Lecture Notes 5

Slides 8 and 10 – Soil vapor extraction

P_r= pressure at radial distance r =0.98 atm
P_w= pressure at extraction well= 0.9 atm
P_{RI}= pressure at radius of influence = 1 atm
r= radial distance from extraction well= 5m
R_I= radius of influence where pressure=atm. Pressure= **?**
R_w= well radius of extraction well= 10 cm = 0.1m

$$P_r^2 - P_w^2 = (P_{RI}^2 - P_w^2)\frac{ln\left(\frac{r}{R_w}\right)}{ln\left(\frac{R_I}{R_w}\right)}$$

$$0.98^2\ atm^2\ - 0.9^2\ atm^2\ = \left(1 - 0.9^2\ atm^2\ \right)\frac{ln\left(\frac{5\ m}{0.1\ m}\right)}{ln\left(\frac{R_I}{0.1m}\right)}$$

0.08/0.1=ln(50)/ln (R_I/0.1)

R_I*0.1= exp(ln(50)/0.8)= **14 m** (rounded up)

Calculate the pumping rate

1 atm= 1.013 *10^5 N/m^2

Q_w= volumetric flow rate entering extraction well (m^3/sec)= **?**
P_w= pressure at extraction well (N/m^2)= 0.9 atm * 1.013 *10^6 (g/(cm.sec^2))/atm =0.912*10^6 g/(cm.sec^2)
P_{RI}= pressure at radius of influence (=atm. pressure) (N/m^2)= 1.013 *10^6 g/(cm.sec^2)
H= length of screen in extraction well (m)= 6 m
R_I= radius of influence where pressure=atm. Pressure= 14 m
R_w= well radius of extraction well= 0.1 m
k= permeability of formation (m^2)= 10^{-12} m^2
μ= air viscosity= 1.8*10^{-4} g/cm.sec
Q_{atm}= volumetric flow rate to atmosphere (m^3/sec)= **?**

$$Q_w\ = H\left(\frac{\pi k}{\mu}\right)\left(\frac{P_w}{ln\left(\frac{R_w}{R_I}\right)}\right)\left(1 - \left(\frac{P_{RI}}{P_w}\right)^2\right)$$

$$Q_{atm} = \left(\frac{P_w}{P_{atm}}\right)Q_w$$

$$Q_w\ = 6\ \boldsymbol{m}\left(\frac{3.14 * 10^{-12}\boldsymbol{m^2}}{1.8 * 10^{-4}\cancel{g}/(c\cancel{m}.\mathbf{sec})}\right)\left(\frac{0.912 * 10^6\cancel{g}/(\cancel{c}m.\boldsymbol{sec^2})}{ln\left(\frac{0.1\ \cancel{m}}{14\ \cancel{m}}\right)}\right)\left(1 - \left(\frac{1.013 * 10^6\cancel{g}/(\cancel{c}m.\cancel{s}ec^2\ )}{0.912 * 10^6\ \cancel{g}/(\cancel{c}m.\cancel{s}ec^2\ )}\right)^2\right)$$

Qw= 0.0045 m^3/sec

Qatm= 0.0045 m^3/s * 0.912/1.013= 0.004 m^3/sec

<u>Bioventing problem, slide 18</u>

$$\boldsymbol{k_0} = \frac{\boldsymbol{k_B * \rho_{wb}}}{\boldsymbol{\epsilon_a * D_{O2} * C}}$$

$$\mathrm{k_o}\left(\frac{vol.O_2 * 100}{vol.air * day}\right) = \frac{k_B(mass\ C/mass\ wet\ soil.day) * \ \rho_{wb}(mass\ wet\ soil/vol.soil)}{\epsilon_a(vol.air/vol.soil) * \ D_{O2}\left(mass\ O_2/vol.O_2\right) * C\ \left(mass\ C/mass\ O_2\right)}$$

We have the following information:

$\epsilon_a = 0.2$ [-]

ρ_{wb}= 1.95 g/cm^3

k_B= 0.6 g C/(kg wet soil.day)

D_{O2}=1.33 g O_2/L O_2

First, we must determine the value of C

C_6H_{14} + 9.5 O_2 ➔ 6 CO_2 + 7 H_2O

MW hexane = 86 g/mol and O_2 = 32 g/mol

For each mole of C_6H_{14} , there are 6 moles of C (6*12 = 72g) and 9.5 moles of O_2 are consumed (=304 g).

Therefore C= 72/304=> C=0.24 g C/g O_2

$$\mathrm{k_o}\left(\frac{vol.O_2 * 100}{vol.air * day} = \%per\ day\right) = \frac{0.6\ \ g\ C/(kg\ wet\ soil.day) * \ 1.95\ (g\ wet\ soil/cm^3) * 1\ kg\ /1000g}{0.2\ \left(\frac{cm^3\ air}{cm^3\ soil}\right) * \ 1.33\left(g\ O_2/L.O_2\right) * 0.28\ \left(g\ C/g\ O_2\right)}$$

$$\mathrm{k_o}\left(\frac{v\%}{day}\right) = \frac{0.6\ g\ C/(kg\ wet\ soil.day) * 0.00195\ (^{kg\ wet\ soil}/_{cm^3})}{0.2\ \left(\frac{cm^3\ air}{cm^3\ soil}\right) * 1.33\ (^{g\ O_2}/_{L.O_2}) * 1L/1000cm^3 * 0.28\ (^{g\ C}/_{g\ O_2})}$$

$$\mathrm{k_o}\left(\frac{\%}{day}\right) = 18.4\% \text{ per day}$$

It means that the oxygen utilization rate is 18.4% of the volume of air (it has to be less than saturation which is 21.5%).

Slide 33 – Air stripping example

$$S = \pi r^2 = 0.29\, m^2$$

$$L = \frac{Q_w \times \rho_L}{S} = \frac{7.13\frac{L}{s} \times \frac{1\mathrm{kg}}{\mathrm{L}}}{0.29\, m^2} = 24.5\frac{kg}{m^2 s}$$

$$\mathrm{R} = \frac{\mathrm{K_H} Q_A}{Q_w} = 5.4$$

$$L_M = \frac{L}{M_{water}} = \frac{24.5\frac{kg}{m^2 s}}{18\frac{g}{mol}} \times \frac{1{,}000\mathrm{g}}{1\mathrm{kg}} = 1{,}361\frac{\mathrm{mol}}{\mathrm{m^2 s}}$$

$$HTU = \frac{L_M}{M_w K_L a} = \frac{1{,}361\frac{mol}{m^2 s}}{55.6\frac{mol}{m^3} \times 16\ \mathrm{s}^{-1}} = 1.52m$$

$$NTU = \left(\frac{R}{R-1}\right) ln\left(\frac{\frac{C_{in}}{C_{out}} \times (R-1) + 1}{R}\right) = 3.87$$

$$Z = HTU \times \mathrm{NTU} = 5.9\ \mathrm{m}$$