Ops Cert: Loading, Removal and BOD Math

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This program is made possible under a cooperative agreement with US EPA.

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Weekly Wastewater Technical Assistance Office Hours

- Troubleshooting, operator certification, training, financials, FOG and other Pretreatment topics, etc.
- Tuesdays 11am-12pm (MST)
- Zoom
- Contact: A.J. Barney ajbarney1@unm.edu
  James Markham jmarkham@unm.edu

Or leave your email in the chat and we will send you a link

Operator Certification

- Certification programs are regulated by the states
  - Texas- TCEQ, New Mexico- NMED, Oklahoma- ODEQ
- Certification levels (1-4, D-A, etc.)
  - Complexity of the system
  - Population
  - Experience
- Available resources
  - California State University, Sacramento- Wastewater operation manuals
  - State distributed resources and need to know lists
- Certification exam- Study!!

Overview

Math Review

Loading and Types of Loading

Removal

Biochemical Oxygen Demand (BOD)

Math Review

Surface Area: $Circle = \pi r^2 = \pi \frac{D^2}{4}$

$Square\ or\ Rectangle = l \times w$

Volume: $Circle = h\pi r^2 = h\pi \frac{D^2}{4}$

$Square\ or\ Rectangle = l \times w \times h$

Concentration: $\frac{mass}{volume}$ $\quad \frac{mg}{L} = ppm$ $\quad 10{,}000 \frac{mg}{L} = 1\%$

Flow: $\frac{volume}{time}$ $\quad velocity \times area$

Math Review Cont'd

Word Problems

1. Identify givens and what you are trying to find
2. Identify needed equations and unit conversions
3. Set up equations and rearrange if needed, then plug in givens
4. Cancel units and solve
5. Check units and decide if the answer makes sense

Wastewater Loading

Loading is the measurement of the amount of a given constituent (X) introduced into a system over time.

$$Loading\ Rate\ for\ X\left(\frac{lbs}{day}\right) = X\ Conc.\left(\frac{mg}{L}\right) \times Flow\ (MGD) \times 8.34\frac{lbs}{gallon}$$

Loading Sample Problem

You work at a wastewater treatment plant (WWTP) with a 900,000 gallon a day flow. You perform a total solids (TS) test by drying a sample of the flow and find that the TS concentration is 1014 mg/L. What is the approximate total suspended solids (TSS) loading of this wastewater if TSS makes up approximately 20% of the sample?

$$Loading\ Rate\ for\ X\left(\frac{lbs}{day}\right) = X\ Conc.\left(\frac{mg}{L}\right) \times Flow\ (MGD) \times 8.34\frac{lbs}{gallon}$$

Loading Sample Problem

1) Identify givens and what we are trying to find.

You work at a wastewater treatment plant (WWTP) with a 900,000 gallon a day flow. You perform a total solids (TS) test by drying a sample of the flow and find that the TS concentration is 1014 mg/L. What is the approximate TSS loading for this plant if TDS makes up approximately 20% of the sample?

2) Identify needed formulas

$$Loading\ Rate\ for\ TDS\left(\frac{lbs}{day}\right) = 20\%\ TS\left(\frac{mg}{L}\right) \times Flow\ (MGD) \times 8.34\frac{lbs}{gallon}$$

Loading Sample Problem

3) Set up equations and rearrange if needed, then plug in givens

$$\frac{20\cancel{\%}}{100\cancel{\%}} = .2$$

$$900{,}000\frac{\cancel{gal}}{day} \times \frac{MG}{1{,}000{,}000\cancel{gal}} = .9MGD$$

$$Loading\ Rate\ for\ TDS\left(\frac{lbs}{day}\right) = \left(.2 \times 1014\frac{mg}{L}\right).9MGD \times 8.34\frac{lbs}{gallon}$$

