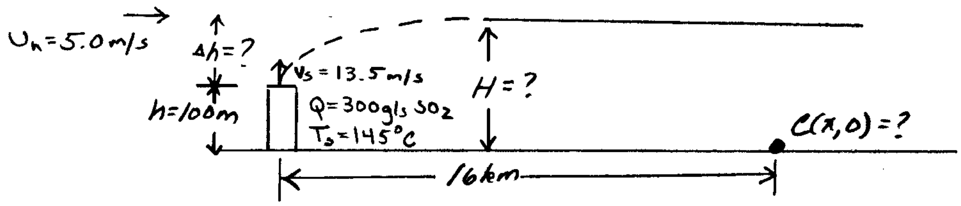
Solution

1) A 200-MW power plant has a 100-m stack with a radius of 2.5 m, flue gas exit velocity 13.5 m/s, and gas exit temperature 145 ^{0}C. The ambient temperature is 15 ^{0}C, wind speed at the stack is 5m/s, and the atmosphere is stable, Class E, with a lapse rate of 5 ^{0}C/km. If the stack emits 300g/s of SO_2, estimate the ground level concentration at a distance of 16 km directly down wind.

(Hints: You will need to calculate plume rise using Eqns. 7.48, 7.49, and 7.50 on page 419 of text. Example 7.14 is representative of required calculations. Once you have plume rise, then can enter effective stack height into equation 7.46 and determine downwind concentration. Example 7.12 illustrates required calculations.)



$$\Delta h = 2.6\left(\frac{F}{u_s S}\right)^{1/3}$$

$$F = g r^2 v_s\left(1 - \frac{T_a}{T_s}\right) = 9.8\frac{m}{s^2}(2.5m)^2(13.5m/s)\left(1 - \frac{15+273}{145+273}\right) = 257\ m^4/s^3$$

$$S = \frac{g}{T_a}\left(\frac{\Delta T_a}{\Delta z} + 0.01°C/m\right) = \frac{9.8\ m/s^2}{(15+273)K}\left(\frac{5°}{1000\ m} + 0.01°K/m\right) = 5.1\cdot10^{-4}/s^2$$

$$\therefore \Delta h = 2.6\left(\frac{257\ m^4/s^3}{(5m/s)(5.1\cdot10^{-4}/s^2)}\right)^{1/3} = \underline{\underline{121m}}$$

$$H = h + \Delta h = 100 + 121 = 221m$$

$\sigma_y = 602$ m (Table 7.10 or Fig 7.48) $\sigma_z = 95$m (Table 7.10 or Fig 7.48)

$$C(x,0) = \frac{Q}{\pi u \sigma_y \sigma_z}\exp\left(-\frac{H^2}{2\sigma_z^2}\right) = \frac{300\cdot10^6 \mu g/s}{\pi(5m/s)(602m)(95m)}\exp\left(-\frac{(221m)^2}{2(95m)^2}\right) = \underline{\underline{22\mu g/m^3}}$$

Solution

2) For the conditions in the previous problem, determine the peak downwind location and concentration. Please show your work on the chart below and report the peak downwind concentration.

