SAFETY
& WORKING PROCEDURES in Industry involving NORM/TENORM

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- Processing
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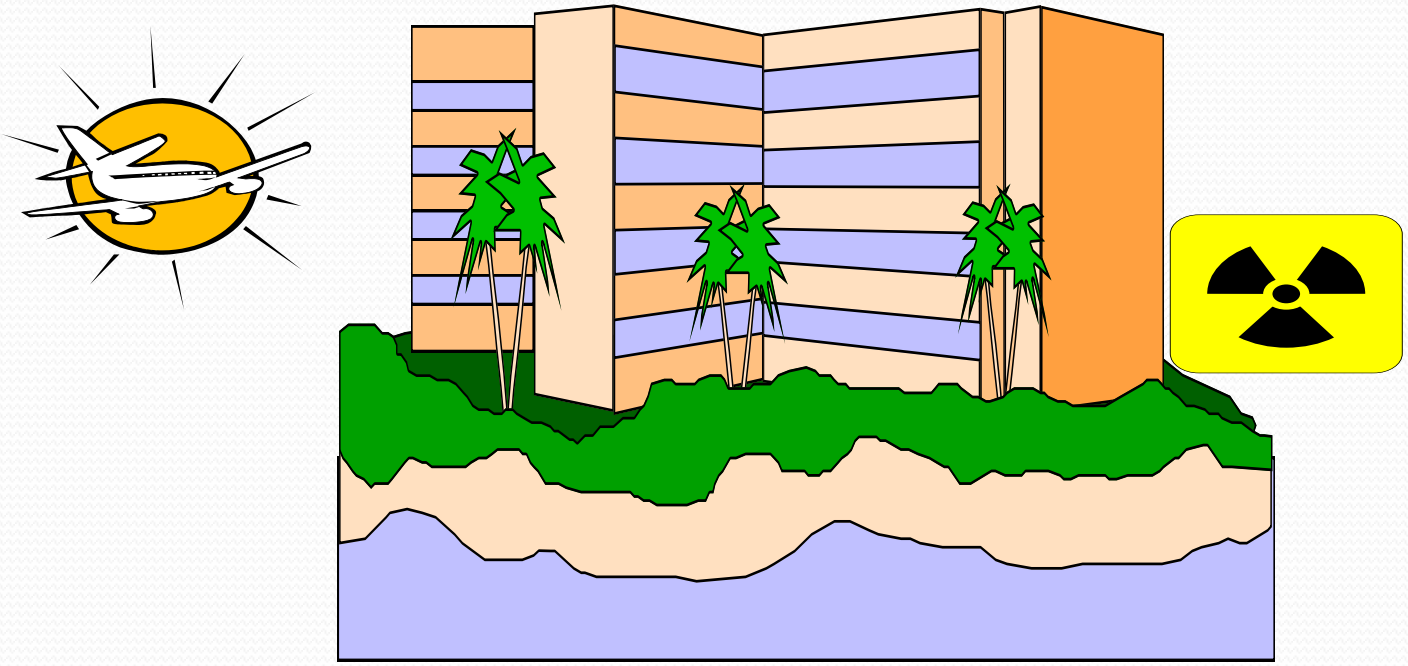
INTRODUCTION

ALL MATERIALS CONTAIN *RADIOACTIVE*



EVERYWHERE IS RADIATION

WHAT MATERIALS ARE TO BE CONTROLLED BY THE AUTHORITY?

- In radiation protection, background radiation or radioactive are not controlled, although the levels are high, e.g. Kerala, Madras state of India; coastal area of Brazil; Niue island in Pacific; Ramsar in Iran (up to 260mSv/y)
- In Malaysia, background radiation ~ 2 mSv/yr
- Only materials / processes potentially to cause additional radiation exposure to people will be controlled
- Authority : AELB

BACKGROUND RADIATION

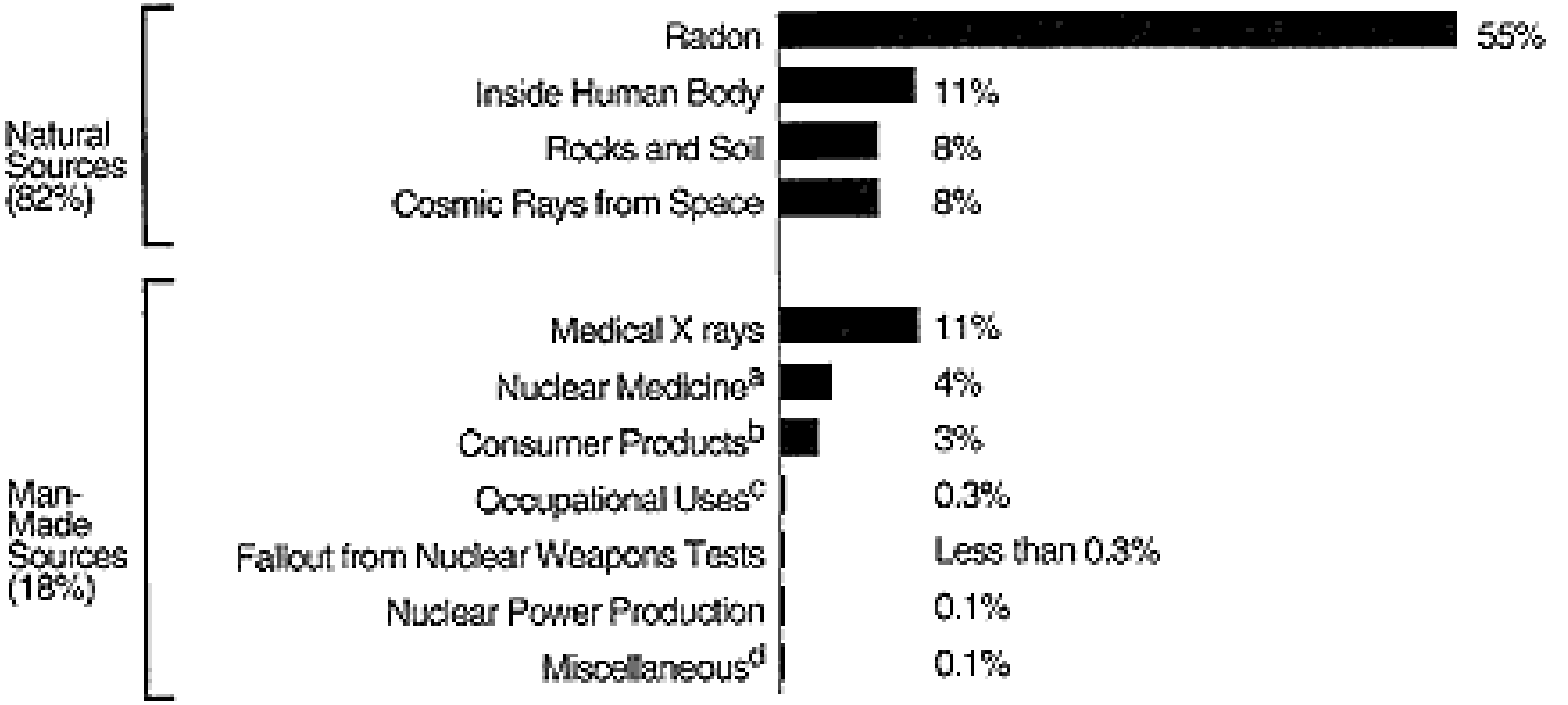
NATURAL RADIATION SOURCES

1. Cosmic rays
2. Cosmogenic nuclides – C-14, H-3, N-15 – resulted from interaction between cosmic rays and particles , e.g. $^{14}N(n,p)^{14}C$; $^{14}N(n,^{3}H)^{12}C$;
3. Primordial radionuclides – coexisted during the creation of Earth
   - Long half-lives (>10^8 years)
   - Series: Uranium-238, Uranium-235, Thorium-232
   - Non-series: Potassium-40, Rubidium-87

MAN-MADE RADIATION SOURCES

- Medical X-ray (0.1 mSv per chest x-ray), nuclear medicine (diagnostic and therapeutic)
- Nuclear weapon test - radioactive fall-out
- Nuclear power
- Nuclear technologies in industries
- Consumer products: smoke detectors, luminous watches, gas mantles, TV. [very low]

GLOBAL RADIATION SOURCES



[a] Involves the use of radioactive materials in diagnosing and treating patients with cancer and other diseases.

[b] Building materials, tobacco, mining and agricultural products, water supplies, etc.

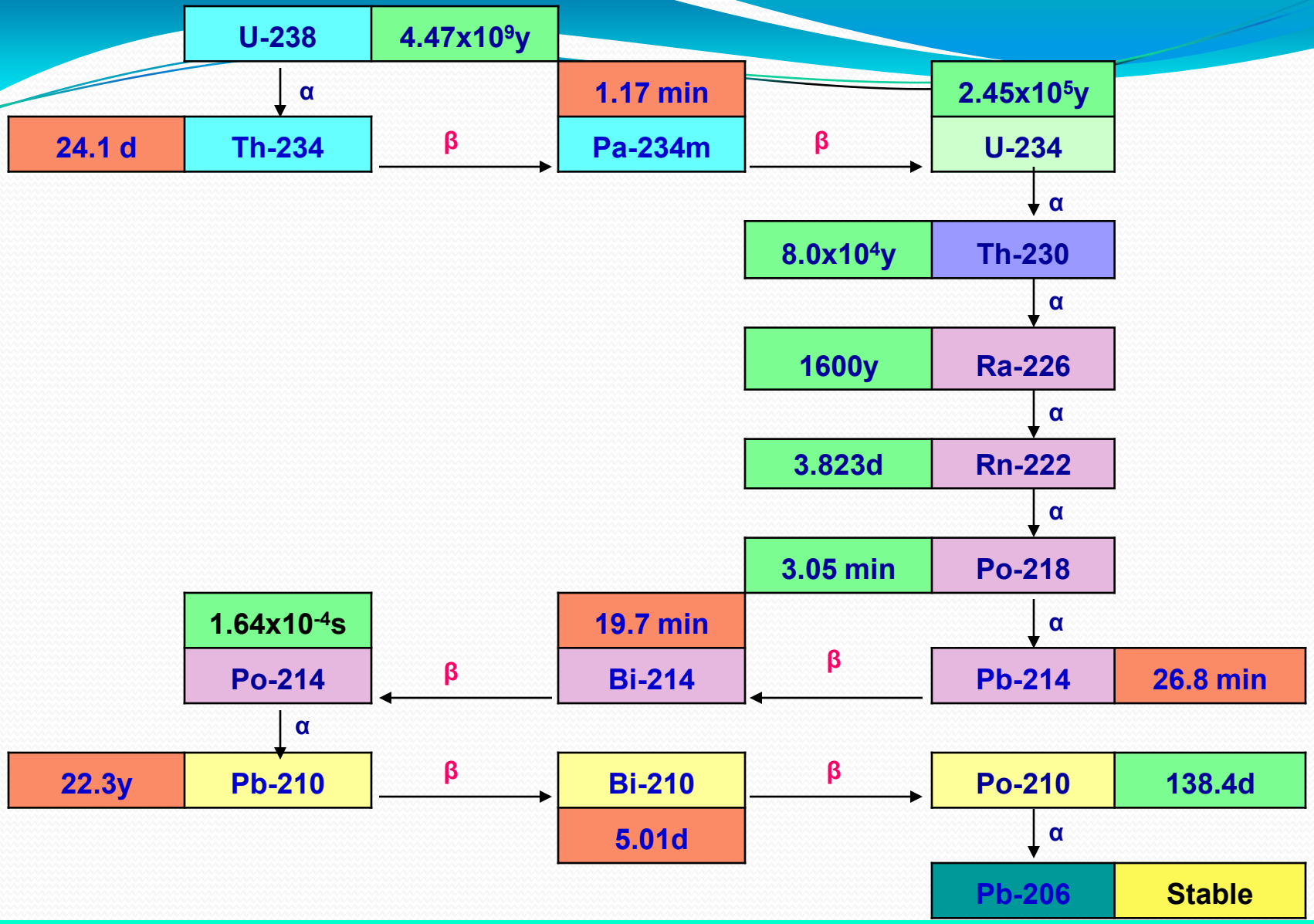
[c] Uranium mines, industrial and medical users, etc.

