Solutions Manual for:

Environmental Engineering: Fundamentals, Sustainability, Design

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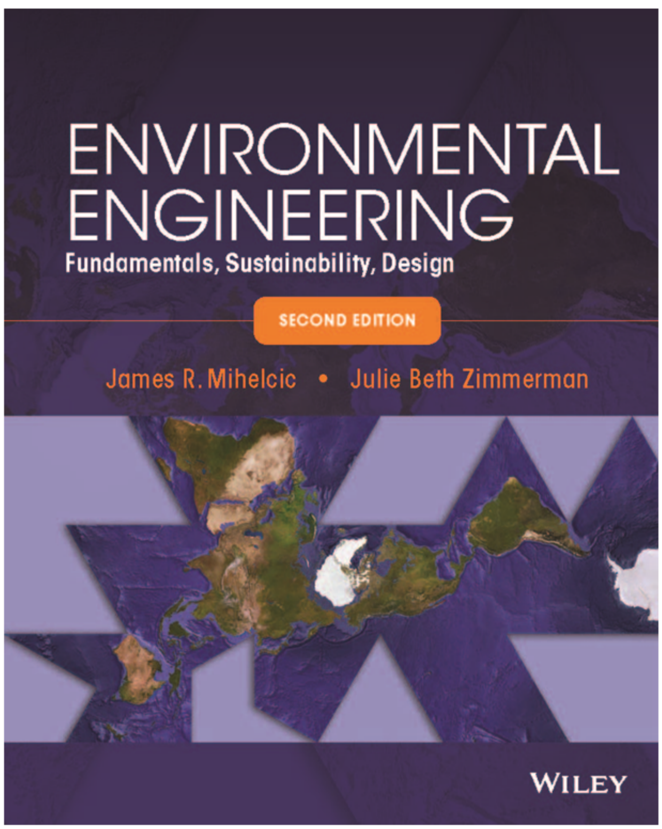
2nd Edition Solution Manual written by:
Colleen C. Naughton
Civil & Environmental Engineering, University of South Florida

1st Edition solutions provided by:
Dr. Heather E. Wright Wendel (University of South Florida)
&
Dr. Ziad Katirji (Michigan Technological University)



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1.2 Write your own definition of sustainable development as it applies to your engineering profession. Explain its appropriateness and applicability in 2-3 sentences.

Solution:

Student responses will vary.

2.4 Coliform bacteria (for example, *E. coli)* are excreted in large numbers in human and animal feces. Water that meets a standard of less than one coliform per 100 mL is considered safe for human consumption. Is a 1 L water sample that contains 9 coliforms safe for human consumption?

Solution:

Standard requires < 1 coliform/100 mL, or 10 coliform/1 L

$$\frac{9\ coliforms}{L} \times \frac{L}{10\ coliforms\ (100\ mL)} = \boxed{0.9\ coliforms / 100\ mL}$$

<u>This value is < 1 coliform/100 mL; therefore, water is safe.</u>

2.24 The concentration of ozone (O_3) in Beijing on a summer day (T = 30°C, P = 1 atm) is 125 ppb_v. What is the O_3 concentration in units of (a) µg/m^3, and (b) number of moles of O_3 per 106 moles of air?

Solution:

a) By definition, ppb_v is related to the volume 0_3 / volume total.

$$\frac{125\ m^3\ O_3}{10^9\ m^3\ air} \times \frac{1\ atm}{8.205\times10^{-5}\ \frac{m^3-atm}{mole-K} \times 303\ K} = 5\times10^{-6}\ \frac{mole\ O_3}{m^3\ air}$$

$$\frac{5\times10^{-6}\ mole\ O_3}{m^3 air} \times \frac{48\ g\ O_3}{1\ mole\ O_3} \times \frac{10^6\ \mu g}{1g} = \boxed{241\ \mu g / m^3}$$

b)

$$125\ ppb_v = \frac{125\ mole\ O_3}{10^9\ mole-air} = \frac{0.125\ mole\ O_3}{10^6\ mole-air}$$

$$\frac{0.125\ mole\ O_3}{10^6\ mole-air} \times 106\ mole-air = \boxed{1.3\times10^{-5}\ mole\ of\ O_3}$$

