Water Treatment Project

Sample Treatment Cost

Consider a prototype system with the following characteristics:

1. coagulant dosage of 40 mg/L
2. flowrate 600 mL/min
3. run time of 45 minutes
4. 2 in. of anthracite and 6 in. of filter sand
5. replace filter material once every five years
6. prototype system uses 2 sedimentation tanks

Compute the total yearly cost of this system

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Coagulation and Flocculation Cost

The weight of coagulant (kg) required per gallon of treated water is estimated as:

$$wt_c\left[\frac{kg}{gal}\right]=\left(\frac{40\text{ mg}}{\text{L}}\right)\left(\frac{3.785\text{ L}}{\text{gallon}}\right)\left(\frac{\text{kg}}{10^6\text{ mg}}\right)$$

$$=1.51\times10^{-4}\frac{kg}{gal}$$

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Coagulation and Flocculation Cost

The number of coagulation and flocculation units *NCF* required are:

20% Factor of Safety

$$NCF=\left[\frac{20(\text{MGD})}{5(\text{MGD})}\right]\times1.2$$

$NCF = 4.8$ or 5 units

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Coagulation and Flocculation Cost

The total yearly cost of the coagulation and flocculation system for 20 MGD is:

$$Cost_{CF}=5\left(\frac{\$25{,}000}{\text{year}}\right)$$

$$+\left(1.51\times10^{-4}\frac{\text{kg}}{\text{gal}}\right)\left(\frac{2\times10^7\text{gal}}{\text{day}}\right)\left(\frac{365\text{ days}}{\text{year}}\right)\left(\frac{\$1}{\text{kg}}\right)$$

$$=\boxed{\$1{,}230{,}220}$$

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Sedimentation System Cost

Step 1 - Compute the prototype sediment tank ***retention time*** t_p

$$\text{Volume}_{\text{tank}}=360\text{ in.}^3\left(\frac{\text{gallon}}{231\text{ in.}^3}\right)=1.56\text{ gallons}$$

Two tanks are in operation

$$t_P=\frac{2(1.56\text{ gallons})}{\left(600\frac{\text{mL}}{\text{minute}}\right)\left(\frac{\text{L}}{1000\text{mL}}\right)\left(\frac{\text{gallon}}{3.785\text{ L}}\right)}=19.68\text{ min}$$

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Sedimentation System Cost

Step 2 - The full-scale ***treatment flowrate*** Q_{ST} (gpm) per sedimentation tanks is:

$$Q_{ST}=\frac{75{,}000\text{ gallons}}{19.68\text{ min}}=3{,}811\text{ gpm}$$

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Sedimentation System Cost

Step 3 - The ***effective flowrate*** Q_{SE} (gpm) in a sedimentation tank is:

$$Q_{SE} = 3{,}811\,\text{gpm}\left(\frac{45\,\text{minutes}}{60\,\text{minutes}}\right) = 2{,}858\,\text{gpm}$$

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Sedimentation System Cost

Step 4 - The number of full-scaled sedimentation tanks, ***NS*** required to handle the daily volume is estimated as:

20% increase for cleaning

$$NS = \left[\frac{2\times10^{7}\,(\text{gpd})}{2{,}858\,(\text{gpm})}\right]\left[\frac{\text{day}}{1{,}440\,\text{min}}\right]\times 1.2$$

$= 5.83$ tanks or 6 tanks

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Sedimentation System Cost

The operation and maintenance costs per tanks is $35,000/tanks

The yearly costs per sediment tank is:

$$Cost_S = 6\,\text{tanks}\left(\frac{\$35{,}000}{\text{tank}}\right) = \boxed{\$210{,}000}$$

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Filtration System Cost

Step 1 - Convert the average flowrate through the prototype filter (the 3.5 in. diameter prototype filter has an area of 0.0668 ft.^{2}) into a prototype ***filter loading rate*** Q_F (gpm/ft.^{2}).

$$Q_F = \left(\frac{600\,\text{mL}}{\text{minute}}\right)\left(\frac{\text{L}}{1000\,\text{mL}}\right)\left(\frac{\text{gallon}}{3.785\,\text{L}}\right)\left(\frac{1}{0.0668\,\text{ft.}^2}\right)$$

$= 2.373\,\text{gpm}/\text{ft.}^2$

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Water Treatment Project

Filtration System Cost

Step 2 - The full-scale ***treatment flowrate*** (Q_T)is:

$$Q_{FT} = 2.373\left(\text{gpm}/\text{ft.}^2\right)\times 1{,}000\,\text{ft.}^2 = 2{,}373\,\text{gpm}$$

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Water Treatment Project

Filtration System Cost

Step 3 - Considering that each filter is inoperable during backwashing, the ***effective flowrate*** Q_E is:

$$Q_{FE} = 2{,}373\,\text{gpm}\left(\frac{45\,\text{minutes}}{60\,\text{minutes}}\right) = 1{,}780\,\text{gpm}$$

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Water Treatment Project

Filtration System Cost

Step 4 - The number of full-scaled filters ***NF*** required to handle the daily volume is estimated as:

20% increase for backwashing

$$NF = \left[\frac{2\times10^{7}\,(\text{gpd})}{1{,}780\,(\text{gpm})}\right]\left[\frac{\text{day}}{1{,}440\,\text{min}}\right]\times 1.2$$

$$= 9.36 \text{ filters} \quad \text{or} \quad 10 \text{ filters}$$

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Filtration System Cost

The yearly cost per filter is:

$$Cost_F = 10 \text{ filters}\left(\frac{\$45{,}000}{\text{filter}}\right) = \boxed{\$450{,}000}$$

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Filtration System Cost

The yearly cost for anthracite is:

Material replaced every 5 years

$$Cost_{FM_A} = 2(\text{in.})\left(\frac{\$9.50}{\text{ft.}^3}\right)\left(\frac{\text{ft}}{12\text{ in.}}\right)(1{,}000\text{ ft.}^2)\left(\frac{NF}{5}\right)$$

The yearly cost for filter sand is:

$$Cost_{FMs} = 6(\text{in.})\left(\frac{\$5.90}{\text{ft.}^3}\right)\left(\frac{\text{ft}}{12\text{ in.}}\right)(1{,}000\text{ ft.}^2)\left(\frac{NF}{5}\right)$$

$$Cost_{FM} = \$3{,}167 + \$5{,}900 = \boxed{\$9{,}067}$$

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Total Treatment System Cost

$$\text{Total Cost} = \$1{,}230{,}220 \quad \text{Coagulation}$$
$$+ \$210{,}000 \quad \text{Sedimentation}$$
$$+ \$450{,}000 \quad \text{Filtration}$$
$$+ \$9{,}067 \quad \text{Filtration Media}$$

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Total Treatment System Cost

$$\text{Total Cost} = \boxed{\$1{,}899{,}287}$$

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Any questions?

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