[d] Department of Energy facilities, smelters, transportation, etc.

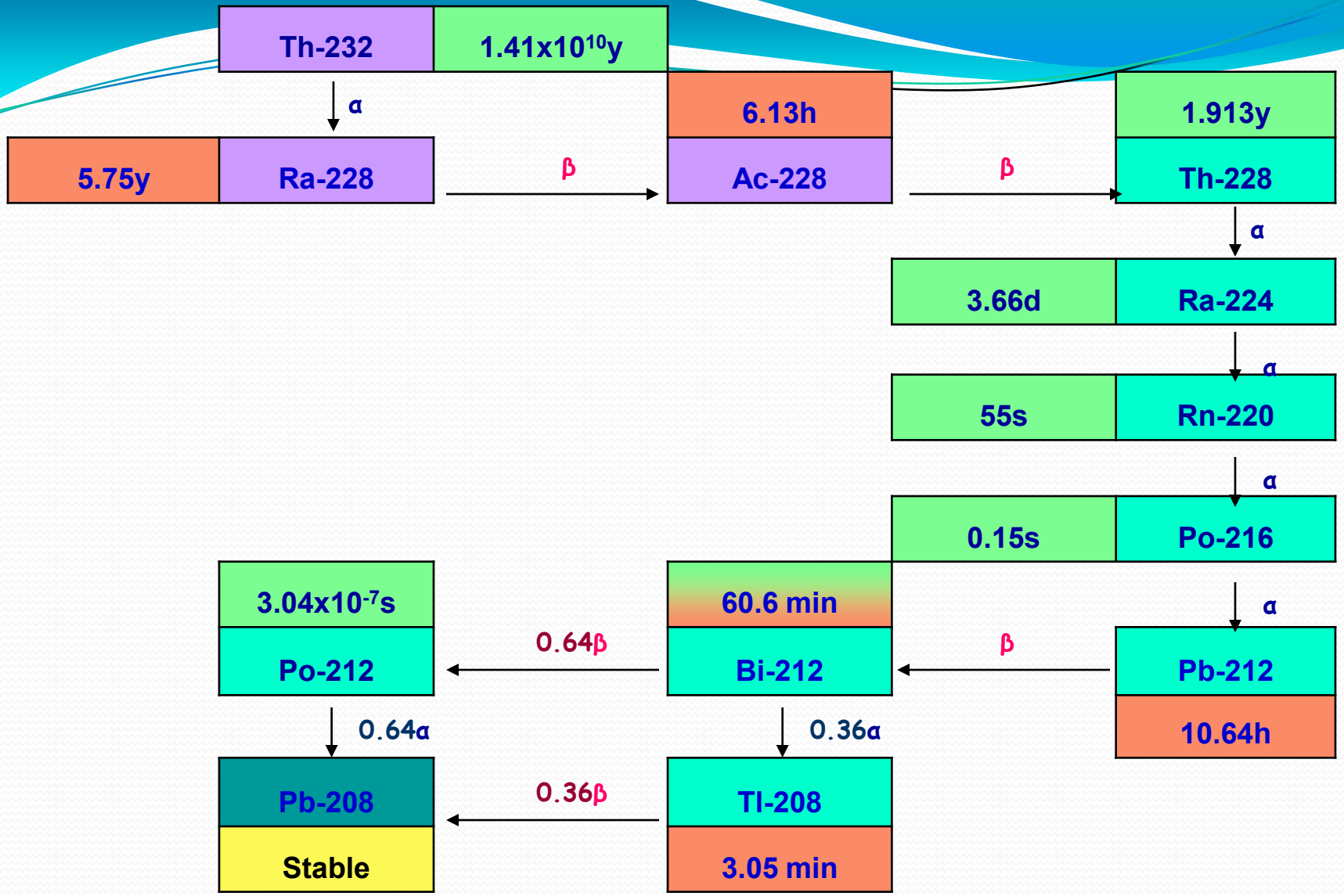
* Source: National Council on Radiation Protection and Measurements, Report No. 93.
(Total adds up to more than 100% due to rounding off of percentages.)

NATURAL RADIONUCLIDES SERIES

SERIES	Emitters	End-up nuclide	Total activity concentration at equilibrium
Uranium U-238 (4n + 2)	8 α 6 β	Pb-206	14x any single radionuclide activity
Actinium U-235 (4n + 1) / (4n - 3)	7 α 4 β	Pb-207	11x any single radionuclide activity
Thorium Th-232 (4n)	6 α 4 β	Pb-208	10x any single radionuclide activity



RADIONUCLIDES IN THE URANIUM-238 SERIES



RADIONUCLIDES IN THE THORIUM-232 SERIES

RADIONUCLIDES & EQUILIBRIUM

Half-life = ?? (revision !)

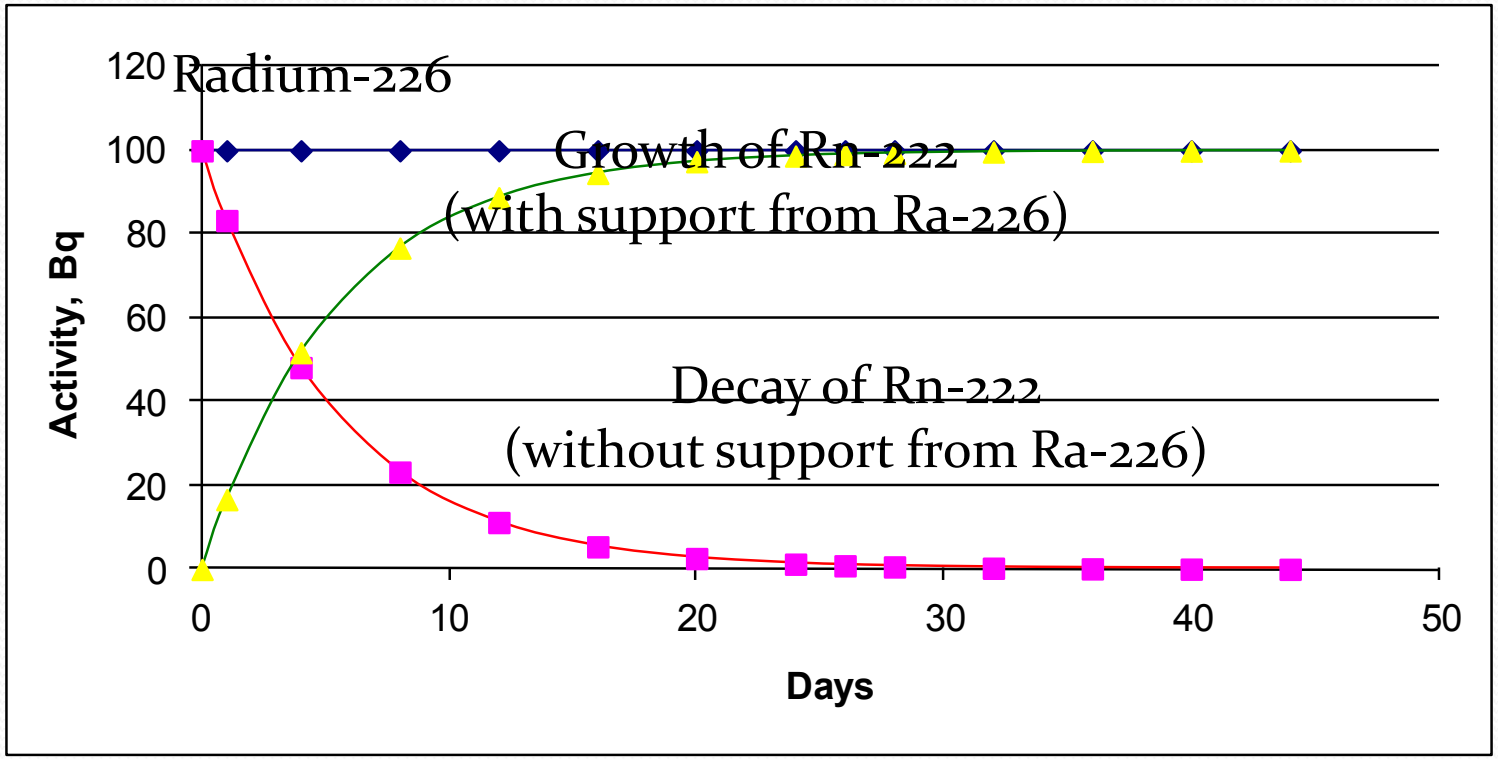
Decay pattern:
long-lived parent – slow decay

Short-lived radionuclide (unsupported long-lived parent) - fast decay

Short-lived radionuclide (Supported by long-lived parent) – slow decay, following parent's decay pattern
→ Secular equilibrium: where each member of the series has the same activity

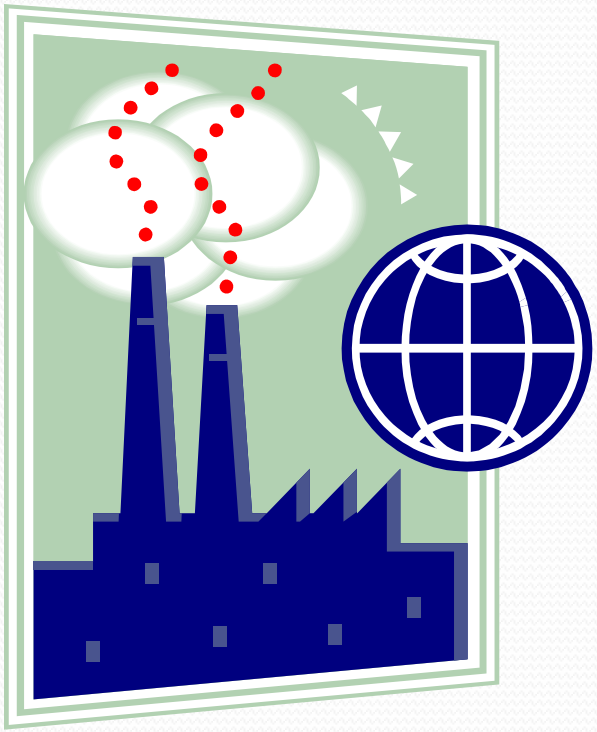
DECAY & GROWTH OF RADON-222

(understanding secular equilibrium)



