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Problem 5.-

Settling velocity for different diameters:

- d = 2 mm

$$v_s = \frac{9.8\ \frac{m}{s^2} \cdot \left(2650\ \frac{kg}{m^3} - 1000\ \frac{kg}{m^3}\right) \cdot (2 \cdot 10^{-3} m)^2}{18 \cdot 9.95 \cdot 10^{-4}\ Pa \cdot s} = 3.6114 \frac{m}{s}$$

- d = 1 mm

$$v_s = 0.9029 \frac{m}{s}$$

- d = 0.5 mm

$$v_s = 0.2257 \frac{m}{s}$$

- d = 0.3 mm

$$v_s = 0.0812 \frac{m}{s}$$

- d = 0.2 mm

$$v_s = 0.0361 \frac{m}{s}$$

Settling time:

$$t_s = \frac{H}{V_s} = \frac{2.1\ m}{V_s(particles)}$$

Length needed for total settling:

$$L_{100} = t_s \cdot v_0$$

$$v_0 = \frac{Q}{Section} = \frac{1.05902\ \frac{m^3}{s}}{1.5\ m\ \cdot 2.1\ m} = 0.336 \frac{m}{s}$$

d (mm)	$t_s(s)$	$L_{100}(m)$	$\eta = \frac{L_{real}}{L_{100}} \cdot 100$	$\eta_i \cdot m_i$
2	0.5815	0.1955	4654% (›100%)	40
1	2.3260	0.7820	1163% (›100%)	25
0.5	9.3039	3.1280	290% (›100%)	20
0.3	25.8442	8.6888	104% (›100%)	10
0.2	58.1494	19.5498	46%	2.327 (5x0.46)

$\sum \eta_i \cdot m_i = 97.33\%$ → Yes, it is adequate to remove at least 80% of the sand.

Problem 6.-

a) Diameter and depth of settling tank

$$S = \pi r^2 \; ; \; S = \frac{Q}{F_c}$$

$$\pi \frac{d^2}{4} = \frac{6000 \; \frac{m^3}{day}}{34 \; \frac{m^3}{m^2 \cdot day}} ; d = 15m$$

$$H = \frac{V}{S}$$

$$V = t_{RH} \cdot Q = 1.5 \; h \cdot 6000 \; \frac{m^3}{day} \cdot \frac{1 \; day}{24 \; h} = 375 \; m^3$$

$$H = 2.152 \; m$$

b) Sludge production

Volume solids:

$$6000 \; \frac{m^3}{day} \cdot \frac{10^3 L}{1 \; m^3} \cdot \frac{200 \; mg \; SS}{1 \; L} \cdot \frac{1 \; kg}{10^6 mg} \cdot \frac{60 \; kg \; SS \; removed}{100 \; kg \; SS} = 720 \; \frac{kg \; SS_{removed}}{day}$$

$$720 \; \frac{kg \; SS_{removed}}{day} \rightarrow 0.41 \frac{m^3 VS}{day}$$

$$720 \; \frac{kg \; SS_{removed}}{day} \rightarrow 0.12 \frac{m^3 FS}{day}$$

Volume water:

$$720 \; \frac{kg \; SS_{removed}}{day} \cdot \frac{98 \; kg \; water}{2 \; kg \; SS_{removed}} \cdot \frac{1 \; m^3}{1000 \; kg \; water} = 35.28 \frac{m^3 water}{day}$$

Total sludge:

$$35.81 \frac{m^3 sludge}{day}$$

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Problem 7.-

a) % efficiency BOD reduction

$$BOD_1 = 60\ mg\frac{O_2}{L} = L\left(1 - e^{-0.23\ days^{-1}\cdot 1\ days}\right);\ L = 292.019\ mg\frac{O_2}{L}$$

$$BOD_2 = 107.7\ mg\frac{O_2}{L} = L\left(1 - e^{-0.23\ days^{-1}\cdot 2\ days}\right);\ L = 292.094\ mg\frac{O_2}{L}$$