Loading Sample Problem

4) Cancel Units and Solve

$$\frac{mg}{L} = ppm = \frac{1}{10^6} = \frac{1}{M}$$

$$TSS\ Loading\left(\frac{lbs}{day}\right) = \left(.2 \times 1014\frac{1}{\cancel{10^6}}\right) \times .9\cancel{MG}D \times 8.34\frac{lbs}{\cancel{gallon}} = 6088.9\frac{lbs}{day}$$

5) Check Units and if the answer makes sense

Loading Practice Problem

The mercury (Hg) limit for most WWTPs is .008 µg/L. You would like to limit loading into the river that the WWTP discharges to, to .001 lbs/day. What is the maximum flow allowed to achieve this goal if the plant is at its Hg limit every day?

$$Loading\ Rate\ for\ X\left(\frac{lbs}{day}\right) = X\ Conc.\left(\frac{mg}{L}\right) \times Flow\ (MGD) \times 8.34\frac{lbs}{gallon}$$

$$1mg = 1000\mu g$$

Loading Practice Problem

Givens: Hg conc. = .008$\frac{\mu g}{L}$ Hg loading = .001$\frac{lbs}{day}$

$$Flow(MGD) = \frac{\text{Hg}\ loading\left(\frac{lbs}{day}\right)}{Hg\ conc.\left(\frac{mg}{L}\right) \times 8.34\frac{lbs}{gallon}}$$

Loading Practice Problem

Givens: Hg conc. = .008$\frac{\mu g}{L}$ Hg loading = .001$\frac{lbs}{day}$

$$.008\frac{\mu g}{L} \times \frac{mg}{1000\mu g} = .000008mg = 8 \times 10^{-6}mg$$

$$Flow(MGD) = \frac{.001\frac{\cancel{lbs}}{day}}{8 \times 10^{-6}\frac{1}{10^6} \times 8.34\frac{\cancel{lbs}}{gallon}} = 15MGD$$

Surface Loading Rate (SLR)

Primary and Secondary Clarifiers: 300-1,200 GPD/ft^2

Trickling Filter Clarifiers: 800-1,200 GPD/ft^2

$$SLR(\frac{GPD}{ft^2}) = \frac{Flow\ (GPD)}{SA\ (ft^2)}$$

SLR Practice Problem

A primary clarifier with a diameter of 42 ft has a flow of 1.1 MGD. What is the SLR of this clarifier?

$$SA\ Circle = \pi r^2 = \pi\frac{D^2}{4}$$

$$SLR(\frac{GPD}{ft^2}) = \frac{Flow\ (GPD)}{SA\ (ft^2)}$$

SLR Practice Problem

A primary clarifier with a diameter of 42 ft has a flow of 1.1 MGD. What is the SLR of this clarifier?

$$SA = \pi\frac{(42ft)^2}{4} = 1385.4ft^2$$

$$SLR\left(\frac{GPD}{ft^2}\right) = \frac{1{,}100{,}000GPD}{1385.4ft^2} = 794\frac{GPD}{ft^2}$$

Weir Overflow Rate

Indicates the relationship between the flow that a clarifier is designed for and the length of its weir, and is important to prevent short circuiting.

Weir Overflow Rate = 10,000-20,000 GPD/ft

$$Weir\ Overflow\ Rate\left(\frac{GPD}{ft}\right) = \frac{Flow\ (GPD)}{ft}$$

$$Circumference(ft) = Diamter(ft) \times \pi$$

Weir Overflow Rate Practice Problem

What is the weir overflow rate of the clarifier from the previous practice problem with a flow of 1.1 MGD and a diameter of 42ft?

$$Weir\ Overflow\ Rate\left(\frac{GPD}{ft}\right) = \frac{Flow\ (GPD)}{ft}$$

$$Circumference(ft) = Diamter(ft) \times \pi$$

Weir Overflow Rate Practice Problem

What is the weir overflow rate of the clarifier from the previous practice problem with a flow of 1.1 MGD and a diameter of 42ft?

$$Circumference = 42ft \times \pi = 131.9ft$$

$$Weir\ Overflow\ Rate\left(\frac{GPD}{ft}\right) = \frac{1{,}100{,}000GPD}{131.9ft} = 8337\frac{GPD}{ft}$$

