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Atoms for Peace and Development

Exposure Pathways: Gamma Radiation

Training Package on Occupational Radiation Protection in Uranium Mining and Processing Industry

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Gamma Radiation

- Introduction to gamma radiation
- Control measures
- Monitoring & dosimetry
- Key messages & facilitating questions

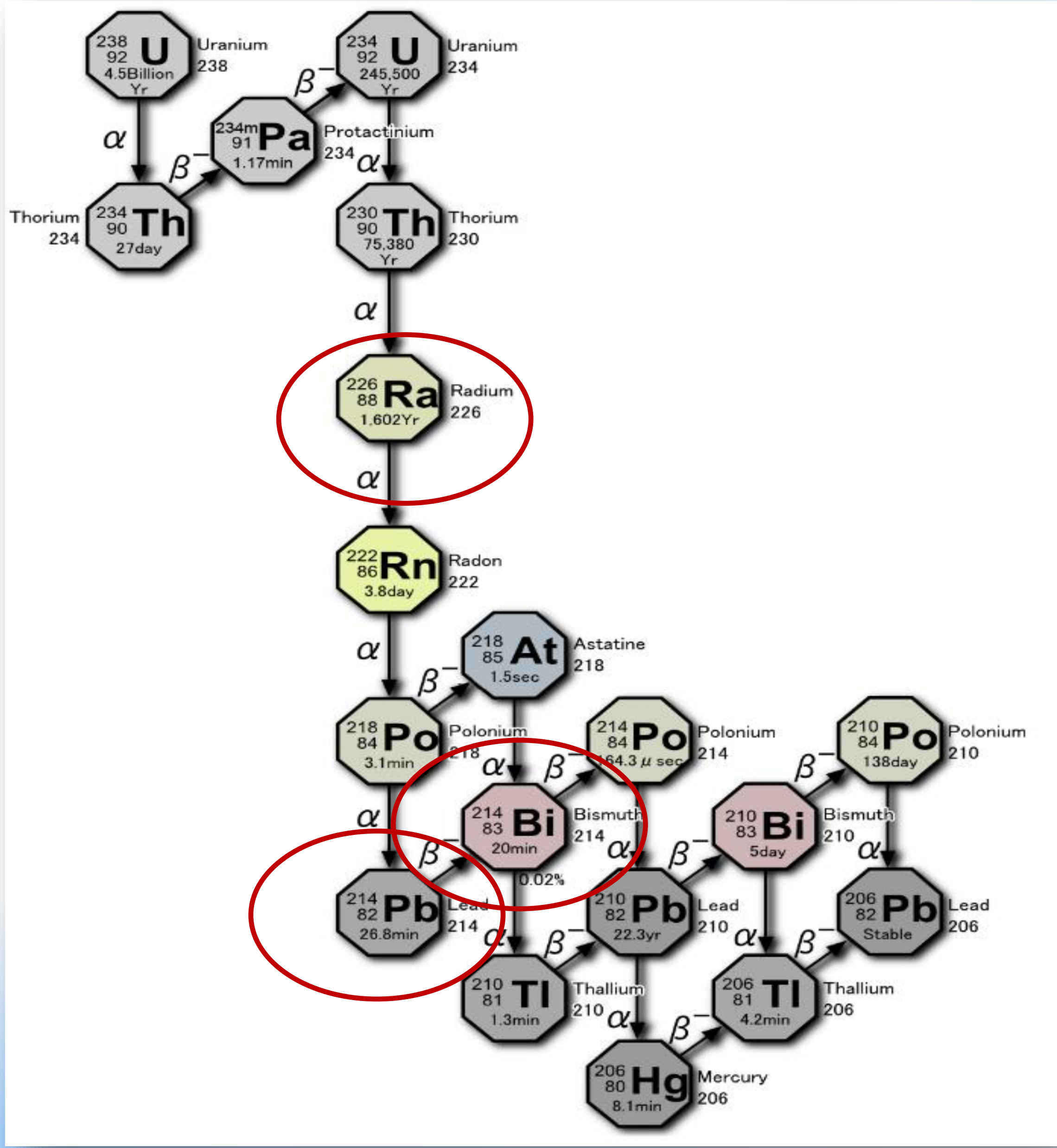
Gamma radiation

- The exposure of the workforce to direct external gamma radiation is often one of the most significant pathways in uranium mining.
- In most cases the orebodies exploited for uranium production contain very low levels of thorium and this decay chain makes an insignificant contribution to occupational gamma dose rates;
  - however, where thorium concentrations comprises more than 10% of an exploited uranium ore, gamma radiation from the thorium chain needs to be considered.
- Gamma radiation can also be elevated near;
  - Aged uranium concentrate
  - Pipes and vessels containing ^{226}Ra bearing sludges and scales

