

NE 602 Radiation Protection Engineering

Open Books and Notes

Final Examination, May 9, 1995

1. Indicate whether the following statements are true (T) or false (F). [45 points]
 - () The main diffusion mechanism for atmospheric dispersion is the random motion of the individual molecules in the air.
 - () A balloon tied to a brick is drop over a 100-m cliff. When the balloon reaches the base of the cliff, the air temperature of the gas in the balloon will have increased by at least 0.5 C.
 - () Increasing the averaging time over which measurements are made of the air concentration of some pollutant released upwind at a steady rate increases the observed averaged concentration.
 - () The ground-level concentration of an air-borne radionuclide always decreases with increasing downwind distance from an elevated release point (which releases radionuclides at a steady rate).
 - () For a slightly stable atmosphere the rate of horizontal dispersion of radionuclides is always greater than that of vertical dispersion at the same downwind distance from the discharge point.
 - () A wind rose is a sandstone formation created by wind erosion.
 - () Thermal stratification in a small pond generally increases pollutant concentrations in the surface water compared to that in the same pond without thermal stratification.
 - () For a polluted discharge into a river, the pollutant concentration after near-field mixing is less than after fully lateral mixing.
 - () The concentration of a contaminant in river water far downstream from the discharge point depends both on the amount of contaminant in the discharge and on the concentration in the discharge.
 - () The diffusion mechanism in underground aquifers is the turbulence eddies in the flowing water.
 - () The *intake-to-food-product transfer factors* can be used in analyses of short-term contaminations from accidental radionuclide releases.
 - () The elemental concentration ratio in some organism is greater for stable isotopes than that for radioactive isotopes of the same element.
 - () The concentration of ^{90}Sr in the muscle of a cow is greater than that of ^{137}Cs for a cow which grazes on pasture grass that is contaminated by equal activities of the two radioisotopes.
 - () Reference Man obtains more of his body water from his food than from his drink.
 - () For a steady release rate into an exposure pathway, an estimate of the radionuclide concentration in a human food source based on a steady-state analysis may be less than an estimate made with a transient model.

2. A three component exposure pathway [$Q \rightarrow X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow \text{human}$] is modeled by the following equations.

$$\frac{dX_1(t)}{dt} = aQ(t) - bX_1(t) \quad (1)$$

$$\frac{dX_2(t)}{dt} = cX_1(t) - dX_2(t) \quad (2)$$

$$\frac{dX_3(t)}{dt} = eX_2(t) - fX_3(t) \quad (3)$$

Derive an expression for the equilibrium concentration factor between a steady input Q_o and the output X_3^∞ . [15 points]

3. Two cooling towers are located in a straight line δy apart. The discharge plume from each has an effective discharge height of h_e , and each is discharging the same gaseous radionuclide (with decay constant λ) at a steady rate of Q Bq/s.

- (a) (a) Derive an expression for the ground level activity concentration in the air at a distance x directly downwind from the midpoint between the towers when the wind is blowing at a constant speed u perpendicularly to the line between the two towers. Use standard notation or define any non-standard symbols used. [10 points]
- (b) (b) To evaluate your expression for clear night time conditions when the wind speed is 2 m/s, what values of the diffusion parameters σ_y and σ_z would you use for a downwind distance of 1 km? Use the Pasquill-Gifford diffusion parameters. [10 points]

4. In a marsh on a federal reservation, the bottom sediment has been contaminated over many years with ^{137}Cs . The present activity concentration in the sediment is 85 Bq per kg of dry sediment. Plants growing in the marsh are found to have a *plant-to-soil concentration ratio* CR of 400 for the green leafy parts (on a dry-mass basis).

- (a) What is the activity concentration of ^{137}Cs in the plant leaves? [5 points]
- (b) Wild ducks feed on these plants and, on the average, each eats about 100 grams (dry weight) of these plant leaves daily. What is the equilibrium activity concentration of ^{137}Cs in the meat of these ducks. Assume the transfer factor for ducks is similar to that for chicken. [5 points]
- (c) If a hunter eats 0.5 kg of meat from these ducks, what committed effective dose equivalent (in mrem) would be received? [10 points]

Part B: Open books and notes.

1. A worker, 25 years of age, accidentally receives an acute, uniform, whole-body exposure of 200 rad due to gamma rays. Minimal medical treatment is available. Give your best estimate of (a) the probability of acute fatality in the short term (bone-marrow related), and (b) the probability of death from cancer at some time in the future.
2. A point source emitting 5×10^{10} 2-MeV gamma rays per second is located in air (with negligible radiation attenuation) 2 m from a 2-mfp thick concrete wall of density 2.35 g/cm^3 . Estimate the maximum exposure rate (mR/h) on the shielded side of the wall.
3. A woman suspects that she is being poisoned by arsenic administered daily by her loving husband, the arsenic being contained in the sugar used to sweeten her tea. Urinalysis reveals $200 \text{ } \mu\text{g/L}$ arsenic. Assume steady conditions and estimate (a) the arsenic content in the woman's liver and, (b) the woman's daily arsenic intake.