3.23 Atrazine is an herbicide widely used for corn and is a common groundwater pollutant in the corn-producing regions of the United States. The log K_{ow} for atrazine is 2.65. Calculate the fraction of total atrazine that will be adsorbed to the soil given that the soil has an organic carbon content of 2.5%. The bulk density of the soil is 1.25 g/cm^3; this means that each cubic centimeter of soil (soil plus water) contains 1.25 g of soil particles. The porosity of the soil is 0.4.

Solution:

Assume that the correlation of Baker et al. (1997) is valid for atrazine.

$$\log K_{oc} = 0.903 (\log K_{ow}) + 0.094$$

$$\log K_{oc} = 0.903 (2.65) + 0.094$$

$$\log K_{oc} = 2.49 \text{ so } K_{oc} = 309 \text{ cm}^3/\text{g oc}$$

$$K = K_{oc} \times f_{oc} = 309 \text{ cm}^3/\text{g oc} \times 0.025 = 7.73 \text{ cm}^3/\text{g soil}$$

Assume a total of 1 cm^3 of soil. From the porosity, it will have 0.6 cm^3 of soil and 0.4 cm^3 of void space (which is assumed to be filled with water). From the bulk density we can determine that the mass of soil is 0.75 grams (1.25 g/cm^3 x 0.6 cm^3). Set up a mass balance on atrazine in water and sorbed to soil. Use the soil-water partition coefficient to substitute for the sorbed phase concentration in terms of aqueous phase concentration.

$$\begin{aligned} \text{Total atrazine} &= \text{sorbed atrazine} + \text{aqueous atrazine} \\ &= M_{soil} \times C_{sorbed} + \text{Vol} \times C_{aqueous} \\ &= \{0.75\text{g} \times (7.73 \text{ cm}^3/\text{g soil}) \times (C_{aqueous})\}+\{0.4 \text{ cm}^3 \times C_{aqueous}\} \\ &= C_{aqueous} [5.80 \text{ cm}^3+0.4 \text{ cm}^3] \end{aligned}$$

Note that in this problem the mass of atrazine sorbed to soil is large relatively to the mass in the aqueous phase. If we knew the total amount of atrazine initially added to the system, we could solve for the equilibrium aqueous phase concentration, then use the soil-water partition coefficient to determine the sorbed phase concentration.

Fraction of total atrazine adsorbed to soil =

$$\left(1-\frac{0.4\ cm^3}{0.4\ cm^3+5.80\ cm^3}\right)\times 100\% = \boxed{94\%}$$

5.41 Excess nitrogen inputs to estuaries have been scientifically linked to poor water quality and degradation of ecosystem habitat. The nitrogen loading to Narragansett Bay was estimated to be 8,444,631 kg N/year and to Chesapeake Bay is 147,839,494 kg N/year. The watershed area for Narragansett Bay is 310,464 ha and for Chesapeake Bay is 10,951,074 ha. The nitrogen loading rates are estimated for Galveston Bay to be 16.5 kg N per ha per year, 26.9 kg N per ha per year for Tampa Bay, 49.0 kg N per ha per year for Massachusetts Bay, and 20.2 kg N per ha per year for Delaware Bay. (a) Rank the loading rates from lowest to highest for these six estuaries.

Solution:

You need to calculate the loading rates for Narragansett and Chesapeake Bay. These are simple unit conversions. The rest of the nitrogen loading rates can be found in the problem statement and ranked from lowest to highest in the final table below.

$$Narragansett\ Bay\ nitrogen\ loading: \frac{8{,}444{,}631\ \frac{kgN}{yr}}{310{,}464\ ha} = 27.2\frac{kgN}{ha\ yr}$$

$$Chesapeake\ Bay\ nitrogen\ loading: \frac{147{,}839{,}949\ \frac{kgN}{yr}}{10{,}951{,}074\ ha} = 13.5\frac{kgN}{ha\ yr}$$