Gamma radiation cont'd

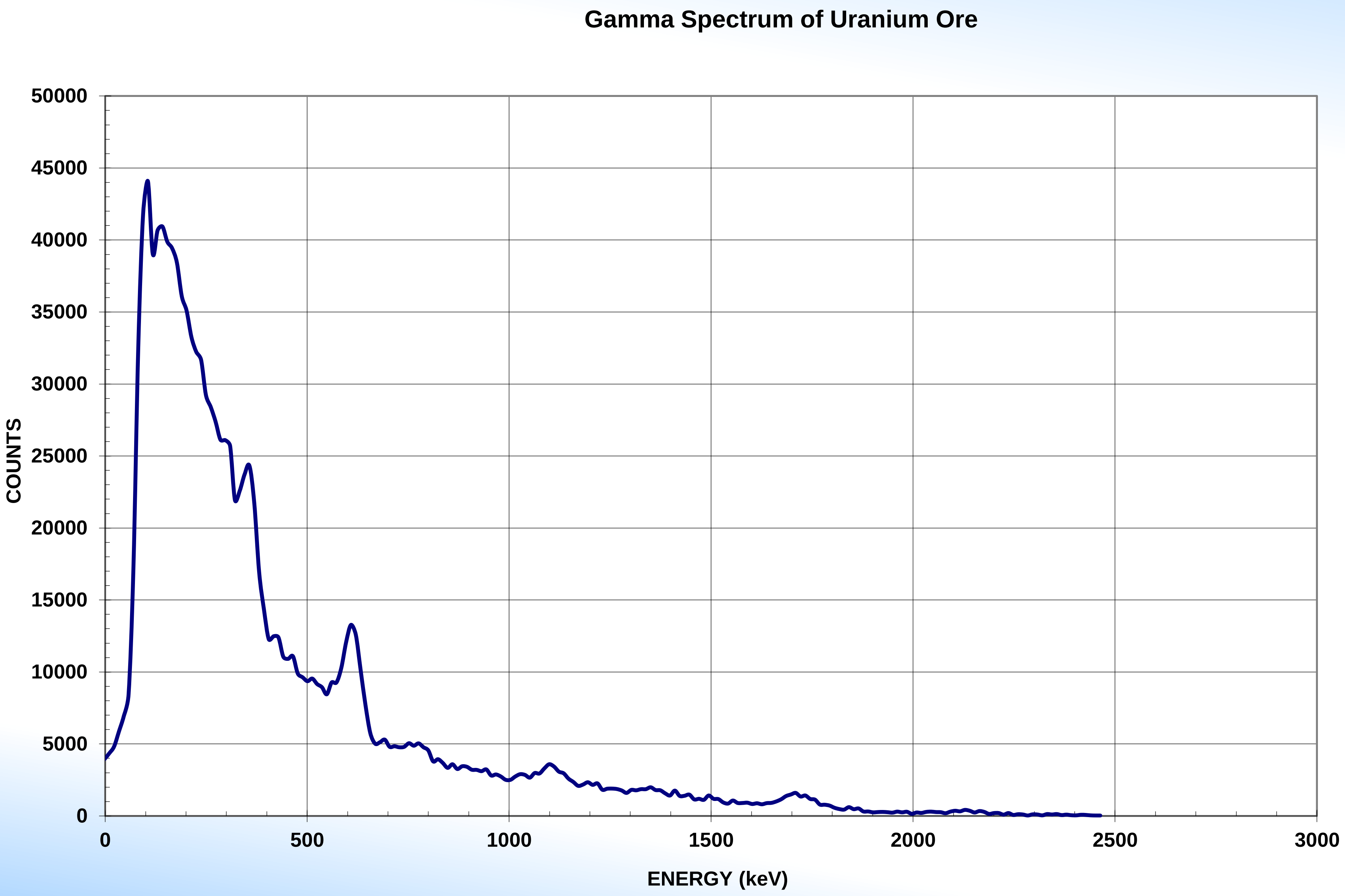
- The uranium and thorium decay chains are comprised of a mixture of alpha, beta and gamma emitting radionuclides.
- As shown on the following slides, the dominant gamma emitters are
  - **^{214}Pb** and **^{214}Bi** from ^{226} Ra in the ^{238}U decay chain, and
  - **^{228}Ac**, **^{212}Pb** and ^{208}Tl from the ^{232}Th decay chain.
- In some situations with very high concentration of ^{222}Rn in groundwater (> 10^6 Bq/m^3), gamma radiation levels can also be elevated.

