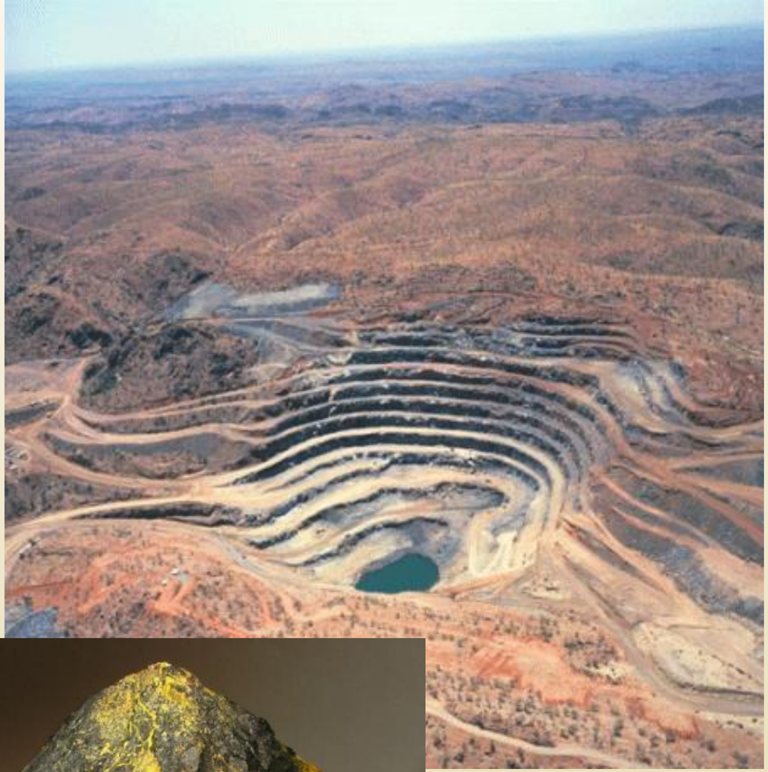


Uranium Mining

- Overburden
- Weakly uranium-enriched waste rock.
- Subgrade ores
- Excavated top soil
- Evaporation pond sludges and scales

These materials typically contain radionuclides (and their decay products), including:

  - Uranium
  - Radium
  - Radon
  - Thorium



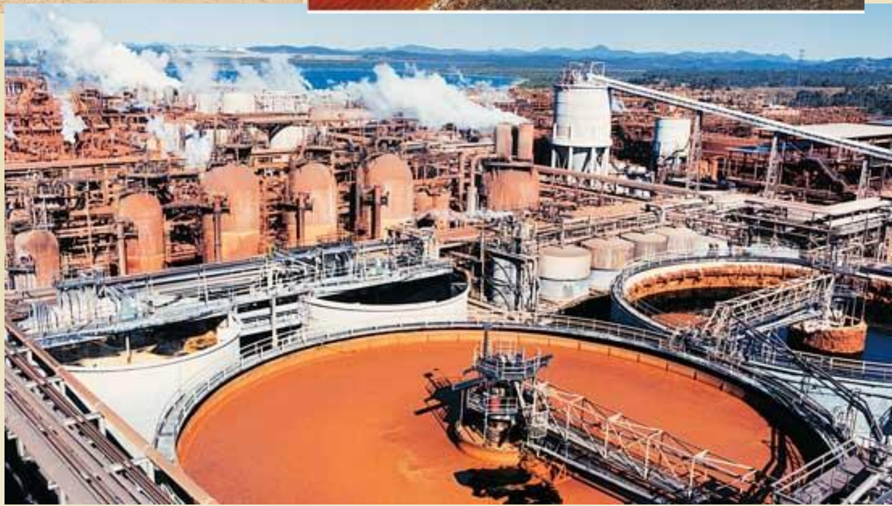
Rare Earth Mining

Rare Earth Metals

- Lanthanides
- Actinides
- Yttrium
- Scandium

Mineral Mining/Processing

- Copper Mining & Processing
- Titanium Producers
- Bauxite Processing
- Alumina Processing



Oil & Gas NORM

<u>Upstream (Exploration & Production)</u>

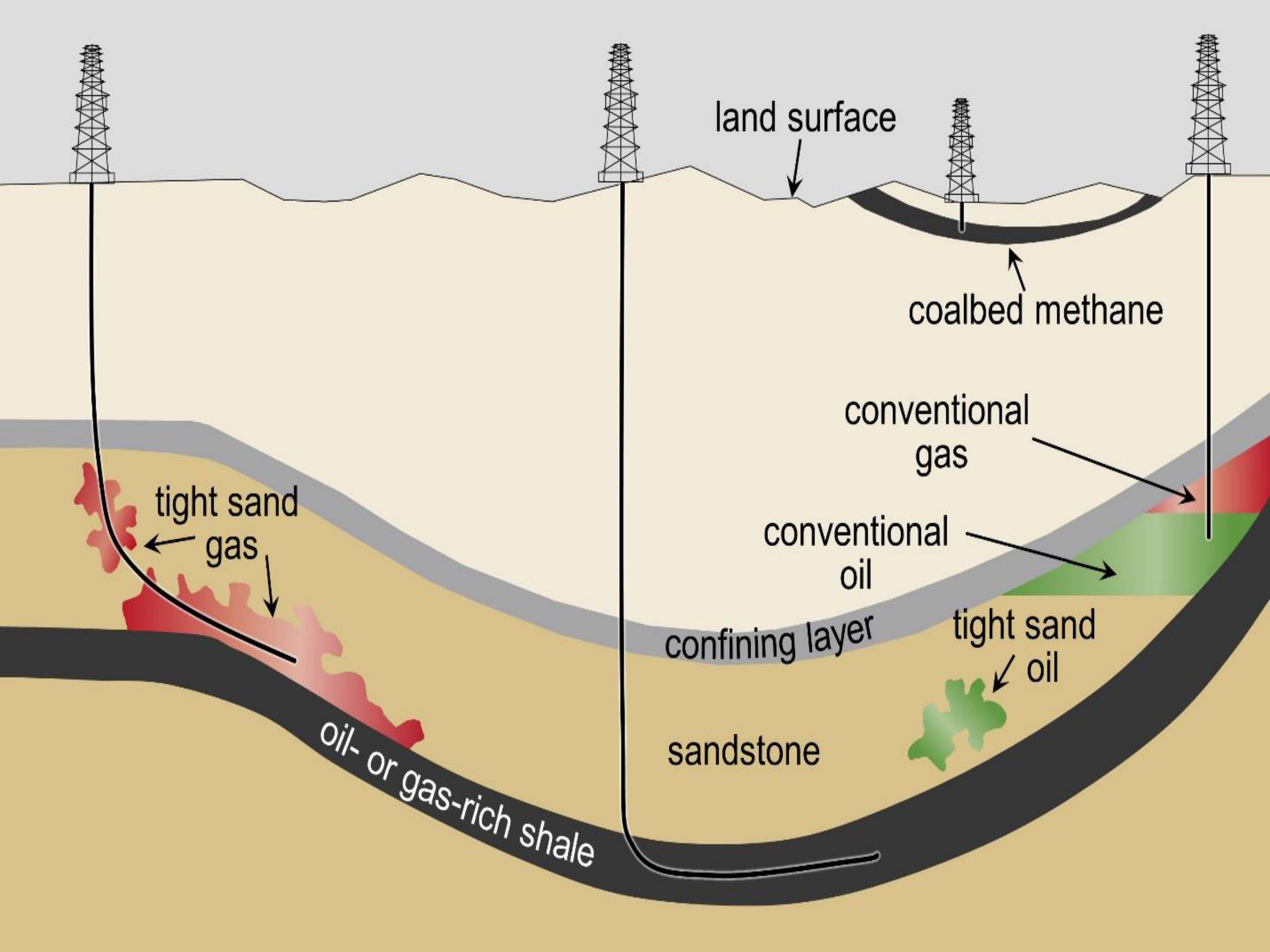
- NORM Scale, Sludge, Sand & Soil in:
  - Tubing/Equipment
  - Tank Bottoms/Treaters
  - Coil Tubing/Back Flow/Tracers
  - Spills/Cleanup

<u>Midstream (Transmission)</u>

- NORM Rouge, Sludge, Films & Soil in:
  - Pigging Operations
  - Spills/Cleanup

<u>Downstream (Refining & Processing)</u>

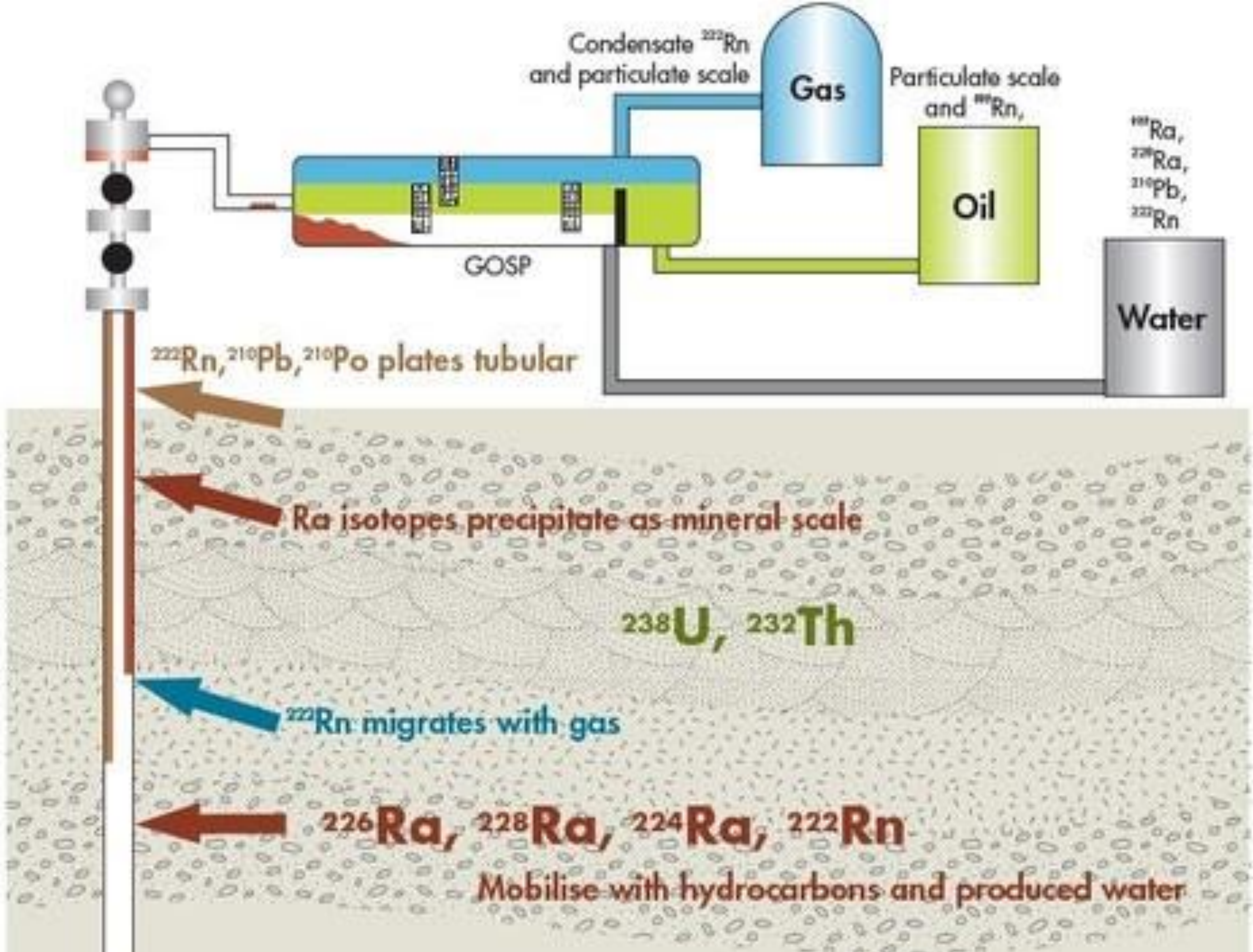
- NORM Scale & Sludge in:
  - Fractionators
  - Exchangers
  - Cracking brick


land surface
coalbed methane
conventional gas
conventional oil
tight sand gas
confining layer
tight sand oil
sandstone
oil- or gas-rich shale

U.S. Shale Formations

NORM in Crude Production

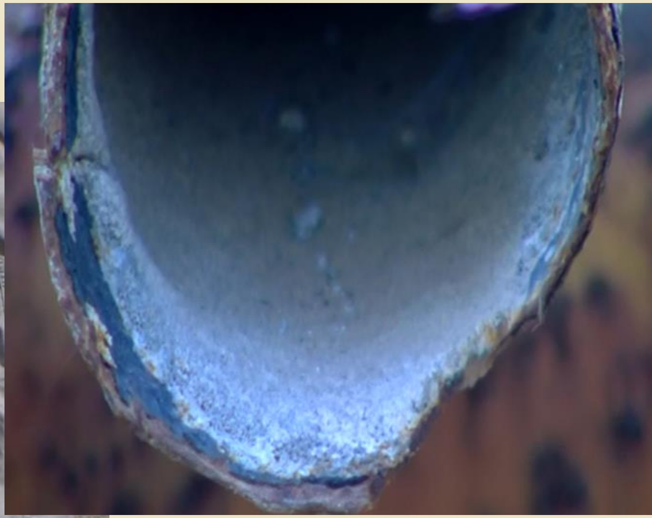
- **Uranium** & **Thorium** elements are naturally found in oil & gas formations but they are **insoluble** and usually remain in place in the sub-surface formation.
- **Radium** can **solubilize** in the production process, and can coprecipitate along w/ Calcium & Barium to form scale and sludge waste products and residuals.



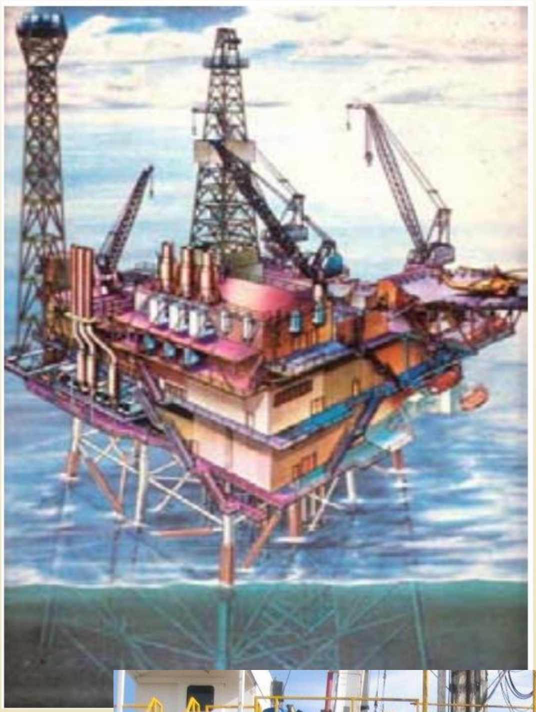
Condensate ^{222}Rn
and particulate scale
Gas
Particulate scale
and Rn,
Ra,
Ra,
^{210}Pb,
^{222}Rn
Oil
GOSP
Water
^{222}Rn, ^{210}Pb, ^{210}Po plates tubular
Ra isotopes precipitate as mineral scale
^{238}U, ^{232}Th
^{222}Rn migrates with gas
^{226}Ra, ^{228}Ra, ^{224}Ra, ^{222}Rn
Mobilise with hydrocarbons and produced water

Radium Concentration

- Many factors are needed for enough radium to solubilize and accumulate (Production process, Temperature, Pressure, pH, Chemical Changes)
- Only about 20-30% of Oil & Gas production (In systems greater than 10 years old) produce regulated levels of NORM.



