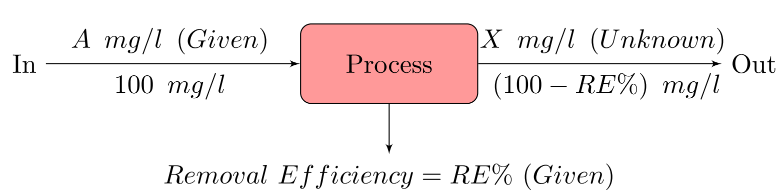
PROCESS REMOVAL RATES OR EFFICIENCY

- Process removal rate or removal efficiency is the percentage of the inlet concentration removed.
- It is used for quantifying the pollutant removal during wastewater treatment and is established based upon the amount of a particular wastewater constituent entering and leaving a treatment process.
- $Process\ \ Removal\ \ Rate\ \ (\%) = \dfrac{Pollutant\ \ In - Pollutant\ \ Out}{Pollutant\ \ In} * 100$
- If 10 units of a pollutant are entering a process and 8 units of pollutant are leaving (process removes 2 units), then the process removal rate for that pollutant is (10-8)/10*100=20%. In this example the process is 20% efficient in removing that particular pollutant.
- The amount of pollutant can be measured in terms of concentration (mg/l) or in terms of mass loading (lbs). The pounds formula is used for calculating the mass loadings.

The above example is for calculating the removal efficiency using the inlet and outlet concentrations or mass loading.

The methods below can be used for calculating either the inlet or outlet pollutant concentrations, if the removal efficiency and the corresponding inlet or outlet concentrations are given.

Case 1: Calculating outlet conc. (X) given the inlet conc. and removal efficiency (RE%):



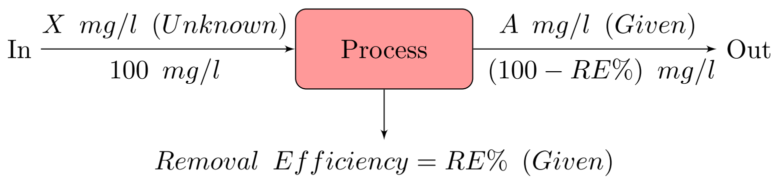
Using the fact that if the inlet concentration was 100 mg/l, the outlet concentration would be 100 minus the removal efficiency.

Setup the equation as: $\dfrac{Out}{In} : \ \dfrac{X\ \ mg/l}{A\ \ mg/l} = \dfrac{100 - RE\%}{100}$

Calculate X using cross multiplication - if $\dfrac{A}{B} = \dfrac{C}{D} \implies A = B * \dfrac{C}{D}$:

$X\ \ mg/l = A\ \ mg/l * \dfrac{100 - RE\%}{100}$

Case 2: Calculating inlet conc. (X) given the outlet conc. and removal efficiency (RE%):



Using the fact that if the inlet concentration was 100 mg/l, the outlet concentration would be 100 minus the removal efficiency.

Setup the equation as: $\dfrac{In}{Out}$: $\dfrac{X\ \ mg/l}{A\ \ mg/l} = \dfrac{100}{100 - RE\%}$

Calculate X using cross multiplication - if $\dfrac{A}{B} = \dfrac{C}{D} \implies A = B * \dfrac{C}{D}$:

$X\ \ mg/l = A\ \ mg/l * \dfrac{100}{100 - RE\%}$

1. Given the following for a primary sedimentation tank: TSS removal efficiency = 63% Effluent TSS concentration = 95 mg/L Calculate the influent TSS concentration (mg/L) Correct Answer(s):

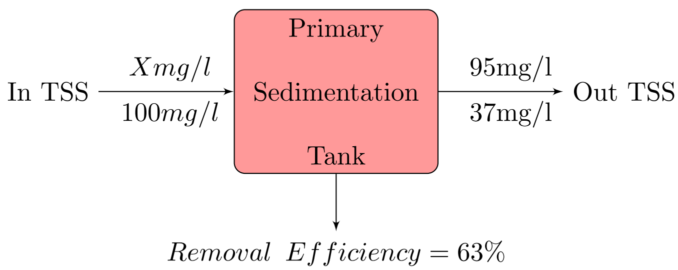
   *a. 257

   b. 356

   c. 94

   d. 220

   Solution:



$$\frac{In}{Out} \quad : \quad \frac{Actual\ \ inlet\ \ (X)}{95} = \frac{100}{100-63}$$
$$\implies \frac{Actual\ \ inlet\ \ (X)}{95} = 2.7$$

   Rearranging the equation: $Actual\ \ inlet(X) = 2.7 * 95 = \boxed{257mg/l}$

2. What is the clarifier influent TSS if its outlet concentration is 60 mg/l and the known clarifier removal efficiency is 75%?