The Uranium (^{238} U) decay chain



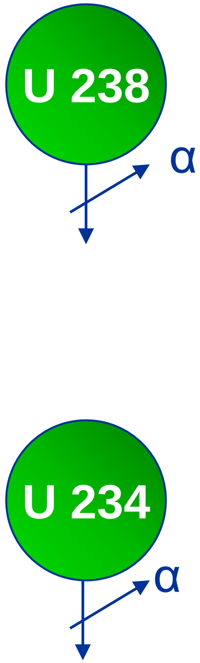
The dominant gamma emitter is ^{226}Ra, in particular, its short-lived daughters ^{214}Pb and ^{214}Bi

Gamma Radiation from Uranium Ore

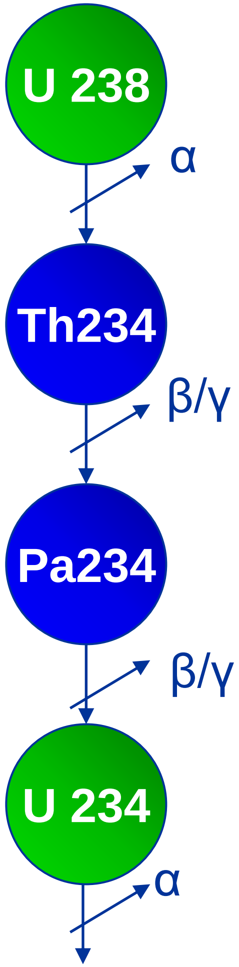


Know your Source

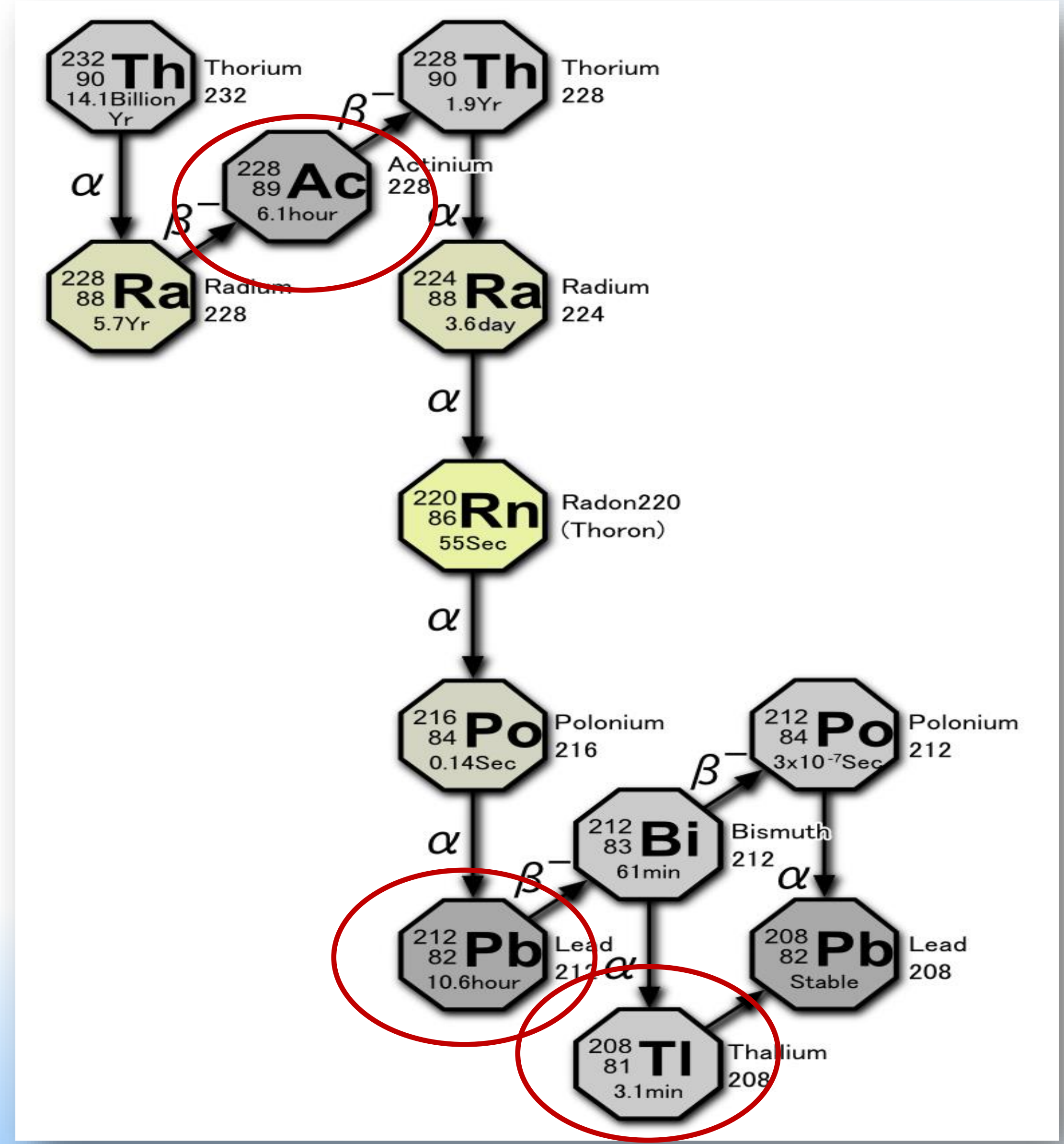
Young Uranium Concentrate



Old Uranium Concentrate



Thorium (^{232} Th) decay chain



The dominant gamma emitters are ^{228}Ac, ^{212}Pb and ^{208}Tl

Factors affecting the magnitude of the gamma radiation fields

- The uranium concentration of the ore;
- The thorium concentration of the ore;
- The quantity of materials involved;
- Details of mining operations including operations and mine equipment
- The presence or absence of the radon progeny;
- Process plant design including plant layout and process;
- The radionuclide composition and activity concentration per gram in the material(s);
- The distance of a localised gamma radiation field from fixed work positions and high occupancy areas.

Control measures for gamma radiation