Solids Loading

Amount of solids removed by a clarifier

Secondary Clarifiers: 24-30 lbs/day/ft2

$$Solids\ Loading\ Rate(\frac{lbs}{day \times ft^2}) = \frac{Solids\ Applied\,\frac{lbs}{day}}{SAft^2}$$

$$Solids\ Applied\left(\frac{lbs}{day}\right) = Flow(MGD) \times SS\left(\frac{mg}{L}\right) \times \frac{8.34lbs}{gal}$$

Solids Loading Practice Problem

A secondary clarifier also with a diameter of 42 ft and a flow of 1MGD has a MLSS concentration of 4000 mg/L. What is the solids loading rate of this clarifier?

$$Solids\ Loading\ Rate(\frac{lbs}{day \times ft^2}) = \frac{Solids\ Applied\,\frac{lbs}{day}}{SAft^2}$$

$$Solids\ Applied\left(\frac{lbs}{day}\right) = Flow(MGD) \times SS\left(\frac{mg}{L}\right) \times \frac{8.34lbs}{gal}$$

Solids Loading Practice Problem

A secondary clarifier also with a diameter of 42 ft and a flow of 1.1MGD has a MLSS concentration of 4000 mg/L. What is the solids loading rate of this clarifier?

$$Solids\ Applied\left(\frac{lbs}{day}\right) = 1.1\cancel{MG}D \times 4000\frac{\cancel{mg}}{\cancel{L}} \times \frac{8.34lbs}{\cancel{gal}} = 36{,}696\frac{lbs}{day}$$

$$Solids\ Loading\ Rate\left(\frac{lbs}{day \times ft^2}\right) = \frac{36{,}696\,\frac{lbs}{day}}{1385.4ft^2} = 26.5\frac{lbs}{day \times ft^2}$$

Organics Loading (BOD)

Trickling Filters

$$Organics\ Loading\left(\frac{lbs\ BOD}{day \times ft^2}\right) = \frac{BOD\ Applied(\frac{lbs}{day})}{SA}$$

$$BOD\ Applied\left(\frac{lbs}{day}\right) = \text{Flow(MGD)} \times BOD\frac{mg}{L} \times 8.34\frac{mg}{L}$$

Organics Loading (BOD)

Rotating Biological Contactors (RBC)

$$Organics\ Loading\left(\frac{lbs\ BOD}{day \times ft^2}\right) = \frac{Soluable\ BOD\ Applied(\frac{lbs}{day})}{SA}$$

$$Soluable\ BOD\ \left(\frac{lbs}{day}\right) = \text{Total}\ BOD\frac{mg}{L} - (K \times SS\frac{mg}{L})$$

Organics Loading (BOD)

Activated Sludge- BOD is effluent conc. Of primary clarifiers

$$Organics\ Loading\left(\frac{lbs\ BOD}{day}\right) = flow(MGD) \times BOD(\frac{mg}{L}) \times 8.34\frac{lbs}{gal}$$

Ponds

$$Organics\ Loading\left(\frac{lbs\ BOD}{day \times acre}\right) = \frac{flow(MGD) \times BOD\frac{mg}{L} \times 8.34\frac{lbs}{gal}}{SA\ (acres)}$$

Removal Efficiency

Shows how effective a process is at removing a desired constituent.

$$Removal\ Efficiency\ (\%) = \frac{C_{inf} - C_{eff}}{C_{inf}} \times 100\%$$

Plant Removal Efficiencies

Parameter	Influent Concentration	Effluent Goal	Minimum Removal Efficiency
BOD5	200 mg/L	< 30 mg/L	85.00%
TSS	200 mg/L	< 30 mg/L	85.00%
Settleable Solids	10 mL/L	< 0.1 mg/L	99.00%
TKN (Ammonia + Organic Nitrogen	30 mg/L	< 10 mg/L Total Nitrogrn	66.67%
Phosphorus	2.0 mg/L	< 1.0 mg/L	50.00%

Removal Efficiency Sample Problem

The average influent BOD of a WWTP that utilizes aeration basins as their biological process is 321 mg/L and the effluent is 26 mg/L. What is the removal efficiency of this plant?

$$Removal\ Efficiency\ (\%) = \frac{C_{inf} - C_{eff}}{C_{inf}} \times 100\%$$

Removal Efficiency Sample Problem

1) Identify givens and what we are trying to find.

