1.

We assume temperature is 25 + 273 = 298K in the water

Using Eq 9-4 $\kappa^{-1} = 10^{10} \times [\frac{2 \times 1000 \times e^2 \times N_A \times I}{\epsilon\epsilon_0 kT}]$

e = electron charge, $1.60219 \times 10^{-19}$ C

$N_A$ = Avagadro's number, $6.02205 \times 10^{23}$/mol

I = ionic strength

M= molar concentration of cationic or anionic species, mol/L

z = magnitude of positive or negative charge on ion

$\varepsilon$ = permittivity relative to a vacuum (ε for water is 78.54, unitless)

$\varepsilon_0$ permittivity in a vacuum, $8.854188 \times 10^{-12}$ $C^2$/J · m

k = Boltzmann constant, $1.38066 \times 10^{-23}$ J/K

T = absolute temperature, K (273 + $^{\circ}$C)

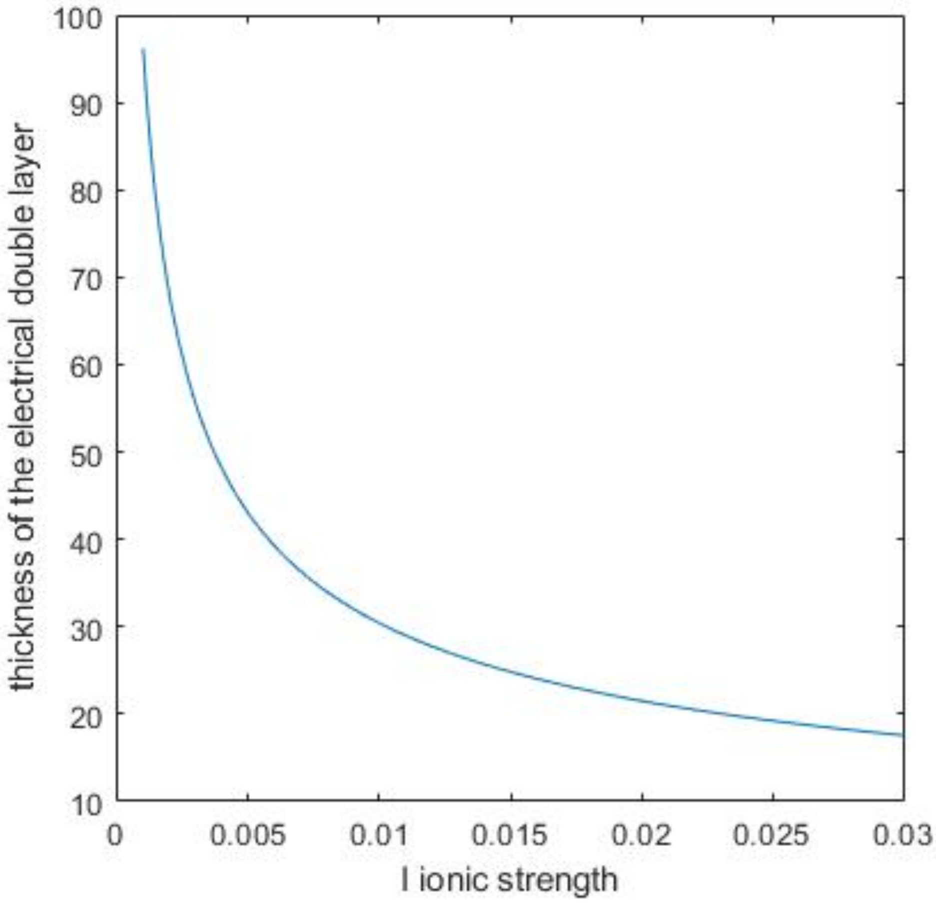
| Cation | Concentration | Anion | Concentration | Double layer Thickness |
|---|---|---|---|---|
| $Ca^{2+}$ | 40 | $HCO_3^-$ | 91.5 | 54.26 |
| $Mg^{2+}$ | 12.2 | $SO_4^{2-}$ | 72 | 36.55 |
| $Na^+$ | 15.1 | $Cl^-$ | 22.9 | 105.84 |
| $K^+$ | 5.1 | $NO_3^-$ | 5.0 | 267.68 |

*detailed calculate process by Python programming

2.

