

Radiation Biology, Protection and
Applications (PHYS-450)

EXERCISE

Calculate the absorbed dose, dose equivalent to the bronchial epithelium & the effective dose for systemic cancer risk from Polonium-210 inhalation in a heavy smoker over the course of one year.

Account for the fact that the lungs are not a sealed box. When Polonium-210 is inhaled, two competing processes occur:

1. Physical Decay: The atom decays, emitting an alpha particle (causing damage).
2. Biological Clearance: The body naturally removes the particle (via mucociliary transport) before it has a chance to decay.

Furthermore, particles do not distribute evenly. They impact at "hot spots" (bronchial bifurcations), meaning the energy is concentrated in a very small mass of tissue.

Problem Data:

1. Smoker Profile: 1.5 packs per day (30 cigarettes).
2. Po-210 Activity: 0.516 pCi per cigarette.
3. Deposition Fraction: Only 50% of the smoke is deposited in the lungs; the rest is exhaled immediately.
4. Target Mass: We are calculating dose to the Bronchial Epithelium (not the whole lung). Assume the specific mass of this irradiated tissue is 20 grams.
5. Physical Data:
 - o Po-210 Alpha Energy = 5.307 MeV
 - o Po-210 Physical Half-life = 138.4 days.
6. Biological Data:
 - o Biological Half-life of Polonium in the lung = 50 days.
 - o Weighting Factors: Alpha $w_R = 20$; Lung Tissue $w_T = 0.12$.

Context:

Naturally-occurring radioactive minerals accumulate on the sticky surfaces of tobacco leaves as the plant grows, and these minerals remain on the leaves throughout the manufacturing process. Additionally, the use of the phosphate fertilizer Apatite – which contains radium-226, lead-210, and polonium-210 – also increases the amount of radiation in tobacco plants.

The radium-226 that accumulates on the tobacco leaves predominantly emits alpha and gamma radiation. The lead-210 and polonium-210 particles lodge in the smoker's lungs, where they accumulate (lead-210 has a half-life of 22.3 years). The tar from tobacco builds up on the bronchioles and traps even more of these particles. Over time, these particles can damage the lungs and lead to lung cancer.

How Polonium Creeps into Tobacco

Uranium 238 decays to radon 222 (a gas) and then to lead 220, which settles on tobacco leaves and later converts into polonium 210.

