BASIC WASTEWATER MATH

Volumes

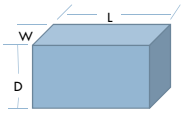
Objectives

- You will be able to solve basic and common calculations used in biosolids management.
- You will learn to work with common units of measure and make simple conversions.
- You will learn where to go for help!

Typical Tank Shapes

- Rectangular
  - Area is Length times Width
- Circular
  - Area is 3.14 *radius ^{2}

Rectangular Example



L = Length
W = Width
D = Depth

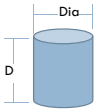
For Example
L= 60 ft
W= 30 ft
D = 12 ft

Area = L x W or 60ft x 30ft ➔ 1800 ft ^{2}

Most of the time we need Volume so we need to Multiply Area x depth

Volume = Area x depth or L x W x D
➔ 60 ft x 30 ft x 12 ft = 21,600 ft^3

Circular Example



For example
Tank Diameter = 40 ft
Tank Radius R = 20 ft
Radius is ½ of the Diameter
Depth = 14 ft

Dia = Diameter
R = Radius
Pi = 3.14
D = Depth

Area = 3.14 x 20 ft ^{2} = 1256 ft ^{2}

Most of the time we need Volume so we need to Multiply Area x depth

Volume = Area x depth ➔ 1256 ft^2 x 14 ft = 17,584 ft ^{3}

In calculating the volume of a digester you generally ignore the cone at the bottom

Problem 1

- Find pounds of biosolids when you only know gallons and concentration (thickness)
- Mass (lb) = Volume (gal) x %TS x 8.34 lb/gal
- Example:
  - Hauling tanker is 6,000 gal
  - Filled with 2% total solids (TS) biosolids liquid
  - How much solid mass (dry pounds) is hauled?

Problem 1 continued

- You know the pounds of biosolids, now convert it to dry tons and dry metric tonnes
- Total dry pounds = 1,000.8
- Ton X 0.9072 = metric tonnes
- Example:
  - Dry pounds / 2,000 =
  - Dry tons X 0.9072 =

Problem 2

- Find pounds of centrate solids returned to the liquid stream when you only know million gallons per day and solids concentration (TSS)
- Mass (lb) = Volume (MGD) x mg/l TSS x 8.34 lb/gal
- Example:
  - Daily centrate hydraulic load 0.075 MGD
  - Filled with 350 mg/l (TSS) centrate liquid
  - How much solid mass (dry pounds) is returned each day?

Problem 3

- Find flow rate (gpm) when you know mass rate (lb/min) and concentration (thickness)
- Liquid flow (gpm) = $\frac{\text{Mass rate (lb/min)}}{\text{\% TS x 8.34 lb/gal}}$
- Example:
  - Biosolids production at WWTP is 10,000 lb/day
  - Product is thickened liquid, 5% TS
  - What is the pumped flow rate of product, gal/day and gal/min?

Problem 4

- Find how many cubic yards (volume) of dewatered cake when you know:
  - concentration (thickness or dryness) %TS
  - mass (pounds)
  - bulk density (lb/cu ft)
- Volume (cu yd) = $\frac{\text{dry weight (lb)}}{\text{density (lb/cu ft) x 27 (cu ft/cu yd) x \%TS}}$
- Example:
  - 10,000 lb/day biosolids production, dry weight basis
  - Bulk density of dewatered cake is 55 lb/cu ft
  - Cake is dewatered to 20% TS
  - How much cake is piled up every day, in cubic yards?

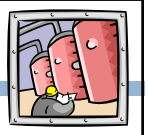
Problem 5

- Find how much are we really hauling on the road (wet weight) when we know dry weight and thickness (%TS)
- Wet weight (lb) = dry weight (lb) / %TS
- Example:
  - 2 tons dry weight of biosolids to be hauled
  - Dewatered cake is 20% TS
  - What is the wet weight in the truck?

Problem 6

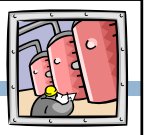
- Find out how many beers it takes over lunch to loose your license (and job) for driving your rig over the legal limit (blood alcohol content)
- BAC = $\frac{\text{(\#drinks x volume/drink (oz) x alcohol \%/drink x 7.14)}}{\text{body weight (lb)}}$ - time (hrs) x .012
- Example:
  - Jim weighs 180 lb.
  - He has two beers at lunch (1 hour), 12 oz. each
  - Beer is about 4.5% alcohol
  - Is Jim trashed at the end of his lunch break? What's his BAC?

Problem 7



- Find the volume of the digester
  - "Box" volume (gal) = length (ft) x width (ft) x depth (ft) x 7.48 gal/cu ft
  - "Tank" volume (gal) = 3.14 x radius (ft) x radius (ft) x depth (ft) x 7.48 gal/cu ft
- Example:
  - Aerobic digester basin is 100' long, 40' wide
  - Water depth is 8'
  - How many gallons of sludge is in the basin?

Problem 7 continued



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  - "Tank" volume (gal) = 3.14 x radius (ft) x radius (ft) x depth (ft) x 7.48 gal/cu ft
- Example:
  - Anaerobic digester tank is 90 feet in diameter
  - Water depth is 18'
  - How many gallons of sludge is in the tank?