Using the same equation, Eq 9-4 $\kappa^{-1} = 10^{10} \times [\frac{2 \times 1000 \times e^2 \times N_A \times I}{\epsilon\epsilon_0 kT}]$

And I choose ionic strength range (I) is from 0.001M/L to 0.3M/L




* data visualization by Python programming

3. I assume that concentration of stock alum chemical as 8.37 percent as $Al_2O_3$ with a specific gravity of 1.32 and for stock chemical, alum concentration if reported as g/L $Al_2(SO_4)_3 \cdot 14H_2O$

Then Calculate the density of stock chemical: $\rho_{stock}$ = 1.32 1 kg/L = 1.32 kg/L

$C_{stock}$ = 0.0837 1.32 kg/L $10^3$ g/kg = 110.5 g/L $Al_2O_3$

$$Al^{3+} = 110.5g/LAl_2O_3 = 2.17mol/L$$

Then Calculate the stock alum concentration if reported as g/L $Al_2(SO_4)_3 \cdot 14H_2$ O.

$$C_{stock} = 110.5g/LAl_2O_3 = 643.5g/L\ alum$$

Calculate the chemical feed rate. By mass balance: $CstockQ_{feed}$ = CprocessQprocess

$$Q_{feed} = \frac{C_{preocess}Q_{process}}{C_{stock}} = \frac{(60mg/L \times 3800m^3/d \times 10^3L/m^3)}{643.5g/L \times 10^3mg/g \times 1440min/d} = 354.3\ L/d$$

Then Calculate the alkalinity consumed using Eq. 9-11

$$Alk = [60mg/L\ alum] \times (\frac{1mmol\ alum}{594mg\ alum}) \times (\frac{3mmol\ SO_4^{2-}}{mmol\ alum}) \times (\frac{2meqSO_4^{2-}}{mmolSO_4^{2-}})$$

$$\times (\frac{1meq\ alk}{meq\ SO_4^{2-}}) \times (\frac{50mg\ CaCO_3}{meq\ alk}) = 30\ mg/L \text{ as } CaCO_3$$

Then Calculate the precipitate formed using Eq. 9-11

$$[Al(OH)_3] = [60\ mg/L\ alum] \times (\frac{mmol\ alum}{594mg\ alum}) \times [\frac{2mmol\ Al(OH)_3}{mmol\ alum}] \times [\frac{78\ mg\ Al(OH)_3}{mmol\ Al(OH)_3}]$$

$$= 15.76\ mg/L\ alum$$

$$[Al(OH)_3] = \frac{15.76\ mg/L \times 3800m^3/d \times 10^3L/m^3}{10^6\ mg/kg} = 59.89\ kg/d$$

4.

Then Calculate the precipitate formed using Eq. 9-13

$$FeCl_3{\cdot}6H_2O \rightarrow Fe(OH)_3 + 3H^+ + 3Cl^- + 3H_2O$$

$$[Fe(OH)_3] = [60\ mg/L\ FeCl_3{\cdot}6H_2O] \times (\frac{mmol\ FeCl_3{\cdot}6H_2O}{418mg\ FeCl_3{\cdot}6H_2O}) \times [\frac{1mmol\ Fe(OH)_3}{mmol\ FeCl_3{\cdot}6H_2O}] \times [\frac{107\ mg\ Fe(OH)_3}{mmol\ Fe(OH)_3}]$$

$$= 15.36\ mg/L\ alum$$

Then Calculate the alkalinity consumed using Eq. 9-13

$$FeCl_3{\cdot}6H_2O \rightarrow Fe(OH)_3 + 3H^+ + 3Cl^- + 3H_2O$$

$$Alk = [60mg/L\ FeCl_3{\cdot}6H_2O] \times (\frac{1mmol}{418mg}) \times (\frac{3mmol\ Cl^-}{mmol}) \times (\frac{2meq\ Cl^-}{mmol\ Cl^-})$$