Half life: Rn-222 = 3.8 days, Ra-226 = 1600 years

NORM/TENORM



NORM

- **N**aturally **O**ccurring **R**adioactive **M**aterials
- Materials containing radionuclides mainly from URANIUM & THORIUM series
- e.g. rocks; soils; sediment; ores; minerals; coal; bricks & other building materials

TENORM

- **T**echnologically **E**nhanced **NORM**
- Enhancement of NORM through technological processes
- e.g. Oil scales, incineration ash, tin slag

ship TANKER SLUDGE

Ra-226 < 0.006 Bq/g

Ra-228 < 0.004 Bq/g

NORM

TECHNOLOGICAL PROCESS

INCINERATION

TENORM

SLUDGE ASH

Ra-226 = 0.12 Bq/g

Ra-228 = 0.15 Bq/g

Radioactivity levels of NORM & TENORM in Malaysia

NORM/TENORM	Ra-226 (Bq/g)	Ra-228 (Bq/g)
MAL normal soils (Peninsular) (Sabah & Sarawak)	0.04 – 0.10 (max 0.24) 0.03	0.07 – 0.13 (max 0.28) 0.03 – 0.04
Amang (tin tailing) Mine sands	0.7 – 1.3 0.04 – 0.11	0.6 – 1.6 0.02 – 0.05
Petroleum Sludge & Scales	0.01 – 430	0.01 – 450
Monazite Zircon Xenotime Ilmenite	8 – 22 13 71 0.7	64 – 180 2.2 14 0.5

ACT 304 PROVISIONS

SECTION 12 (1)(b)

- Cannot deal in, posses or dispose any radioactive materials, nuclear materials, prescribed substances or irradiating apparatus without having a valid license issued under section 16 (5) Act 304.
- Dealing: Any activity involving manufacturing, trading, producing, processing, purchasing, owning, using, transporting, transferring, handling, selling, storing, importing or exporting radioactive material

CLASS OF LICENSE

Class of license	Type of material/equipment	Purpose
Class A	Radioactive material	To manufacture, trade-in, produce, process, purchase, own, posses, use , transfer, handle, sell or store
Class B	Nuclear material	As above
Class C	Irradiating apparatus	As above
Class D	Radioactive materials, nuclear materials, prescribed substances or their waste	To transport

CLASS OF LICENSE

Class of license	Type of material/equipment	Purpose
Class E	Radioactive materials, nuclear materials, irradiating apparatus, prescribed substances or their waste	To export and import
Class F	Nuclear installation	To site, to construct or to operate
Class G	Radioactive materials, nuclear materials, prescribed substances or their waste	To do disposal, storage and decommissioning
Class H	Others	To control activities which are not covered by Class A to G and maintenance

Class of License involved in NORM/TENORM

Class of License	Permitted Activities
A	Radioactive materials (e.g. milling)
D	Radioactive materials (Transport)
E	Radioactive materials (Export or import)
G	Disposal, storage and decommissioning of milling installation, waste treatment facility
H	Miscellaneous activities related to NORM (e.g. consultation)

PROCESSING
OIL & GAS

OIL & GAS INDUSTRY

NORMAL OPERATION

- a) EXPLORATION
- b) PRODUCTION
- c) TRANSPORTATION
- d) REFINERY

- MAINTENANCE
  - VESSEL & TANK CLEANING

OIL & GAS INDUSTRY

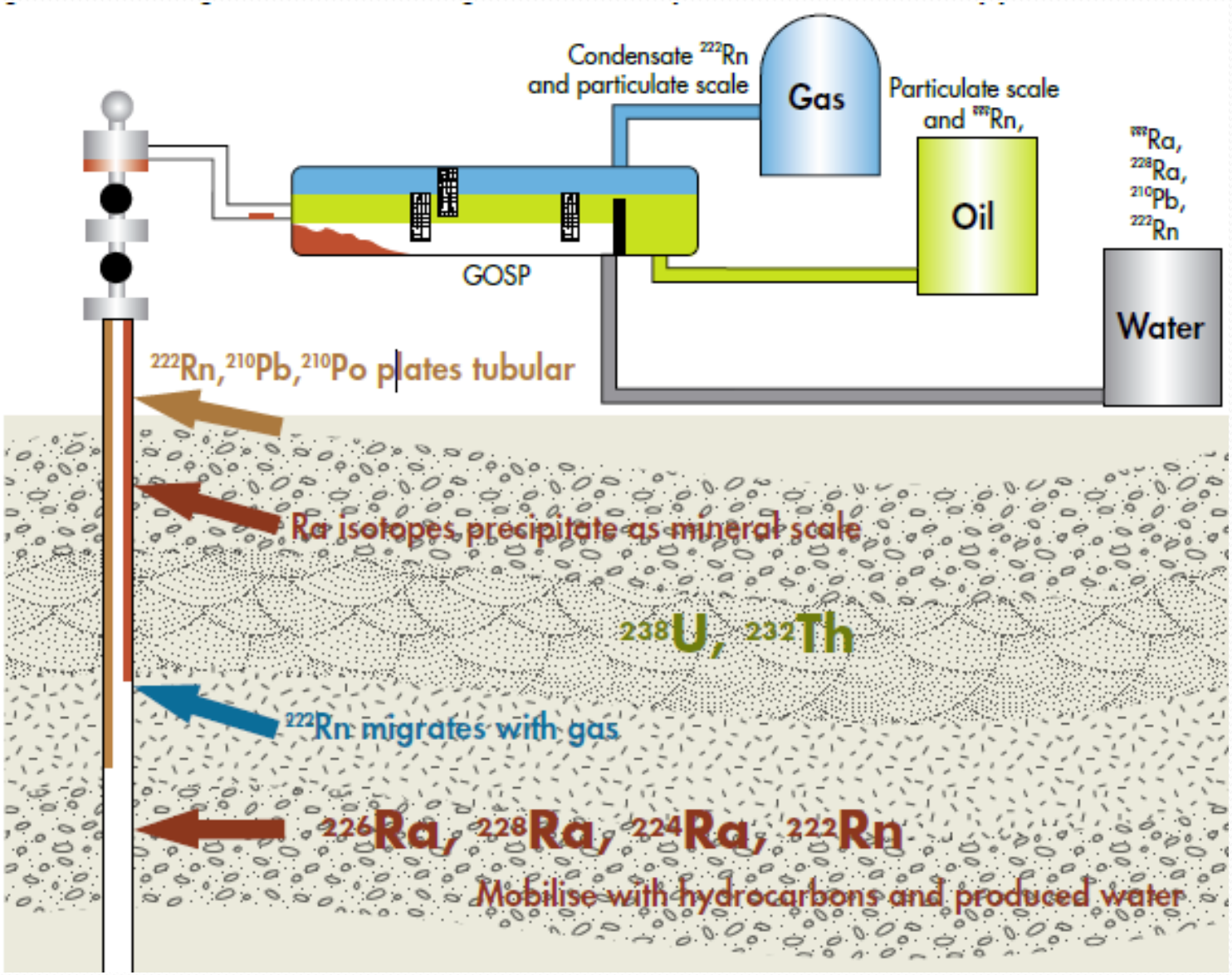
PRODUCTION

- Offshore & nearshore platforms → producing sludge
- Onshore Crude Oil Terminal (COT) → producing sludge

- Radium is more soluble than Uranium & Thorium in formation water (low sulfate) in reservoir rocks, brought up in crude oil, then precipitated as scales together with calcium, strontium & barium (usually as carbonate & sulfate compounds) when there is pressure & temperature drop. Scale accumulation will increase with platform age.

- Uranium & Thorium concentrations are usually low in the oil sludge & scales

Scale build-up on internal pipe surface


Condensate ^{222}Rn and particulate scale
Gas
Particulate scale and ^{222}Rn,
^{226}Ra, ^{228}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

OIL & GAS INDUSTRIES WASTE

a) SLUDGE : mixture of hydrocarbon (oil), water, sand/clay containing Ra-226 + Ra-228

b) SCALES : barium sulfate, calcium sulfate & calcium carbonate → radium (Ra-226 + Ra-228) co-precipitated

c) PHYROPHORIC IRON SULPHIDE (spontaneously self-ignition when contact with air) : 0.9 Bq/g U-238 (no radium & thorium)

d) NON-RADIOLOGICAL HAZARD
Gas Processing: hydrogen sulfide, mercury (Hg)
Oil Processing: benzene

OIL & GAS SLUDGE TREATMENT

- Sludge Farming - Biodegradation.
- Chemical Extraction
- Incineration – produce water vapour & carbon dioxide at high temperature (1200 C)
- Steam Method - steam at 500 ^{0}C to separate hydrocarbon (non-destructive) from sediment

TOTAL ACTIVITY CONCENTRATION (TAC) FOR SCALE & SLUDGE

- In the oil and gas industry, as sludge and scales normally contain Ra-226 and Ra-228 as their major parent radionuclides:

- TAC_{SS} (Bq/g) = (6 x $Act._{Ra\text{-}226}$) + (8 x $Act._{Ra\text{-}228}$)

- Where $Act._{Ra\text{-}226}$ and $Act._{Ra\text{-}228}$ are the activity concentrations in Bq/g of Ra-226 and Ra-228 respectively.

GUIDELINES FOR OIL & GAS INDUSTRY

- Refer LEM/TEK/30 from AELB
  - Radiological Impact Assessment
  - Tenorm contamination
  - Entry, inspect, repair large vessels
  - Equipment maintenance & inspection
  - Cleaning contaminated equipment
  - Pulling contaminated well tubular
  - Transport contaminated equipment

PROCESSING MINERAL

RADIOACTIVE MATERIAL
(as defined by the regulatory authority)