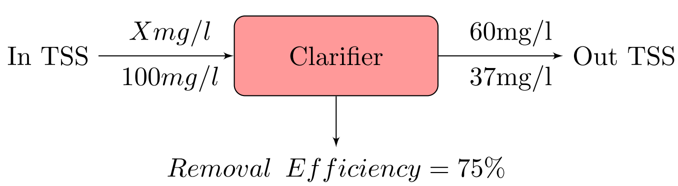
   *a. 240 mg/l

   b. 300 mg/l

   c. 80 mg/l

   d. 120 mg/l

   Solution:



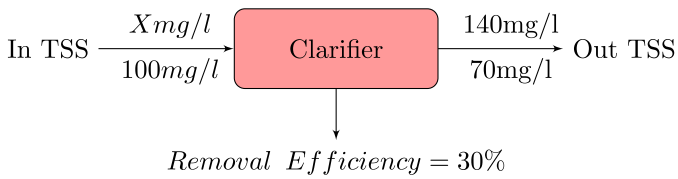
$$\frac{In}{Out} \quad : \quad \frac{Actual\ \ inlet\ \ (X)}{60} = \frac{100}{100-75}$$

$$\implies \frac{Actual\ \ inlet\ \ (X)}{60} = 4$$

Rearranging the equation: $Actual\ \ inlet(X) = 4 * 60 = \boxed{240mg/l}$

3. If a primary clarifier consistently operates at 30% efficiency and produces an effluent which averages 140 mg/l BOD, what is the influent BOD?

   Solution:



$$\frac{In}{Out}\ :\ \frac{Actual\ \ inlet\ \ (X)}{140} = \frac{100}{100-30}$$
$$\implies Actual\ \ inlet\ \ (X) = \frac{140*100}{70} = \boxed{200mg/l}$$

4. What is the clarifier removal efficiency if the inlet and outlet concentrations are 300 mg/l and 60 mg/l respectively?

   a. 20%

   b. 30%

   *c. 80%

   d. 72%

5. A primary clarifier has an influent suspended solids concentration of 250 mg/L. If the suspended solids removal efficiency is 60%, what is the primary effluent suspended solids concentration?

   a. 10 mg/L

   *b. 100 mg/L

   c. 50 mg/L

   d. 150 mg/L

6. The influent to a trickling filter plant is 200 mg/L and the effluent BOD is 20 mg/L. What is the BOD removal efficiency (%)? Correct Answer(s):

   a. 90.0

7. If a plant removes 35% of the influent BOD in the primary treatment and 85% of the remaining BOD in the secondary system, what is the BOD removal (lbs/day), if the BOD of the final effluent is 20mg/l

   a. 2445 lbs/day *b. 2211 lbs/day c. 3800 lbs/day d. 4200 lbs/day

8. If a plant removes 35% of the influent BOD in the primary treatment and 85% of the remaining BOD in the secondary system, what is the BOD of the raw wastewater if the BOD of the final effluent is 20mg/l

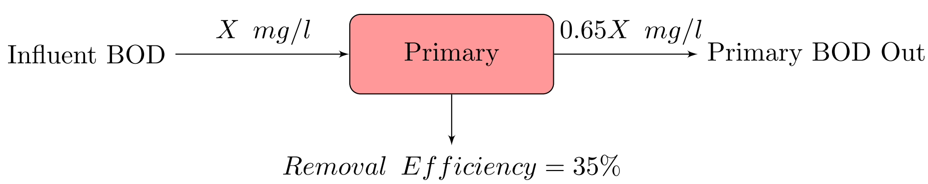
   a. 48 mg/l

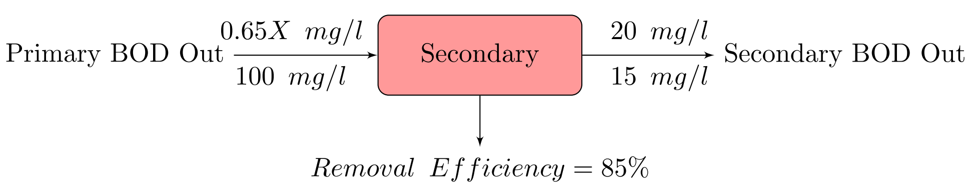
   b. 67 mg/l

   c. 86.7 mg/l

   d. 155 mg/l

   *e. 205 mg/l Solution:





For the Secondary process:

$$\frac{In}{Out}:\quad \frac{0.65X}{20} = \frac{100}{15} \implies X\ \ mg/l = \frac{100*20}{15*0.65} = \boxed{205\ \ mg/l}$$

Alternate Solution #1

$$\xrightarrow[\text{X}\frac{mg}{l}]{\text{Influent BOD}} \boxed{Primary} \xrightarrow[\text{X-0.35X=X*(1-0.35)=0.65X}\frac{mg}{l}]{\text{Primary Effluent BOD}} \boxed{Secondary} \xrightarrow[\text{0.65X-0.5525X=(0.65-0.5525)X=0.0975X}]{\text{Secondary Effluent BOD}}$$

$\downarrow$ (0.35X)BOD Removed $\qquad$ $\downarrow$ (0.65*0.85)X = 0.5525X BOD Removed

$$\implies 0.0975X = 20 \implies X = \frac{20}{0.0975} = \boxed{205\frac{mg}{l}}$$

Alternate Solution #2:

$$\xrightarrow[\text{X}\frac{mg}{l}]{\text{Influent BOD}} \boxed{Primary} \xrightarrow[\text{0.65X}]{\text{Primary Effluent BOD}} \boxed{Secondary} \xrightarrow[\text{(0.65*0.15)X}]{\text{Secondary Effluent BOD}}$$

$\downarrow$ (0.35X)BOD Removed $\qquad$ $\downarrow$ (0.65X*0.85)BOD Removed

Primary Effluent BOD = Influent BOD * (1-Primary BOD Removal), and

Secondary Effluent BOD=[Primary Effluent BOD]*(1-Secondary BOD Removal)

Secondary Eff. BOD=[Influent BOD * (1-Primary BOD Removal)]*(1-Secondary BOD Removal)

Therefore, 20 = [X*(1-0.35)] * (1-0.85)= X*0.65*0.15

$$\implies 20\ \frac{mg}{l} = 0.0975X \implies X = \frac{20}{0.0975} = \boxed{205\ \frac{mg}{l}}$$

9. Calculate the inlet concentration if the outlet concentration is 80 mg/l and the process removal efficiency is 60%

$$\text{In} \xrightarrow[100mg/l]{Xmg/l} \boxed{\text{Process}} \xrightarrow[\text{40mg/l}]{\text{80mg/l}} \text{Out}$$

$$\downarrow$$

$$Removal\ \ Efficiency = 60\%$$

$$\frac{In}{Out}\ :\ \frac{Actual\ \ inlet\ \ (X)}{80} = \frac{100}{100-60}$$
$$\implies \frac{Actual\ \ inlet\ \ (X)}{80} = 2.5$$

Rearranging the equation: $Actual\ \ inlet(X) = 2.5 * 80 = \boxed{200mg/l}$

10. Calculate the outlet concentration if the inlet concentration is 80 mg/l and the process removal efficiency is 60%

Solution:

$$\text{In} \xrightarrow[100mg/l]{80mg/l} \boxed{\text{Process}} \xrightarrow[\text{40mg/l}]{Xmg/l} \text{Out}$$

$$\downarrow$$

$$Removal\ \ Efficiency = 60\%$$

$$\frac{Out}{In}\ :\ \frac{Actual\ \ Outlet(X)}{80} = \frac{100-60}{100}$$
$$\implies \frac{Actual\ \ Outlet(X)}{80} = 0.4$$
$$\implies Actual\ \ Outlet(X) = 0.4 * 80 = \boxed{32mg/l}$$

11. Calculate the primary clarifier influent solids concentration if its outlet concentration is 60 mg/l and the known clarifier removal efficiency is 75%?