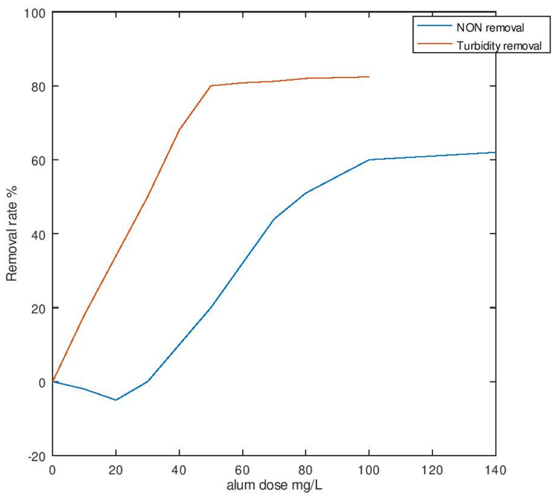
$$\times (\frac{1meq\ alk}{meq\ Cl^-}) \times (\frac{50mg\ CaCO_3}{meq\ alk}) = 43.06\ mg/L$$ as $CaCO_3$

5. The particulate fraction of NOM is easily removed from water following coagulation because particulate NOM is destabilized in the same way that inorganic particles are destabilized. The dissolved fraction of NOM, however, also interacts with coagulants and can complicate efforts to determine the correct coagulant dose for turbidity removal.

| Alum dose | DOC | Turbidity | NOM removal % | Turbidity removal % |
|---|---|---|---|---|
| 0 | 5 | 2.5 | 0 | 0 |
| 10 | 5.1 | 2.05 | -2 | 18 |
| 20 | 5.25 | 1.65 | -5 | 34 |
| 30 | 5 | 1.25 | 0 | 50 |
| 40 | 4.5 | 0.8 | 10 | 68 |
| 50 | 4 | 0.5 | 20 | 80 |
| 60 | 3.4 | 0.48 | 32 | 80.8 |
| 70 | 2.8 | 0.47 | 44 | 81.2 |
| 80 | 2.45 | 0.45 | 51 | 82 |
| 100 | 2 | 0.44 | 60 | 82.4 |
| 120 | 1.95 | Nan | 61 | Nan |
| 140 | 1.9 | Nan | 62 | Nan |

$$NOM\ removal_i = \frac{COD_0 - COD_i}{COD_0} \times 100\,\%$$

And $$Turbidity\ removal_i = \frac{Turbidity_0 - Turbidity_i}{Turbidity_0} \times 100\,\%$$




*detailed calculate process and data visualization by Python Programming

6.