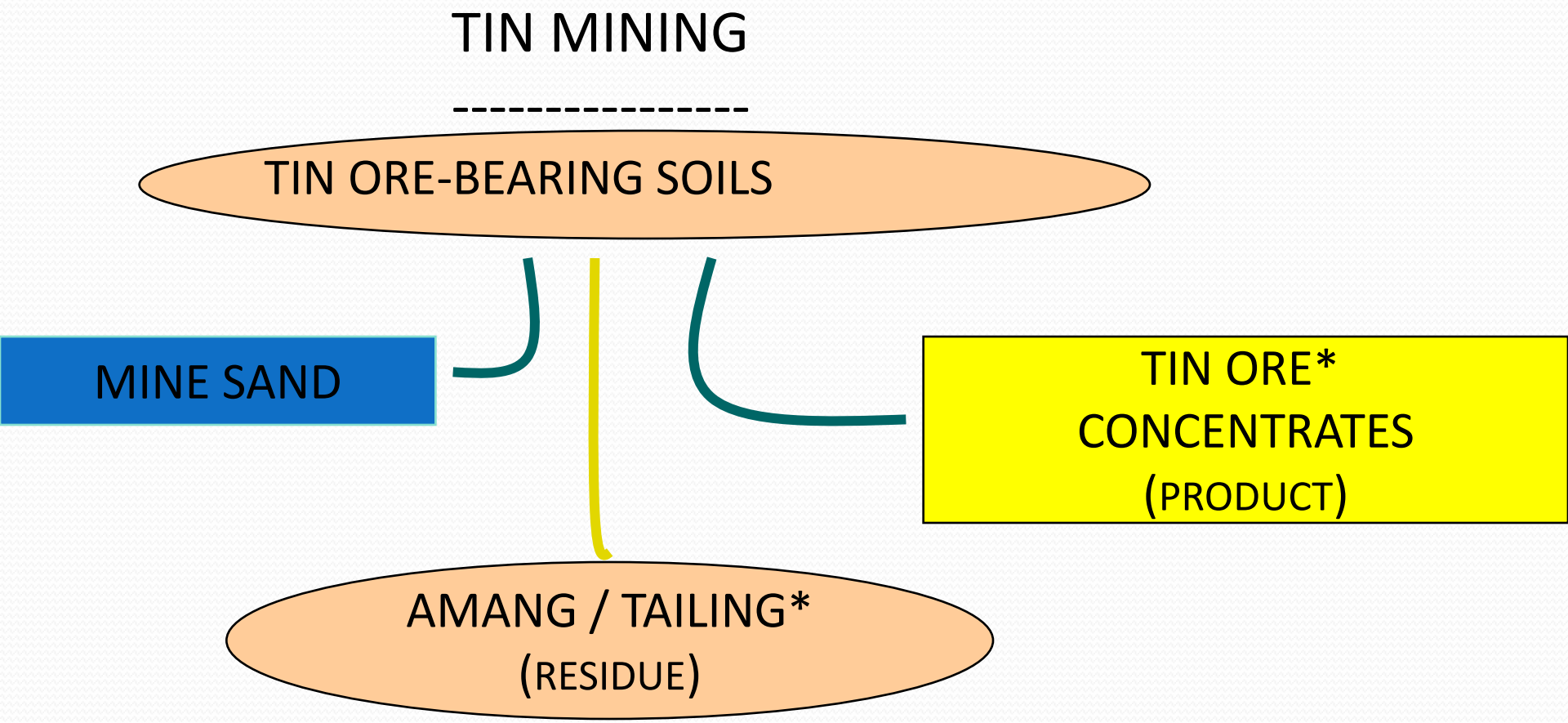
- Monazite, Zircon, Xenotime & Ilmenite minerals
- Materials contain uranium + thorium concentrations >0.05% (500 ppm)
- Any material decided by AELB

MINERAL PROCESSING

- Chemical Process
  - TiO_2 production
  - Synthetic rutile using chloride
  - Rare earth elements from Monazite and Xenotime

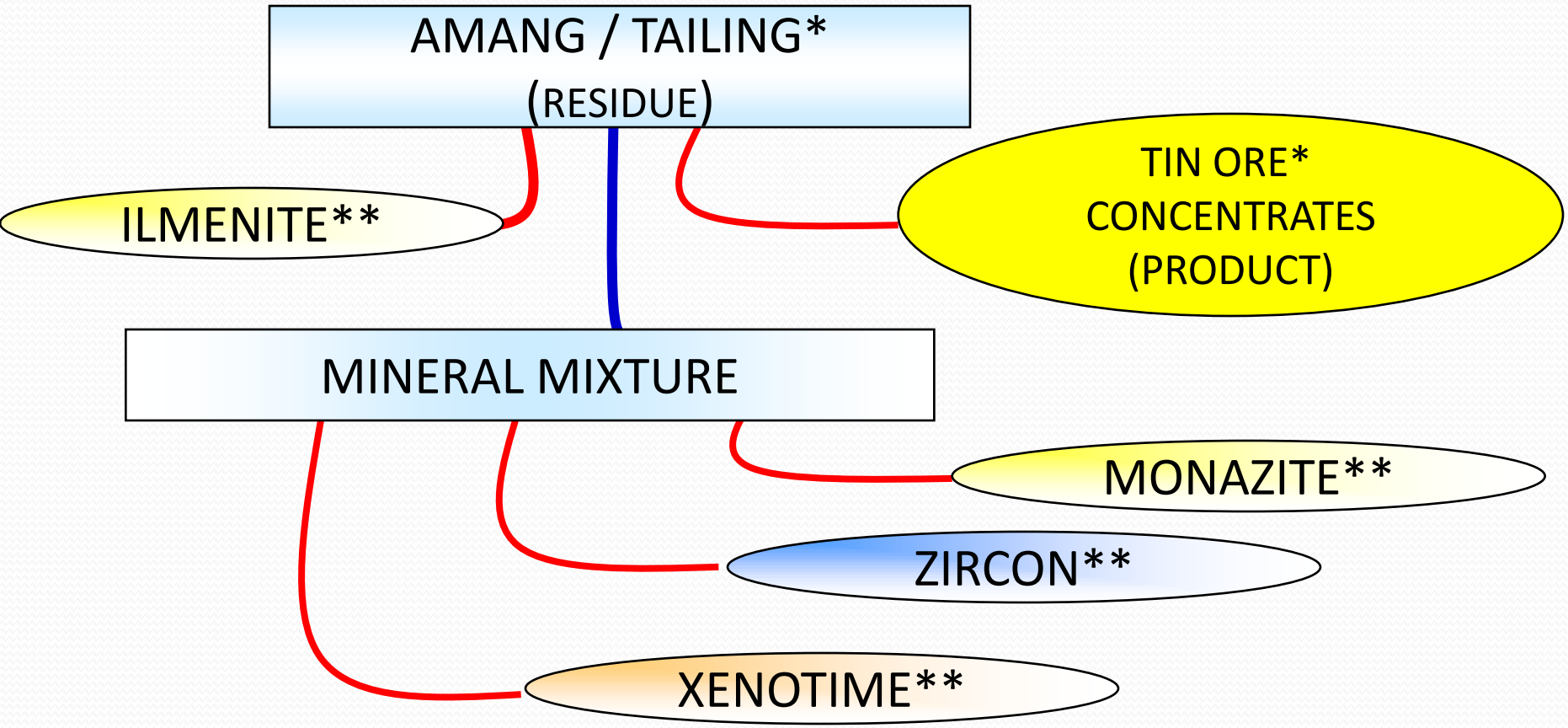
- Physical Process
  - Tin ore mining
  - Tin ore smelting
  - Zircon milling
  - Amang processing
  - Ceramic industry
  - Polishing glass panel using zircon

TIN-MINE RELATED PROCESSES



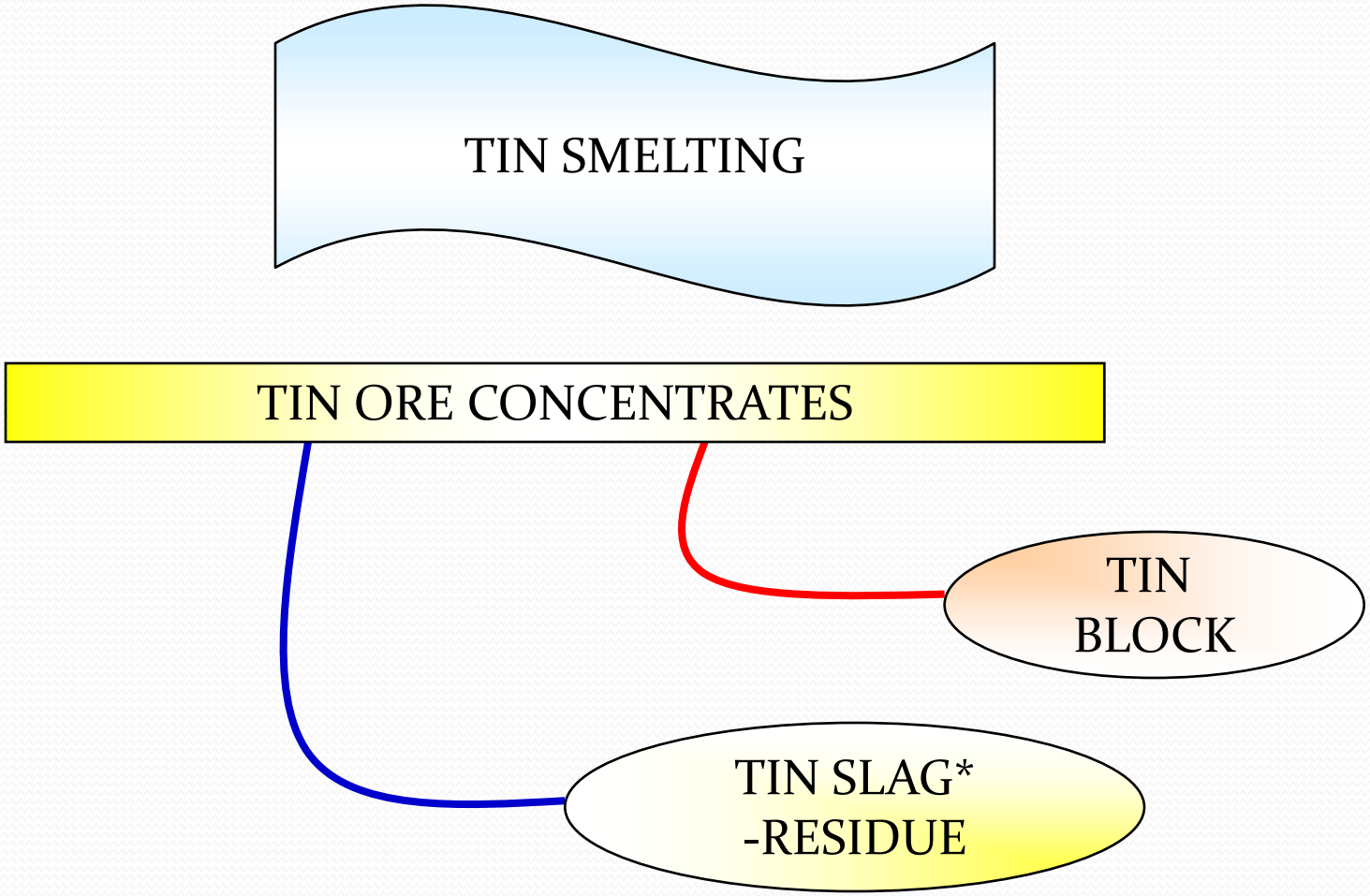
*radioactive/contains radioactive materials

TIN-MINE RELATED PROCESSES (Cont.)