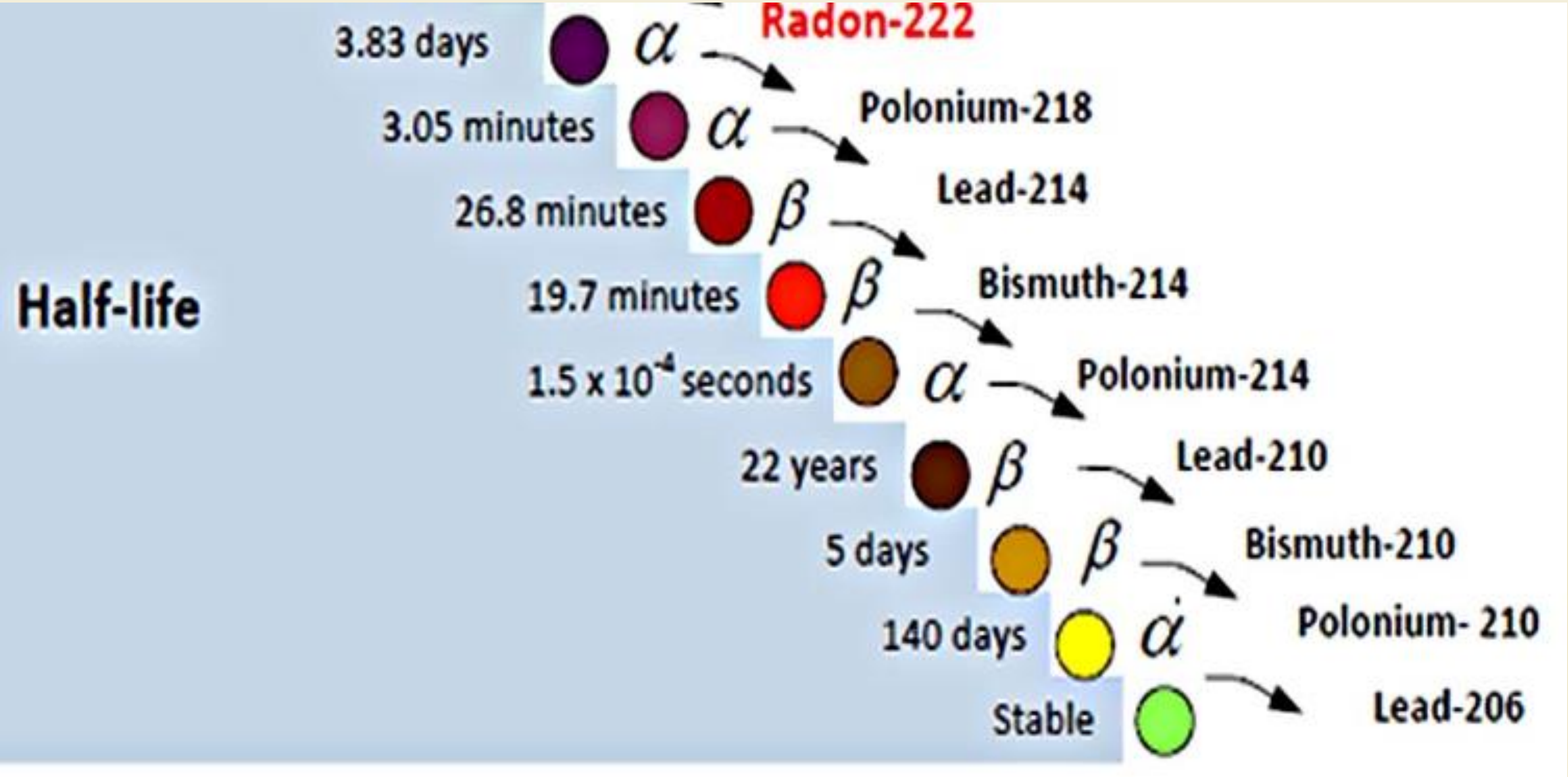
Production



Production

NORM in Natural Gas Production, Transmission & Refineries

Rn-222, Pb-210, Bi-210 and Po-210 tend to be a concern with gas wells, gas transmission lines, refineries, and NGL facilities.

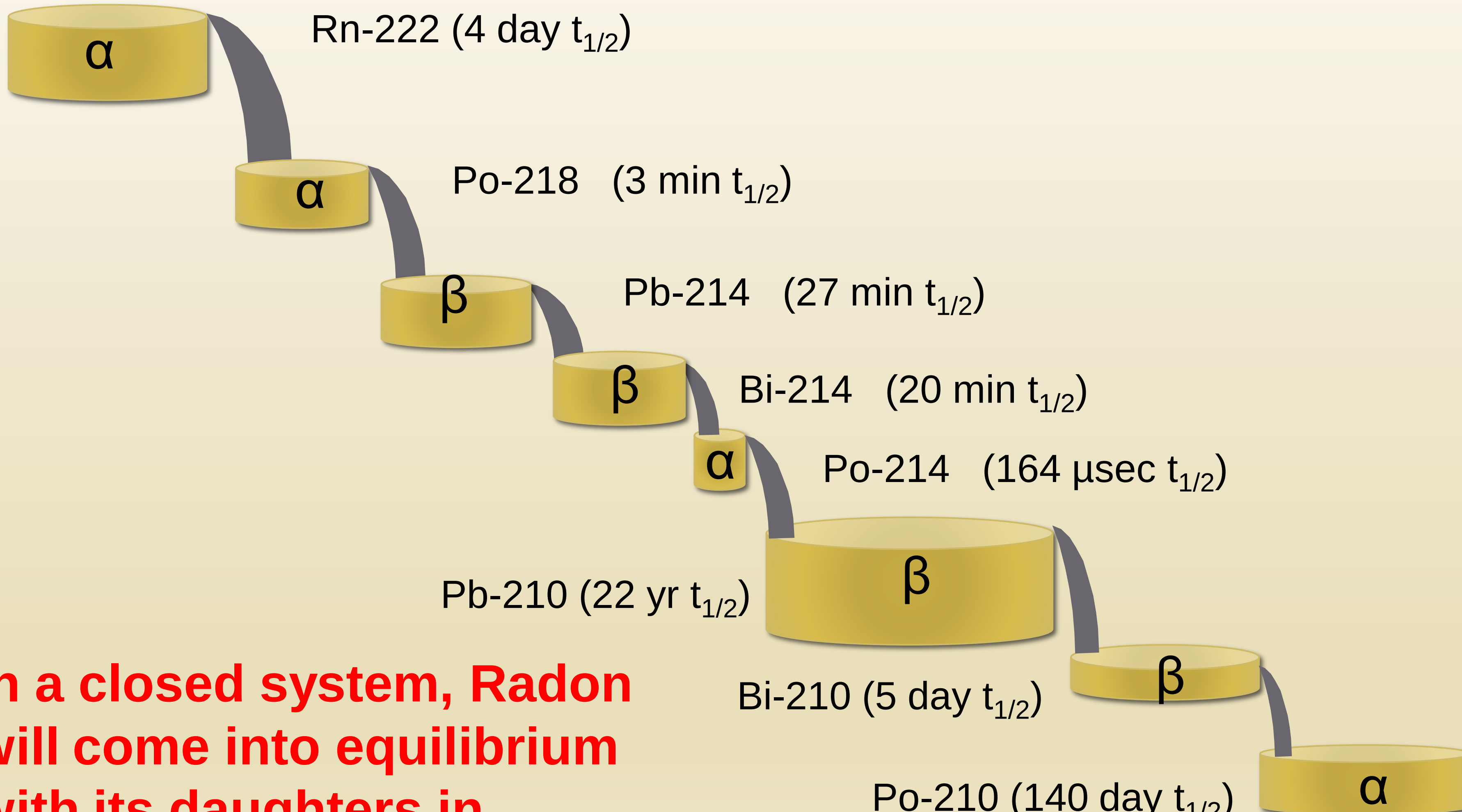


Radon Chemistry

- **Radon** gas (Rn-222) and its daughter products will accompany most all hydrocarbon processes.
- Given the right circumstances, **Lead (Pb-210)** and **Polonium (Po-210)** can plate out and concentrate in refined/ processed equipment & waste
- These isotopes do not have a strong gamma signature so they are not easily measured (especially on closed systems)

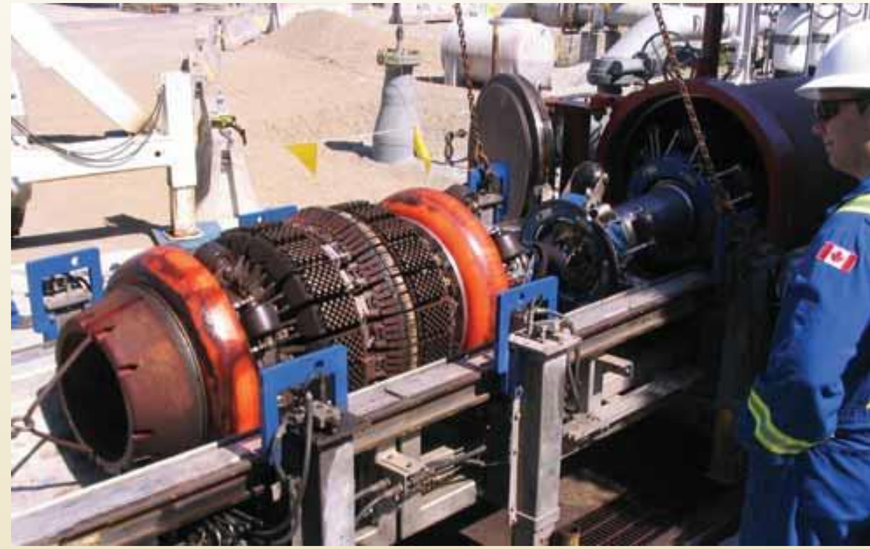
What Remains after Radon Dissipates

Radon Equilibrium



In a closed system, Radon will come into equilibrium with its daughters in about 26 days

Transmission



Boiling Points

	Fahrenheit
Methane	- 258.0
Ethylene	- 154.8
Ethane	- 127.0
Radon	**- 79.2**
Propylene	- 53.9
Propane	- 43.7
Butane	+ 31.1

Because the boiling point of radon is very close to that of ethane and propylene, radon gas tends to collect in those areas of the refineries and olefins plants where ethane, ethylene, propylene, and propane are being produced and processed

Refining & Processing

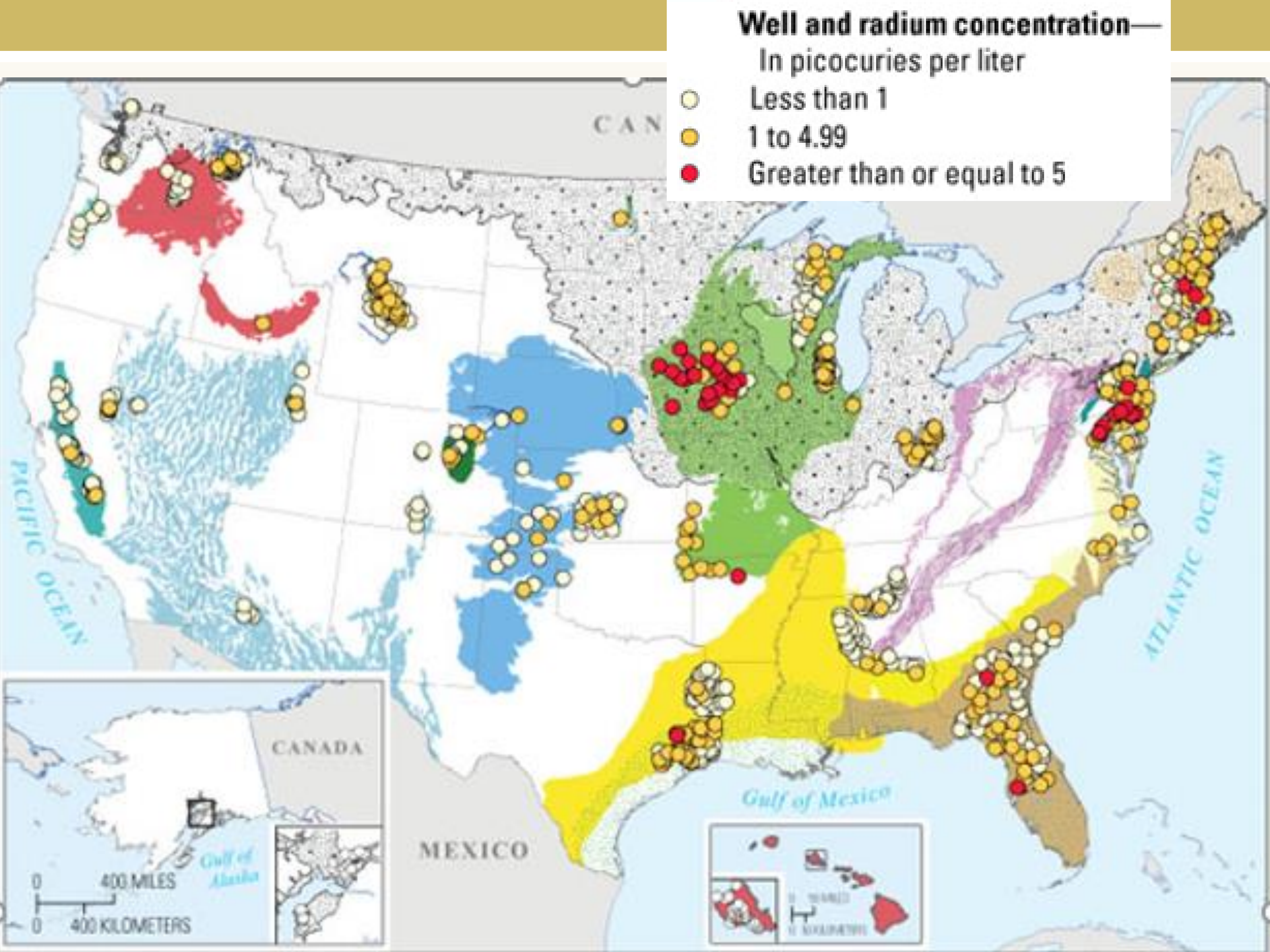
Hydrocarbon & Chemical Refining

- Heat Exchanger
- Cooling Towers

Mismanagement/Disregard

Coal Combustion

Drinking/Waste Water Treatment



Well and radium concentration—
In picocuries per liter
Less than 1
1 to 4.99
Greater than or equal to 5
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
Gulf of Mexico
MEXICO
CANADA
Gulf of Alaska
0 400 MILES
0 400 KILOMETERS

Phosphate Fertilizer

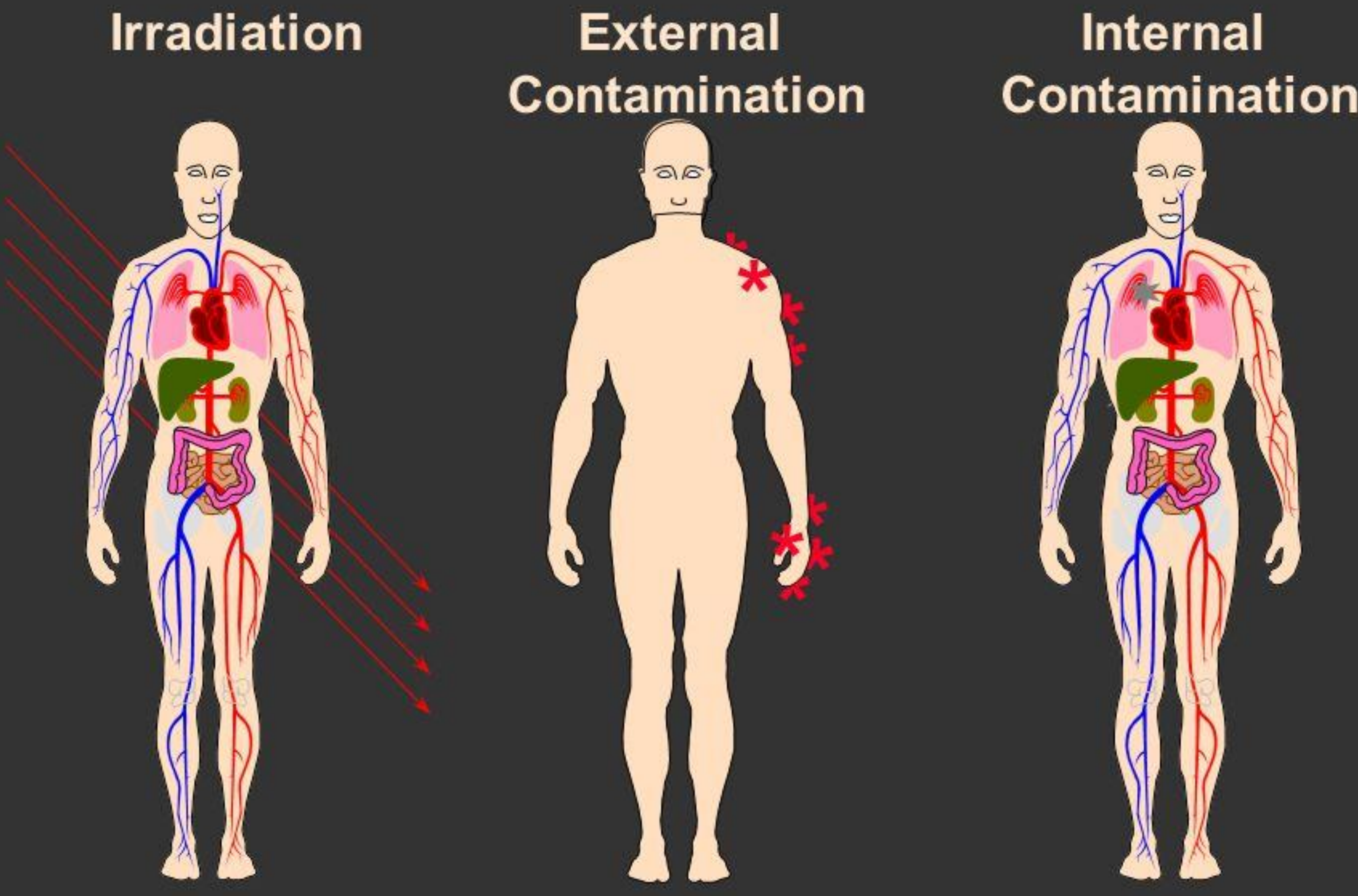
- Phospho-gypsum
- Phosphate Processing

Building Materials

Construction Materials
- Gypsum
- Granite
- Refractory brick

NORM Survey & Characterization

Radiation Exposure Types



Radiation vs. Contamination

Radiation is **energy**, contamination is **material.**

Contamination is *radioactive material* that has been deposited on the surfaces of equipment, structures, areas, objects or personnel.

