5 points total for entire homework

Homework #6. Coagulation, Flocculation, Sedimentation

1. The design flow for a water treatment plant (WTP) is 1 MGD ($3.8x10^3$ m^3/d). The rapid mixing tank will have a mechanical mixer and the average alum dosage will be 30 mg/L. The theoretical mean hydraulic detention time of the tank will be 1 minute. Determine the following:
   a) the quantity of alum needed on a daily basis in kg/d,
   b) the dimensions of the tank in meters for a tank with equal length, width, and depth,
   c) the power input required for a G of 900 sec^{-1} for a water temperature of 10 ^oC – express the answer in kW

1 point for #1

Answer:

a) the quantity of alum needed on a daily basis in kg/d,

$$amount\ needed = Q\ x\ dose$$
$$= 3.8x10^3 \frac{m^3}{d}\ x\ 30 \frac{mg}{L} \left\{\frac{1Kg}{10^6 mg} \frac{1000L}{m^3}\right\}$$
$$= 114\ \frac{Kg}{d}$$

$$\boxed{amount\ needed = 114 \frac{Kg}{d}}$$

b) the dimensions of the tank in meters for a tank with equal length, width, and depth,

$$V = Qt_R$$
$$= 3.8x10^3 \frac{m^3}{d} x 1min \left\{\frac{1d}{1440min}\right\}$$
$$= 2.64m^3$$

$$V = LxWxH = 2.64m^3$$

For a tank of equal length, width and height, L=W=H, so:

$$V = x^3 = 2.64m^3$$
$$x = 1.4m$$

$$\boxed{Length = Width = Depth = 1.4m}$$

c) the power input required for a G of 900 sec^{-1} for a water temperature of 10 ^oC – express the answer in kW

$$G = \left(\frac{P}{\mu V}\right)^{0.5}$$

So

$$P = \mu V G^2 = 1.307x10^{-3}\frac{Kg}{m-s}2.64m^3(900s)^2 = 2795\frac{Kg-m^2}{s^3} = \boxed{2.8kW}$$

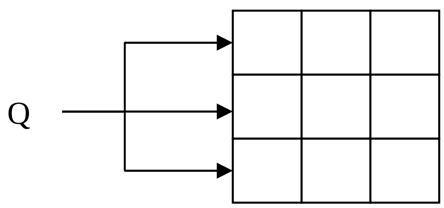
Note that:

$$\frac{Kg-m^2}{s^3} = \frac{Kg-m}{s^2}\left(\frac{m}{s}\right) = N\frac{m}{s} = \frac{J}{s}=W$$

2. Flocculation tanks are to be designed for a total flow rate of 49,200 m^3/d. The following conditions apply to the design: water temperature of 10 °C, total mean detention time of 45 min, basin depth of 3.5 m, 3 parallel trains of flocculators (each train receives one third of the total flow), 3 flocculation stages of the same dimensions for each train (so a total of 9 flocculators), the first stage G is 50 sec^{-1}, the second stage G is 35 sec^{-1}, and the third stage G is 20 sec^{-1}. Determine:

   a) The dimensions of the tank for each stage as well as the overall dimensions, in meters,

1 point for #2



$V=t_R/Q$,where t_R per stage is 45/3 or 15 min

Q per train is 1/3 times 49,200 m^3/d or 16,400 m^3/d

$$V_{tank} = t_R Q = 15min\left(16{,}400\frac{m^3}{d}\right)\left(\frac{d}{1440min}\right) = 171m^3$$

$$V_{overall} = 9 * V_{tank} = 9 * 171m^3 = 1{,}538m^3$$

If the depth must be 3.5 m, then the product of the length and width must be:

$$LxW_{tank} = \frac{V_{tank}}{Depth} = \frac{171m^3}{3.5m} = \boxed{48.8m^2}$$

$$LxW_{overall} = \frac{V_{overall}}{Depth} = \frac{1{,}538m^3}{3.5m} = \boxed{439m^2}$$

Any combination of length x width that gives the above square meter areas is OK, as long as the L/W ratio doesn't become too great (i.e, it should be below 10).