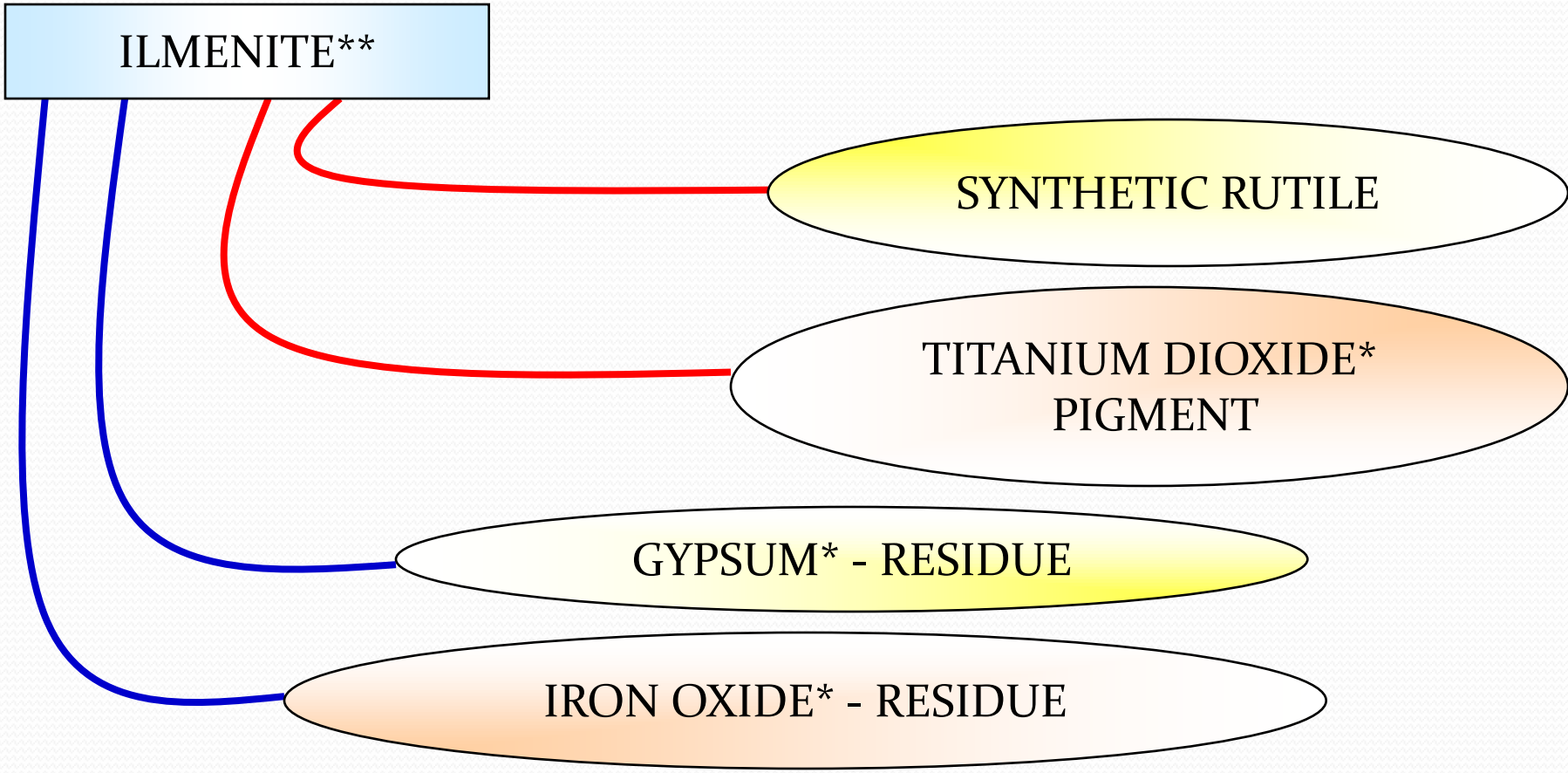


**mineral contain radioactive material as define by AELB

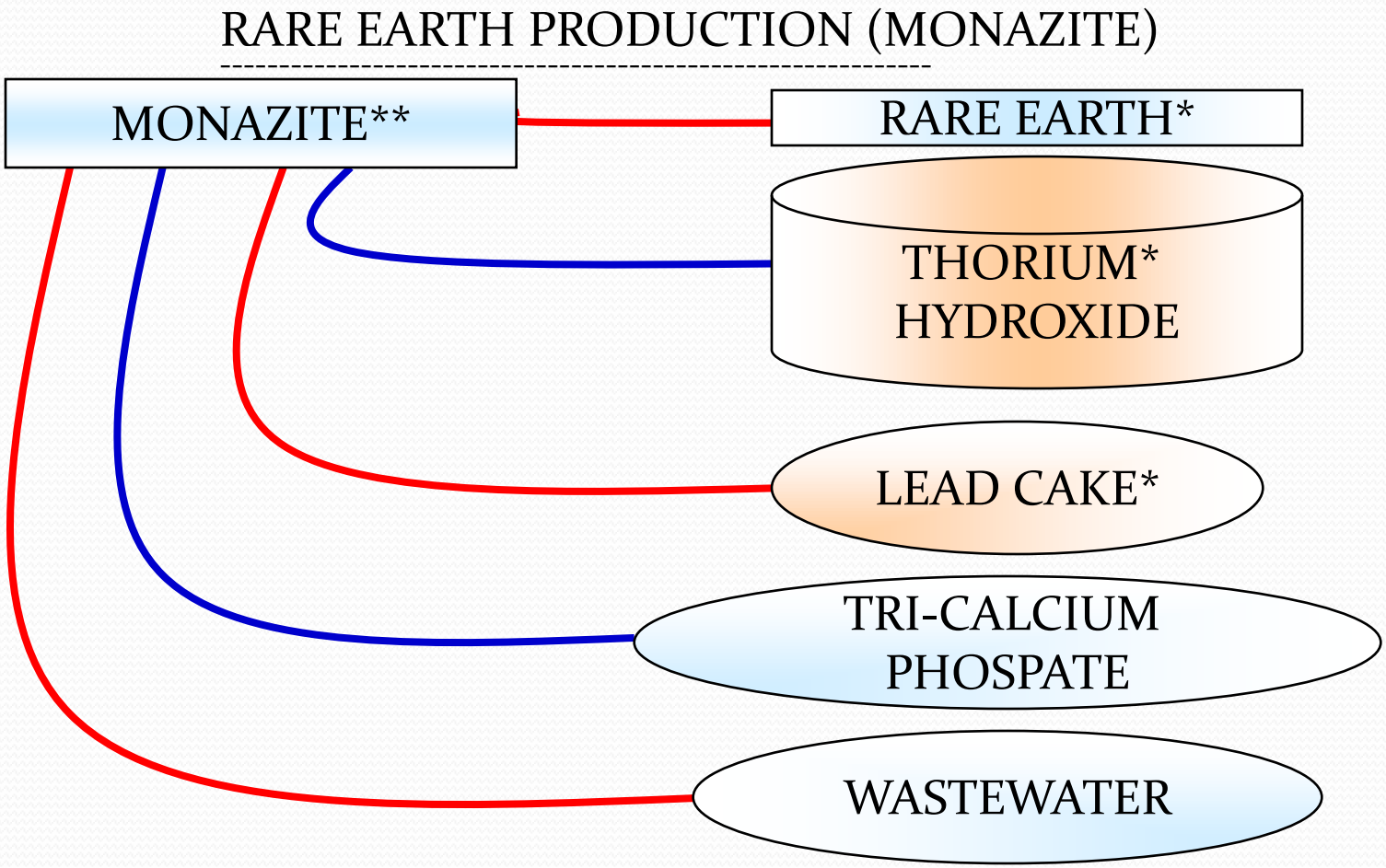
TIN-MINE RELATED PROCESSES (Cont.)



TIN-MINE RELATED PROCESSES (Cont.)

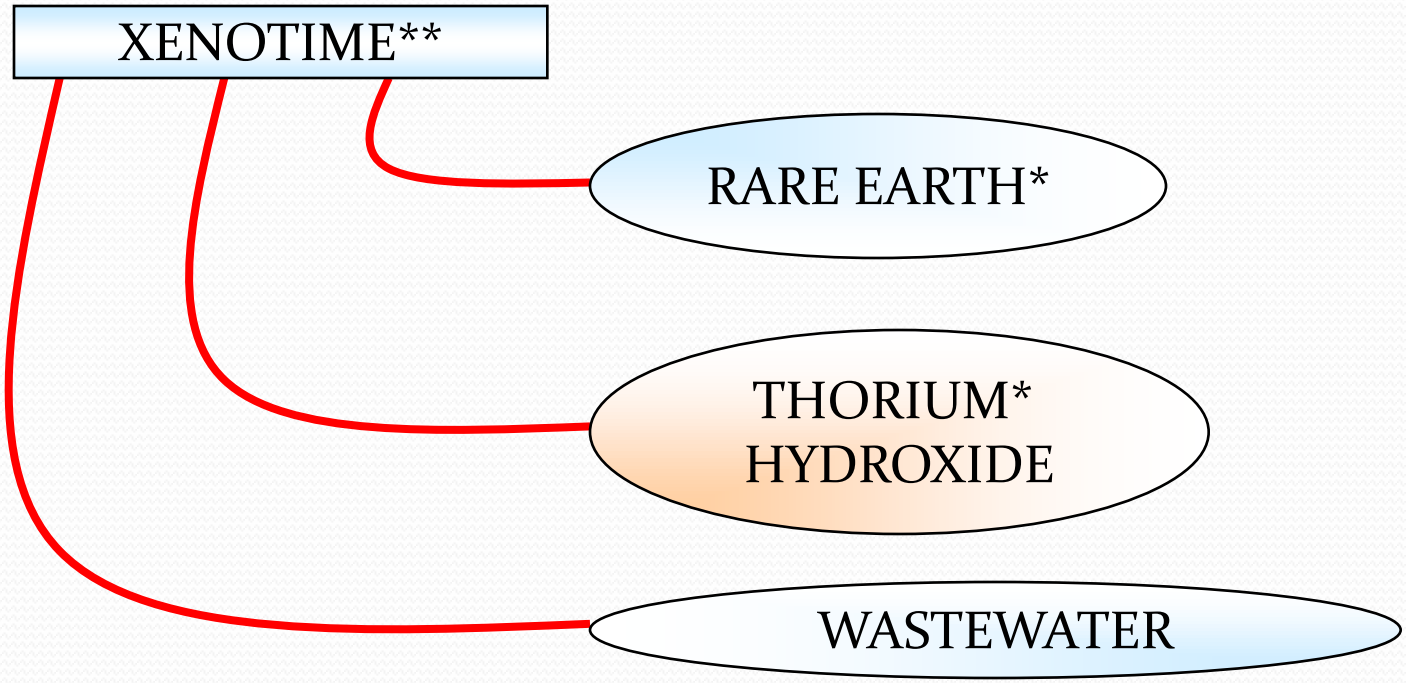


TIN-MINE RELATED PROCESSES (Cont.)



TIN-MINE RELATED PROCESSES (Cont.)