The average influent BOD of a WWTP that utilizes aeration basins as their biological process is 321 mg/L and the effluent is 26 mg/L. What is the removal efficiency of this plant?

2) Identify needed formulas

$$Removal\ Efficiency\ (\%) = \frac{C_{inf} - C_{eff}}{C_{inf}} \times 100\%$$

Removal Efficiency Sample Problem

3) Set up equations and rearrange if needed, then plug in givens

$$Removal\ Efficiency\ (\%) = \frac{321\frac{mg}{L} - 26\frac{mg}{L}}{321\frac{mg}{L}} \times 100\%$$

Removal Efficiency Sample Problem

4) Cancel Units and Solve

$$Removal\ Efficiency\ (\%) = \frac{295\cancel{\frac{mg}{L}}}{321\cancel{\frac{mg}{L}}} \times 100\% = 91.9\%$$

5) Check Units and if the answer makes sense

Removal Efficiency Practice Problem

The operators of the same WWTP with an influent BOD of 321 mg/L would like to increase their removal efficiency to 99%. What would the required effluent BOD need to be to meet this goal?

$$Removal\ Efficiency\ (\%) = \frac{C_{inf} - C_{eff}}{C_{inf}} \times 100\%$$

Removal Efficiency Practice Problem

The operators of the same WWTP with an influent BOD of 321 mg/L would like to increase their removal efficiency to 99%. What would the required effluent BOD need to be to meet this goal?

$$C_{eff} = C_{inf} - \frac{C_{inf} \times Removal\ Efficiency\ (\%)}{100\%}$$

Removal Efficiency Practice Problem

The operators of the same WWTP with an influent BOD of 321 mg/L would like to increase their removal efficiency to 99%. What would the required effluent BOD need to be to meet this goal?

$$C_{eff} = 321\frac{mg}{L} - \frac{321\frac{mg}{L} \times 99\cancel{\%}}{100\cancel{\%}} = 3.21\frac{mg}{L}$$

Biochemical Oxygen Demand

The amount of oxygen consumed by wastewater and its impact on receiving water.

It is referred to as the strength of the wastewater.

Microorganisms in the WW and in receiving water consume organics, non-organics, and other microorganisms, which utilize dissolved oxygen.

Excessive BOD increases the effects of Eutrophication and the two are closely related.

BOD Analysis

BOD_5 Test

Volume: 300 mL

Temp: 20°C

Time: 5-day

Measure the difference between O_2 at the beginning of the test and after 5 days. Bottle is seeded with nutrients (N, P, K, etc.)

BOD Sample Problem

A standard sample of WW used for a 5-day, 20°C BOD test results in 84.5 mg of oxygen consumed. What is the BOD of this wastewater? Volume = 300 mL

$$BOD\ Concentration\left(\frac{mg}{L}\right) = \frac{O_2 consumed\ (mg)}{Sample\ Volume\ (L)}$$

$$\frac{84.5\ mg}{.3L} = 282\frac{mg}{L}$$

BOD Practice Problem

A standard sample of WW used for a 5-day, 20°C BOD test results in 67.8 mg of oxygen consumed. What is the BOD of this wastewater?

BOD Practice Problem

A standard sample of WW used for a 5-day, 20°C BOD test results in 67.8 mg of oxygen consumed. What is the BOD of this wastewater?

$$\frac{67.8\ mg}{.3L} = 226\frac{mg}{L}$$

CONTACT INFORMATION

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