Critical Thinking Questions – Landfill Leachate

I. Leachate Generation, Quantity, Quality, and Treatment

1. What landfill operational phase would a landfill be in if the BOD is 5 mg/l, COD is 1000 mg/l and NH_3 is 500 mg/l? What would be the best treatment approach for this leachate?

2. List the advantages and disadvantages of biological and physical/chemical treatment of leachate.

3. Considering the changing characteristics of leachate, design the optimal treatment process that will remove nutrients, biodegradable organics, dissolved ions, and non-biodegradable organics. This should be in a single unit process. The process does not necessarily have to be in use yet.

II. Leachate Collection and Liner System Design

1. A landfill located in Central Florida is 25 m deep and has a 1 m cover of silty loam soil. In 2012 the landfill received 2,000 mm/yr of rain (P), the runoff at the site was 8% of precipitation (SR), and the rate of evapotranspiration was 1,500 mm/yr (E). During 2012, the soil field capacity (300 mm/yr) of the cover was not reached and the soil moisture content was 45% by volume (450 mm/m). The waste disposed in the landfill that year had a field capacity of 300 mm/m and an incoming moisture content of 50% by volume (500 mm/m).

   a. What is the percolation rate (mm/yr) through the **soil** layer (C)?

      Use the equation below:

      $$C = P(1\text{-}SR) – S – E$$

   b. What is the rate of moisture movement (m/yr) through the landfill prior to the solid waste reaching field capacity?

      Use the equation below:

      $$\text{Rate} = C/S$$

   c. Given the percolation through the soil layer and movement of moisture through the landfill how long will it take to produce leachate (yr)?

      Use the equation below:

      $$\text{Time} = \text{Depth/Rate}$$

2. Using the equation and values below explore the variation of head on the liner as a function of slope, spacing, and drainage hydraulic conductivity. Use Excel and plot results. What conclusions can you draw?

- Design storm (25 years, 24 hours): 0.00024 cm/s (hold constant)
- Hydraulic conductivity: 10^{-2} , 10^{-3} , 10^{-4} cm/s (slope 2%, pipe spacing 120 cm)
- Drainage Slope: 2, 5, and 10% (k = 10^{-3} cm/sec, pipe spacing 120 cm)
- Pipe Spacing 120 cm, 200 cm, 300 cm (k = 10^{-3} cm/sec, slope 2%)

$$Y_{max} = \frac{P}{2}\left(\frac{q}{K}\right)\left[\frac{Ktan^2\alpha}{q} + 1 - \frac{Ktan^2\alpha}{q}\left(tan^2\alpha + \frac{q}{K}\right)^{\frac{1}{2}}\right]$$

Using Darcy's Equation (below) determine the leakage rate (Q, m^3/sec) for the heads on liner calculated in question 1. Assume a compacted 30-cm thick clay single liner and 1000 m^2 area. Compare these values to those of a good geomembrane to Table 1 below. What conclusions can you draw?

$$Q = kA\left(\frac{h+t}{t}\right)$$

Where:

k=liner $hydraulic\ conductivity$, 10^{-7} cm/sec
A=$Area$
h=$head\ on\ the\ liner$ (Y_{max})
t=$Clay\ Layer\ Thickness$

Table 1. Generalized Leakage Rates through Liners (Giroud and Bonaparte, Jour G&G, 1989)

Type of Liner	**Leakage Mechanism**	**Liquid Height on Top of the Geomembrane**			
		0.03 m	0.3 m	3 m	30 m
Geomembrane alone (between two sand layers)	Diffusion	0.01	1	10	300
	Small Holes*	300	1,000	3,000	10,000
	Large Holes*	10,000	30,000	100,000	300,000
Composite liner (poor field conditions, i.e., waves)	Diffusion	0.01	1	100	300
	Small Holes*	0.8	6	50	400
	Large Holes*	1	7	60	500
Composite liner (good field conditions, i.e., flat)	Diffusion	0.01	1	100	300
	Small Holes*	0.15	1	9	75
	Large Holes*	0.2	1.5	11	85
Values of leakage rate are in Liters per hectare per day [lphd] (values can be divided by approximately 10 to obtain values express in gallons per acre per day [gpad])					

* assumes 3 holes /ha (i.e., 1.0 hole/acre

3. Define the following terms:

Term	**Definition**
Hydraulic conductivity	
Geosynthetic	
Geotextile	
Geonet	
Composite liner	
Geocomposite	
Leachate detection zone	