The key concepts of minimizing occupational exposures are **time**, **distance** and **shielding**:

- Reducing time spent in gamma radiation fields;
- Increasing the distance away from the gamma radiation source;
- Shielding the gamma radiation source.

Gamma Radiation from Uranium Ore

- gamma field depends upon size, distance, and shielding
- Remember "TIME - DISTANCE - SHIELDING"
- Can calculate gamma fields with sophisticated programs (e.g. MCNP, MicroShield)
- Simpler alternative:
  – Gamma Field = Contact Dose Rate × Shape factor × Shielding factor
- contact dose rate for uranium ore about 45 µSv/h per % U_3O_8
- Shape factor can be calculated for a variety of geometries

Gamma Radiation Calculations

- Pipe Shape factor = $w/(\pi\ d)$
  - w = width of source
  - d = distance to source
  - assumes $d >> w$
- pipes usually only modest source in mill

Gamma Radiation Calculations

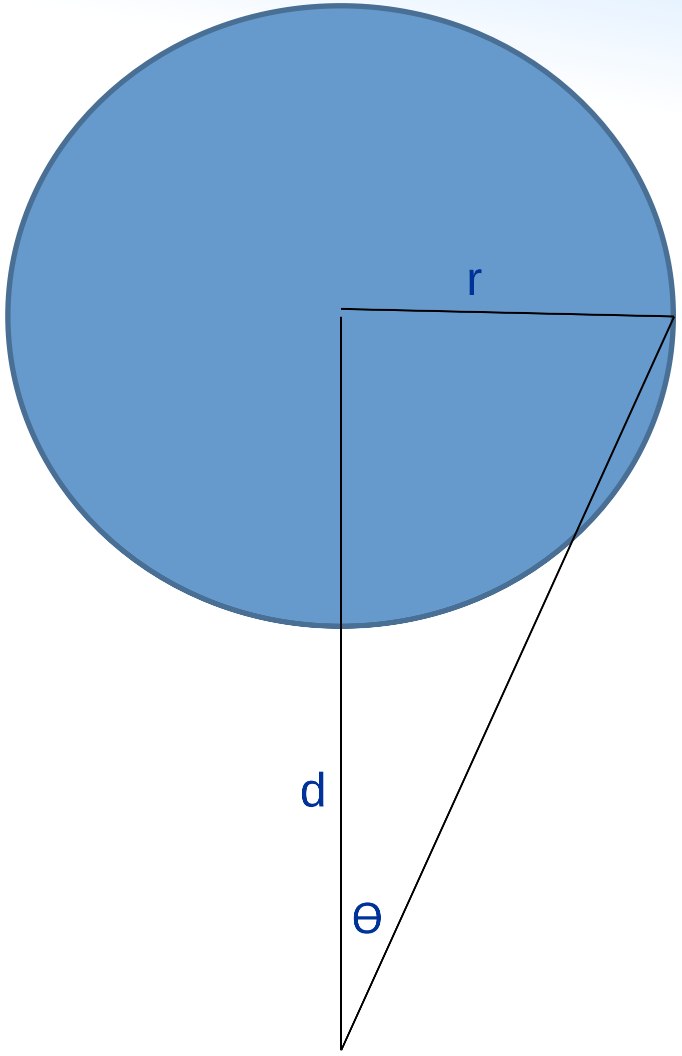
- Rectangular Source Shape Factor

- Shape factor = $\sum_{i=1}^{n} w * d / \pi * 1 / \left(d^2 + w^2 * (i - 1)^2\right) * (\mathrm{Sin}[t1] + \mathrm{Sin}[t2]) / 2$