RARE EARTH PRODUCTION (XENOTIME)



TREATMENT OF MINERAL PROCESSING WASTE

WASTE: Gypsum, iron oxide, polishing sludge, thorium hydroxide, tin slag

- In solid form, cannot be treated anymore
- Options are reuse or disposal
- Disposal with or without conditioning
  - E.g. : conditioning with cement

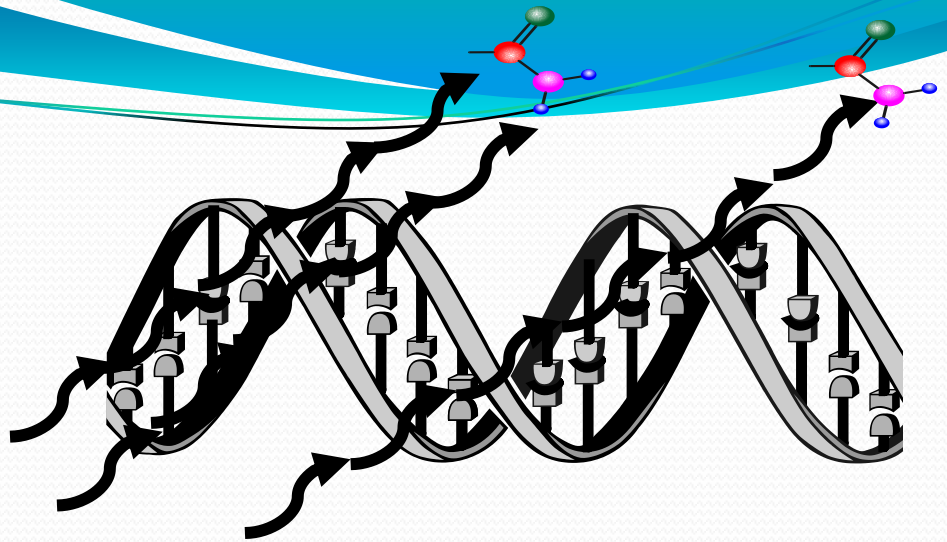
TOTAL ACTIVITY CONCENTRATION (TAC) FOR ORE & MINERAL

- In the case of ores and minerals, where radioactive equilibrium is assumed :

- TAC_{OM} (Bq/g) = (14 x $Act._{U}$) + (10 x $Act._{Th}$)
- Where $Act._{U}$ and $Act._{Th}$ are the activity concentrations in Bq/g of any member of U-238 and Th-232 series respectively.

TOTAL ACTIVITY CONCENTRATION (TAC) - DEVIATION

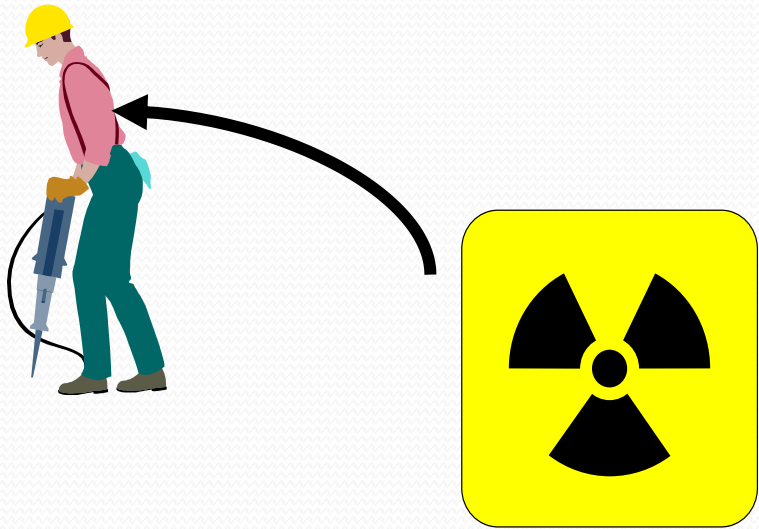
- Deviation from the state of equilibrium normally occurs whenever there is a chemical separation.
- e.g. During monazite processing to obtain rare earth element,
  - Thoria cake: U-238, U-235, U-234, Th-234, Th-232, Th-230, Th-228
  - Lead cake: Ra-224, Ra-226, Ra-224, Pb-212 and Pb-210.



SOURCES OF RADIATION HAZARD FROM NORM/TENORM

SOURCES OF RADIATION EXPOSURES

- EXTERNAL RADIATION
- EXTERNAL + INTERNAL RADIATION
  - Radon and Thoron Daughters
  - Airborne Dust
  - Surface Contamination



SOURCES OF RADIATION EXPOSURES

1. EXTERNAL RADIATION

WHAT ?

- RESIDUES: Gypsum, iron oxides, thoria, oil & gas, sludge & scales, contaminated component

WHERE ?

- Storage & approved dumping areas

HOW TO PREVENT?

- Controlled by using STD principles

SOURCES OF RADIATION EXPOSURES

2. RADON AND THORON DAUGHTERS

SOURCES: Raw Materials & residues; storage and processing areas

- sources are exposed in open ground or kept in polyester bags
- can be deposited along the respiratory tract. may cause detrimental effect to the surrounding cells by depositing α energies.
- very much influenced by ventilation

- radon & thoron will be trapped in metal drum if sealed properly

WORKING LEVEL (WL) – unit for radon daughters concentrations in air

- 1 WL = combined short-lived radon daughters in 1 L of air that produce potential α energies of 1.3×10^5 MeV. A smaller unit, mWL is also used.

- Working Level Month (WLM) = unit of exposure to radon or thoron daughters for 170 h.

- Annual Limits for workers: 4 WLM for radon & 12 WLM for thoron daughters
  - Thus, dose conversion factor = 10 mSv/WLM for radon & 3.3 mSv/WLM for thoron (based on annual dose limit of 50 mSv)

SOURCES OF RADIATION EXPOSURES

3. AIRBORNE DUST

SOURCES: Raw materials & residues; storage and processing areas

- dusty operation - dry and open process
- dry milling, collection areas
- also influenced by ventilation

SOURCES OF RADIATION EXPOSURES

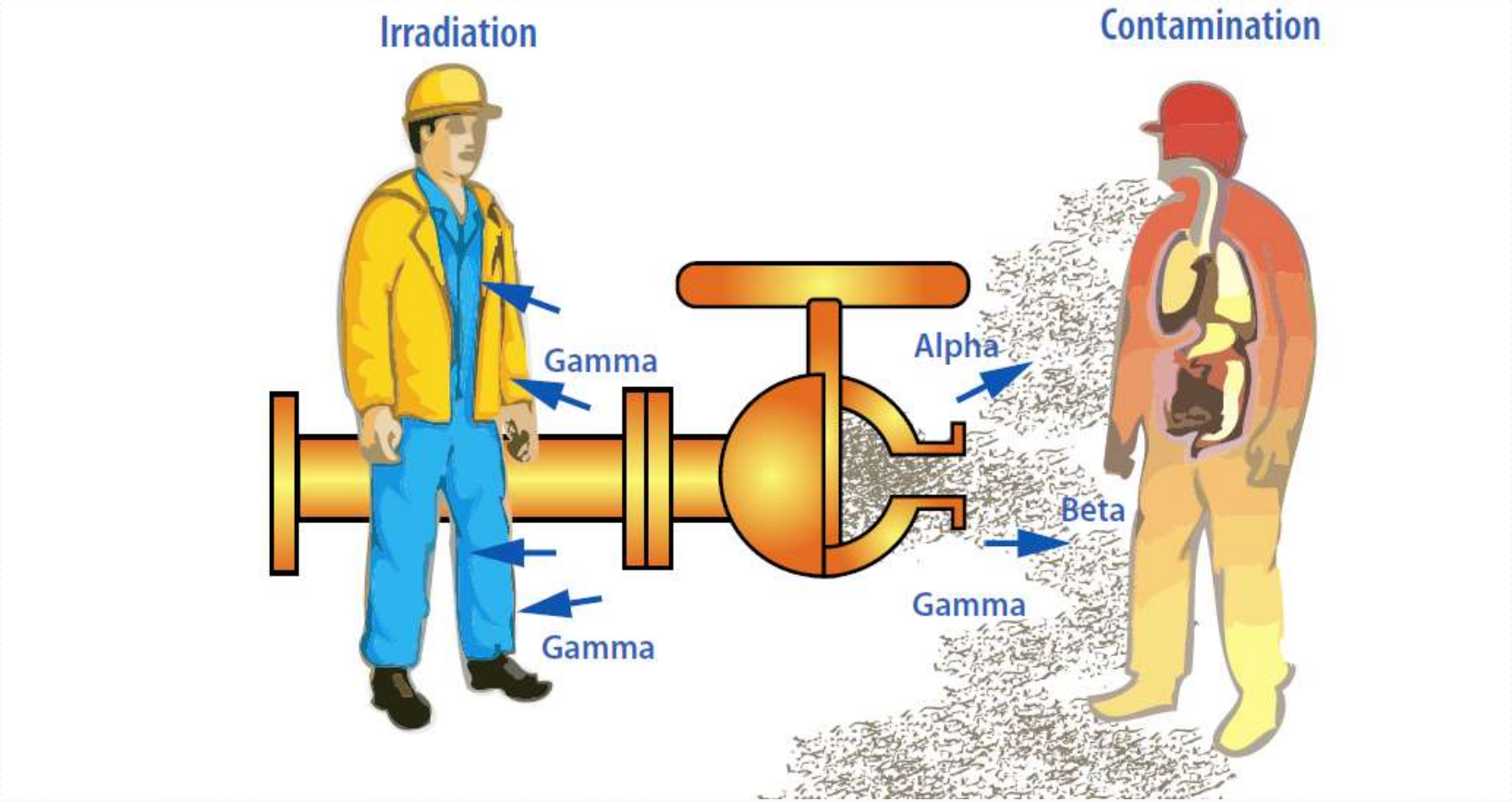
4. SURFACE CONTAMINATION

Happen when sources - deposit onto surfaces

- Loosed contamination:
  - when dry, can be re-suspended
  - can lead to internal exposure through inhalation, ingestion & cut wound

- Fixed contamination: external exposure

NORM Exposure scenario



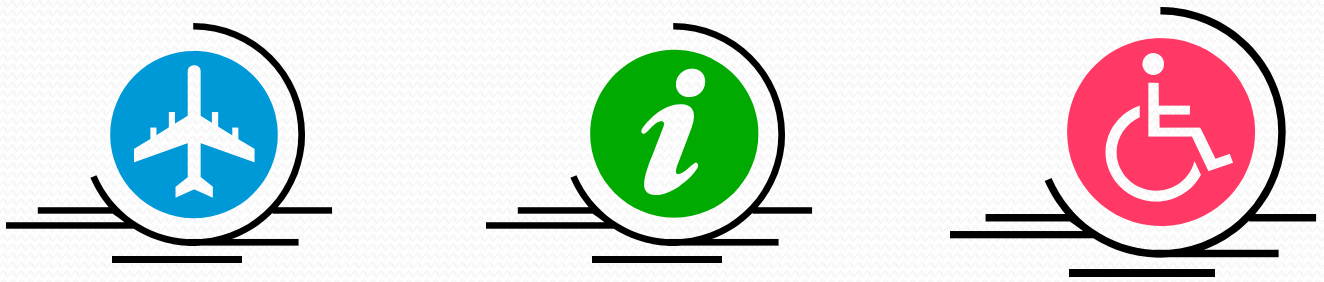
INTERNAL DOSE (Revision)

Intake - the amount of activity taken into the body.