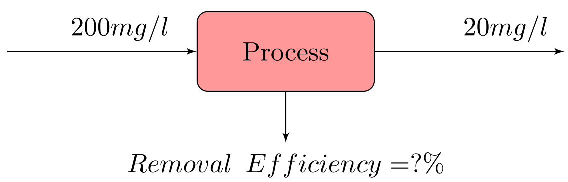
$$\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$$
$$\frac{Actual\ \ inlet\ \ (X)}{60} = \frac{100}{100 - 75} = 4$$
$$\implies Actual\ \ inlet\ \ (X) = 4 * 60 = \boxed{240mg/l}$$

12. What is the % removal efficiency if the influent concentration is 10 mg/L and the effluent concentration is 2.5 mg/L?

$$Removal\ \ Rate(\%) = \frac{In - Out}{In} * 100 \implies \frac{10 - 2.5}{10} * 100 = \boxed{75\%}$$

13. The influent to a trickling filter plant is 200 mg/L and the effluent BOD is 20 mg/L. What is the BOD removal efficiency (%)?

Solution:



$$Removal\ \ Efficiency\ \ (\%) = \frac{In - Out}{In} * 100 \implies \frac{200 - 20}{200} * 100 = \boxed{90\%}$$

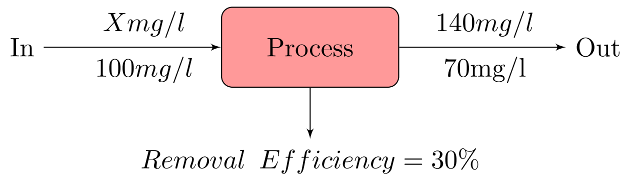
14. Calculate the primary clarifier influent solids concentration if its outlet concentration is 60 mg/l and the known clarifier removal efficiency is 75%?

$$\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$$
$$\frac{Actual\ \ inlet\ \ (X)}{60} = \frac{100}{100 - 75} = 4$$
$$\implies Actual\ \ inlet\ \ (X) = 4 * 60 = \boxed{240mg/l}$$

15. If a primary clarifier consistently operates at 30% efficiency and produces an effluent which averages 140 mg/l BOD, what is the influent BOD?

Solution:

$$\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$$



$$\frac{Actual\ \ inlet\ \ (X)}{140} = \frac{100}{100-30} = 1.43$$
$$\implies Actual\ \ inlet\ \ (X) = 1.43 * 140 = \boxed{200 mg/l}$$

16. If a primary clarifier consistently operates at 30 % efficiency and produces an effluent which averages 140 mg/l BOD, what is the influent BOD?

a. 100 mg/l

b. 125 mg/l

c. 175 mg/l

*d. 200 mg/l

e. 225 mg/l

17. A primary clarifier has an influent suspended solids concentration of 250 mg/L. If the suspended solids removal efficiency is 60%, what is the primary effluent suspended solids concentration

a. 10 mg/L

*b. 100 mg/L

c. 50 mg/L

d. 150 mg/L

18. The influent to a trickling filter plant is 200 mg/L and the effluent BOD is 20 mg/L. What is the BOD removal efficiency (%)?

a. 20%

*b. 90%

c. 10%

d. 180%

19. A 3.1 MGD flow with a 190 mg/l TSS concentration is treated in a primary clarifier which averages

55% removal efficiency. Calculate the pounds/day TSS in the primary effluent.

a. 2701 lbs/day

*b. 2211 lbs/day

c. 3800 lbs/day

d. 4200 lbs/day

20. Calculate the outlet concentration if the inlet concentration is 80 mg/l and the process removal efficiency is 60%

*a. 32mg/l

b. 63mg/l

c. 20mg/l

d. 48mg/l

21. What is the % removal efficiency if the influent concentration is 10 mg/L and the effluent concentration is 2.5 mg/L?

a. 25%

b. 97.5%

*c. 75%

d. 2.5%

22. A rectangular sedimentation tank is 85 feet long, 35 feet wide, and 14 feet deep including 3 feet of freeboard. Flow to this tank is 2.3 MGD. Calculate the surface loading to this tank in gpd per ft2.

a. 318 gpd/ft2

*b. 773 gpd/ft2

c. 845 gpd/ft2

d. 1932 gpd/ft2

23. If a primary clarifier consistently operates at 30 % efficiency and produces an effluent which averages 140 mg/l BOD, what is the influent BOD?

a. 100 mg/l

b. 125 mg/l

c. 175 mg/l

*d. 200 mg/l

24. A primary clarifier has an influent suspended solids concentration of 250 mg/L. If the suspended solids removal efficiency is 60%, what is the primary effluent suspended solids concentration

a. 10 mg/L

*b. 100 mg/L

c. 50 mg/L

d. 150 mg/L

25. The influent to a trickling filter plant is 200 mg/L and the effluent BOD is 20 mg/L. What is the BOD removal efficiency (%)?

