22.55 Spring 2004
Professor Coderre
April 16, 2004
Due: April 23, 2004

Problem Set 6

1. A working chamber in a uranium mine measures 15 meters x 10 meters x 2.5 meters. The air inside contains the nuclide inventory shown in Table 1.

Table 1

Nuclide	Activity Concentration
^{222}Rn	180 pCi/L
^{218}Po	170 pCi/L
^{214}Pb	140 pCi/L
^{214}Bi	120 pCi/L
^{214}Po	125 pCi/L

a) Calculate the working level (WL) concentration.
b) Calculate the total potential alpha particle energy (PAEC) in the chamber in J/m^3.

2. a) If a person spends an average of 8 hours per day, 5 days per week, 12 months per year in the mine chamber in Problem 1, what is the exposure in WLM, after one year of activity?

   b) If the dose conversion factor for lung epithelial cells is 1.5 mGy/WLM, what are the physical dose and the equivalent dose per year to the lung epithelium? What is the effective dose per year for this person? (consider the dose to the lung epithelium as the lung dose).

3. A person spends an average of 14 hours per day at home, where the average concentration of radon is 4.5 pCi/L. What is his exposure in WLM over a six-month period.

4. Calculate the effective dose to an individual who has received the following exposures:
   5 mGy alpha to the lung
   10 mGy thermal neutron, to the skin
   5 mGy gamma, whole body
   100 mGy beta to the thyroid.

5. An atmosphere contains the numbers of atoms per liter shown in Table 2.

Table 2

Nuclide	Atoms L^{-1}
^{222}Rn	2.3×10^5
^{218}Po	5.2×10^3
^{214}Pb	4.1×10^3
^{214}Bi	2.1×10^3
^{214}Po	200

a) Calculate the PAEC in J/m^3.
b) Calculate the working level (WL) concentration.

6. Boron neutron capture therapy is carried out at two *different* reactors. The GOOD scientists at Reactor A carry out careful radiobiology experiments and calculate the RBEs for each of the beam dose components and for the boron neutron capture reaction. The patients treated at Reactor A do well. The BAD scientists at Reactor B believe that radiobiology is a waste of time because the error bars on biological experiments are large compared to physical dose measurements. Patients treated at Reactor B are given the same dose of the same boron compound and the exact same *total physical dose* as the patients treated at Reactor A. The patients treated at Reactor B develop a severe radiation burn on the *skin* in the treated field requiring skin grafts. How is this possible?

7. Cell irradiations are performed on a mylar film above a plutonium alpha particle source. The LET of the alpha particles at the cell surface is 125 keV/µm. The particle fluence is 1900 particles/mm^2/sec. Cell survival experiments generated the D_0 values given in the table (D_0^N). You can assume that the dose rate at the cell surface is the same as in the cell nucleus.

Fill in the rest of this table. For both cell lines:

- Calculate N_T, the number of alpha particles traversing the nucleus at D_0.
- Calculate σ, the inactivation cross section, in µm^2.
- Calculate the total track length, i.e., the sum of all alpha particle tracks through the nucleus at D_0.

Cell line	**Mean nuclear thickness (µm)**	**Mean nuclear area (µm)^2**	D_0^N **(cGy)**	N_T	**σ (µm)^2**	**Total track length (µm)**
CHO-10B	3.7	105	76			
HS-23	7.1	65	74			

D_0^N is the mean dose to the cell nucleus at D_0.

$\mathbf{N_T}$ is the number of nuclear traversals by alpha particles at D_0.

σ is the inactivation cross section, at D_0.