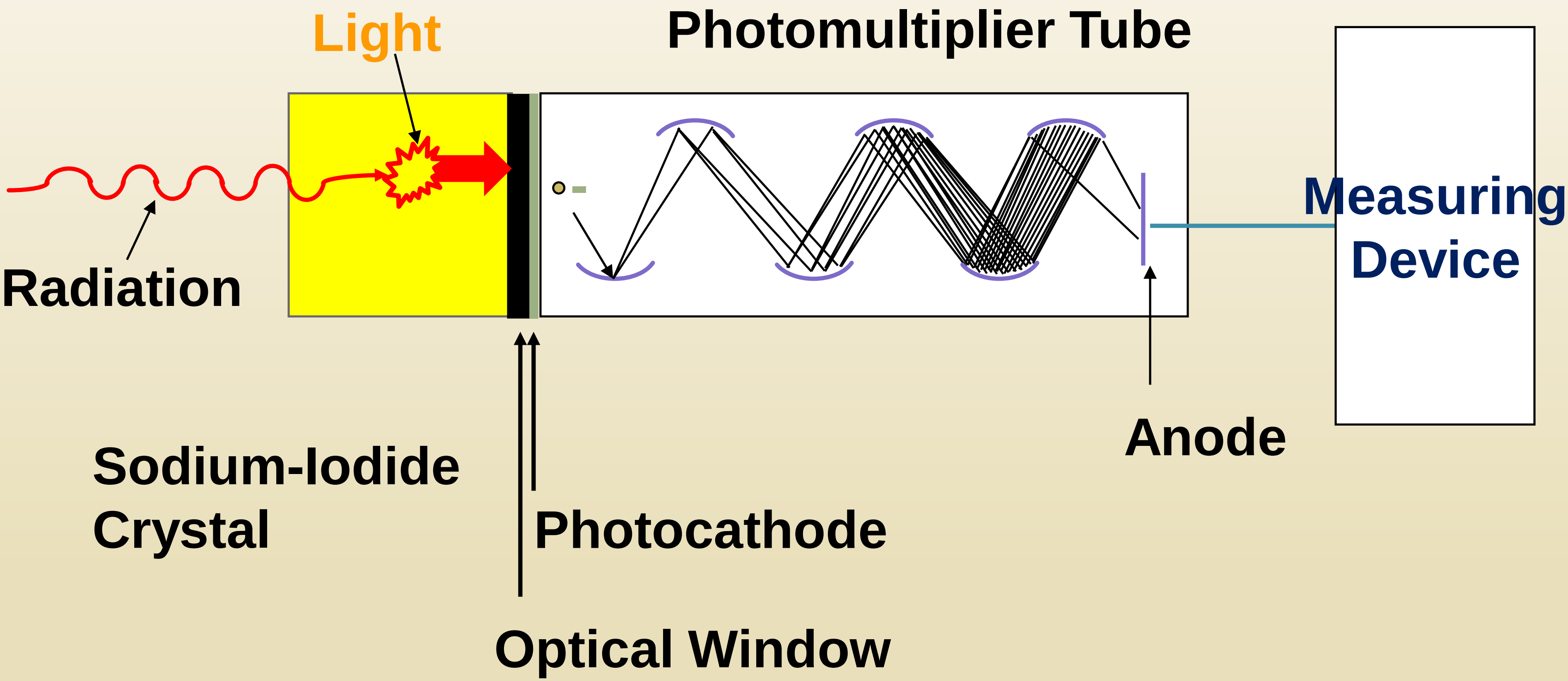
Contamination refers to the actual *radioactive material* which emits radiation.

NORM Detector Types

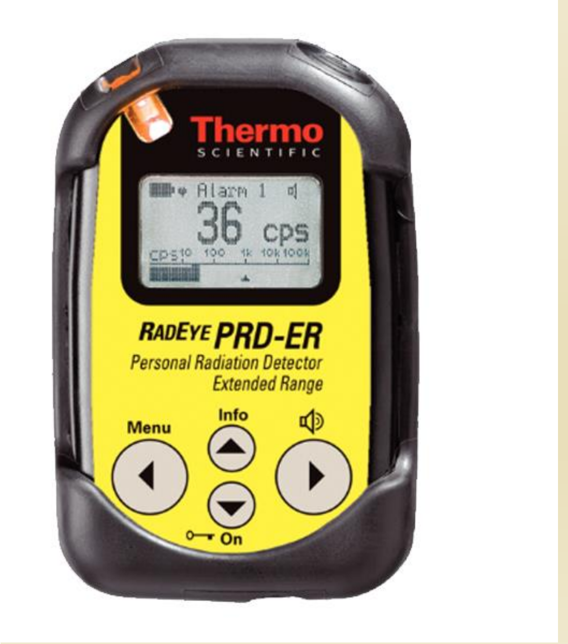
- **Radiation Monitors:** Scintillation Detectors
  - Light Production
  - Typically used for Gamma Radiation Exposure Surveys

- **Contamination Monitors:** Ionization Detectors [i.e. Geiger Mueller (GM) Pancake Probe]
  - Electrical Collection of Ions (gas-filled or solid)
  - Typically used for contamination survey/monitoring

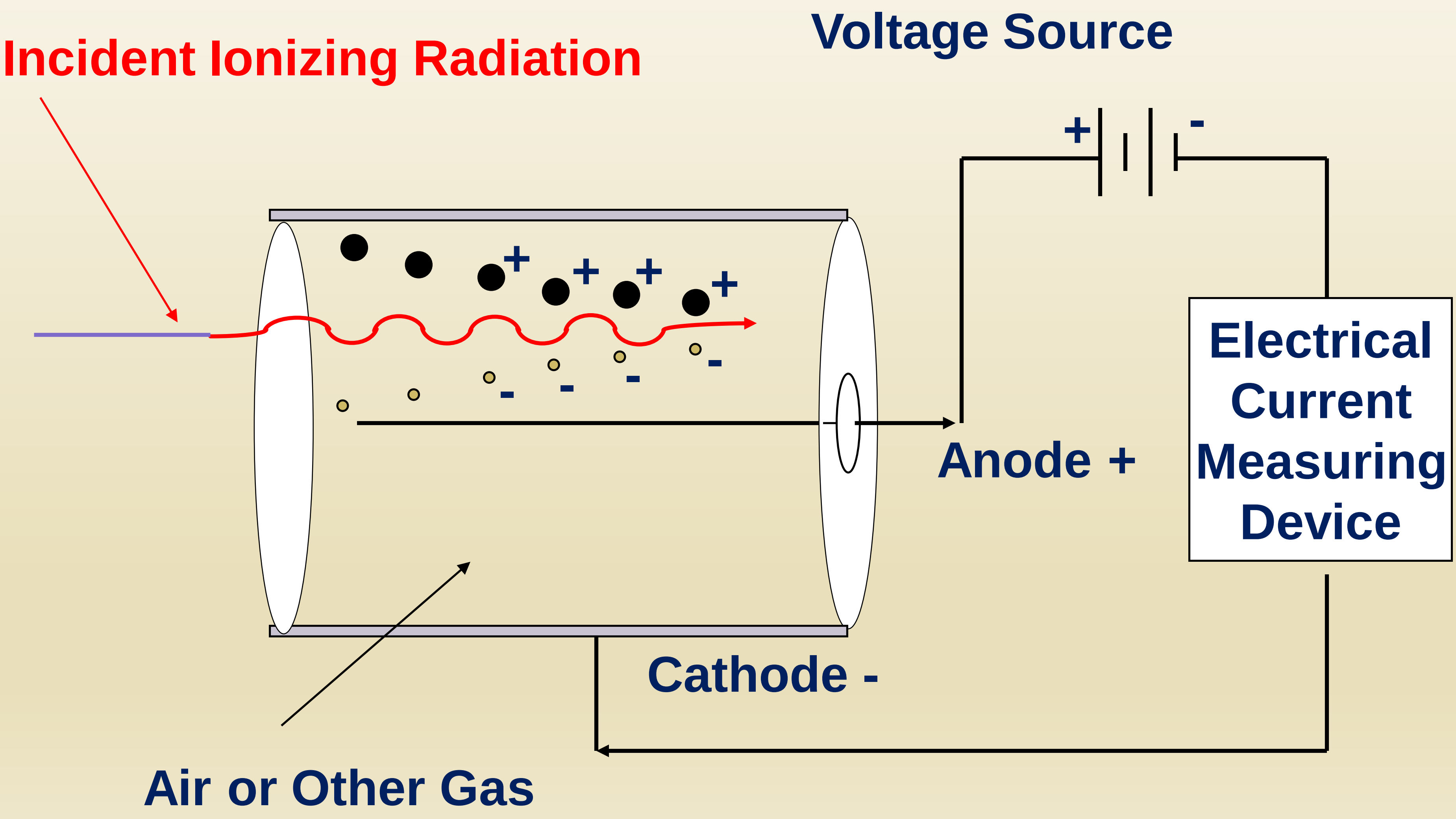
Gamma Scintillation Detectors



NORM Radiation Exposure Detectors



Gas Filled Detectors (GM Tubes)

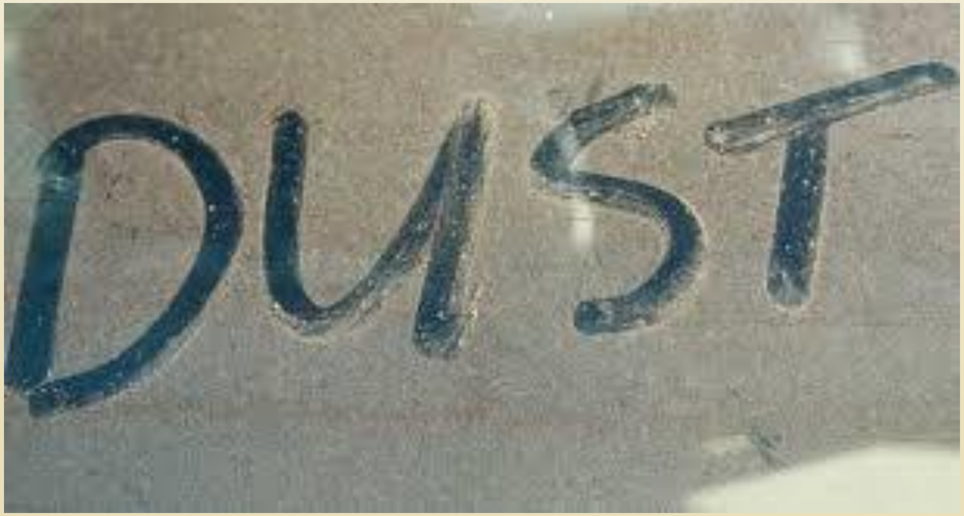


NORM Contamination Detectors

Contamination

Contamination can be either

"Fixed" or "Loose"



Fixed Contamination

- Tightly adherent to the surface on which it lies.
- Cannot be removed by causal contact and can not be easily removed by wiping the surface on which it lies.
- May be released and become airborne by using aggressive activities (welding, torch cutting, grinding).

Loose Contamination

- Easily removed from the surface on which it lies by casual contact or wiping.
- A concern because it is easily spread and may become airborne when activities such as welding, torch cutting, grinding, needle gunning, polishing and buffing are performed.
- Protective clothing should be worn when working around loose contamination.

Characterizing NORM Contamination

- Assess all Environmental, Safety and Health (ES&H) Risks
- Identify the Source & Potential Cause
- Determine the Chemical/Physical Form
- Determine the Extent of Contamination
- Support of Engineering Design and Project Management
- Determine Radiological Impacts & Dose Assessments.
- Characterization should be proportionate to the extent of the likely remediation/decontamination effort.

Assess All Potential ES&H Risks

Source & Potential Cause

- Historical investigation
  - Site layout
  - Operational characteristics
  - Materials handled,
  - Accidents, etc.
- Determine if part of the process has malfunctioned and/or failed
- Look for signs of visual & radiological contamination

Chemical/Physical Form of Contamination

Identify Contaminants

- Alpha/Beta/Gamma
- Surface Soil
- Subsurface Soil
- Ground Water
- Surface Water
- Sediments
- Air

