CEE 370	Fall 2019

Homework #9

0.5 pts each

Solid Waste Problems

1. Waste container sizing based on population:
The student population of a high school is 881. The school has 30 standard classrooms. Assuming a 5-day school week with solid waste pickups on Wednesday and Friday before school starts in the morning, determine the size of storage containers required. Assume waste generation rate = 0.11 kg/capita/day and 3.6 kg/room, density of waste = 120 kg/m^3, standard containers are 1.5, 2.3, 3.0, and 4.6 m^3

Solution:

a. Determine total waste production

waste = 881 persons x (0.11 kg/capita/d) + 30 rooms x (3.6 kg/room/d) = 204.91 kg/d

b. Total volume of waste

$$\forall_{waste} = \frac{204.91 \text{ kg/d}}{120 \text{ kg/m}^3} = 1.708 \text{ m}^3\text{/d}$$

Since the maximum storage period is 3 days (Friday, Monday & Tuesday), we have

Volume = 3d * 1.708 m^3/d = 5.12 m^3

One solution to this would be: 1 container of 2.3 m^3 and 1 container of 3.0 m3

2. More MSW volume calculations:
The Pleasant Valley landfill serves a population of 253,000. Each week 325 trucks bring a total of 2180 tons of MSW. The volume of the landfill is 11,240,000 m^3. At the present time 63% of the landfill is used. The ratio of cover to compacted fill is 1.9. Determine the projected life remaining for the landfill. Assume the density of the compacted waste to be 490 kg/m^3.

Solution:

$$volume\ remaining = 11{,}240{,}000\ m^3\ (1 - 0.63) = 4{,}158{,}800\ m^3$$

$$future\ volume\ compacted\ waste = 4{,}158{,}800\ m^3 \frac{1}{1+1.9} = 1{,}434{,}069\ m^3$$

$$mass\ of\ future\ waste = (1{,}434{,}069\ m^3)490\ {}^{kg}/_{m^3} = 702{,}693{,}793\ kg$$

$$time\ to\ fill = \frac{702{,}693\ tons}{2{,}180\ {}^{tons}/_{wk}} = \mathbf{322\ weeks = 6.2\ yrs}$$

Note: this assumes a metric ton

3. **Landfill areas & volumes:**
   A sanitary landfill is being designed to handle solid waste generated by the town of Bernie, VT, at a rate of 50 Mg/day. It is expected that the waste will be delivered by compactor truck on a 5 days/wk basis. The density as spread is 122 kg/m^3. It will be spread in 0.50 meter layers and compacted to 0.25 meters. Assuming three such lifts per day and a daily cover of 0.15 meters, determine the following: (a) annual volume of landfill consumed in cubic meters, and (b) daily horizontal area covered by the solid waste. Ignore the soil volume between the stacks.

Solution:

a. Annual $\forall_{landfill}$ consumed

$$\forall_{waste} = (50\ Mg/d)(5\ d/wk)(52\ wk/y) = 13000\ Mg/y$$

$$\forall_{waste} = \frac{13000\ Mg/y}{(2)0.122\ Mg/m^3} = 53278.7\ m^3/y$$

$$E = \frac{\forall_{sw} + \forall_c}{\forall_{sw}}$$

$$E = \frac{3(0.25) + (0.15)}{3(0.25)} = 1.2$$

$$\forall_{LF} = \frac{PEC}{D_c} = \frac{(13000)(1.2)}{(2)(0.122)} = 63{,}934\ m^3 \text{ or } 64{,}000\ m^3$$

b. Daily horizontal area covered

50 Mg/d

$$\forall = \frac{\quad}{(2)(0.122\ Mg/m^3)} = 204.9\ m^3/d$$

$$A = \frac{204.9\ m^3/d}{(3)(0.25\ m)} = 273.2\ m^2/d$$

4. **Energy from Waste:**
A developer plans to build a completely self-contained city. The city will have a population of 555,000. The homes in the city are to be heated with methane gas generated at the landfill. The landfill will have a gas collection system. Through education and conservation, MSW generation will be reduced to a rate of 0.45 kg/capita/day. It is anticipated that gas can be produced at an annual rate of 25 L of gas per Kg of MSW delivered to the landfill and the gas will contain 58% methane. Gas recovery is 25% of that which is generated. The heat content of the methane gas is approximately 18,000 kJ/m^3 (a value lower than the theoretical value because of dilution of the methane with air during recovery). The homes are estimated to use an average of 40 x 10^6 kJ of heat energy per year. Peak usage during the winter is 1.5 times the average usage. Is this proposal feasible from the standpoint of generating sufficient heat for domestic use? What are the alternative sources of "waste" materials that could be used as a resource to generate heat?

Solution:

a. Heat produced

heat = (555,000)(0.45 kg/capita/d)(25 L/kg)(1 m^3/1000 L)(0.25)(18,000 kJ/m^3)(0.58)

heat = (1.629 x 10^7 kJ/d)(365 d/y) = 5.95 x 10^9 kJ/y

b. Assuming each home houses 4 people

houses = (555,000/4) = 138,750 houses

heat required = (138,750)(40 x 10^6 kJ/y) = 5.55 x 10^{12} kJ/y

c. Energy available

Heat produced – heat required = (5.95 x 10^9 kJ/y) – (5.5 x 10^{12} kJ/y)

Δ = -5.49 x 10^{12} kJ/y

Therefore, the heat produced would not be enough to heat the houses based on the average heating requirement.

d. Alternative sources of waste material could be from wastewater. Methane can be produced from anaerobic digestion of biological solids.

