Project 1 – Treatment Cost

- The objective of this project is to utilize, within given constraints, a prototype water filter system to design a full-scale system.
- The effectiveness of the filter design will be evaluated by the yearly ***operational and maintenance costs***.

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Project 1 – Treatment Cost

Group Problem - Treatment Cost

Consider a prototype system with the following characteristics:

1. coagulant dosage of 25 mg/L
2. flowrate 1,000 mL/min
3. run time of 60 minutes
4. 2 inches of anthracite and 4 inches of filter sand
5. replace filter material once every five years
6. 4 prototype sedimentation tanks

Compute the total yearly cost of this system

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Project 1 – Treatment Cost

Coagulation and Flocculation Cost

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

$$wt_c\left[\frac{kg}{gal}\right]=\left(\frac{25\text{ mg}}{\text{L}}\right)\left(\frac{3.785\text{ L}}{\text{gallon}}\right)\left(\frac{\text{kg}}{10^6\text{ mg}}\right)$$

$$=9.462\times10^{-5}\frac{kg}{gal}$$

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Project 1 – Treatment Cost

Coagulation and Flocculation Cost

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

20% Factor of Safety

$$NCF=\left[\frac{2\times10^7\,(\text{gpd})}{5\times10^6\,(\text{gpd})}\right]\times1.2$$

$NCF=4.8$ or 5 units

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Project 1 – Treatment Cost

Coagulation and Flocculation Cost

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

$$Cost_{CF}=5\left(\frac{\$25{,}000}{\text{year}}\right)+\left(9.462\times10^{-5}\frac{\text{kg}}{\text{gal}}\right)\left(\frac{2\times10^7\text{gal}}{\text{day}}\right)\left(\frac{365\text{ days}}{\text{year}}\right)\left(\frac{\$1}{\text{kg}}\right)$$

$$=\boxed{\$815{,}763}$$

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Project 1 – Treatment Cost

Sedimentation System Cost

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

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

Four tanks are in operation

$$t_p=\frac{4(1.56\text{ gallons})}{\left(1{,}000\frac{\text{mL}}{\text{minute}}\right)\left(\frac{\text{L}}{1000\text{ml}}\right)\left(\frac{\text{gallon}}{3.785\text{ L}}\right)}=23.62\text{ min}$$

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Project 1 – Treatment Cost

Sedimentation System Cost

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

$$Q_{ST} = \frac{75{,}000 \text{ gallons}}{23.62 \text{ min}} = 3{,}175 \text{ gpm}$$

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Project 1 – Treatment Cost

Sedimentation System Cost

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

$$Q_{SE} = 3{,}175 \text{ gpm}\left(\frac{60 \text{ minutes}}{60 \text{ minutes}}\right) = 3{,}175 \text{ gpm}$$

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Project 1 – Treatment Cost

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

$$NS = \left[\frac{2\times10^{7}\,(\text{gpd})}{3{,}175\,(\text{gpm})}\right]\left[\frac{\text{day}}{1{,}440\,\text{min}}\right]\times 1.2$$

$$= 5.25 \text{ tanks} \quad \text{or} \quad 6 \text{ tanks}$$

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Project 1 – Treatment Cost

Sedimentation System Cost

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

The yearly cost for the sediment tanks is:

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

$$= \boxed{\$210{,}000}$$

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Project 1 – Treatment Cost

Filtration System Cost

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

$$Q_F = \left(\frac{1{,}000\,\text{mL}}{\text{minute}}\right)\left(\frac{\text{L}}{1{,}000\,\text{mL}}\right)\left(\frac{\text{gallon}}{3.785\,\text{L}}\right)\left(\frac{1}{0.0668\ \text{ft.}^2}\right)$$

$$= 3.955\,\text{gpm / ft.}^2$$

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Project 1 – Treatment Cost

Filtration System Cost

Step 2 - The full-scale ***treatment flowrate*** Q_{FT} is:

$$Q_{FT} = 3.955\left(\text{gpm}/\text{ft.}^2\right)1{,}000\,\text{ft.}^2$$

$$= 3{,}955 \text{ gpm}$$

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Project 1 – Treatment Cost

Filtration System Cost

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

$$Q_{FE} = 3{,}955\ \text{gpm}\left(\frac{60\ \text{minutes}}{60\ \text{minutes}}\right)$$

$$= 3{,}955\ \text{gpm}$$

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Project 1 – Treatment Cost

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

$$NF = \left[\frac{2\times10^{7}\,(\text{gpd})}{3{,}955\,(\text{gpm})}\right]\left[\frac{\text{day}}{1{,}440\text{min}}\right]\times 1.2$$

$$= 4.21\ \text{filters} \quad \text{or} \quad 5\ \text{filters}$$

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Project 1 – Treatment Cost

Filtration System Cost

The yearly cost for the filters is:

$$Cost_F = 5\ \text{filters}\left(\frac{\$45{,}000}{\text{filter}}\right) = \boxed{\$225{,}000}$$

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Project 1 – Treatment Cost

Filtration System Cost

The yearly cost for anthracite is:

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

Material replaced every 5 years

The yearly cost for sand is:

$$Cost_{FM_S} = (4\text{in.})\left(\frac{\$5.90}{\text{ft.}^3}\right)\left(\frac{\text{ft.}}{12\ \text{in.}}\right)(1{,}000\ \text{ft.}^2)\left(\frac{NF}{5}\right)$$

$$Cost_{FM} = \$1{,}583 + \$1{,}967 = \boxed{\$3{,}550}$$

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Water Treatment Project

Total Treatment System Cost

$$\text{Total Cost} = \$815{,}763 \quad \text{Coagulation}$$

$$+ \$210{,}000 \quad \text{Sedimentation}$$

$$+ \$225{,}000 \quad \text{Filtration}$$

$$+ \$3{,}550 \quad \text{Filtration Media}$$

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Water Treatment Project

Total Treatment System Cost

$$\text{Total Cost} = \boxed{\$1{,}254{,}313}$$

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Water Treatment Project

Any questions?

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