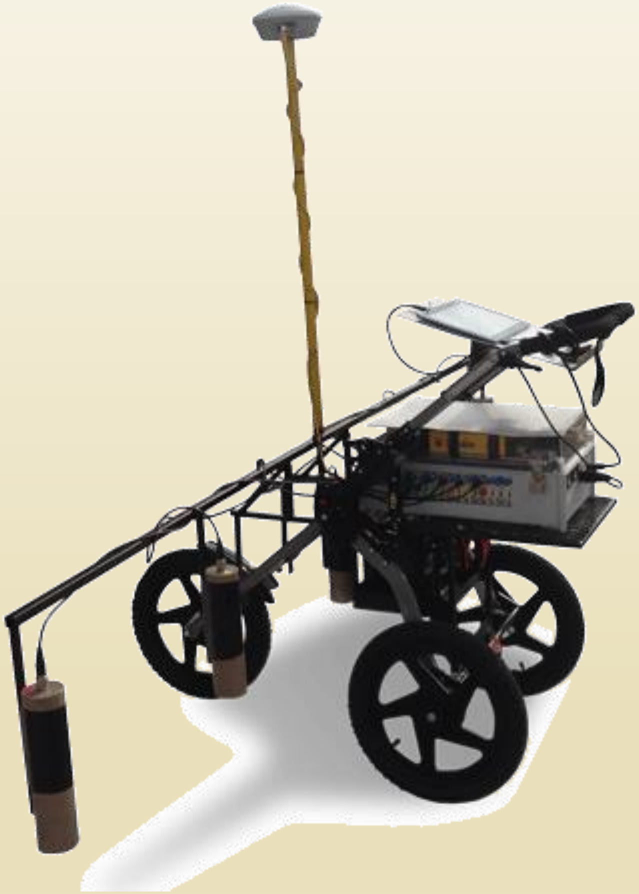
Observation/Sampling

Analysis

UAV Gamma Survey

GPS Gamma Ground Survey

GPS Gamma Ground Survey



Equipment/Tank Gamma Survey

Alpha/Beta Contamination Survey

Soil/Media Samples

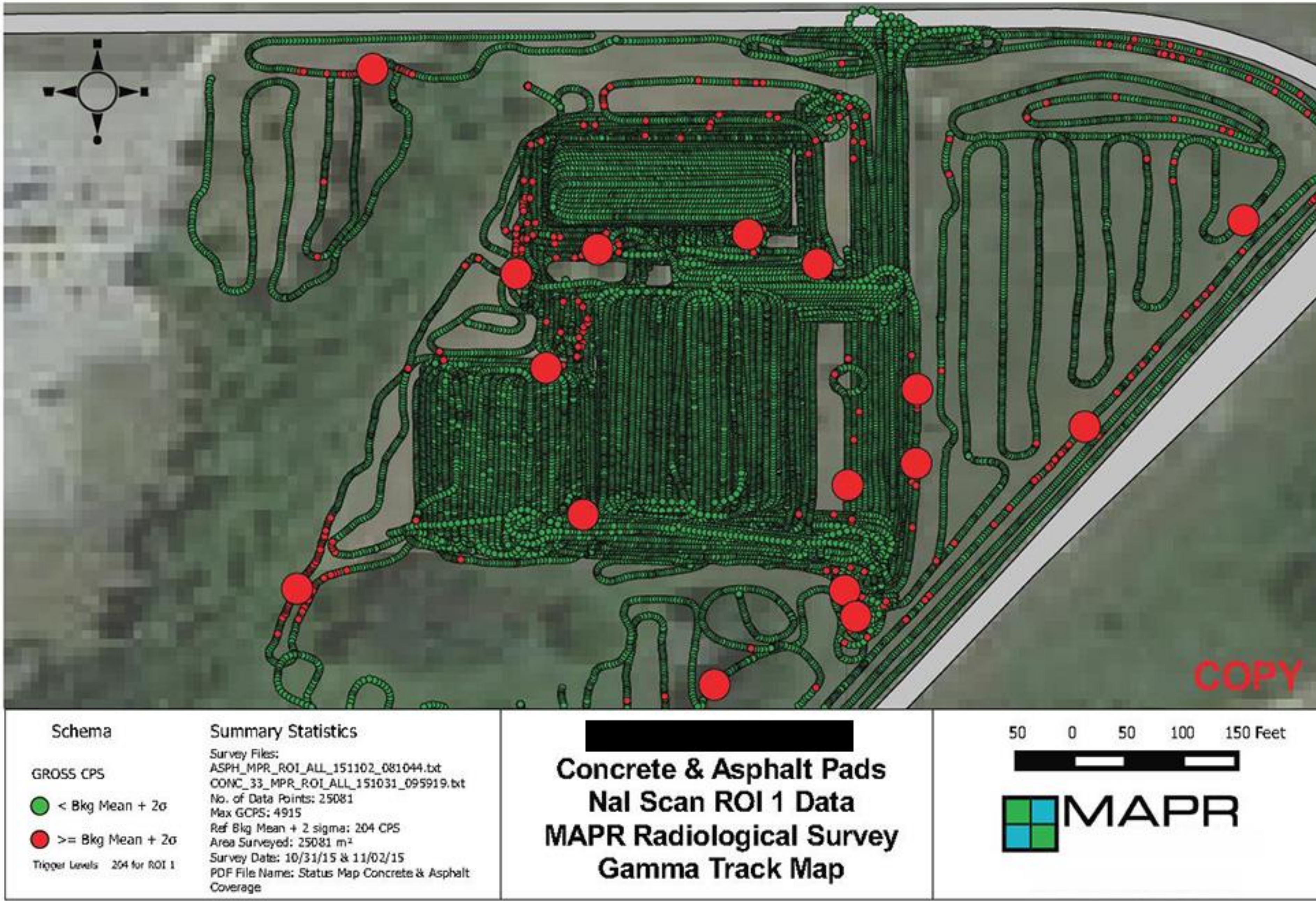
Sludge Samples

Surface & Ground Water Samples

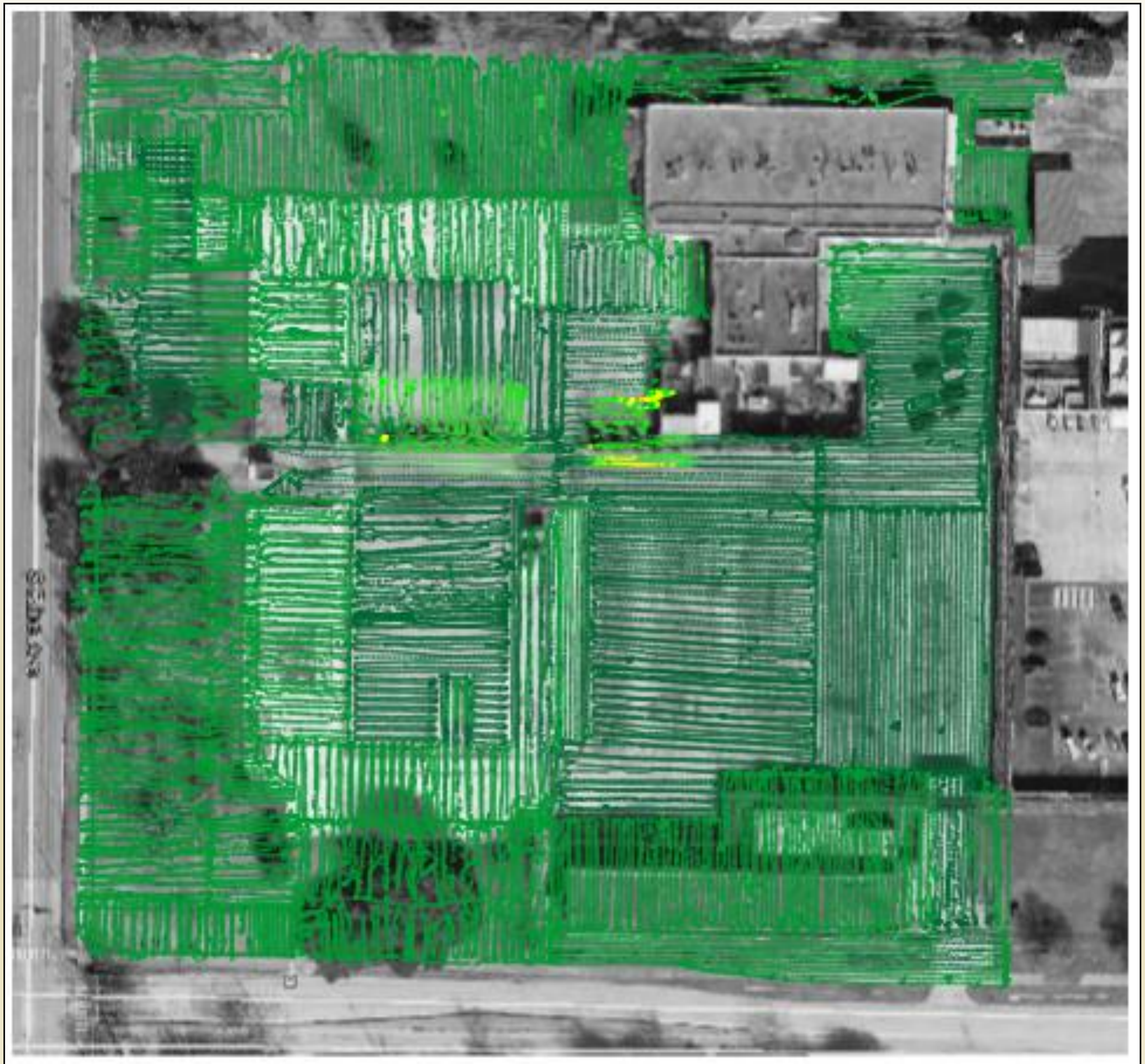
Sediments/Run-off

Environmental Air Sampling

Location Mapping



GPS Gamma Mapping

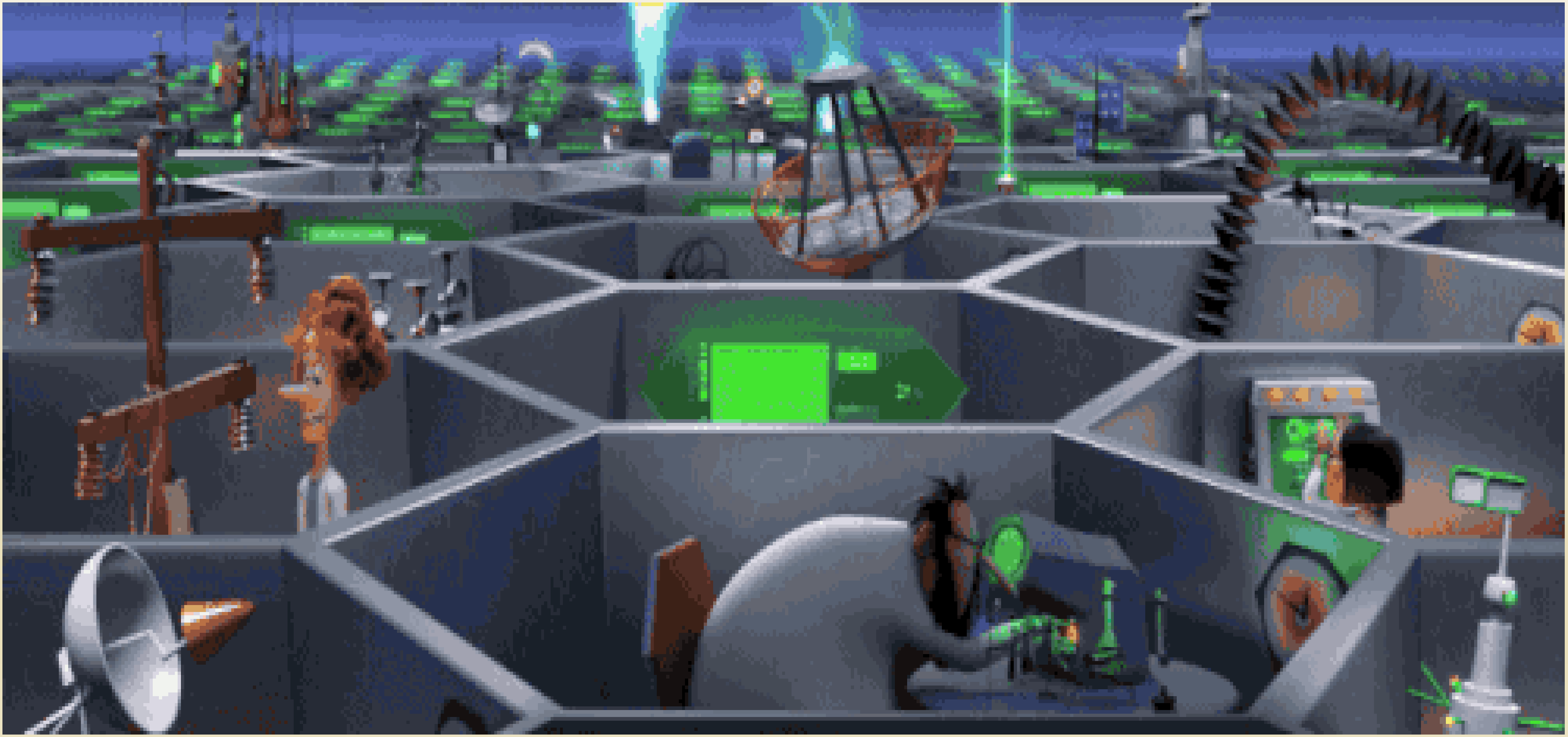


Extent of Contamination

- Investigations, history, data measurements and assumptions must be made to determine the extent of the contamination on any project.
- The more data you have, the more you will be capable of delineating the vertical and horizontal extent of contamination
- It is not an exact science.

Processing Decisions & Options

Finding a Safe & Effective “Mouse-Trap” at the Best Price with the Least Exposure



Considerations

- Selection of the most effective remedial action should be based on:
  - Economics
  - Practicality
  - Health & Safety
  - Time Frame
  - Regulatory Action
  - Environmental Impact
  - Public Relations
  - Liability & Exposure

Equipment/Tank Decontamination

- Waste Extraction/Removal
- Hydro/Water Blasting
- Dry/Wet Sand Blasting
- Dry Ice/CO_2 Blasting
- Robotic Decontamination
- Chemical Cleaning/Circulation
- Recycle

Waste Extraction/Removal

Waste Extraction/Removal

A-Bear Consult LLC

Hydro/Water Blasting

Hydro/Water Blasting

Fixed/Flex Lance

Dry/Wet Media Blasting

Dry Ice/CO_2 Blasting

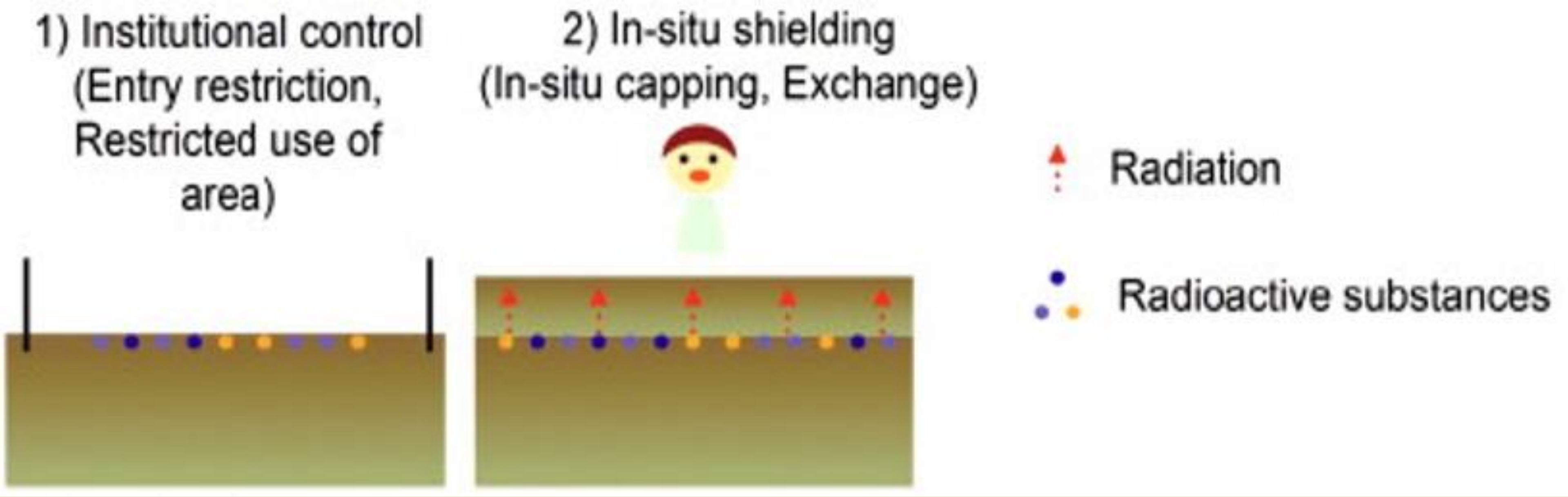
Before After

Robotic Decontamination

Chemical Cleaning/Circulation

Soil/Media Remediation (Isolation)

1. Restrict Access 2. Shielding

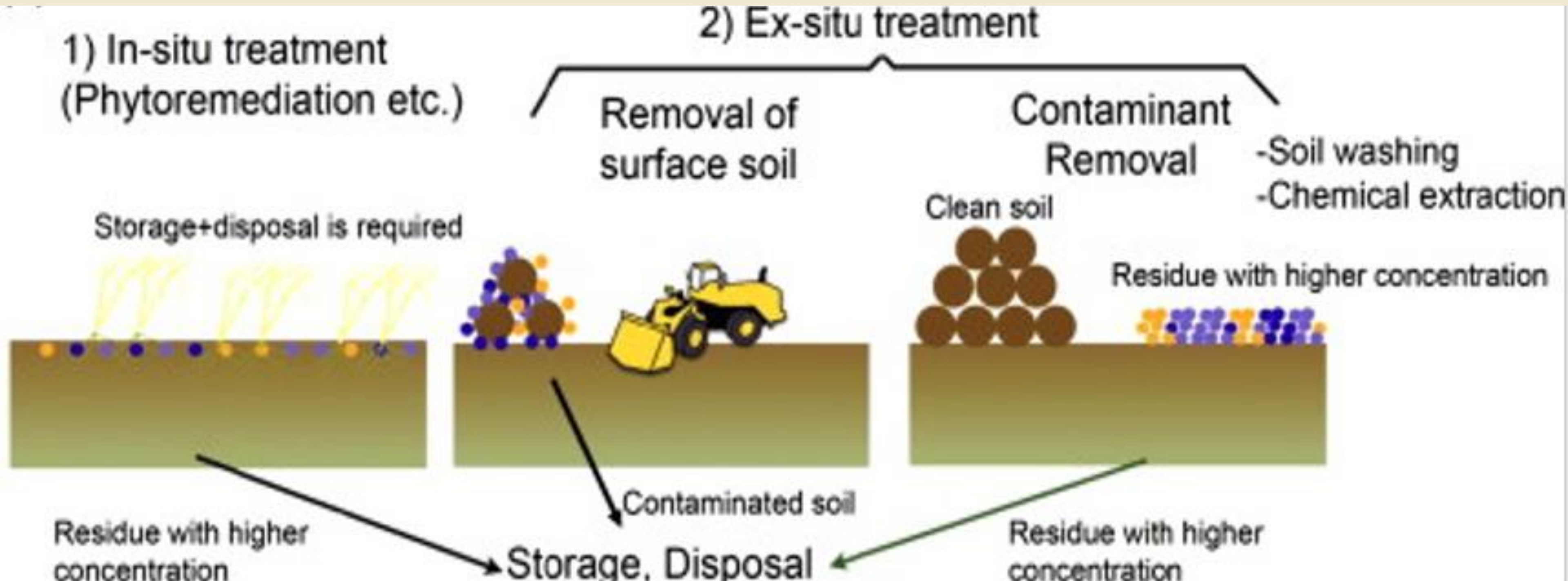


Soil/Media Remediation (Treatment)

1. In-Situ Soil **Treatment** (Phytoremediation, Bioremediation)

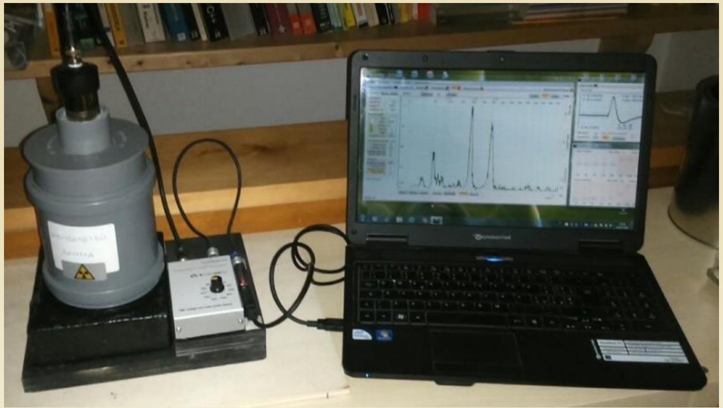
2a. Surface Soil **Excavation & Removal** (Disposal)

2b. Surface Soil **Excavation & Treat** (Contaminant Removal)



NORM Process Monitoring
(Field Measurements for Project Progression)

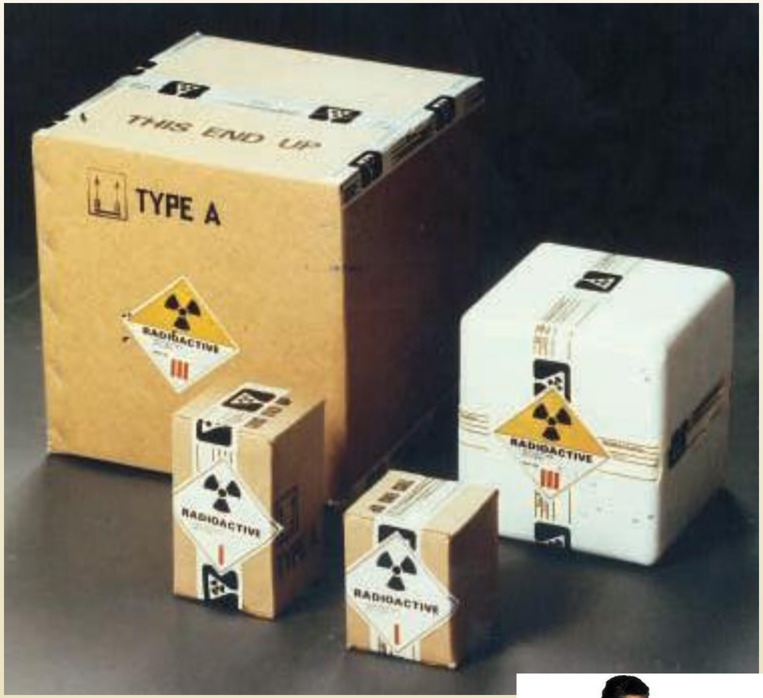
- Sorting/Segregation
  - Direct Gamma/Contamination Survey
- Waste/Contamination Discrimination
  - Gamma Single Channel Analyzer (SCA)
  - Field Lab Contamination Verification
- Offsite/Third Party Confirmation
  - Gamma Spectroscopy
  - Air Sample Analysis
  - Water Sample Analysis



NORM Packaging

NORM should be packaged and prepared for shipping for the **mode** of transport being used and with the **end storage/disposal option** understood.