Ranking	**Estuary**	**Nitrogen Loading** $\frac{kgN}{ha\ yr}$
1	Chesapeake Bay	13.5
2	Galveston Bay	16.5
3	Delaware Bay	20.2
4	Tampa Bay	26.9
5	Narragansett Bay	27.2
6	Massachusetts Bay	49.0

6.32 Is there an unsafe risk associated with a 70 kg adult eating 15 g fish every day that contains 9.8 µg/ kg of Arochlor 1254? Arochlor 1254 can exhibit noncarcinogenic effects in humans. Use the IRIS database to find any other information required to solve this problem.

Solution:

The RfD was not given. IRIS reports that the RfD for Arochlor 1254 is 2 x 10^{-5} mg/kg-day. Determine the average daily dose the individual is exposed to and divide this value by the RfD to determine the hazard quotient. 9.8 µg/kg is equal to 0.0098 mg/kg. The average daily dose is:

$$\frac{\left(0.0098\frac{mg}{kg}\right)\left(15\frac{gm}{day}\right)\left(\frac{kg}{1000\ gm}\right)}{70\ kg} = 2.1\times10^{-6}\ \frac{mg}{kg\text{ - }day}$$

Use this value of the dose and the RfD to determine the HQ:

$$\text{Hazard Quotient (HQ)} = \frac{2.1\times10^{-6}\ \frac{mg}{kg\text{ - }day}}{2.0\times10^{-5}\ \frac{mg}{kg\text{ - }day}} = 0.1$$

<u>Because the HQ is less than 1; the concentration of the chemical in the fish will not result in adverse noncarcinogenic effects.</u>

7.37 An industry discharges 0.5 m^3/s of a waste with a 5-day CBOD of 500 mg/L to a river with a flow of 2 m^3/s and a 5-day CBOD of 2 mg/L. Calculate the 5-day CBOD of the river after mixing with the waste.

Solution:

$$CBOD_5 \ after \ mixing = \frac{Q_{river} \times CBOD_{5 \ \ river} + Q_{waste} \times CBOD_{5 \ \ waste}}{Q_{river} + Q_{waste}}$$

$$CBOD_5 \ after \ mixing = \frac{2\frac{m^3}{s} \times 2\frac{mg}{L} + 0.5\frac{m^3}{s} \times 500\frac{mg}{L}}{2.5\frac{m^3}{s}} = \boxed{102\frac{mg}{L}}$$

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9.31 (a) Estimate the volume of gas production produced from one metric ton of food waste and one ton of wastewater solids. (b) Based on the results from part (a), assuming the mass of food waste and wastewater solids generated in a community is the same, would you recommend a municipality develop a program to collect and digest (with energy recovery) food waste or wastewater solids? Explain your answer based on potential energy production but also an implementation stand point. Assume the methane production potential of wastewater solids is 120 m^3/ metric ton, food waste has 3 times the methane production potential per volume of wastewater solids, and methane makes up 60% of the total gas produced from anaerobic digestion.

Solution.

a) 1 metric ton wastewater solids × 120 m^3 methane / ton biosolids × 1/ 0.6 = 200 m^3 gas produced

   1 metric ton food × 360 m^3 methane / ton food × 1/ 0.6 = **600 m^3** gas produced

b) Assuming the same mass of food and wastewater solids are produced by the community, you can see from part (a) that anaerobically digesting food results in more gas and more methane production. Therefore, digesting food waste is preferable from an energy production viewpoint. However, in a community that has a centralized treatment system, the collection system is already in place to collect wastewater solids via sewer collection systems and systems at a centralized treatment plant. Starting up a food collection system could take advantage of collection systems already in place for solid waste and yard waste. You would have to develop an understanding of household behavior on how food waste is handled by homeowners and things might be different in northern and southern U.S. climates as temperature impacts the rate at which food waste would produce odors. In a community with decentralized treatment (e.g., individual septic tanks), developing a collection system for food waste may be more implementable because a septic tank functions partially as a digester where the energy is not collected.