Entry into the body can occur via:

- Inhalation (dust, gas or volatile materials)
- Ingestion (contaminated food or water)
- Wound (dust, solid or liquid materials)
- Direct absorption (tritium)

CLASSIFICATION OF WORKING AREAS



CLASSIFICATION OF WORKING AREAS

1. CLEAN AREA

   means an area where the annual dose received by a worker is not likely to exceed the dose limit for a member of the public;

2. SUPERVISED AREA

   means an area for which occupational exposure conditions are kept under review even though specific protective measures and safety provisions are not normally needed.. Likely to exceed 1/10 but unlikely to exceed 3/10 of the Annual Dose Limit

CLASSIFICATION OF WORKING AREAS

3. CONTROLLED AREA

- means any area in which specific protection measures and safety provisions are required for controlling normal exposures or preventing the spread of contamination during normal working conditions, and preventing or limiting the extent of potential exposures

- An Area where the dose received by the worker is likely to exceed 3/10 ADL (6 mSv y^{-1}).

  - This area is subject to special rules for the purposes of protection against ionizing radiation and to which access is controlled.

WORKING PROCEDURES

WORKING PROCEDURES

Procedures are developed to reduce radiation dose to workers & public

e.g.:

- Good housekeeping – reduce surface contamination
- No eating, drinking and smoking at the work place
- Wear face mask
- Wear protective clothing

WORKING PROCEDURES

Reduce External Radiations

- SHIELDING: keep NORM In sealed containers, concrete stores
- TIME: avoid unnecessary exposures
- DISTANCE: handling from a distance, e.g. use forklift
- minimise NORM quantity

WORKING PROCEDURES

Reduce exposure to airborne dust & Radon/Thoron progeny

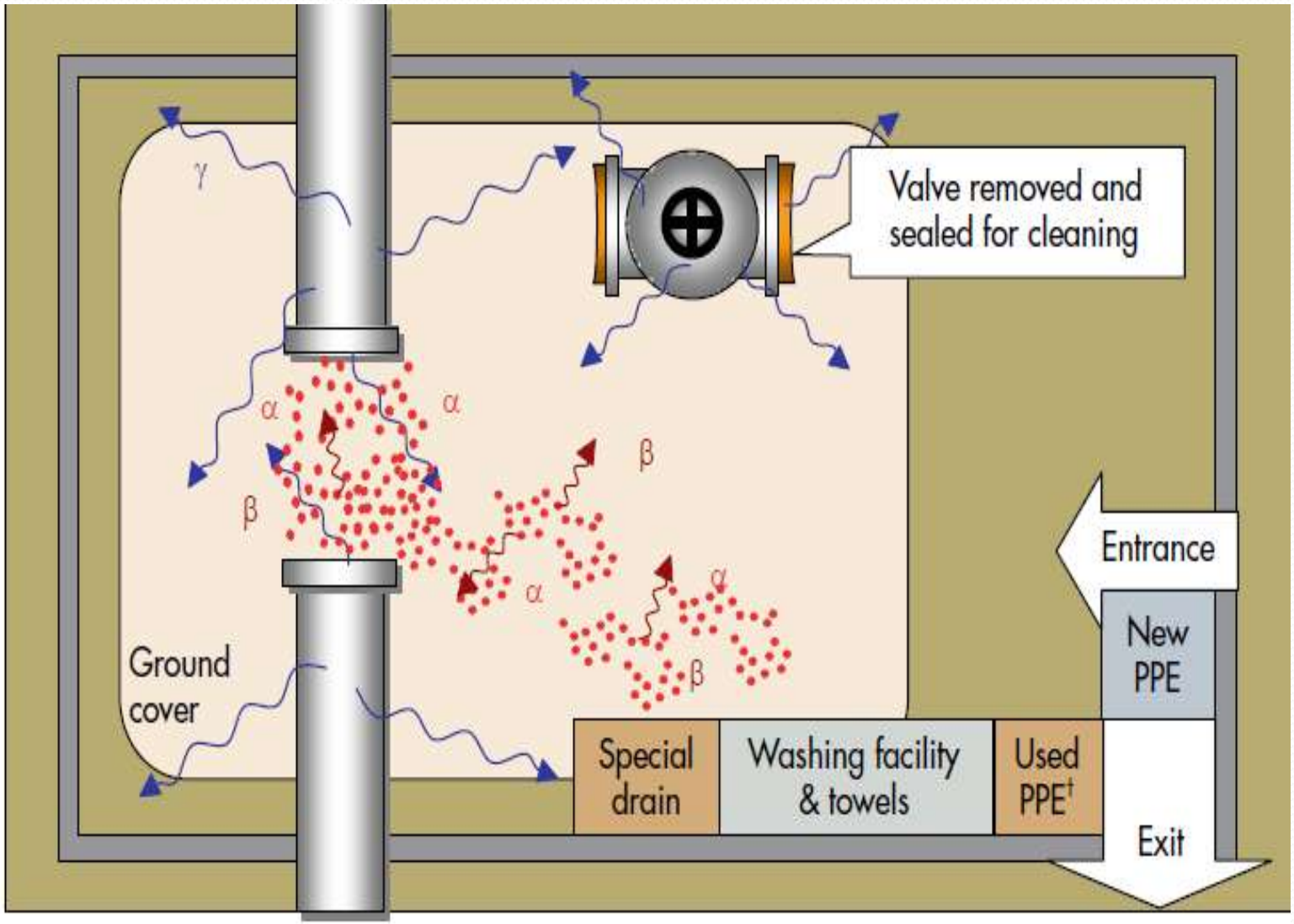
- Processing NORM in closed vessels, wet condition.
- Provide good ventilation – extraction fan, ‘open’ plant design, natural air movement, dilute & disperse

PERSONAL PROTECTIVE EQUIPMENT

EXAMPLE

- Respirator
- Mask
- Laboratory coat
- Coverall/apron
- Safety shoes
- Safety helmets
- Gloves
- Self-contained breathing apparatus (SCBA)

NORM Contamination Control requirements



† PPE: Personnel Protective Equipment


NORM
DECONTAMINATION
IN
PROGRESS

STORAGE OF NORM/TENORM

STORAGE

In NORM/TENORM activities, the waste storage require approval from the AELB.

Waste storage:

- Large volume – above ground dumps
- Medium & Small sizes – in store, drums, polyester bags

Storage place should be Isolate, Label, Radiation Sign, Control Access (Administrative and Technical)

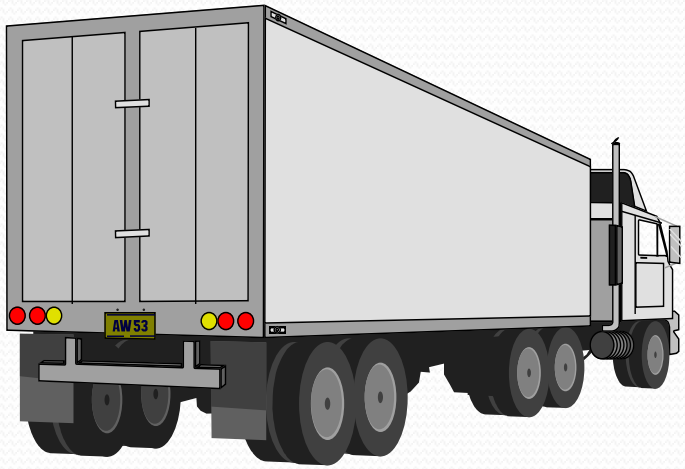
EXAMPLE OF ACCESS CONTROL

- Administrative control
  - access control procedures;
  - alarmed access points (e.g. with radiation detectors);
  - key control procedures;
  - video cameras or personal surveillance;
  - records related to the management of sources
- Technical control
  - fences;
  - walls;
  - cages;
  - transport packaging;
  - locks and interlocks for doors (or access points)
  - locked, shielded containers

STORAGE - Amang

- Access should be restricted or prohibited
- Guidelines for Amang storage, LEM/TEK/37
  - store must be far from office, lab, residential areas
  - strong structure foundation
  - equipped with good ventilation
  - container must be placed > 1m from the wall
  - must be fenced & locked
  - must have warning & radiation signs
  - must ensure dose outside the fence be ALARA

TRANSPORTATION



TRANSPORTATION OF NORM/TENORM

- General Procedures
  - within Premise
    - Radiation Protection (Transport) Reglations 1989 not applicable for transportation within premise where NORM/TENORM is produced, used or stored but some guides need to be followed
  - outside Premise
    - Transportation of NORM by land, sea & air must comply Radiation Protection (Transport) Regulations 1989

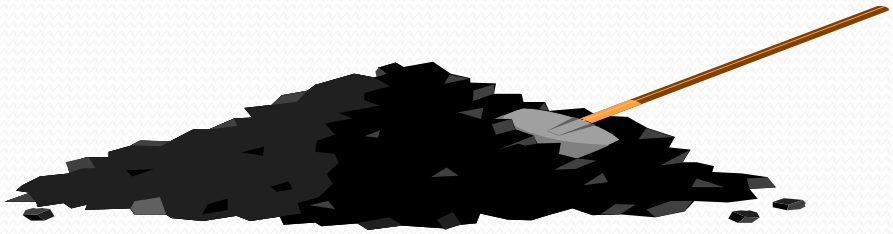
TRANSPORTATION

- NORM/TENORM = Low Specific Activity (LSA) Material

- Use Industrial Package Type 1 (IP-1)
- Radiation level:
  - < 0.1 mSv/hr at 1 meter
  - < 2 mSv/hr on the surface
  - Transport Index ≤ 10

- Oil & Gas – contaminated Items: RPO to estimate scale quantity & labeled properly

RADIOLOGICAL IMPACT ASSESSMENT (RIA)



RADIOLOGICAL IMPACT ASSESSMENT (RIA) – WHAT IS IT?

- A process where a dose assessment is carried out for an activity decided by AELB

  e.g. NORM/TENORM waste disposal by landfill

- dose assessment for critical group living on the disposal site (worst case scenario) using a recognised computer code such as RESTRAD, AMBER etc.

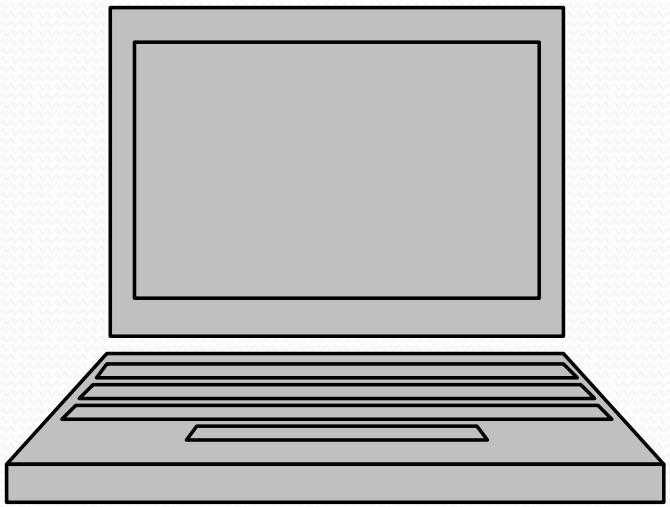
RIA – DISPOSAL SCENARIO

- Identify disposal site (clear ownership & approved for disposal – usually within company's premises)
- Dig a trench / big hole and with no liner
- Place the waste, e.g: treated sludge, tin slag
- Cover the waste with soils to suitable thickness
- Assume people living on the site – exposed to radiation, dust & Radon/Thoron from the waste, rely on ground water as a source of drinking water, cooking, irrigation & for livestock etc.
- Erosion of cover is also to be considered
- All critical exposure pathways are considered

RIA (Cont.)