Small Quantity



Overpacks


NO PARKING
PARKING
JUSTRITE
OVERPAC
28001
DOT-E 9618
SALVAGE DRUM


ENPAC


SALVAGE
SALVAGE DRUM
SALVAGE DRUM

Super Sacks

Intermodal Containers

Bulk Quantity

Oversize Packaging

Marine Transport

Marine Transport

Vacuum Trucks

Hydro Vacuum/Super Sucker

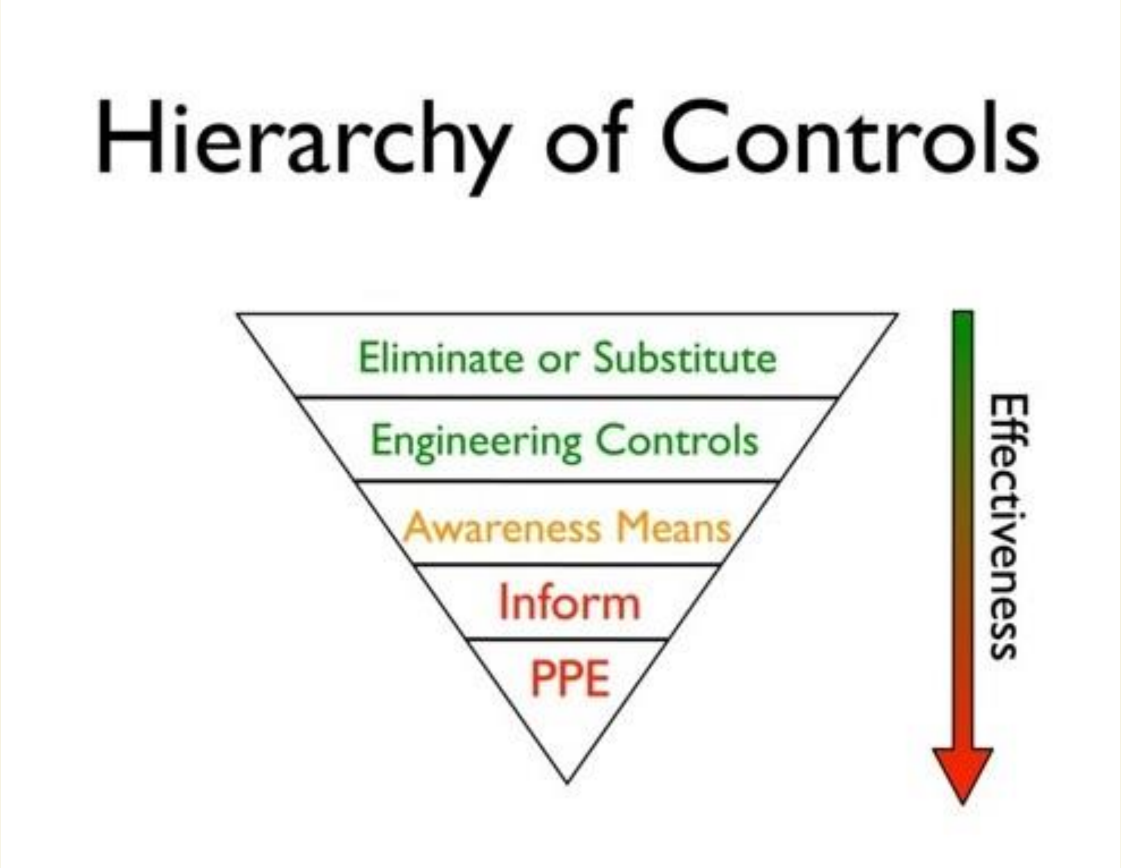
Project Management

- Initiation
- Planning
- Execution
- Performance/ Monitoring
- Project Closeout

Worker Protection, Health Physics & Compliance

Site Specific JSEA

A Job Safety Environmental Analysis (JSEA) is designed for analyzing a job, specifically in the area of health, safety and environment hazards and risks toward the ultimate objective of eliminating the likelihood of workplace incidents or negative environmental impacts.

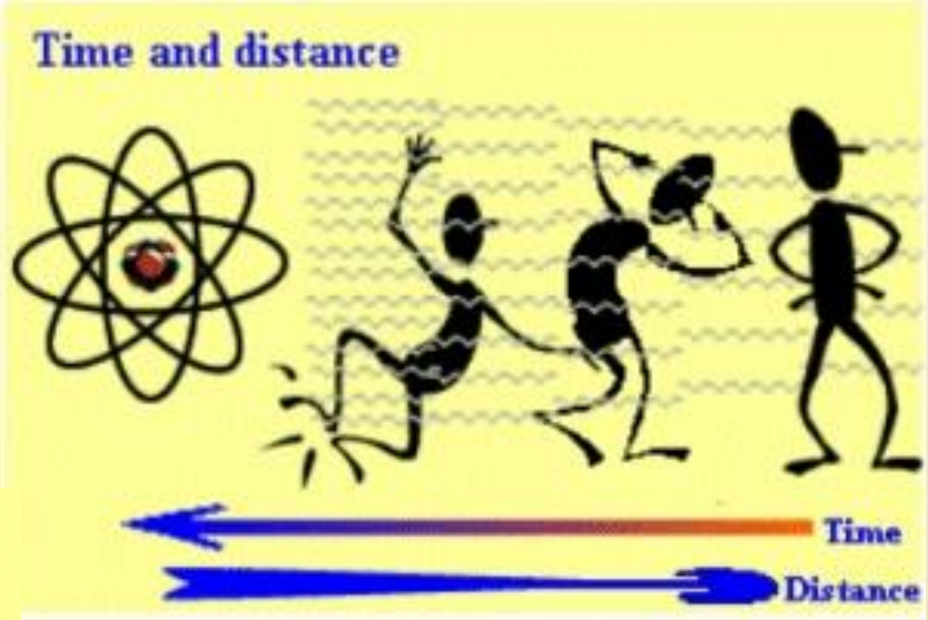


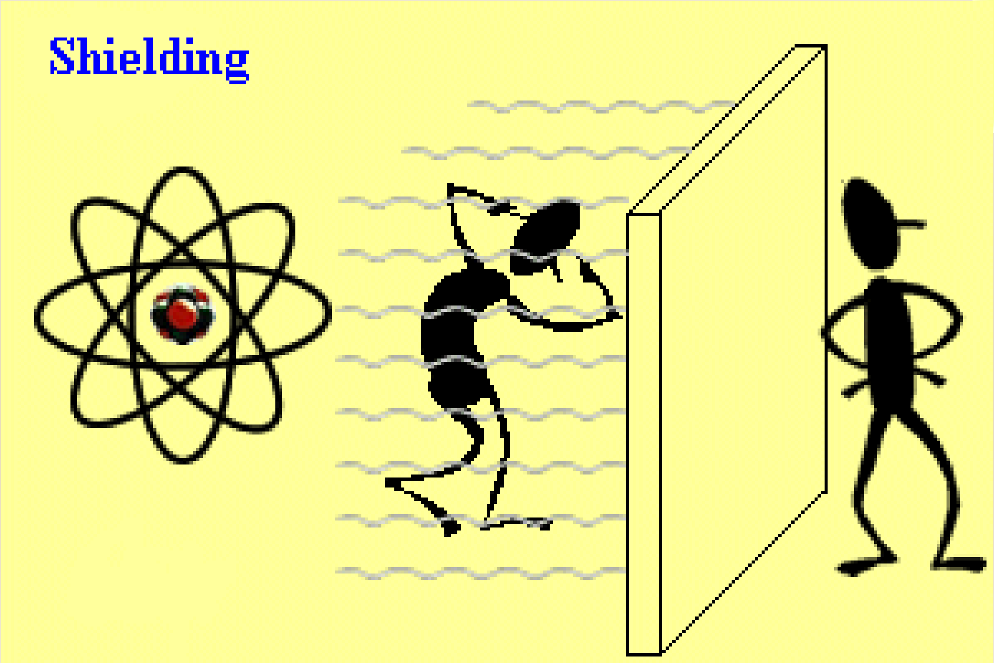
Radiation Work Permits (RWP)

- RWPs are used to control radiological work by specifying protective clothing requirements for a job, respiratory protection requirements, dosimetry requirements, and work restrictions.
- RWPs are also used to inform workers of radiological working conditions, radiological hazards, and any special work instructions for the job.

NORM Radiation Safety Principles

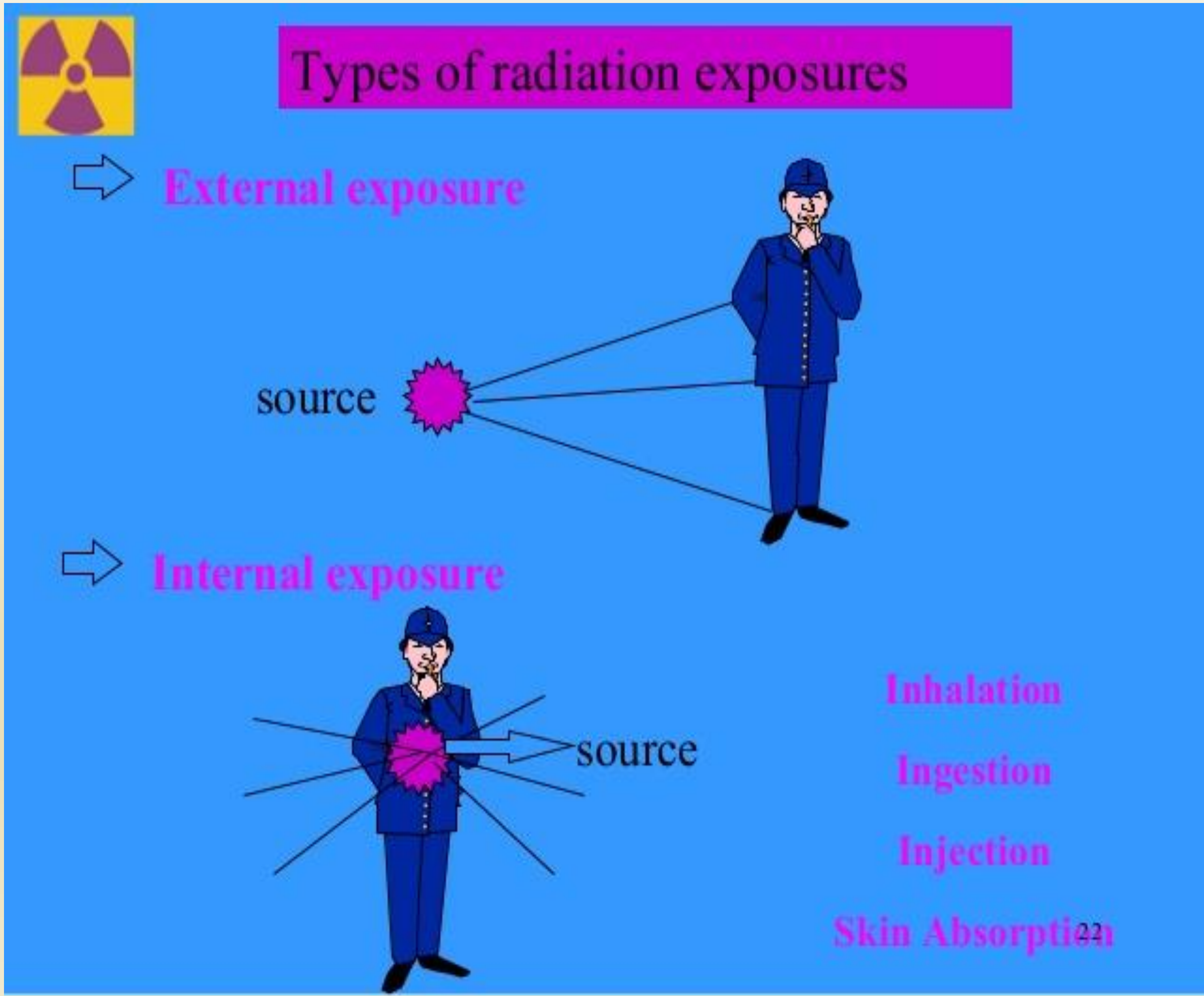
- ❖Protect the Workers
- ❖Protect the Public
- ❖Protect the Environment





NORM Radiation Dose Pathways

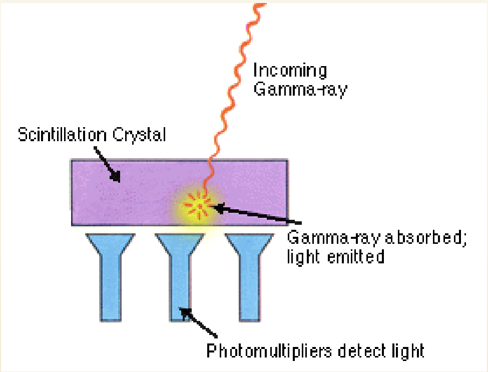
- External Gamma Exposure
- Dust Inhalation
- Radon Inhalation
- Food Ingestion
- Skin Absorption



NORM Worker/Public Monitoring (Radiation, Contamination, Air, Water)

- **Gamma Survey** (to document public and worker external exposure)
- **Contamination Survey** (to document worker internal and external exposure)
- **Air Sampling** (to document public and worker internal exposure)
- **Surface Water Sampling** (to document environmental impact)

NORM Radiation Detection

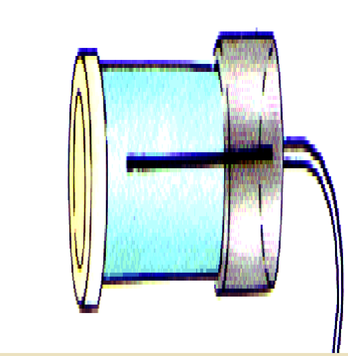


Scintillation Detectors [i.e. Gamma Probe]

- Light Production
- Typically used for Gamma Survey

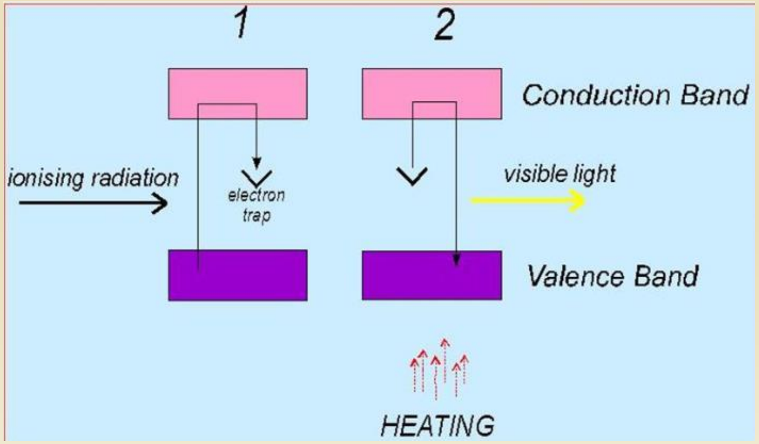
Ionization Detectors [i.e. Pancake Probe]

- Electrical Collection of Ions (gas-filled or solid)
- Typically used for contamination survey/monitoring



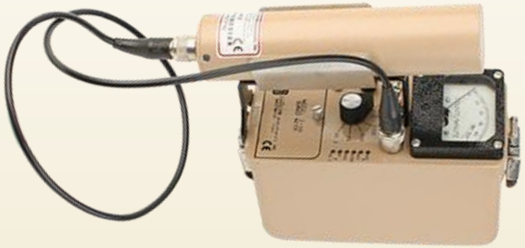
Passive Detectors [i.e. TLDs]

- Crystal thermolescent
- Typically used for individual dose record



Gamma Dose

- Gamma Surveys (Survey meters)
  - Can measure dose rate, total dose and accumulative dose



- Active Dosimetry Instruments (Real time monitors)
  - Can measure dose rate, total dose and accumulative dose

- Passive Dosimetry (TLDs, OSRs)
  - Can measure accumulative dose

NORM Worker/Public Monitoring

- **Contamination Survey** (to document worker internal and external exposure)

- **Air Sampling** (to document public and worker internal exposure)
- **Surface Water** Sampling (to document environmental impact)

Estimating a Radiation Exposure

Need to determine:

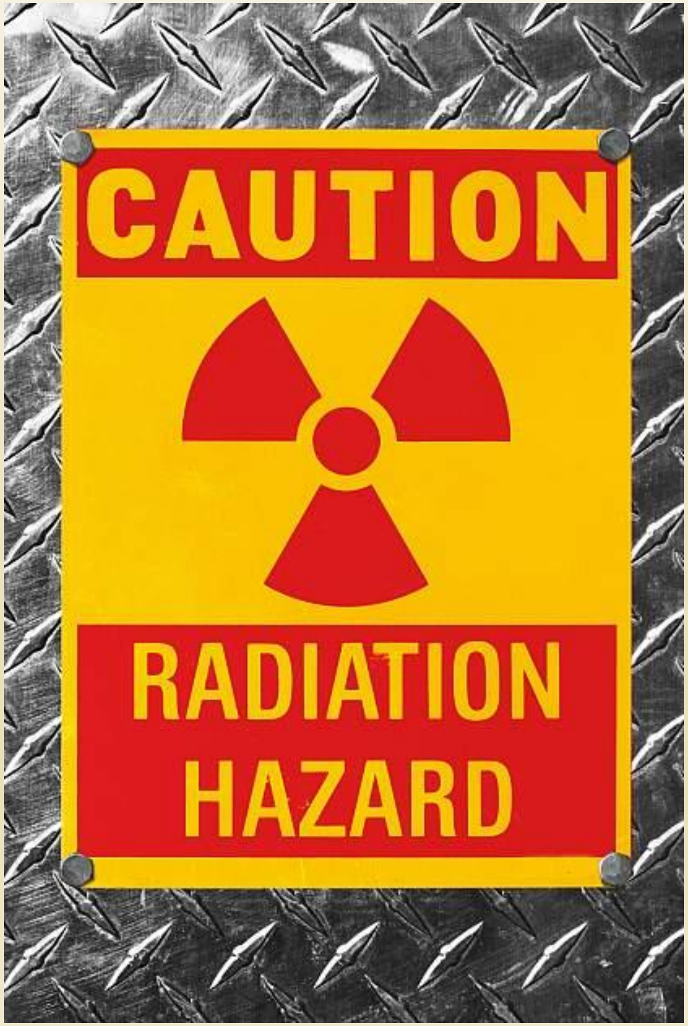
- How much the person was exposed to
- What type of radiation (α, β, γ, x-ray, n)
- How much gets inside the body
- How susceptible the organs/tissues are to the rad exposure
- Age/Development/Health of the person