For example, if you assume each floc tank is square, then the dimensions are just the square root of above:

- Each individual tank is 7m x 7 m x 3.5 m depth
- Overall size is 21m x 21m x 3.5 m depth

b) the average G times detention time product (the "Gt" Camp parameter) for the overall process and compare to the Camp criterion, and

overall G is just the average for all of the flocculator tank volume

$$G = \frac{50s^{-1} + 35s^{-1} + 20s^{-1}}{3} = 35s^{-1}$$

$$Gt = 35s^{-1}45min\left(60\frac{s}{min}\right) = 94{,}500$$

This is OK as it falls between 50,000 and 100,000

c) the power required for each stage, in kW.

Recall that:

$$P = \mu V G^2 = 1.307x10^{-3}\frac{Kg}{m-s}171m^3(G)^2$$

which results in the following

Stage	G	P (kW)
1	50	**0.56**
2	35	**0.27**
3	20	**0.089**

3. Using Stokes Law for particle settling velocity,

a) Calculate the settling velocity in m/hr of a 100 μm particle with a density of 1050 kg/m^3 for water temperatures of 4, 10, 20, and 30 ^{o}C. Tabulate your results.

1 point for #3

Assume low Reynolds number which allows use of the simple stokes equation:

$$v = \frac{(\rho_p - \rho_w)d^2 g}{18\mu}$$

Which leads to the following:

Temp (^{o}C)	ρ_w (Kg/m^3)	μ (10^3 Kg/m-s)	v (m/hr)	v/v$_{20}$ (%age)
4	1000	1.57	**0.62**	**62%**

10	999.7	1.307	**0.75**	**74%**
20	998.2	1.002	**1.01**	**100%**
30	995.7	0.798	**1.33**	**132%**

b) Using 20 °C as a reference temperature, compute the relative settling velocity in % (i.e., the settling velocity for the stated temperature divided by the 20 °C settling velocity) for water temperatures of 4, 10, 20, and 30 °C. Tabulate these results along with those of part a).

See table above

4. Settling of Alum floc

a) Compute the settling velocity (in m/hr) of alum floc particles of 100 and 200 μm diameter at water temperatures of 4 and 20 °C (four calculations are required). Alum floc has a density of 1010 kg/m³.

1 point for #4

Again, you should assume a low Reynolds number which allows use of the simple stokes equation (you will check this assumption in part b):

$$v = \frac{(\rho_p - \rho_w)d^2 g}{18\mu}$$

This leads to the following:

Temp (°C)	d (μm)	ρ_w (Kg/m³)	μ (Kg/m-s)	v (m/hr)	Re
4	100	1000	1.57×10^{-3}	**0.13**	**0.0022**
	200			**0.50**	**0.018**
20	100	998.2	1.002×10^{-3}	**0.23**	**0.0064**
	200			**0.92**	**0.051**

b) Compute the Reynolds numbers for all settling velocities of part a). Does Stokes Law for laminar flow conditions hold for these particles?

Calculate Reynolds number for each

$$Re = \frac{v d \rho_w}{\mu}$$

See table above

Since all are less than 0.2, we can assume laminar flow conditions[1]

5. For a WTP with a design flow of 1.5 MGD, determine the dimensions (in ft) for a rectangular sedimentation basin with a detention time of 4 hr, an overflow rate of 700 gpd/ft², and length to width ratio of 3 to 1.

[1] This is the value commonly used to distinguish laminar flow for discrete settling; note that this is different than the value used with open channel flow or flow in pipes (2000-4000)

1 point for #5

OFR = Q/A

So:

$$A = \frac{Q}{OFR} = \frac{1.5x10^6 \frac{gal}{d}}{700 \frac{gal}{d-ft^2}} = 2143ft^2$$

And

$$A = LxW$$

But since L/w = 3:

$$A = 3WxW = 3W^2$$

or

$$W = \sqrt{A/3} = \sqrt{2143ft^3/3} = 26.7ft$$

So, use <u>27 ft nominal width</u>
And thus, <u>81 ft nominal length</u>

Now determine the depth from the detention time

$$t_R = \frac{V}{Q} = \frac{LxWxD}{Q}$$

Or rearranging:

$$D = \frac{t_R Q}{LxW} = \frac{4hr\left(1.5x10^6 \frac{gal}{d}\right)\frac{1ft^3}{7.48gal}}{81ft(27ft)} = 15.3ft$$

So, use <u>16 ft nominal depth</u>