Problem 8

- Find the hydraulic retention time (HRT) in the anaerobic digester, in days (mixed, no decant!)
- HRT (days) = volume (gal) / flow (gal/day)
- Example:
  - Round anaerobic digester is 50' diameter, 12' deep
  - Digested biosolids is pumped out at 12,000 gal/day
  - What is the hydraulic detention time in the digester in days?

Problem 9

- Find the solids retention time (SRT) in the aerobic digester, in days (decanted!)
- SRT (days) = $\frac{\text{total mass in digester (lb)}}{\text{mass removal rate (lb/day)}}$
- Example:
  - 100' x 40' x 8' box-shaped aerobic digester
  - 2% TS sludge in the digester
  - 4,000 gal/day sludge pumping rate out of digester
  - 2,000 gal/day water (decant) rate out of digester
  - What is the SRT in the digester, in days?

Problem 10

- Find the degree-days in the digester
  - Degree-days (°C-days) = temperature (°C) x SRT (days)
- Example:
  - Anaerobic digester is kept at 95°F
  - SRT was calculated at 60 days (problem 7)
  - How many degree-days does the digester provide?

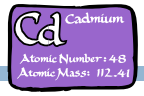
Problem 11 Van Kleek

- Find the volatile solids reduction (VSR) through a digester, in %
- VSR % = $\frac{(VS_{in}\ \% - VS_{out}\ \%) \times 100}{VS_{in}\ \% - (VS_{in}\ \% \times VS_{out}\ \%)}$
- Example:
  - Waste sludge to the digester has 70% volatile solids (VS) content according to the lab
  - Digested biosolids pumped out has 52% VS content
  - What is the volatile solids reduction through the digester?

Problem 12

- Find the application rate (dry tons/acre) of biosolids on a field
- Loading rate (DT/acre) = $\frac{\text{biosolids mass (DT)}}{\text{application area (acres)}}$
- Example:
  - 240 dry tons of biosolids is produced each year from a plant, which is land applied on a field
  - The application area is a quarter section
  - What is the application rate of biosolids, in DT/acre?

Problem 13



- Find the annual metals loading rate on an application site
- Annual metals loading rate (lb/acre) = metal concentration (mg/kg) x 0.002 x biosolids applied (DT/year) / acres used (acres)
- Example:
  - Concentration of cadmium in biosolids is 22 mg/kg from lab
  - Same site as Problem 12 (160 acres)
  - Same biosolids application rate (1.5 DT/acre)
  - What is the annual metals loading rate on the site?

Problem 14

- Find the cumulative metal loading on a site
- Cumulative load (lb/acre) = annual load (lb/acre) x years applied
- Example:
  - Cumulative load limit for a site based on cadmium is 35 lb/acre, per EPA regulations
  - Using problem 13, how many years can the site be used, based on cadmium loading only?

Problem 15

- Find the agronomic loading rate (based on nitrogen), if you know the type of crop grown and nitrogen data about the soil and biosolids
- Agronomic rate (DT/acre) = $\frac{A - (B \times 3.6)}{(20 \times C \times F) + (20 \times D) + (4 \times E)}$

Where:

A = nitrogen required per crop planted (lb/acre)
B = nitrate in soil (ppm)
C = ammonia-N in biosolids (%)
D = nitrate-N in biosolids (%)
E = organic-N in biosolids (%)
F = application method factor

0.2	liquid surface application
0.5	liquid surface application, incorporated
0.8	cake surface application
1.0	other cases

Problem 15 continue

- Example:
  - Soil testing shows 5 ppm nitrates at field
  - Biosolids lab data shows:
    - 3% organic-N
    - 0.5% ammonia-N
    - 0.01% nitrate-N
  - Crop to be dryland wheat, which needs 70 lb/acre of nitrogen
  - Biosolids is liquid, to be disked into soil
  - What biosolids application rate will supply the nitrogen needed on the field, in DT/acre?

Problem 16

- Find the amount of biosolids cake, wood chips and recycle to blend in a compost pile, using a mix "recipe"
- Volume (cu yd) = $\frac{\text{mass (wet lb)}}{\text{bulk density (wet lb/cu ft)} \times 27 \text{ cu ft/cu yd}}$
- Example:
  - 2 wet tons of biosolids cake delivered
  - Biosolids 1,700 lb/cu yd, 22% TS
  - Wood chips 400 lb/cu yd, 60% TS
  - Recycle 1,300 lb/cu yd, 65% TS
  - Mix recipe is 1 part wood chips, 1 parts recycle, 2 parts biosolids by volume
  - How much wood chips & recycle is needed to make a compost pile, in pounds and cu yds of each material?

Problem 17

What is the centrifuge recovery rate?

- Centrifuge Feed 120 gpm at 2.0% TS
- Centrate 0.02% TS
- Polymer Usage 120 gph at 0.5%TS

Removal Efficiency

$$\% \text{ removal} = \frac{\text{influent - effluent}}{\text{influent}} \times 100$$

Problem 17 continue

What is the polymer usage rate in pounds per DT?

- Centrifuge Feed 120 gpm at 2.0% TS
- Centrate 0.02% TS
- Polymer Usage 120 gph at 0.5%TS

$$\frac{\text{pounds of polymer}}{\text{dry tons of biosolids}}$$

Questions?