

ENVIRONMENTAL TRANSPORT AND FATE

Final Exam

Assigned: 9 a.m., Monday 10 March 2008

Due: 5:00 p.m., Thursday 13 March 2008

1. (10 points) A pond is being designed to help treat glycine. The plans call for 500 kg of glycine being dumped in the pond daily, where it is expected to decay by oxidation, such that every lost gram of glycine removes 1.5 grams of dissolved oxygen, and at a rate known to be 0.050 /day at 20°C. The pond will be fed by a small, fully oxygenated stream carrying 0.4 m³/s at 15°C and it is estimated that re-aeration through the pond's surface will occur at a rate of 0.010 /day at 20°C. Surface evaporation and precipitation are neglected in the design.

- a. (3 points) If the pond is to have a uniform depth of 4 m, what should be its surface area so that the glycine concentration in the stream immediately downstream of the pond is no more than 10 mg/L?
- b. (3 points) What is then the fraction (in %) of the glycine discharge that is removed by the pond?
- c. (2 points) What is the exit level of dissolved oxygen?
- d. (2 points) What is the exit BOD?

2. (10 points) A cannery discharges in a nearby river water loaded with residual biomass, causing downstream oxygen depletion. On a day when the temperature was 10°C and water was flowing at a speed of 0.15 m/s, measurements of dissolved oxygen taken along the river indeed reveal oxygen depletion (sag curve) with a minimum level of 2.80 mg/L located 35.3 km downstream from the cannery. Upstream of the cannery, the dissolved oxygen level was 11.3 mg/L. The average depth of the river over the stretch under consideration is 2.1 m.

- a. (1 point) Estimate the reaeration rate (K_r , in 1/day) in the river.
- b. (2 points) Estimate the decay rate (K_d , in 1/day) of the cannery waste in the river.
- c. (1 point) Adjust this latter value to 20°C.
- d. (2 points) What is the BOD in the river at the level of the cannery.
- e. (4 points) Assuming that this BOD comes exclusively from cannery (no upstream BOD), by what percentage should the BOD of the cannery waste be reduced to insure a healthy stream with at least 5.0 mg/L of dissolved oxygen everywhere?

3. (10 points) A smokestack is being planned for a power plant in a suburb of Atlanta, Georgia. For the design, four of the most frequent meteorological conditions over Atlanta are selected:

Wind speed	Wind direction	Time of day	Stability class	Air temperature	dT/dz
5.4 m/s	From West to East	day	Neutral	15°C	- 0.01°C/m
2.7 m/s	From West to East	night	Slightly stable	9°C	0.00°C/m
6.7 m/s	From NW to SE	day	Slightly unstable	20°C	- 0.015°C/m
3.3 m/s	From NW to SE	night	Neutral	15°C	- 0.01°C/m

The smokestack is expected to emit 647 g of SO₂ per second in 140°C fumes blowing at 15 m/s through a 2-m diameter top opening.

- (8 points) If the smokestack's physical height is 60 m, what is the maximum ground concentration in each meteorological situation (in mg/m³)? And, how far downwind would each maximum be?
- (2 points) What should be the height of the smokestack so that the maximum concentration never exceeds 0.8 mg/m³?

4. (5 points)



Describe the smokestack plume shown in the photograph above. Then, infer one characteristic of the atmosphere at the time when the picture was taken.

5. (5 points) A bonfire emits carbon monoxide at the rate of 20 g/s on a clear night when the wind is blowing at 2 m/s. The effective stack height of the fire is 6 m. Estimate the maximum ground-level concentration.

6. (10 points) True or false? Explain each answer in a few words.

- (a) A system is at steady state when all fluxes are zero.
- (b) Diffusion always acts to reduce the highest concentration.
- (c) The maximum concentration at the location of an instantaneous release decreases faster in three dimensions than in two.
- (d) In a diffusive system, the concentration near an impermeable boundary is always higher than if there were no boundary.
- (e) In steady diffusion from a continuous release of a decaying substance, the peak concentration decays with increasing diffusivity.
- (f) At constant flowrate of a polluted discharge through a pipe, the narrower the outlet, the higher the concentration along the centerline at a fixed distance downstream.
- (g) In a lake, vertical motions are more vigorous in winter than in summer.
- (h) A meteorological inversion occurs when the temperature decreases with height faster than the adiabatic lapse rate.
- (i) Now, 22 years after the Chernobyl accident, all radionuclides have decayed and former residents could be allowed to return home.
- (j) Stratospheric ozone holes are slowly expanding toward lower latitudes.