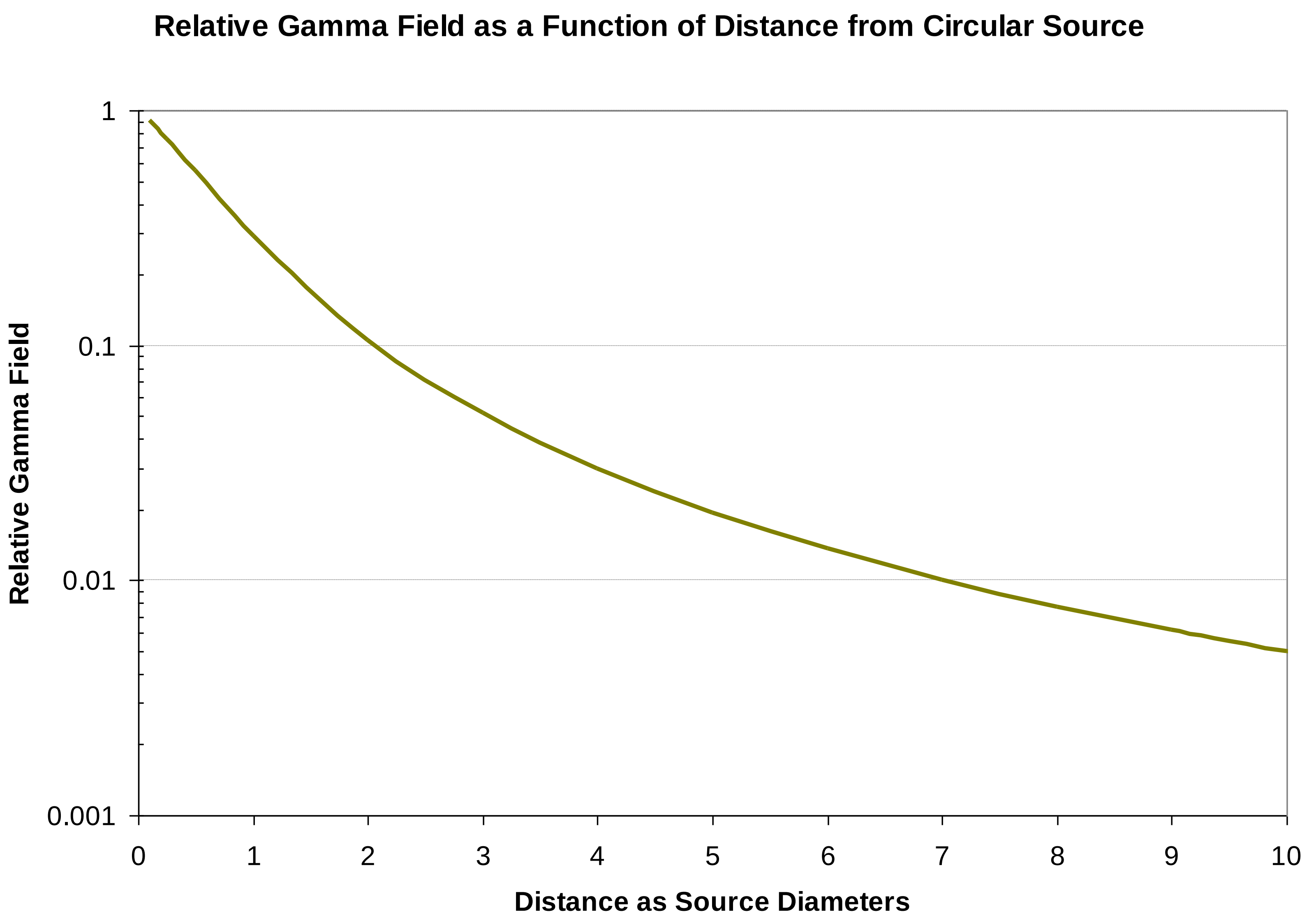
w = width
n = number of strips
d = distance to source
p1 = distance to right edge
p2 = distance to left edge
t1 = angle to right edge
t2 = angle to left edge

Gamma Radiation Calculations

- Circular Shape Factor = 1 - cos θ
  - θ = angle that subtends surface
  - θ = arctan (r/d)
  - r = radius of source
  - d = distance to source