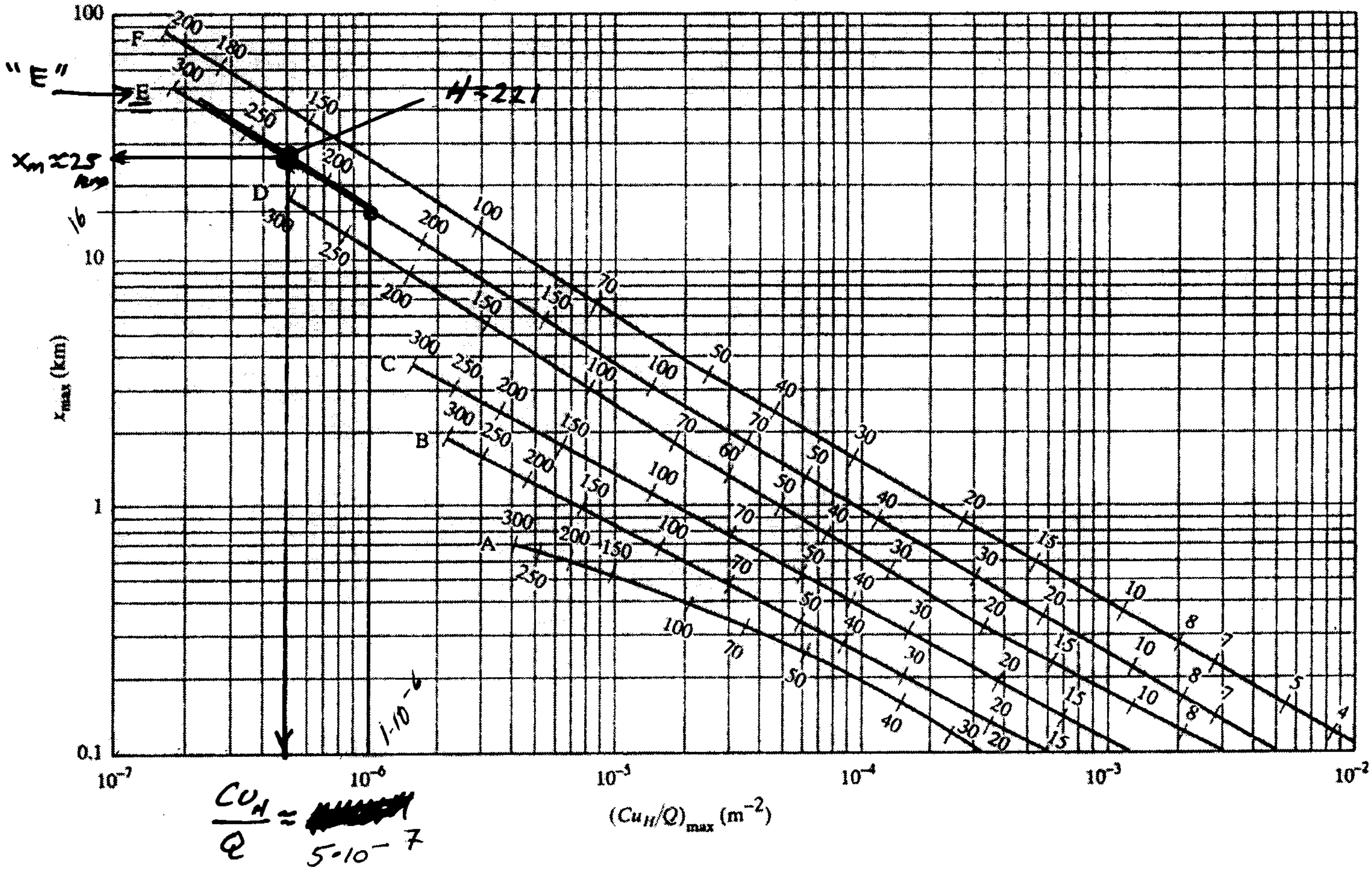


FIGURE 7.50 To determine the downwind concentration peak, enter the graph at the appropriate stability classification and effective stack height (numbers on the graph in meters) and then move across to find the distance to the peak, and down to find a parameter from which the peak concentration can be found (Turner, 1970).

$H = 221$ m

Stability = E

$$C_{max} = \frac{Q}{u_s}\left(\frac{Cu_H}{Q}\right) = \frac{300\cdot10^{+6}\ \mu g/s}{5\ m/s}\cdot\frac{5\cdot10^{-7}}{m^2} = 30\ \mu g/\ldots$$

$$\frac{300\cdot10^{6}}{5}\cdot 5\cdot10^{-7} = 30\ \mu g/m$$

Solution

3) A sample of water has the following concentration of ions:

Cations	mg/L	Anions	mg/L
Ca^{2+}	40.0	HCO_3^-	110.0
Mg^{2+}	10.0	SO_4^{2-}	67.2
Na^+	?	Cl^-	11.0
K^+	7.0		

a) Assuming all constituients are present, use an anion-cation balance to estimate the concentration of Na^+.
b) What is the total hardness (TH)?
c) What is the carbonate hardness (CH)?
d) What is the noncarbonate hardness (NCH)?
e) Draw an ion concentration diagram.

(Hint: Express concentrations in mg/L as $CaCO_3$)

Ion	mg/L	mg/meq	meq/L	mg/L as $CaCO_3$
Ca^{2+}	40	20	$40/20 = 2$	$(2)(50) = 100$
Mg^{2+}	10	12.2	$10/12.2 = 0.82$	$(0.82)(50) = 41$
Na^+	x	23	$x/23$	$\frac{x}{23}(50) = Y$
K^+	7	39.1	0.18	9.0
HCO_3^-	110	61	1.8	90.2
SO_4^{2-}	67.2	48	1.4	70.
Cl^-	11.0	35.5	0.31	15.5

a) Ion balance

$100 + 41 + Y + 9 = 90.2 + 70 + 15.5$

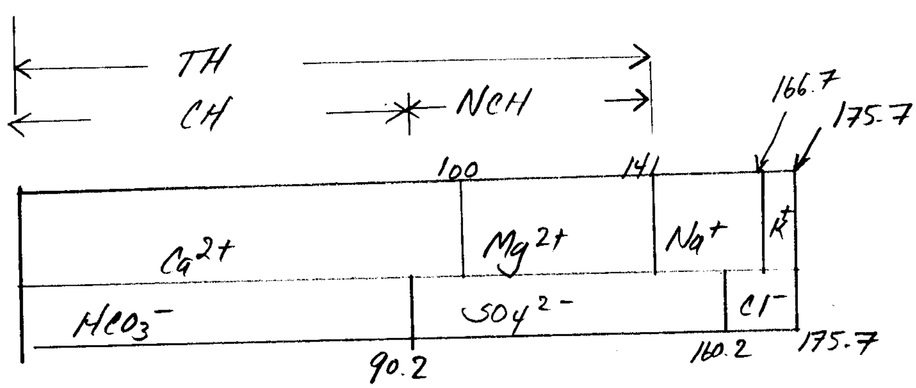
$\underline{Y = 25.7 \text{ mg/L as } CaCO_3}$