$$L = L_{avg} = \frac{(292.019 + 292.094)}{2} = 292.057\ \frac{mg\ O_2}{L}$$

$$BOD_5 = 292.057\ mg\frac{O_2}{L}\left(1 - e^{-0.23\ days^{-1}\cdot 5\ days}\right);\ L = 199.581\ mg\frac{O_2}{L}$$

$$\%\ BOD\ reduction = \frac{(199.581 - 4)}{199.581}\cdot 100 = 98\ \%$$

b) Surface loading factor or overflow rate and retention time

$$F_c = \frac{Q}{S} = \frac{100000\ m^3\cdot day^{-1}}{1963.5\ m^2} = 50.93\ \frac{m^3}{m^2\cdot day}$$

$$t_{RH} = \frac{V}{Q} = \frac{1963.5\ m^2\cdot 5\ m}{100000\ m^3\cdot day^{-1}}\cdot\frac{24\ h}{1\ day} = 2.356\ h$$

c) Sludge production

$$320\ \frac{mg\ SS}{L}\cdot\frac{80\ mg\ SS_{removed}}{100\ mg\ SS} = \frac{256\ mg\ \ SS_{removed}}{L}$$

$$\frac{256\ mg\ solids}{L}\cdot\ 1\cdot 10^8\frac{L}{day}\cdot\frac{1\ kg}{10^6 mg}\cdot\frac{1\ m^3}{1200\ kg\ solids}\cdot\frac{100\ m^3 sludge}{4\ m^3 solids} = \mathbf{533.33\frac{m^3 sludge}{day}}$$

Problem 8.-

a) Sludge production

$$300\ \frac{\text{mg SS}}{\text{L}} \cdot \frac{70\ \text{mg SS}_{\text{removed}}}{100\ \text{mg SS}} \cdot \frac{11250 \cdot 10^3\ \frac{\text{L}}{\text{day}}}{\frac{10^6 \text{kg}}{\text{mg}}} = \frac{2362.5\ \text{kg SS}_{\text{removed}}}{\text{day}}$$

$$\text{FS} = \frac{2362.5\ \text{kg SS}}{\text{day}} \cdot \frac{30\ \text{kg FS}}{100\ \text{kg SS}} = 708.75\ \frac{\text{kg FS}}{\text{day}}$$

$$\text{VS (not transformed)} = \frac{2362.5\ \text{kg SS}}{\text{day}} \cdot \frac{70\ \text{kg VS}}{100\ \text{kg SS}} \cdot \frac{40\ \text{kg VS n. tr.}}{100\ \text{kg VS}} = 661.5\ \frac{\text{kg VS n. tr.}}{\text{day}}$$

$$\text{Total sludge} = \frac{(708.75 + 661.5)\text{kg solids}}{\text{day}} \cdot \frac{100\ \text{kg sludge}}{5\ \text{kg solids}} \cdot \frac{1\ \text{m}^3\text{sludge}}{1000\ \text{kg sludge}}$$
$$= \frac{27405\ \text{m}^3\text{sludge}}{\text{day}}$$

b) Biogas production

$$\frac{2362.5\ \text{kg SS}}{\text{day}} \cdot \frac{70\ \text{kg VS}}{100\ \text{kg SS}} \cdot \frac{600\ \text{kg VS tr.}}{100\ \text{kg VS}} \cdot \frac{0.35\ \text{m}^3\text{CH}_4}{1\ \text{kg VS tr.}} \cdot \frac{100\ \text{m}^3\text{biogas}}{50\ \text{m}^3\text{CH}_4} = 694.58\ \text{m}^3\text{biogas}$$

c) Volume of anaerobic digester

$$\frac{2362.5\ \text{kg SS}}{\text{day}} \cdot \frac{100\ \text{kg sludge}}{2\ \text{kg SS}} \cdot \frac{1\ \text{m}^3\text{sludge}}{1000\ \text{kg sludge}} = 118.125\ \frac{\text{m}^3\text{sludge}}{\text{day}}$$

$$\text{V} = \text{t}_\text{R} \cdot \text{Q} = 25\ \text{day} \cdot 118.125\ \frac{\text{m}^3\text{sludge}}{\text{day}} = 2953.13\ \text{m}^3$$