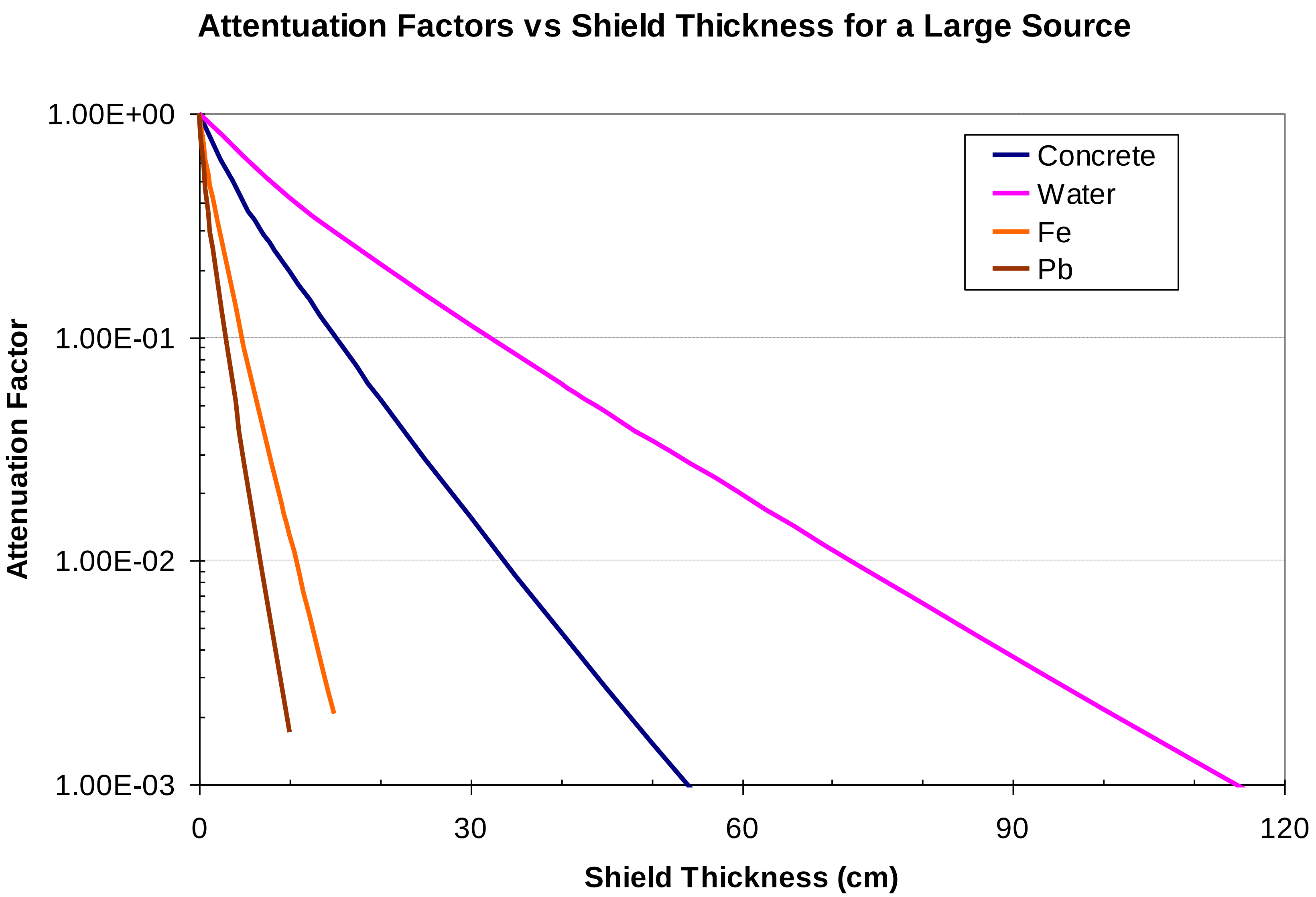
Gamma Radiation Calculations



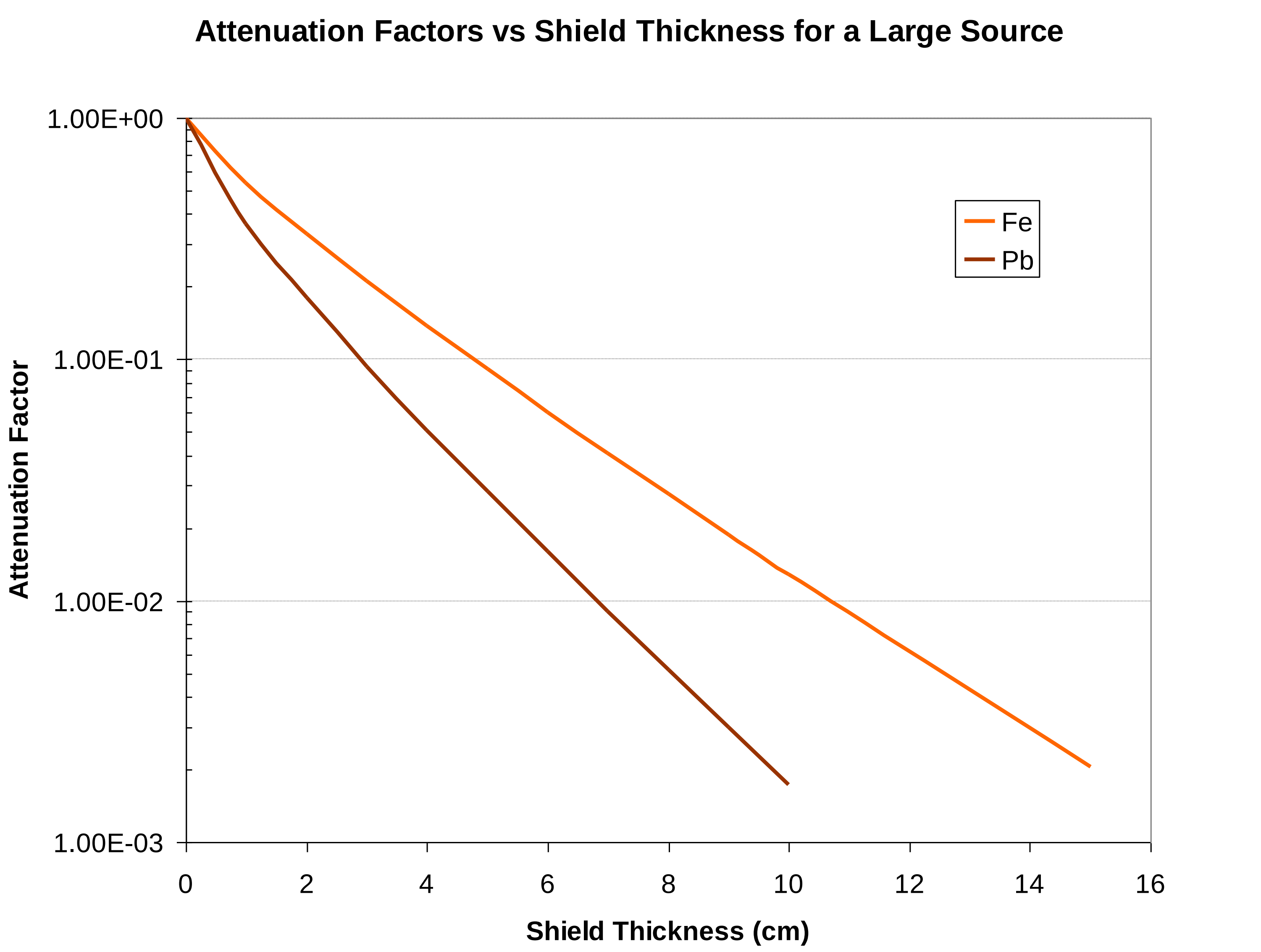
Gamma Radiation Calculations

- distance sometimes insufficient
- shielding used
- effectiveness of shield roughly proportional to its density
- concrete often preferred shield for large sources

Gamma Radiation Calculations – Uranium Ore



Gamma Radiation Calculations – U ore



Administrative measures to control gamma radiation

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- Planning work tasks to reduce exposure times;
- Knowledge of gamma dose rates (especially localized enhanced dose rates) in all areas of the mine and process plant;
- Restricting the time that the workforce spends in areas of enhanced gamma dose rates (i.e., minimizing the occupancy factor);
- Monitoring and control of access to enhanced dose rate areas;
  - Locating fixed work positions in low dose rate areas where practicable;
  - Place warning signs at entry to enhanced dose-rate areas;
  - Use barriers and fences to restrict access to enhanced dose-rate areas;
- Workers issued with Electronic Personal Dosimeters (EPDs) when working in high dose-rate areas.
- Training of workers

Control measures for gamma radiation - Shielding

- The large size and density of the mining equipment can often provide substantial shielding
- In underground mining additional shielding can be provided by shotcrete (*spray on concrete on the exposed rock often used to decrease the risk of rock falls*)
- In uranium mines with high uranium grades (e.g. >1%)
  - mining may have to be carried out using special methods, remote controlled machinery and handling methods that limit worker occupation in enhanced dose rate areas;
  - the shielding design of the mine is a vital tool in managing occupational doses;

Control measures for gamma radiation- Shielding

- In most processing plants shielding is not necessary due to the low dose rates or since there is sufficient open space in the plant to reduce the radiological impact without the need for shielding.
- In uranium mines with very high uranium grades
  - the shielding design the process plant is an important tool in managing occupational doses
  - certain areas of the process will need to be shielded
  - the shielding design of the process plant is an important tool in managing occupational doses
- The uranium concentrate storage area should be remote from normally occupied areas of the process plant or may require shielding.