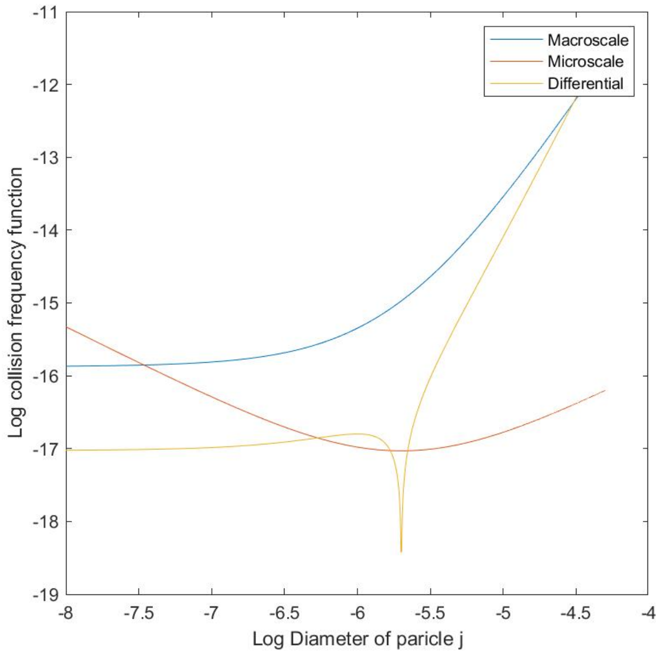
Using Eq 9-35 9-47 and 9-55

I assume the density of particle is $2560\ kg/m^3$

$$\beta_M = \frac{1}{6}\overline{G}(d_i + d_j)^3$$

$$\beta_\mu = (\frac{2kT}{3\mu})(\frac{1}{d_i} + \frac{1}{d_j})(d_i + d_j)$$

$$\beta_{DS} = \frac{\pi(\rho_p - \rho_l)g}{72\mu}[(d_i + d_j)^3(d_i - d_j)]$$

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7.

(a)

I assume the viscosity of the water is $1.31 \times 10^{-3}\ kg/m{\cdot}s$ Using Eq 9-62

$$Re = \frac{D^2 N_\rho}{\mu} = \frac{2^2 \times 20 \times 997}{60 \times 1.31 \times 10^{-3}\ kg/m{\cdot}s} = 1.01 \times 10^6$$

(b)

From the Table of 9-12, the power number and pumping number of Rushton turbine is 5 and 0.72, respectively.

Then, using the equation 9-63

$N_p = \dfrac{P}{\rho N^3 D^5}$ where P = power requirement and N is rotational speed

Then

$$P = N_p \rho N^3 D^5 = 5 \times 997 \times 25^3 \times 2^5 = 2.49 \times 10^6\ KW$$

(c)

Then, using the equation 9-64

$N_Q = \dfrac{Q}{ND^3}$ where $N_Q$ is pumping number and Q is flow rate imparted by impeller

Then

$$Q = N_Q N D^3 = 0.72 \times 25 \times 2^3 = 144\ m^3/s$$

8.

Using the Eq 9-68

$$\overline{G} = (\frac{P}{\mu V})^{1/2} = (\frac{\rho g h Q}{\mu V})^{1/2} = (\frac{\rho g h}{\mu \tau})^{1/2}$$

where

ρ = density of water, kg/m3

g = acceleration due to gravity, 9.81 m/s2

h = head loss through basin, m

μ = dynamic viscosity of water, N·s/m2 (kg/m·s)

τ = detention time, s

Then $\overline{G} = (\frac{P}{\mu V})^{1/2} = (\frac{7.79 \times 10^7}{1.139 \times 10^{-3} \times 64})^{1/2} = 1.85 \times 10^5 s^{-1}$

$$\tau = \frac{\rho g h}{\mu \overline{G}^2} = \frac{997 \times 9.81 \times 4}{1.139 \times 10^{-3} \times (1.85 \times 10^5)^2} = 0.001 s$$

9.

From the information given in Example 9-9, the Volume = 208.3 $m^3$ / stages

$$P = \overline{G}^2 \mu V = 30 \times 1.31 \times 10^{-3} \times 208.3 = 245.6 J/s$$

Substitute known values in the paddle power equation

$$P_s = \frac{\rho C_D A_p}{2}(V^3_{inside\ paddle} + V^3_{mille\ paddle} + V^3_{outside\ paddle}) = 2664.7 \times 2.85 \times 10^{-4} \times 9.321$$

Where

$$V_{inside\ paddle} = 0.67 - 0.15/2 = 0.595m$$

$$V_{middle\ paddle} = 1.33 - 0.15/2 = 1.255m$$

$$V_{outdie\ paddle} = 2 - 0.15/2 = 1.925m$$

Equate the required power determined in step 2 to meet the $\overline{G}$ value to the power required by the paddles as determined in step 3 above and solve for N:

$$N = (\frac{P}{P_s})^{\frac{1}{3}} = (\frac{246.3}{2664.7 \times 2.85 \times 10^{-4} \times 9.321})^{\frac{1}{3}} = 2.73\ rev/min$$