Coagulation with Alum

CENG 340–Introduction to Environmental Engineering
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Introduction

You have been asked to design a water treatment facility to meet the following criteria:

- Design capacity = 3.25 MGD
- Source is river water with an initial turbidity of 10 NTU, an alkalinity concentration of 50 mg/L, at 10 ^{0}C and pH = 7.
- Unit operations: coagulation (rapid mix), flocculation, sedimentation, rapid sand filtration, disinfection
- Additional Constraints: units must be sized according to acceptable ranges. Design must accommodate maintenance and repair.

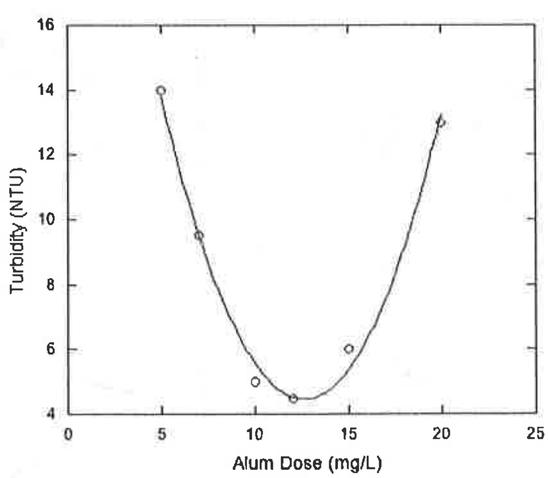
Today, you will design the rapid mix tank used for coagulation.

Background

The purpose of coagulation is to neutralize the charge of small particles (or colloids) in raw (untreated) water, so they can adhere to each other in the subsequent flocculation process. A positively charged *coagulant* is added to water to accomplish coagulation. The most commonly used coagulant is aluminum (Al^{3+}) added as alum $Al_2(SO_4)_3 \bullet 14H_2O$.

Alum Dose:

Estimate the optimal alum dose for turbidity removal based on the following results of a jar test:



Alum

Optimal dose ≅ 12.5 mg/L

Consumption of Alkalinity in units of $CaCO_3$

Estimate the alkalinity consumed at the optimal dosage using the following chemical reaction (Eq. 10.1 on p. 412 of the textbook):

594 g/mole

$$Al_2(SO_4)_3 \bullet 14H_2O + 6\,HCO_3^- \rightarrow 2\,Al(OH)_{3(s)} + 3\,SO_4^{2-} + 6\,CO_2 + 14\,H_2O$$

$$12.5\ \frac{mg\ alum}{L} \times \frac{1\ mole\ alum}{594\ g} \times \frac{6\ eq\ alk}{1\ mol\ alum} \times \frac{100\ g\ CaCO_3}{2\ eq} = 6.3\ mg/L \text{ as } CaCO_3$$

Addition of Alkalinity

If the raw water had an alkalinity of 25 mg/L as calcium carbonate, how much alkalinity (in tons per year) would the plant need to add to the rapid mix tank?

Have 25, need 6.3 for alum addition & coagulation

Since $25 > 6.3$, don't need to add alkalinity

Size and Power

Size a rapid-mix tank and determine the power requirements for coagulation? To do so you will need to use *typical values* used in the design of rapid-mix tanks. The following values were taken from Table 10.13 in the textbook:

Table 1: Typical values used in design of a rapid-mixing system (adapted from Mihelcic and Zimmerman).

System Category	RMS Velocity Gradient, $\bar{G}$ (s^{-1})	Retention Time, θ, (s)	$\bar{G}t$ Values
Mechanical Mixing	600–1,000	60–120	5.0×10^3 to 5.0×10^5
In-line Mixing	3,000–5,000	1	5.0×10^3 to 5.0×10^5

Volume

Given: $Q = 3.25\times10^6$ G/day

$T = 10°C \Rightarrow \mu = 1.307\times10^{-3}\ \frac{N \cdot s}{day}$

Pick θ from Table: $\theta = 1$ min

$\forall = \theta \times Q = 3.25\times10^6\ gal/day \times 1\ min \times \frac{1\ day}{24\ h} \times \frac{1\ h}{60\ min} =$

$\forall = 2257$ Gal

Since $\theta = 1$-2 min, say $\forall = 2300$ Gal

Specify FRP tank, and don't need spare.

fiberglass reinforced plastic

Power

$P = \bar{G}^2 \mu V$; choose $\bar{G} = 800\ s^{-1}$

$P = (800\ s^{-1})^2 \times 1.307\times10^{-3}\ \frac{N \cdot s}{m^2} \times 2300\ gal$

$\times\ 3.785\ L/gal \times 1\ \frac{m^3}{L}$

$P = 7282\ \frac{N \cdot m}{s} = 7282\ \frac{J}{s} = 7.3\ kW$

(round up)

Specify 2 mixers w/ $P = 8$ kW, one spare.