5. Waste Classification:
Using the data in the attached tables, calculate: (A) the specific weight of a typical composite US residential MSW; (B) the specific weight of the Davis, CA residential MSW (You can assume that the specific weight of misc. organics is 220 pounds per cubic yard), and (C) the moisture content of a typical composite US residential MSW.

Composition of residential MSW excluding recycled materials and food wastes discharged with wastewater (values are in percent by weight)

Component	**Typical U.S.**	**Davis, CA**
Organic		
Food wastes	9	6
Paper	34	33.1
Cardboard	6	7.9
Plastics	7	10.7
Textiles	2	2.4
Rubber	0.5	2.5
Leather	0.5	0.1
Yard Wastes	18.5	17.7
Wood	2	5
Misc. Organics		0.4
Inorganic		
Glass	8	5.8
Tin cans	6	3.9
Aluminum	0.5	0.4
Other metal	3	3.6
Dirt, ash, etc.	3	0.5
TOTAL	100.0	100.0

Typical Properties of Residential, uncompacted MSW

Type of Waste	Specific Weight (lb/yd^3)	Moisture Content (% by wt.)
Food wastes (mixed)	490	70
Paper	150	6
Cardboard	85	5
Plastics	110	2
Textiles	110	10
Rubber	220	2
Leather	270	10
Yard wastes	170	60
Wood	400	20
Glass	330	2
Tin cans	150	3
Aluminum	270	2
Other metals	540	3
Dirt, ashes, etc.	810	8
Ashes	1255	6
Rubbish	220	15

(A) the specific weight of a typical composite US residential MSW;

Component	**Typical U.S. % by wt.**	Specific Weight (lb/yd^3)	Volume yd^3
Organic			
Food wastes	9	490	0.02
Paper	34	150	0.23
Cardboard	6	85	0.07
Plastics	7	110	0.06
Textiles	2	110	0.02
Rubber	0.5	220	0.00
Leather	0.5	270	0.00
Yard Wastes	18.5	170	0.11
Wood	2	400	0.01
Misc. Organics	220		
Inorganic			
Glass	8	330	0.02
Tin cans	6	150	0.04
Aluminum	0.5	270	0.00
Other metal	3	540	0.01
Dirt, ash, etc.	3	810	0.00
TOTAL	100.0		0.59

Recognize that you can calculate the volume of each category, for a given total weight. Then determine the "weighted average" specific weight. The easiest way to do this is simply to assume a total mass of 100 lb of MSW. Then the weight of each component above is simply the number in the "% by wt" column in lb.

$$volume = 100\ lb \sum_{all\ x} (\%\ by\ wt)_x (specific\ wt)_x = 0.59 yd^3$$

The individual component volumes and the sum are shown in the table above. And the specific weight is just the aggregate total weight (100 lb) divided by the aggregate total volume (0.59 yd^3)

$$Specific\ Weight = \frac{total\ weight}{total\ volume} = \frac{100\ lb}{0.591\ yd^3} = \mathbf{169}\ {}^{\boldsymbol{lb}}/_{\boldsymbol{yd^3}}$$

(B) the specific weight of the Davis, CA residential MSW (You can assume that the specific weight of misc. organics is 220 pounds per cubic yard)

Component	**Davis, CA**	Specific Weight (lb/yd^3)	Volume yd^3
Organic			
Food wastes	6	490	0.01
Paper	33.1	150	0.22
Cardboard	7.9	85	0.09
Plastics	10.7	110	0.10
Textiles	2.4	110	0.02
Rubber	2.5	220	0.01
Leather	0.1	270	0.00
Yard Wastes	17.7	170	0.10
Wood	5	400	0.01
Misc. Organics	0.4	220	0.00
Inorganic			
Glass	5.8	330	0.02
Tin cans	3.9	150	0.03
Aluminum	0.4	270	0.00
Other metal	3.6	540	0.01
Dirt, ash, etc.	0.5	810	0.00
TOTAL	100.0		0.63

This problem is done the same way as above.

$$Specific\ Weight = \frac{total\ weight}{total\ volume} = \frac{100\ lb}{0.63\ yd^3} = \mathbf{159\ {}^{lb}/_{yd^3}}$$

(C) the moisture content of a typical composite US residential MSW.

Component	**Typical U.S.**	Moisture Content (% by wt.)	**Dry wt. (lbs)**
Organic			
Food wastes	9	70	2.7
Paper	34	6	31.96
Cardboard	6	5	5.70
Plastics	7	2	6.86
Textiles	2	10	1.80
Rubber	0.5	2	0.49
Leather	0.5	10	0.45
Yard Wastes	18.5	60	7.40
Wood	2	20	1.60
Misc. Organics			
Inorganic			
Glass	8	2	7.84
Tin cans	6	3	5.82
Aluminum	0.5	2	0.49
Other metal	3	3	2.91
Dirt, ash, etc.	3	8	2.76
TOTAL	100.0		78.78

For this one you take the same approach, but this time calculating the individual dry weights and then the aggregate dry weight (78.78 lb).

Moisture Content = {(100-79)/100}*100% = 21%