

Water Treatment System Cost

Each prototype filter will be scaled up to handle a flowrate of 20 million gallons per day (MGD). The effluent water must have an average turbidity of less than 2 NTU. To handle backwashing and cleaning of the treatment system, the overall size of the treatment system should be increased by 20% or a factor of safety of 1.2

The full-scale treatment system may be constructed with any combination of the following three processes: coagulation and flocculation basins (5 MGD); sedimentation tanks (each tank is 75,000 gallons); and gravity granular-media filters (1,000 ft.² per filter).

Coagulation and Flocculation System

Operation and maintenance costs for the coagulation and flocculation system depend on the system flowrate. A single full-scale coagulation and flocculation unit capable of treating 5 MGD costs \$25,000 per year. Ferric chloride and associated chemicals cost \$1/kg. The weight of coagulant, wt_c (kg/gallon), required per gallon of treated water is estimated as

$$wt_c = D \left(\frac{3.785 \text{ L}}{\text{gallon}} \right) \left(\frac{\text{kg}}{10^6 \text{ mg}} \right) \quad (1)$$

where D is the dosage (mg/L) of ferric chloride used in the treatment system. The number of coagulation and flocculation units NCF required is:

$$NCF = \text{Roundup} \left[\left(\frac{20 \text{ (MGD)}}{5 \text{ (MGD)}} \right) \times 1.2 \right] \quad (2)$$

The cost of coagulation and flocculation, $Cost_{CF}$, is:

$$Cost_{CF} = NCF \left(\frac{\$25,000}{\text{year}} \right) + wt_c (2 \times 10^7 \text{ (gpd)}) \left(\frac{365 \text{ days}}{\text{year}} \right) \left(\frac{\$1}{\text{kg}} \right) \quad (3)$$

Sedimentation System

The size of the prototype sedimentation tank can be varied - each sedimentation basin contains four individual tanks. Each prototype tank is approximately 6 in. wide, 6 in. long, and 10 in. deep (volume = 360 in³ or 1.56 gallons). Each full-scale sedimentation tank has a volume of 75,000 gallons.

To estimate the cost of sedimentation: first, compute the prototype sediment tank retention time, t_p (minutes) as

$$t_p = t_p = \frac{n_t (1.56 \text{ gallons})}{\left(Q \frac{\text{ml}}{\text{minute}}\right) \left(\frac{\text{liter}}{1,000 \text{ml}}\right) \left(\frac{\text{gallon}}{3.785 \text{ liter}}\right)} \quad (4)$$

where n_t is the number of prototype tanks and Q (mL/min) is the prototype water treatment system flowrate. The full-scale treatment flowrate Q_{ST} (gpm) per sedimentation tank is:

$$Q_{ST} = \frac{75,000 \text{ gallons}}{t_p} \quad (5)$$

Then, compute the effective flowrate Q_{SE} (gpm) in a sedimentation tank as:

$$Q_{SE} = \frac{Q_{ST} \times \text{filter run time}}{60 \text{ minutes}} \quad (6)$$

Next, estimate the number of full-scale sedimentation tanks NS required to handle the daily volume as:

$$NS = \text{Roundup} \left[\left(\frac{20 \times 10^6 \text{ (gpd)}}{Q_{SE} \text{ (gpm)}} \right) \left(\frac{\text{day}}{1,440 \text{ min}} \right) \times 1.2 \right] \quad (7)$$

The operation and maintenance cost per full-scale sedimentation tank is \$35,000/tank. The cost of the sedimentation system $Cost_s$ is:

$$Cost_s = NS \left(\frac{\$35,000}{\text{tank}} \right) \quad (8)$$

Filtration System

The full-scale filters will have the following characteristics: each filter will be about 32 ft. by 32 ft. (1,000 ft.²), with a 20% factor of safety (to accommodate backwashing time), and the filter media will be replaced every 5 years. The annual operation and maintenance cost for a full-scale filter is \$45,000. The unit cost for anthracite and filter sand is \$9.50/ft.³ and \$5.90/ft.³, respectively.

To estimate the cost of filtration: first, 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) as:

$$Q_F = Q \left(\frac{\text{gallon}}{3,785 \text{ mL}} \right) \left(\frac{1}{0.0668 \text{ ft.}^2} \right) \quad (9)$$

Then, compute the full-scale treatment flowrate Q_{FT} (gpm) as:

$$Q_{FT} = Q_F \times 1,000 \text{ ft.}^2 \quad (10)$$

Next, the effective flowrate Q_{FE} (gpm) is:

$$Q_{FE} = \frac{Q_F \times \text{filter run time}}{60 \text{ minutes}} \quad (11)$$

Then, compute the number of full-scaled filters, NF , required for the daily volume as:

$$NF = \text{Roundup} \left[\left(\frac{20 \times 10^6 \text{ (gpd)}}{Q_{FE} \text{ (gpm)}} \right) \left(\frac{\text{day}}{1,440 \text{ min}} \right) \times 1.2 \right] \quad (12)$$

The cost of filtration $Cost_F$ is:

$$Cost_F = NF \left(\frac{\$45,000}{\text{filter}} \right) \quad (13)$$

The yearly cost for anthracite $Cost_{FMa}$ is

$$Cost_{FMa} = t_a \left(\frac{\$9.50}{\text{ft.}^3} \right) \left(\frac{\text{ft.}}{12 \text{ in.}} \right) (1,000 \text{ ft.}^2) \left(\frac{NF}{R} \right) \quad (14)$$

where t_a is the thickness (in.) of the anthracite in the prototype filters, and R is the number of years until the next replacement cycle of the media. The yearly cost for the filter sand $Cost_{FMs}$ is

$$Cost_{FMs} = t_s \left(\frac{\$5.90}{\text{ft.}^3} \right) \left(\frac{\text{ft.}}{12 \text{ in.}} \right) (1,000 \text{ ft.}^2) \left(\frac{NF}{R} \right) \quad (15)$$

where t_s is the thickness (in.) of the filter sand in the prototype filters.

The total yearly capital, operation, and maintenance cost for a 20 MGD water treatment system is estimated as follows:

$$Cost = Cost_{CF} + Cost_S + Cost_F + Cost_{FMa} + Cost_{FMs} \quad (16)$$