- Assessment uses as much as possible site specific data collected for calculation
  - IF calculated Public Annual Dose < Dose Constraint (0.3 mSv/y), disposal is exempted from regulatory control.
  - IF calculated Public Annual Dose > Dose Constraint, the disposal is controlled under the regulation, environmental monitoring may be required to be conducted for a specific period decided by AELB
- Approval is VALID only for the proposed scenario

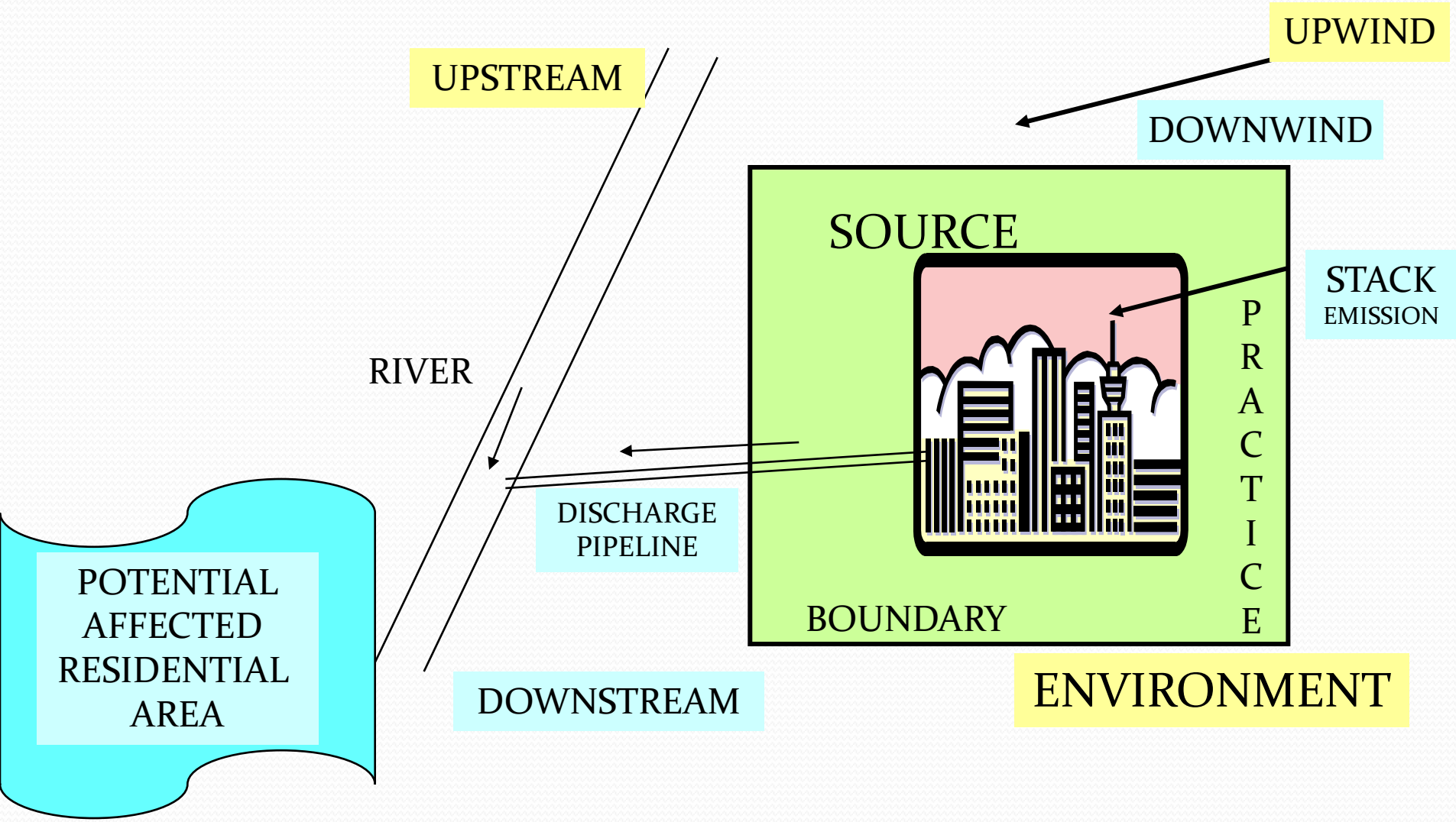
MONITORING PROGRAM



MONITORING PROGRAM

- Personnel Monitoring
  - Worker – potential risk
  - Monitored by Film or TLD badge
  - Worn for 1 month before sending to established lab for analysis
  - Report will be received by companies
  - Personnel monitoring report to AELB
- Working Area Monitoring
  - Routine monitoring in working areas
  - Use calibrated survey meters for external radiation
  - Indirect measurement for exposure to workers
  - Radon/thoron
  - Airborne dust sampling & analysis
  - Wipe test for surface contamination
- Environmental Monitoring
  - Ensure safety of public

SOURCE & ENVIRONMENT



ENVIRONMENTAL MONITORING

- EFFLUENT
  - liquid or gas
  - sources of exposures to public

- PATHWAYS: modes of exposures
  - liquid – river – irrigation – food
  - gas – dilution & diffusion – inhalation
  - solid waste on the ground – radionuclides – groundwater – drinking water

ENVIRONMENTAL MONITORING (Cont.)

- OBJECTIVES
  - To ensure effectiveness of effluent control program
  - To assess the potential exposure of the public to radioactive materials & radiation in the environment for protection purposes
  - Carry out trend analysis of radioactive release
  - Improve public relation
  - To comply with the license condition issued by AELB

ENVIRONMENTAL MONITORING (Cont.)

- required to be carried out by class A & G licensees
- or specified in the license conditions

ENVIRONMENTAL MONITORING (Cont.)

- MONITORING STAGES
  - PRE-OPERATIONAL
    - prior to plant construction
    - to determine background/baseline radiation & radioactivity level in the environment (5 km radius)
  - OPERATIONAL
    - during operation
    - to ensure the effectiveness of the effluent control system & program and compliance with standards (1 km radius)
  - POST-OPERATIONAL
    - after cease of operation
    - To verify that the site is free from radioactive contamination

ENVIRONMENTAL MONITORING (Cont.)

- FREQUENCY
  - proposed by licensee/consultant, approved by AELB
  - Pre-Operational: once a MONTH or once in two MONTH for a period of one year
  - Operational: BIMONTHLY, can be reviewed by AELB
  - Post-Operational: determined by AELB

ENVIRONMENTAL MONITORING (Cont.)

- Monitoring area
  - inside & outside (1 km) plant premise

- Monitoring stations
  - locations & no. of stations: depending on method of waste and wastewater disposal, weather conditions, the use of surrounding areas (e.g. household, other industries, plantations)

ENVIRONMENTAL MONITORING (Cont.)

- SAMPLING
  - selection of sample depends on types of industries/processes, disposal method & conditions of environment
  - Samples collected: soils, flora, fauna, water, sediment, airborne dust, etc.
- SAMPLE PREPARATION
  - Drying, Ashing, Evaporation
- ANALYSIS
  - Radium-226, Radium-228 using Gamma S

ENVIRONMENTAL MONITORING (Cont.)

- MONITORING PARAMETERS
  - External radiation level, using
    - Thermoluminicence Dosemeter (TLD)
    - Survey Meter
      - Shall ≤ 0.5 μSv/h (=1.0 mSv/yr) base on 24 hr exposure
  - Radon & Thoron daughters
    - RDA-200, Alpha Dosimeter

ENVIRONMENTAL MONITORING (Cont.)

- MONITORING PARAMETERS
  - Surface contamination, consider contaminate if
    - Alpha emitter > 0.04 Bq/cm^2
    - Others > 0.4 Bq/cm^2
  - Airborne contamination, must be monitor in dusty working environment, dust sampled and analyzed for gross alpha and gross beta activity for determination of U-238 and Th-232. It is consider contaminate if dust
    - Uranium > 0.01 Bq/m^3
    - Thorium > 0.001 Bq/m^3

ENVIRONMENTAL MONITORING (Cont.)

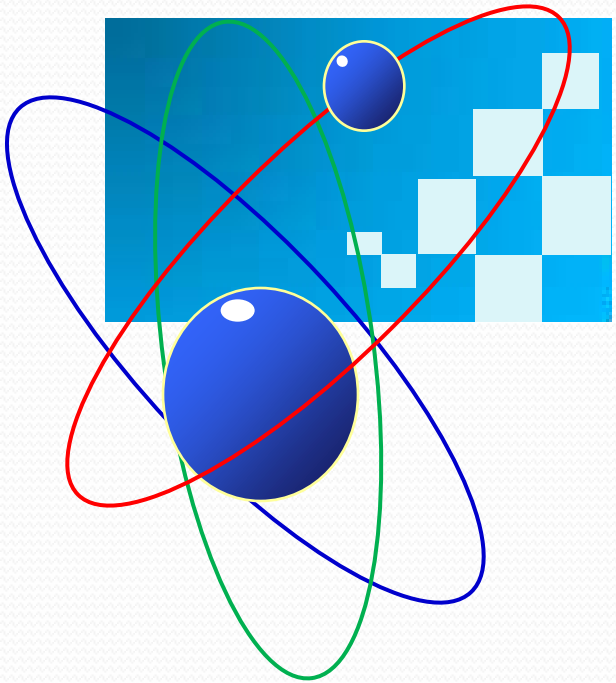
- MONITORING PARAMETERS (e.g)
  - For waste treatment of TENORM, radionuclide that need to be monitor in:
    - Air particulate – conc. of U-238 & Th-232;
    - Effluent – conc. of Ra-226 & Ra-228;
    - Soil – conc. of Ra-226, Ra-228, U-238 & Th-232;
    - Sludge – conc. of Ra-226, Ra-228, U-238 & Th-232;
    - Underground water – conc. of Ra-226 & Ra-228;

ENVIRONMENTAL MONITORING (Cont.)

- REPORT
  - Report for environmental radiation and radioactivity levels during OPERATIONAL period are compared with the levels during PRE-OPERATIONAL period
  - To monitor any ENHANCEMENT of environmental radiation and radioactivity levels
  - Licensee/consultant to submit the report to AELB for evaluation within 14 days after receiving results from laboratory

Related Document for NORM/TENORM

- LEM/TEK/28: License for Milling
- LEM/TEK/30: Monitoring Guideline Oil & Gas
- LEM/TEK/32: Safety Transporting Amang
- LEM/TEK/37: Safety Small Amang Factory
- LEM/TEK/38: Decommissioning TENORM Facilities
- LEM/TEK/45E: TENORM Activities
- LEM/TEK/58: Code of Practice on radiation Protection Relating to Technically Enhanced Naturally Occurring Radioactive Material (TENORM in Oil and Gas Facilities



Terima Kasih

Thank You