Monitoring

- The extent of the gamma monitoring programme needs to be commensurate with
  - the nature and extent of the gamma radiation sources in the workplace,
  - the annual exposures received by the workforce.
- The need for gamma monitoring is not just confined to the operating life of the uranium mining and milling facility but is also needed;
  - during exploration activities,
  - during baseline environmental studies,
  - prior to hot commissioning,
  - during operations, and
  - during decommissioning activities.

Monitoring

- Monitoring programmes are a tool used to demonstrate that;
  - the operational radiation protective measures function as intended,
  - to signal whether further protective measures are to be considered, and
  - to audit whether the operations maintain the desired level of radiation protection.
- There is also a need to develop other monitoring programmes with specific objectives such as;
  - Monitoring for clearance of items from the site,
  - Monitoring prior to maintenance activities inside the process plant
  - Monitoring of non-designated (i.e., clean) areas of the plant and site.

Monitoring

- In a uranium mining and milling operation both **area** and **personal** gamma monitoring programmes are needed.
- Gamma radiation needs to be monitored for the following purposes:
  - Measuring gamma radiation dose rates in the workplace;
  - Measuring individual occupational exposures to gamma radiation;
  - To detect the build-up of gamma emitting materials (e.g., scales) within the process;
  - To verify the efficiency of designed engineered controls in the mine and process plant;
  - To confirm and verify area designations.

Monitoring


905-856-5950
health physics instruments
UNITS: .01 mR xxxx.xx
.1 µGy xxxxx.x
Model 4084
CANARY 4
Electronic Dosimeter

Monitoring

- In developing the monitoring strategy for a mine or process plant, the following need to be considered:
  - the areas that need to be monitored;
  - the role of personal monitoring
  - the appropriate monitoring equipment;
  - the temporal frequency of monitoring;
  - the number(s) of measurements associated with a area or group of items.

Dosimetry

- Personal monitoring of individual workers is necessary for dose tracking, for optimisation purposes, and for the official annual dose records.
- Gamma dose rates vary widely by area and the following area classification scheme can be used as a guide to determine which workers need to be considered for personal monitoring.

Area Classification	Total Projected Annual Doses From all Exposure Pathways (mSv/y)	Personal Monitoring Options
Uncontrolled	<1	Not needed
Supervised	1-6	Dose assignment by area surveys and occupation factors or selective personal monitoring of representative individuals.
Controlled	>6-20	Workers need more intensive personal monitoring

Dosimetry

- Occupational gamma doses can be assessed by a variety of methods including:
  - Prospective assessments based on modelling and calculation as for example in planning a new mine or process plant;
  - Individual monitoring of each worker or representative workers from a larger group of workers (SEG);
  - Using the results of area monitoring and occupancy factors to estimate annual gamma doses.

Monitoring & dosimetry

Other Considerations

- Selection of portable gamma monitoring equipment
- Select personal dosimeter(s)
  - TLDs (currently the most popular method of assessment);
  - OSLD;
  - EPDs (these electronic dosimeters provide dose rate readings and total dose tracking).
- Calibration and daily checks
- Quality Control
- Corrections for natural background
- Interpretation of monitoring results

Key Messages

- The exposure of the workforce to direct external gamma radiation is often one of the most significant pathways in uranium mining.
- In simple terms, the higher the grade, the higher the gamma dose rate.
- Gamma exposures are controlled through planning and monitoring.
- The key concepts of minimizing occupational exposures are time, distance and shielding.

Guidance Questions

Q1:

- What are the key concepts of minimizing occupational gamma exposures?

Q2:

- How is gamma dose assessed?

Guidance Answers

A1:

- Reducing time spent in gamma radiation fields;
- Increasing the distance away from the gamma radiation source;
- Shielding the gamma radiation source.

A2:

- Predicting doses by modelling in planning a new mine or process plant;
- Use individual monitoring of each worker or representative workers from a larger group of workers (SEG);
- Use the results of area monitoring and occupation factors to estimate annual gamma doses.

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Thank you!