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In-Class Exercise-Solution

1. A typical compactor truck has a capacity of 30 yd^3. The truck can make 3 trips per day, 4 days a week. If each residence in a neighborhood contains 3.5 persons, how many residences can the truck serve per week?

Assume each residence generates 4lbs solid waste/person-day and the approximate density of the waste is 500 lb/yd^3.

The residences that the truck can serve per week is:

a) 12,867
b) 1836
c) 1000
d) None of the above

$\frac{30yd^3 * 3trips * 4days}{Trip * day * week} = 360yd^3/week$

$\frac{4lbs * 3.5persons * 7days}{Person\text{-}day * week} = 98lbs/week\text{-}residence$

Volume of waste = (98lbs)/(500lbs/yd3)=0.196yd^3/residence

\# of residences = 360yd^3/0.196yd^3 = 1836 residences

2. A waste generated by an office has the following composition

Component	Percentage (by weight)	Uncompacted bulk density (lb/ft^3)
Miscellaneous paper	50	3.81
Garden waste	25	4.45
Glass	25	18.45

Assume that the compaction in the landfill is 1200 lb/yd^3 (44.4 lb/ft^3). Estimate the percent volume reduction achieved during compaction of the waste. Estimate the overall uncompacted bulk density if the miscellaneous paper is removed.

Average bulk density of office waste (50*3.81+25*4.45+25*18.45)/(50+25+25) = 4.97 lbs/ft^3
If office waste volume is 100 ft3 then by mass balance laws

100 ft3 * 4.97 lbs/ft^3 = 44.4 lbs/ft^3 * New Volume of waste in landfill

New volume = 11.2 ft^3 Percent reduction in volume = 88.8%

3. Estimate the theoretical production of the two major gases from a landfill from the degradation of 3.3 kg of slowly degradable MSW ($C_{20}H_{29}O_9N$). The density of methane is 0.7167 kg/m^3 and CO_2 is 1.9768 kg/m^3 at STP.

MW of MSW = 427 g/mole

Moles of CH_4 = (4*20+29-2*9-3*1)/8 = 11 moles MW CH_4 =16 g/mole

Moles of CO_2 = (4*20-29+2*9+3*1)/8 = 9 moles MW CO_2 = 44 g/mole

Therefore CH_4 = 11*16*3.3/427 = 1.36 kg and CO_2 = 9*44*3.3/427 = 3.06 kg

Volume of CH_4 = 1.36kg/0.7167 kg/m^3 = 1.90 m^3

Volume of CO_2 = 3.06/1.9768 = 1.55 m^3

Total gas volume = 1.9+1.55 = 3.45 m^3

Once the expected yield is determined, a model is selected to describe the pattern of gas production over time. As mentioned above, many models have been proposed, ranging from single valued, to linear increase/linear decline, to exponential decline. The EPA has published a model called LandGEM based on the following equation:

$$Q_T = \sum_{i=1}^{n} 2kL_oM_ie^{-kt_i}$$

where

Q_T = total gas emission rate from a landfill, volume/time
n = total time periods of waste placement
k = landfill gas emission constant, time^{-1}
L_o = methane generation potential, volume/mass of waste
t_i = age of the ith section of waste, time
M_i = mass of wet waste, placed at time i

This model can be downloaded at http://www.epa.gov/ttn/catc/products.html#software. The following example shows how this model is applied for a simple case.

A landfill cell is open for three years, receiving 165,700 tonnes of waste per year (recall that 1 tonne = 1000 kg). Calculate the peak gas production if the landfill-gas emission constant is 0.0307 yr^{-1} and the methane generation potential is 140 m^3/tonne.

For the first year,

$$Q_T = 2\,(0.0307)\,(140)\,(165{,}700)(e^{-0.0307(1)}) = 1{,}381{,}000 \text{ m}^3$$

For the second year, this waste produces less gas, but the next new layer produces more, and the two are added to yield the total gas production for the second year.

These results are plotted as Figure 4-7. The annual peak gas production is found from this figure as about 4,000,000 m^3/yr.

Year	Mass tons/yr	$2kL_o$m^3/ton-yr	e^{-kt}	Q m^3	Q/10^6 m^3
1	165700	8.596	0.969766	1381294	1.381293839
2	331400	8.596	0.940447	2679065	2.679064871
3	497100	8.596	0.912014	3897101	**3.897100881**
4	497100	8.596	0.884441	3779278	3.779277723
8	497100	8.596	0.782235	3342546	3.342546404
10	497100	8.596	0.735651	3143488	3.14348769
12	497100	8.596	0.69184	2956284	2.956283523
14	497100	8.596	0.650639	2780228	2.780227928
15	497100	8.596	0.630968	2696172	2.696171794
17	497100	8.596	0.593392	2535607	2.535606637
19	497100	8.596	0.558054	2384604	2.384603619