Total Effective Dose Equivalent (TEDE)

External Radiation Exposure Calculation (from TLDs, Survey Data, Assumptions)

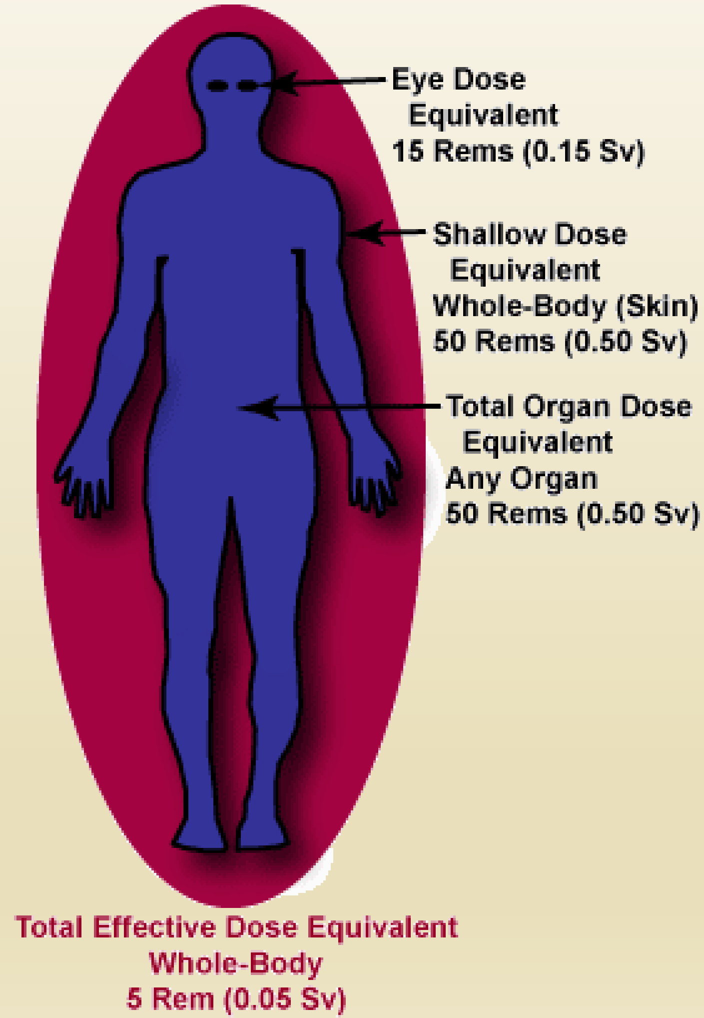
+

Internal Radiation Exposure Dose Calculation (From Air Monitoring or Assumptions)



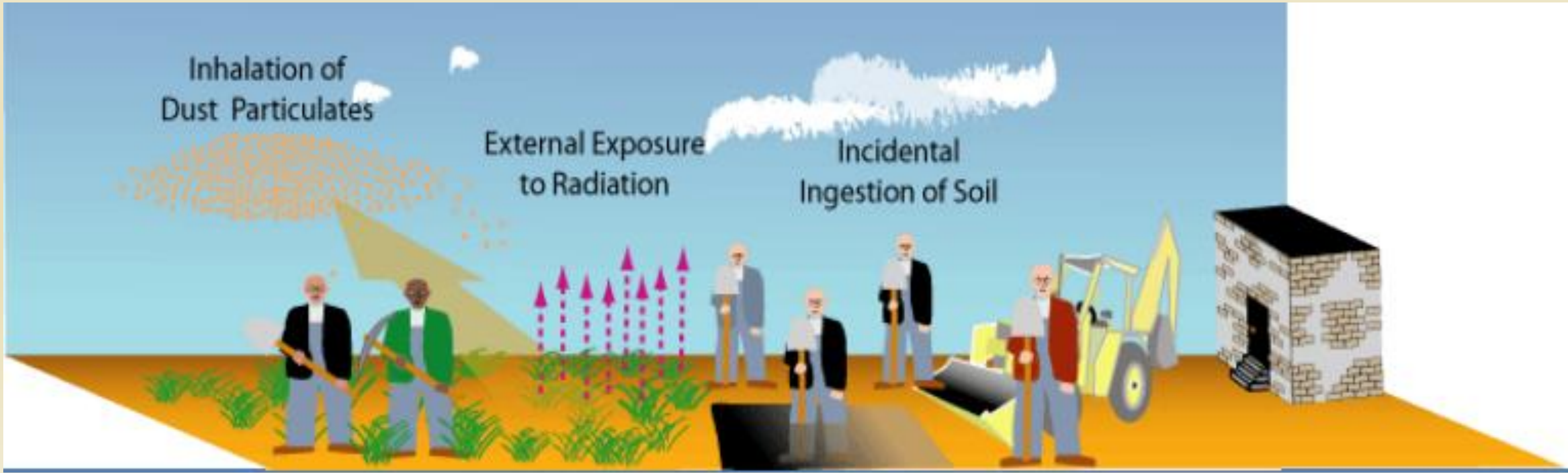
Radiological Impact to Workers

- Determine potential exposure pathways & receptors for workers
- Calculate the Total Effective Dose Equivalent (TEDE) to workers
- Workers are limited to a TEDE < 5 Rem (5000 mrem) per calendar year



Radiological Impact to the Public

- Determine present and potential exposure pathways & receptors for the public
- Calculate Total Effective Dose Equivalent (TEDE) to the public
- The general public is limited to a TEDE < 100 mrem per calendar year above background (Remember, the average background for a US citizen = 620 mrem/year)



Compliance/Regulatory Considerations

- Regulatory Compliance by the Generator as well as the licensed operator is imperative
- Fines and fees are just a small part of a Notice of Violation (NOV) or a compliance order.
- Once a generator/operator gets out of compliance with the regulatory authority, it may be targeted for greater scrutiny.
- Although the operator is responsible for their operations, the generator will still have liability.

ALARA Considerations

- Generators and Operators must always maintain the principals of As Low As Reasonably Achievable (ALARA)
- Mandated to make every reasonable effort to maintain exposures of ionizing radiation to workers and the public as far below the dose limits as practical.

Environmental/PR Considerations

- Include the environment in decision making
- Reduce the environmental footprint
- Operate responsibly
- Steward your sites

- PR Specialists serve as the mediator between the environmental issues and to public

Liability & Exposure

- Litigation gives rise to negative public relations and more regulations.
- To date there have been basically two types of NORM suits:

  (1) Those where significant personal injuries are alleged

  (2) Those which are basically damage to real property cases.

NORM Lawsuits

1992 - Investigators discovered significant levels of radioactivity in pipe scale at the Street facility in Laurel, MS (**Street vs. Chevron**)

- ❖ The suit sought $35 million in damages. Chevron settled early in the process

1997 - Contamination of property adjacent to pipe-yard near New Orleans, LA (**Grefer v. Alpha Technical, et al**)

- ❖ Jury rendered a verdict for $56 million in compensatory damages, and $1 billion in punitive damages (On appeal, reduced to $112 million).

Oil & Gas NORM Litigation

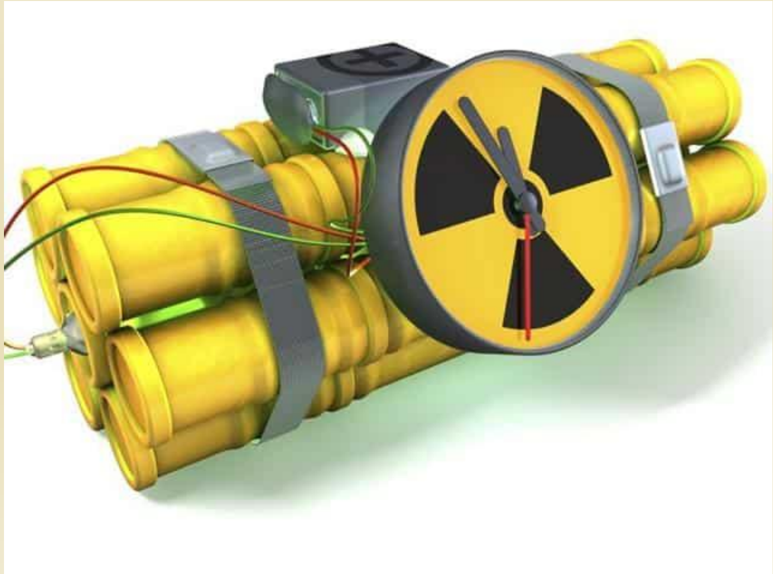
- Litigation over NORM contamination of oil and gas well sites is in its infancy. Although many cases have been filed, only one has reached the appellate level.
- Under current existing and proposed NORM regulations, a significant number of well sites will be deemed contaminated and remediation will be an enormous expense for those who have owned, operated, or worked at such a site.
- The certainty of this expense along with the continued threat of litigation is capable of bringing drilling and production activity to a complete halt, especially in marginal fields.

NORM Accidents & Emergencies

- Can be applied to all radiological situations
- Most NORM incidents are not life-threatening and, in fact, pose little actual physical risk.
- The radioactivity is a nuisance, a regulatory problem, and a complicating factor, but it is rarely an IDLH situation
- Don’t Panic – Think through your “Actions” before “Reacting”

Action for Radiological Terrorism

- General guidelines because each situation will be unique. “Dirty Bombs” are intended to cause Fear
- Protect your Personnel
- Rescue Injured Personnel
- Recover from any physical damage (fires, etc.)
- Establish Radiological Boundaries
- Survey of personnel leaving contamination areas



NORM Transport

NORM Transport

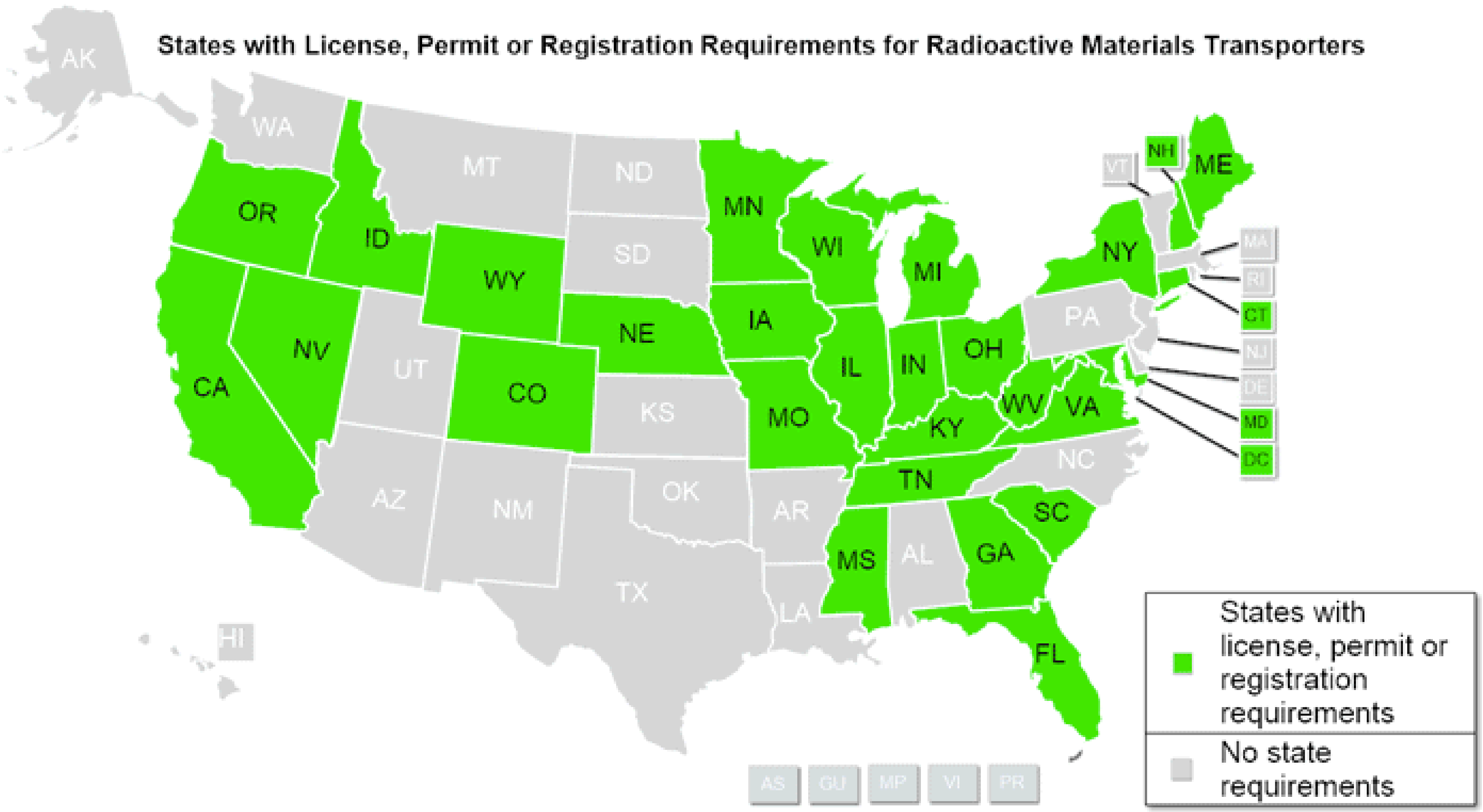
- **US DOT**
  - US DOT Reg. 49 CFR – Hazardous Material Regulations (Trucking & Rail)
- **State Regulations**
  - NORM Specific (Requirements/Manifests)
- **US Imports/Exports**
  - US/Mexico – Mexico Regulation for the Land Transport of Hazardous Materials and Wastes
  - US/Canada – Canada Transportation of Dangerous Goods (TDG) Regulations
  - Other Countries – International Atomic Energy Agency (IAEA) No. SSR-6 publication titled “Regulations for the Safe Transport of Radioactive Material.”

Hazardous Material Regulations (HMR)

Hazardous materials are regulated in order to:

- ✓ Prevent accidents, leaks and spills
- ✓ Help emergency responders
- ✓ Ensure that HAZMAT employees are aware of the hazards of materials they handle

Rad Material Transporter License



Compliance Steps for HMR

1. Identify – (Classification)
2. Count – (Volume & Packaging)
3. Notify – (Permission & Emergency Information)
4. Manage – (Marking, Labeling & Placarding)
5. Transport – (Manifest & Shipping Papers)
6. Recycle/Treat/Dispose – (Authorization)

NORM Material Classification

The first step in the NORM shipping process is determining if the material being shipped meets the definition of radioactive material Class 7.

Radioactive Material – means any material containing radionuclides where both the *activity concentration* **and** the *total activity in the consignment* exceed the table in 49CFR 173.436 or values derived according to the instructions in 49CFR173.433.

UN #	Description
2910	Radioactive Material, excepted package – limited quantity of material
2912	Radioactive Material, low specific activity (LSA-I) *non-fissile*
3321	Radioactive Material, low specific activity (LSA-II) *non-fissile*
3322	Radioactive Material, low specific activity (LSA-III) *non-fissile*
2913	Radioactive Material, surface contaminated objects (SCO-I or SCO-II)

Exemption for NORM

49CFR173.401, Subpart I, titled “Class 7 (Radioactive) Materials” states that the U.S. DOT regulations do not apply to:

Natural material and ores containing naturally occurring radionuclides which are not intended to be processed for use of these radionuclides, provided the activity concentration of the material does not exceed 10 times the values specified in the Table in 49CFR173.436.

Exempt NORM Limits (10 X Rule)

Activity Concentrations for Exempt Material and Activity Limits for an Exempt Consignment Values (49CFR173.401, Subpart I)		
Radionuclide	**Activity Concentration for Exempt Material**	**Activity Limit for an Exempt Consignment**
Ra-226	2700 pCi/g	2,700,000 pCi
Ra-228	2700 pCi/g	27,000,000 pCi
Th-228	270 pCi/g	2,700,000 pCi
Pb-210	2700 pCi/g	2,700,000 pCi

It is important to note that the regulations do not define radioactive material for shipping purposes based radiation levels.