a. 20%

*b. 90%

c. 10%

d. 180%

26. A 3.1 MGD flow with a 190 mg/l TSS concentration is treated in a primary clarifier which averages 55% removal efficiency. Calculate the pounds/day TSS in the primary effluent.

a. 2701 lbs/day

*b. 2211 lbs/day

c. 3800 lbs/day

d. 4200 lbs/day

27. Calculate the outlet concentration if the inlet concentration is 80 mg/l and the process removal efficiency is 60%

*a. 32mg/l

b. 63mg/l

c. 20mg/l

d. 48mg/l

28. What is the % removal efficiency if the influent concentration is 10 mg/L and the effluent concentration is 2.5 mg/L?

a. 25%

b. 97.5%

*c. 75%

d. 2.5%

29. Use the information below to answer the following questions.

Plant Flow: 4.5 MGD

Influent P concentration: 1.5 mg/l

Aeration tank volume: 2000 cu.ft.

Effluent P concentration: 0.5 mg/l

What is the phosphorus removal efficiency?:

a. 34 percent

b. 67 percent

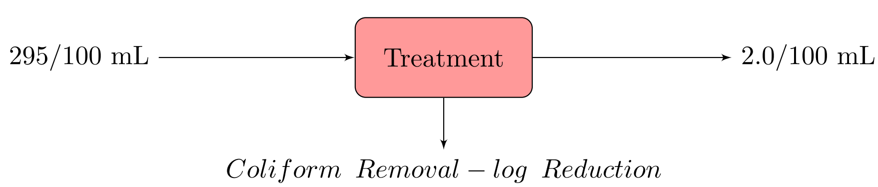
c. 1.0 percent

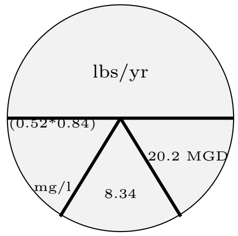
d. 10 percent

Solution:

$$\frac{1.5 - 0.5}{1.5} * 100 = \boxed{67\%}$$

30. Calculate the log removal for a water treatment plant if the samples show a raw water coliform count of 295/100 mL (through extrapolation) and the finished water shows 2.0/100 mL. a. 1.8 log removal b. 2 log removal c. 2.1 log removal *d. 2.2 log removal





Log Reduction = $\log_{10} C_{In}$ - $\log_{10} C_{Out}$ = $\log_{10}$ 295 - $\log_{10}$ 2 = 2.47 - 0.30 = $\boxed{2.17\ \textit{log removal}}$

31. Which is the percentage of removal across a settling basin, if the influent is 17.1 NTU and the effluent is 1.13 NTU ?

32. Calculate the percent removal across a settling basin and filter complex, if the raw water influent is 5.45ntu and the effluent (post filters) is 0.018ntu. Give answer to three significant figures.

33. Calculate the amount of iron removed in pounds per year from a water plant that treats an average of 20.2mgd if the average iron concentration is 0.52 mg/l and the removal efficiency is 84 %.

    a. 26,859lb/yr of Fe removed

    *b. 27,000lb/yr of Fe removed

    c. 31,975lb/yr of Fe removed

    d. 32,000lb/yr of Fe removed

$$\frac{\text{lbs}}{\text{yr}} = \text{Flow}\frac{\text{MG}}{\text{yr}} * \text{Concentration iron removed}\frac{\text{mg}}{\text{l}} * 8.34$$

$$\frac{\text{lbs}}{\text{day}} = 20.2\frac{\text{MG}}{\cancel{\text{day}}} * 365\frac{\cancel{\text{days}}}{\text{yr}} * (20.2 * 0.84)\frac{\text{mg}}{\text{l}} * 8.34 = \boxed{26,859\frac{lbs}{yr}}$$

34. Determine the amount of iron removed per year, if the iron concentration is 0.21 mg/l, the plant treats an average of 14.1mgd, and the removal efficiency is 95.7% (0.957).

    a. 8,000lb/yr

    b. 8,200lb/yr

    *c. 8,600lb/yr

    d. 9,000lb/yr

A: $(0.21 * 0.957)\frac{mg}{l} * 14.1\frac{MG}{day} * 8.34 * 365\frac{days}{yr} = \boxed{8,626 \ \ lbs/day}$