$\left\{ \frac{(25.7)(23)}{(50)} = \underline{11.8 \text{ mg/L } Na^+} \right\}$

b) $TH = Ca^{2+} + Mg^{2+} = 100 + 41 = 141$ mg/L as $CaCO_3$

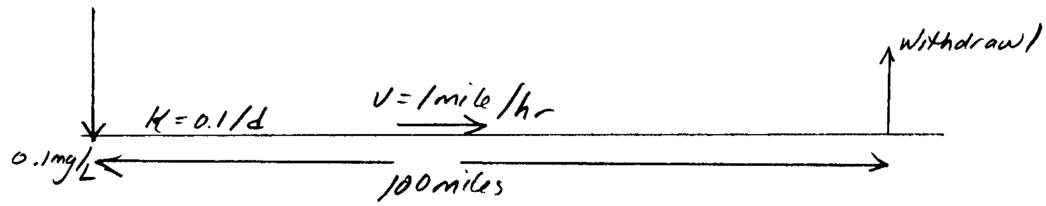
c) $CH = HCO_3^- = 90.2$ mg/L as $CaCO_3$

d) $NCH = TH - CH = 50.8$ mg/L as $CaCO_3$



4) Assume a factory releases a continuous flow of wastewater into a stream that results in an in-stream carcinogen concentration of 0.1 mg/L at the outfall. Assume this carcinogen has an oral slope factor (potency) of 0.30 $(mg/kg/d)^{-1}$ and it biodegrades in the stream with a reaction rate coefficient K of 0.10/day. Assume the stream is uniform in cross section, flows at a rate of 1 mile per hour, and has no other sources or sinks for this carcinogen. At a distance of 100 miles downstream, a town uses this water for drinking water. Estimate the individual residential lifetime cancer risk caused by drinking this water.

potency = $0.30 (mg/kg/d)^{-1}$



time of travel

$$t = \frac{100 \text{ miles}}{1 \text{ mile/hr}} = 100 hr \cdot \frac{1d}{24hr} = 4.1667\ d$$

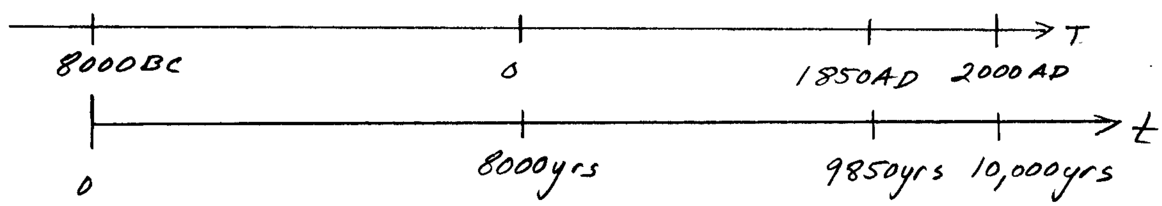
$$C_{100mile} = C_0 e^{-Kt} = (0.1 mg/L) \exp(-0.1/d \cdot 4.1667 d) = 0.066 mg/L$$

$$CDI = \frac{(0.066 mg/L)(2 L/d)(360 d/yr)(30 yr)}{(70 kg)(365 d/yr)(70 yr)} = 0.000796\ mg/kg/d$$

$$Risk = CDI * Potency = 0.000796 mg/kg/d \cdot \frac{0.30}{mg/kg/d} = \underline{\underline{2.4 \cdot 10^{-4}}}$$

solution

5) Assume the current year is 2000AD. The world's population 10,000 years ago was about 5 million. What exponential rate of growth would have been required for the population to reach 1 billion in 1850? Had the rate continued what would the population be in the year 2000?



$P = P_0 e^{rt}$

$P_0 = 5 \cdot 10^6$

$P_{9850} = 1 \cdot 10^9$

$$\frac{1 \cdot 10^9}{5 \cdot 10^6} = e^{r(9850\,yrs)}$$

$$\ln\left(\frac{1 \cdot 10^9}{5 \cdot 10^6}\right) \cdot \frac{1}{9850\,yr} = r = 0.000538/yr$$

Projections

t	yr	P
0	8000BC	$5 \cdot 10^6$ (5 million)
8000	0	$3.7 \cdot 10^8$ (370 million)
9850	1850AD	$1 \cdot 10^9$ (1 billion)
10,000	2000AD	$1.08 \cdot 10^9$ (1 billion + 80 million)