Radiochemical Analysis

A-Bear Consult LLC

Sample Type: Solid
Sample Condition: Intact/ Ambient deg C
Lab ID#: 523597-001
Project Name:
Project # : 8298
Project Location: Midland, TX

Sample Date: 01/25/16
Sample Time: 10:05
Receiving Date: 01/26/116
Analysis Date: 01/27/16
Analysis Time: 10:12
Field Code: OT 2534

Analysis Description	Analysis Results pCi/G	Analysis Error +/- 2s	Analysis Results Bq/G	Analysis Error +/- 2s	Analysis Test Method	Analysis Technician
Ra-226	87.8	10.3	3.3	0.38	EPA 901.1M	MBH
Ra-228	52.4	16.9	1.9	0.63	EPA 901.1M	MBH
Pb-210	<15.3	N/A	<.6	N/A	EPA 901.1M	MBH
Th-228	26.4	10.5	1.0	0.7	EPA 901.1M	MBH
Total Activity	225.1	N/A	24.8	N/A	EPA 901.1M	MBH

Notes:

NORM Packaging

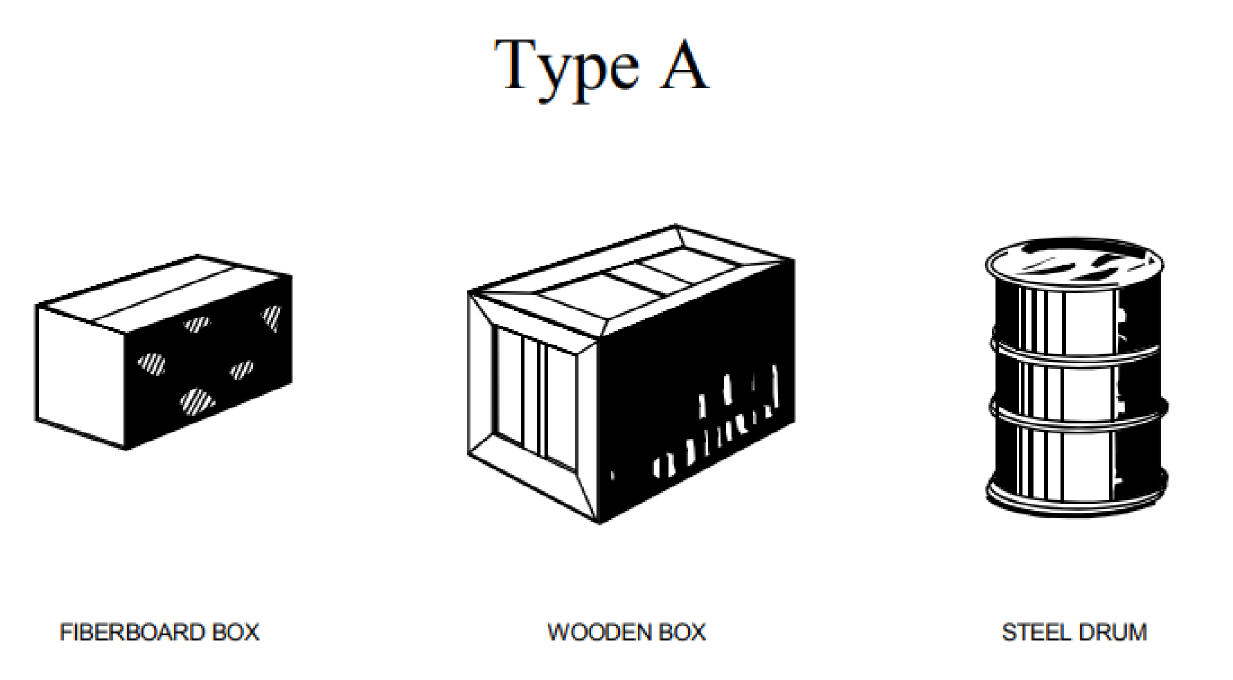
- NORM packaging decisions should include the following criteria and conditions:
  - Storage/Staging Environmental Conditions
  - Storage/Staging Time
  - Transport Requirements
  - Disposal Offloading Requirements
  - Waste/Material/Equipment Transport Options
- Requirements for most “Exclusive Use” Shipments require a “Strong, Tight Container”

Strong Tight Container

Designed to survive normal transportation handling. In essence, if the material makes it from point X to point Y without being released, the package was a strong tight container.

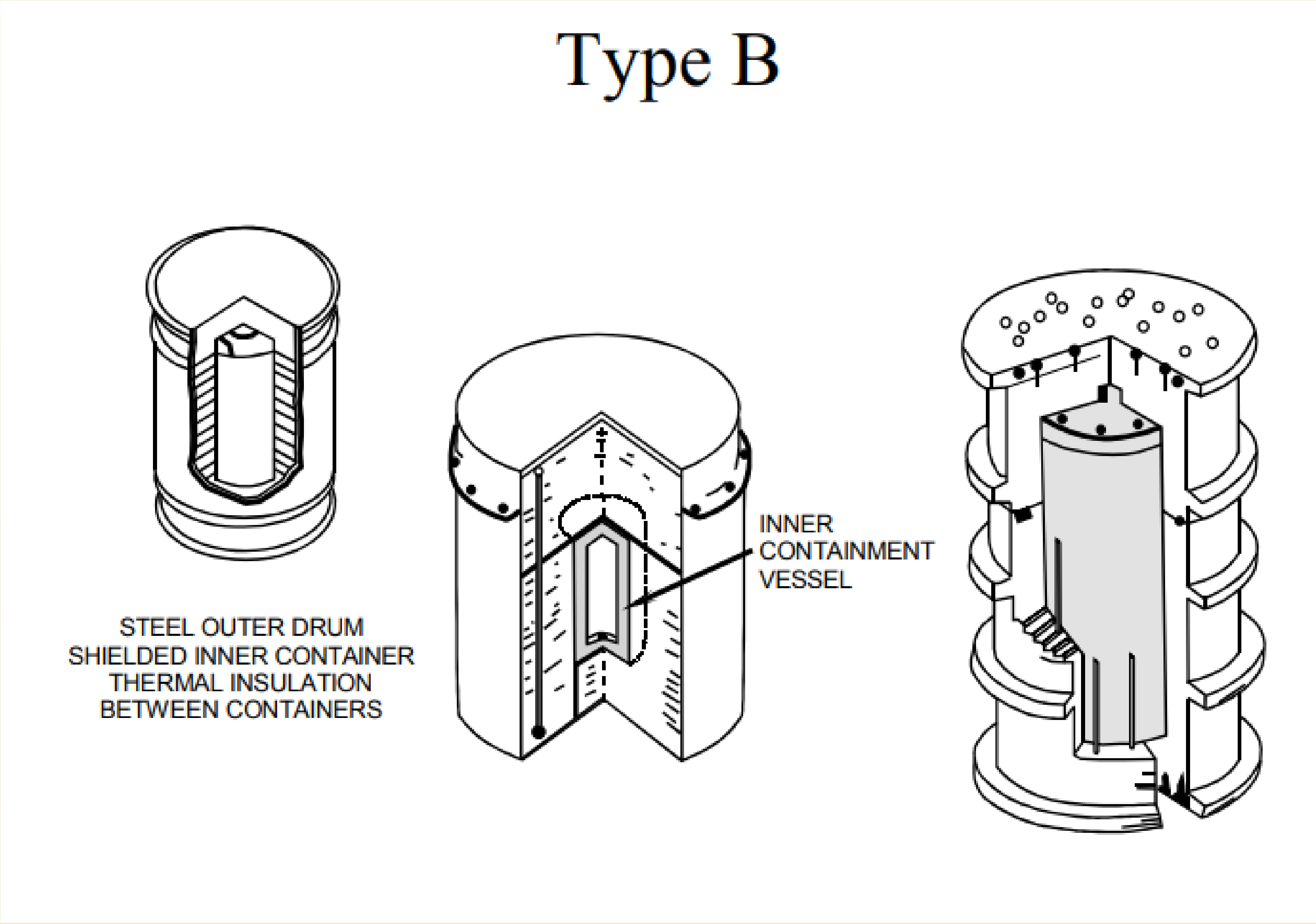
Type A Packaging

Designed to survive normal transportation handling and minor accidents



Type B Packaging

Must have the ability to survive serious accident damage tests



Road Transport

Road Transport

Rail Transport

Marine Transportation

US Waters

Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) – US Offshore Transportation

International Waters

International Maritime Dangerous Goods Code (IMDG Code) - Outside US territorial waters

Air Transportation

Commercial Air

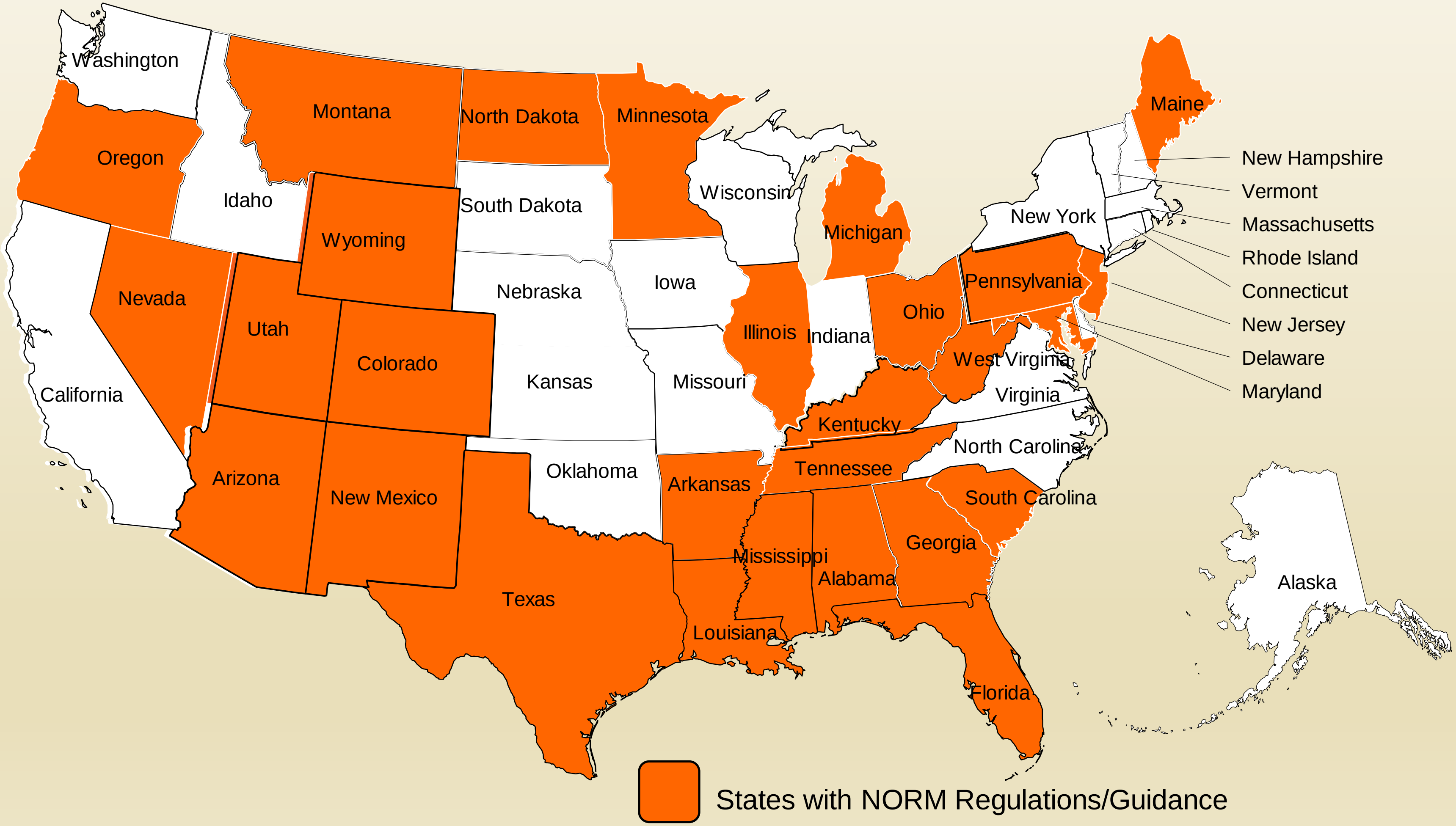
IATA Dangerous Goods Regulations (International Air Transportation Association)

International Air

ICAO Technical Instructions International Air Transport (International Civil Aviation Organization)

NORM Disposal

United States Guidance of O&G NORM Waste



State NORM Regulations/Exemptions

Depending on the State but Typically:

- Equipment is regulated by most state agencies when it exceeds **50 uR/hr**
- Soil or soil-like material is regulated by most state agencies when it exceeds **5 pCi/g** of Radium-226 or Radium-228
  (Some States have exemptions of **30 - 100 pCi/g**).
- **Observation**: Waste with gamma readings > 2X background levels have a high probability of exceeding **30 pCi/g**.

NORM Disposal Options

State Approved Methods:

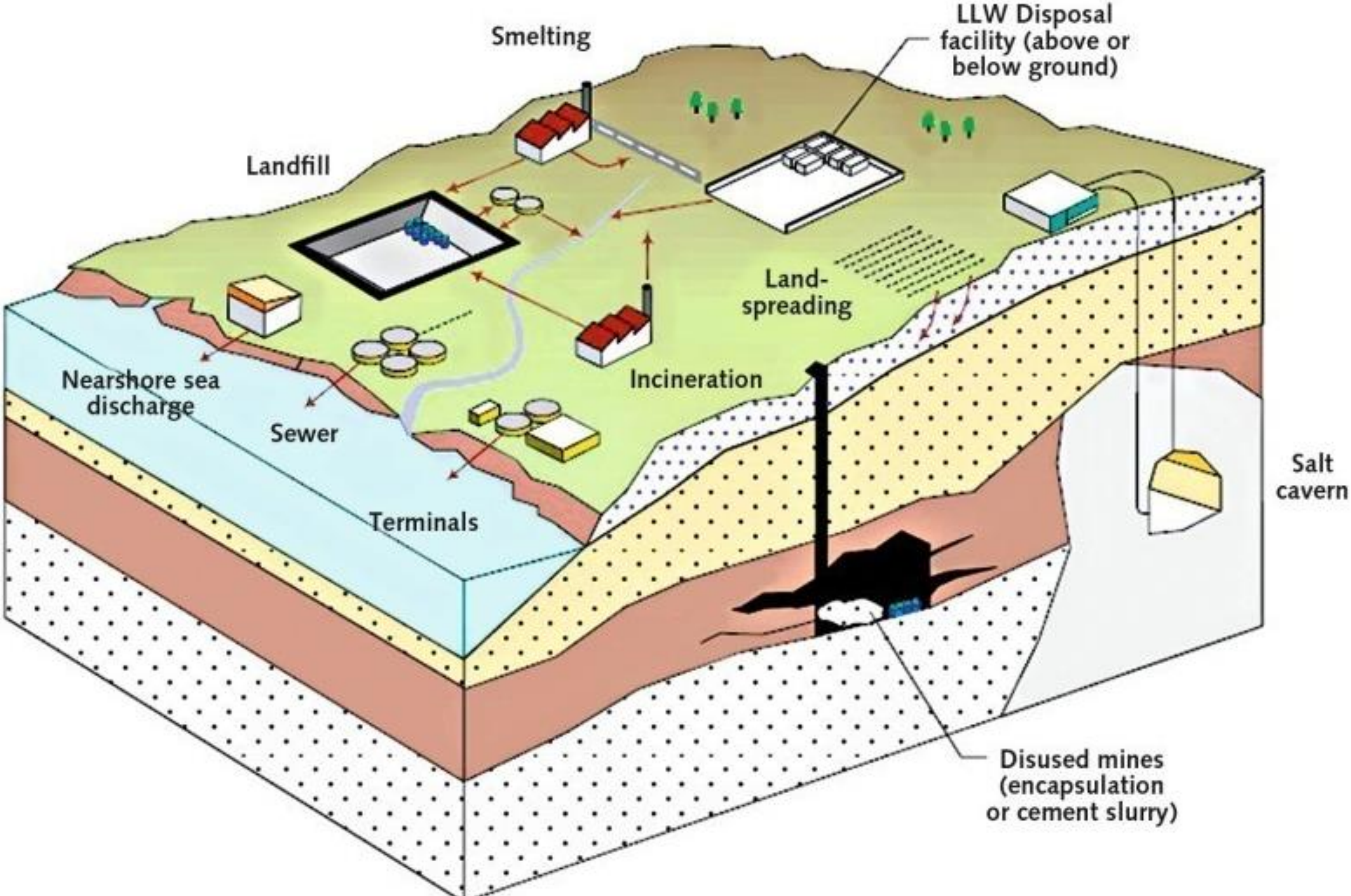
1. RCRA Subtitle D Landfill
2. Shallow Land Burial
3. Treatment/Dilution to Non Regulated Oilfield Waste
4. Encapsulation in Plugged & Abandoned (P&A) Wells
5. Land-spreading with Dilution On Site

State Licensed Facilities:

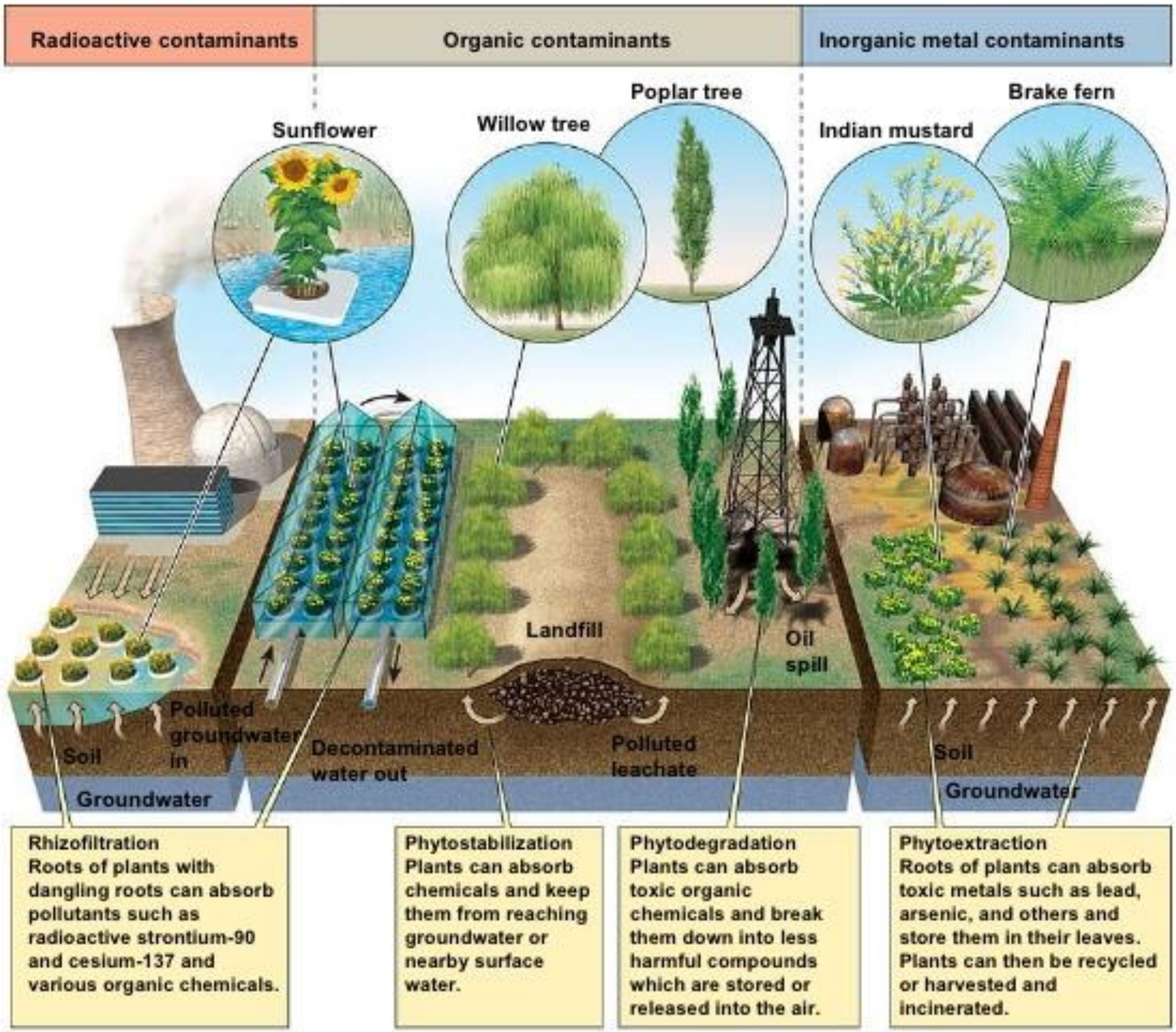
1. Low-Level Radioactive Waste Sites
2. RCRA Subtitle C Landfills
3. Deep Well Injection (Cavern/Cap Rock)

United States NORM Disposal

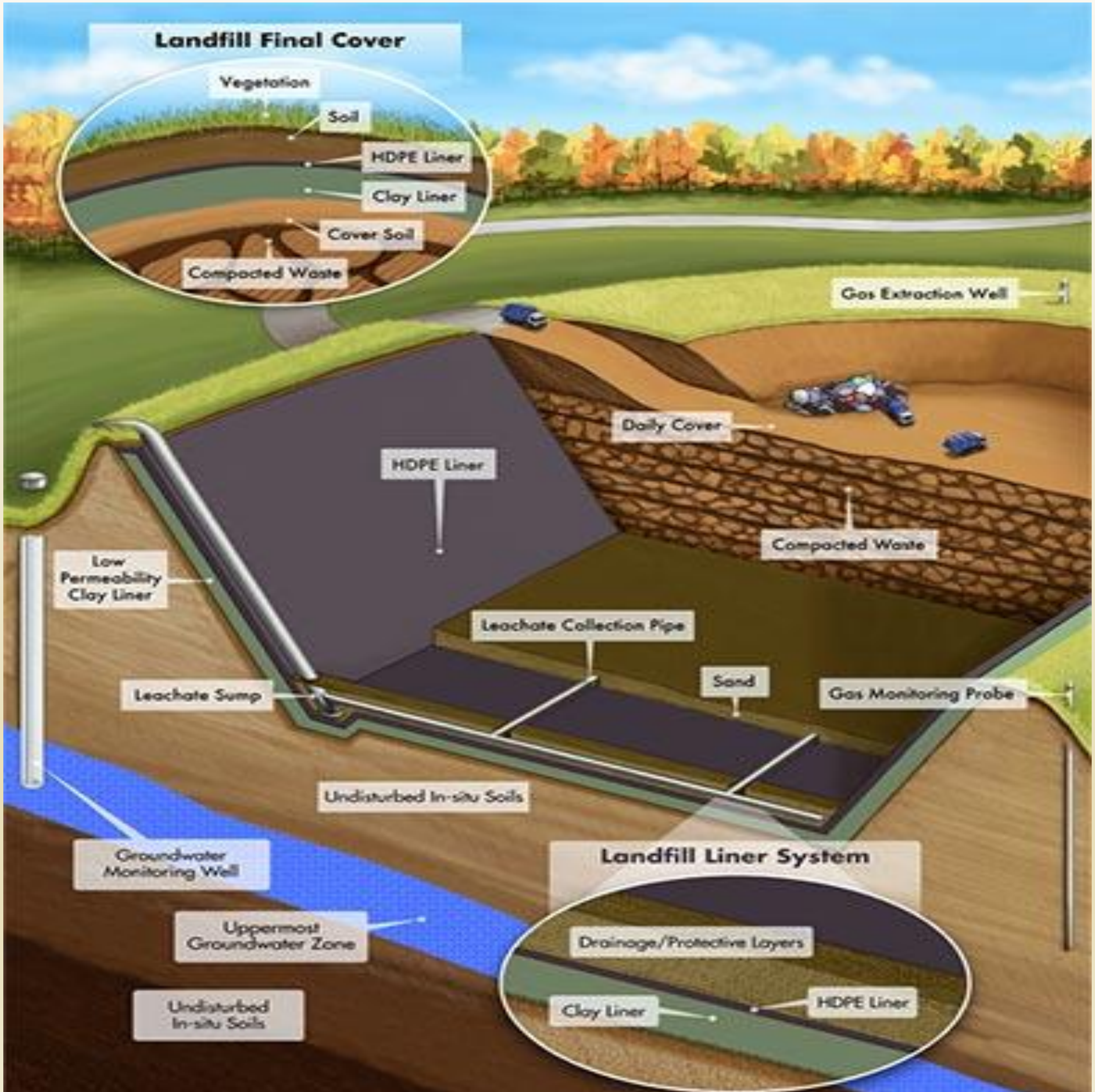
State	Ra-226 Limit (pCi/g)	Notes/Basis
Colorado	400	RCRA Sub-C
Idaho	1500	RCRA Sub-C
Illinois	100	Requires IEMA approval
Kentucky	100	Via State Licensing Exemption
Louisiana	30	Via State Licensing Exemption
Michigan	500	RCRA Sub-C and Sub-D
Mississippi	30	Mississippi Oil & Gas Board
Montana	50	Via State Licensing Exemption
New Mexico	30	Via State Licensing Exemption
North Dakota	50	Approved “Special Waste” Landfills
Ohio	6.99	5 + Background (1.99 pCi/g)
Pennsylvania	No Limit	RCRA Sub D - Dose/Vol Dependent
Texas*	30	Via State Licensing Exemption
Utah		RCRA Sub-C
Washington		RCRA Sub-C
Texas*	*No E&P Limit	*TRRC Permit Approved Waste (E&P)


Smelting
LLW Disposal
facility (above or
below ground)
Landfill
Land-
spreading
Nearshore sea
discharge
Sewer
Incineration
Salt
cavern
Terminals
Disused mines
(encapsulation
or cement slurry)

Phytoremediation

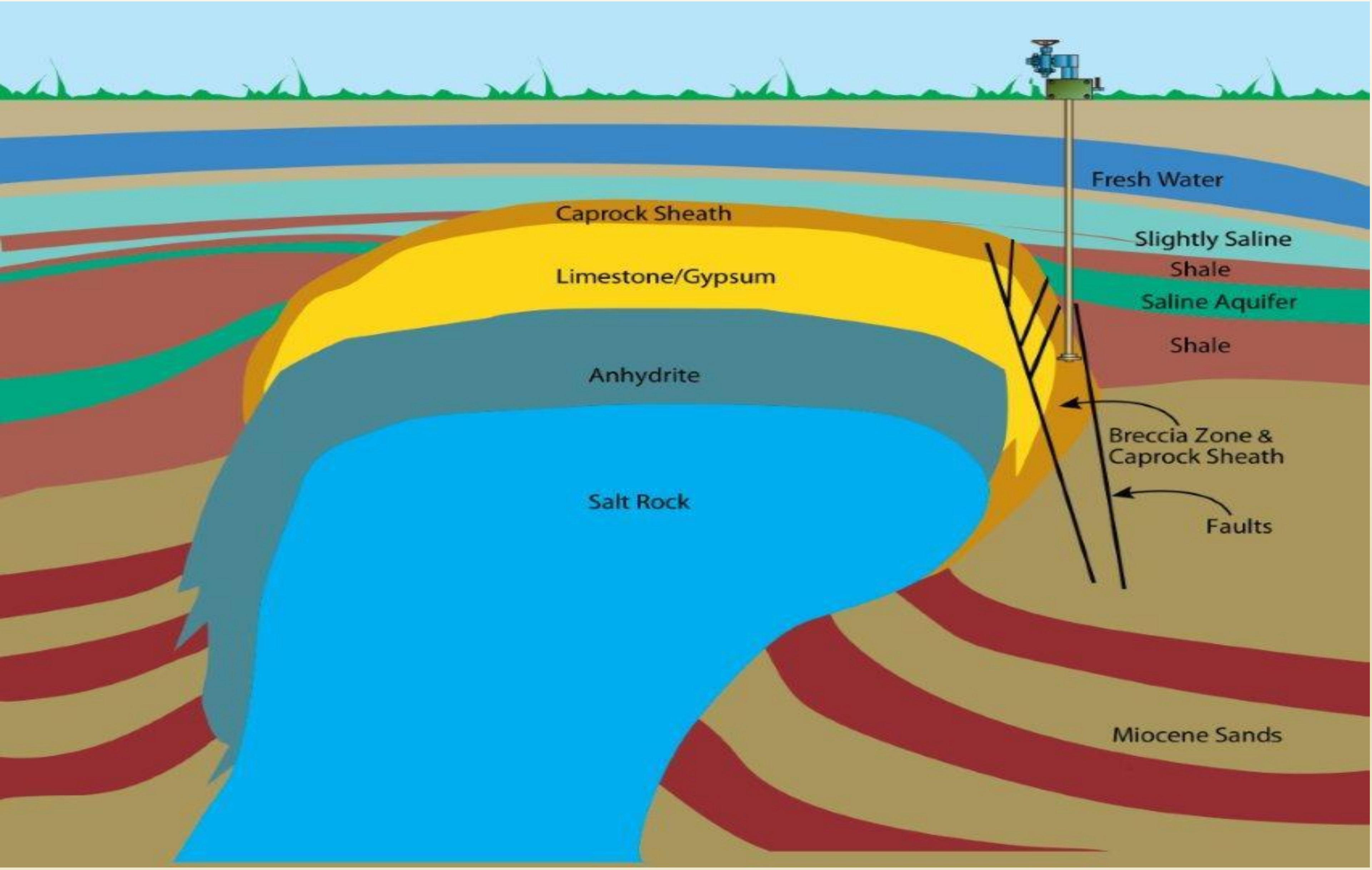


Subtitle D Landfill

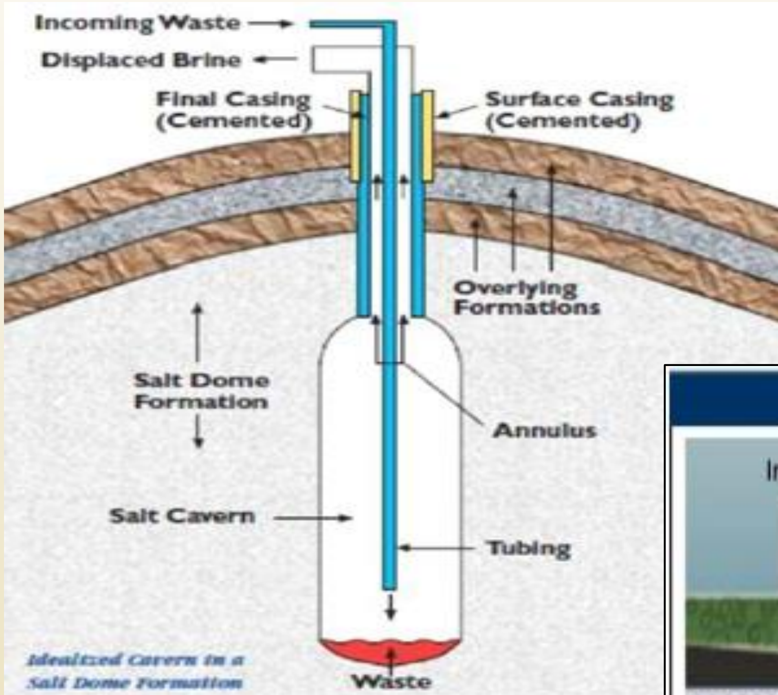


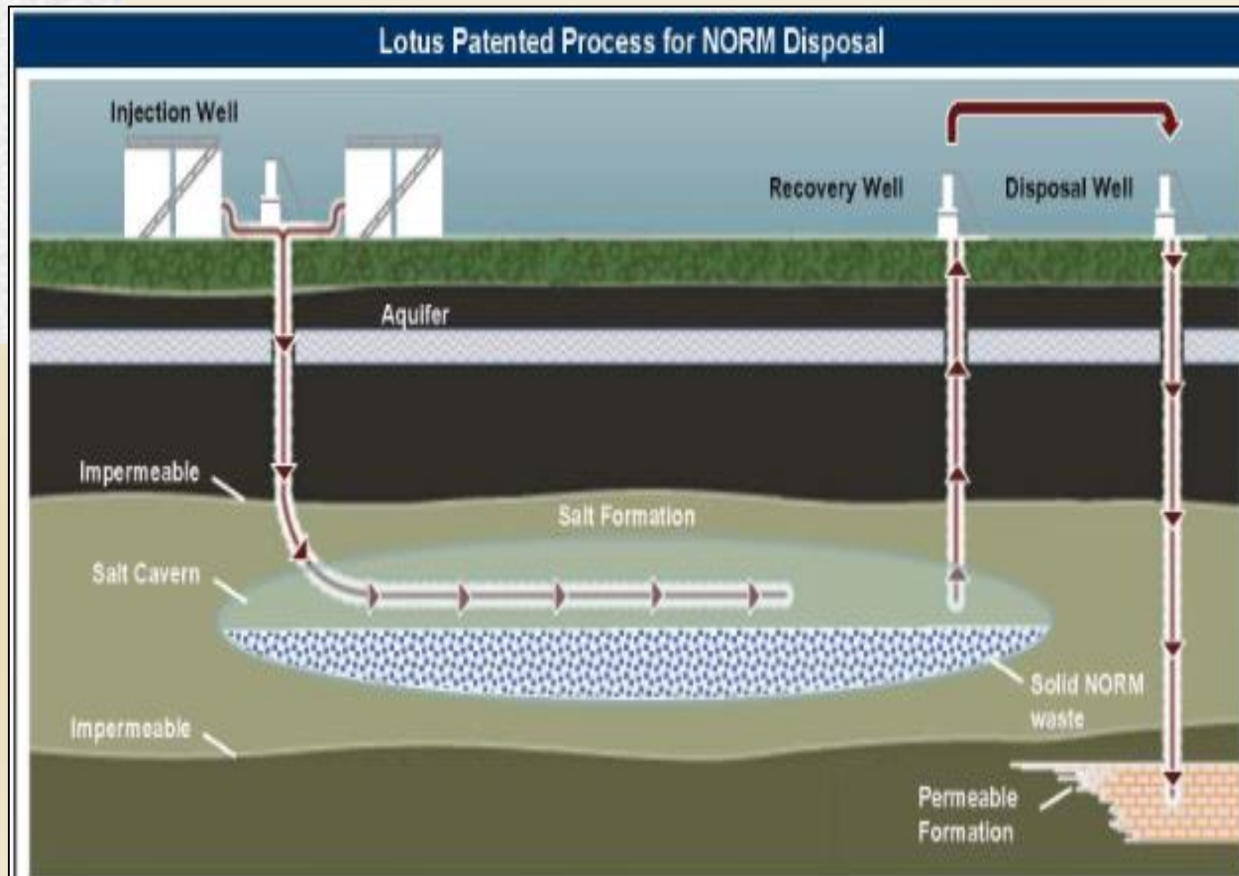
Subtitle C Landfill

Deep Well Injection (Cap Rock)



Deep Well Injection (Salt Dome)





Commercial E&P NORM Disposal

- **Clean Harbors** (**Landfill**) – Hazardous Waste (Not Exempt)
- **Ecoserv** (**Caprock Injection**) – RCRA Exempt
- **Energy Solutions** (**Landfill**) – Hazardous Waste (Not Exempt)
- **Lotus** (**Cavern Injection**) – RCRA Exempt
- **Sabine** (**Caprock Injection**) – RCRA Exempt
- **Trinity** (**Cavern Injection**) – RCRA Exempt
- **US Ecology** (**Landfill**) – Hazardous Waste (Not Exempt)
- **Waste Control Specialists** (**Landfill**) – Hazardous Waste (Not Exempt)
- Other state licensed Subtitle D **Landfills** with limitations

Commercial Industrial NORM Disposal

- Clean Harbors (**Landfill**) – Subtitle C Landfill
- Energy Solutions (**Landfill**) – Subtitle C Landfill
- US Ecology (**Landfill**) – Subtitle C Landfill
- Waste Control Specialists (**Landfill**) – Subtitle C Landfill
- Other state licensed **Landfills** with limitations

Discussion/Summary