WASTEWATER TECHNOLOGY
TRAINERS

Transforming today's operators into tomorrow's water quality professionals

---

Problem of the Day

2014.Dec.11

Introduction

I understand that math gives many operators angst. Math gives many people angst. But as operations professionals, we can't dwell on the angst that math causes us because it is self defeating. Instead, we need to put that negative energy into understanding the problem at hand and practice, practice, practice.

Without being disrespectful, I would venture that the root cause of math anxiety for many of us can largely be explained by one or more poor math teachers in the beginning of our schooling. I don't have any statistics or scholarly papers to back up that assertion, but from my own experience as a trainer I have observed, over and over, this scenario: (1) a talented operator during introductions at the beginning of one of our certification review classes admits, "I can't do math; I have never been able to do math; I am going to fail," and (2) said operator passes his/her certification exam with "... no problem with the math; made only a couple of stupid mistakes" (http://wastewatertechnologytrainers.com/testimonials/). Success.

The solution to water and wastewater math problems for folks who struggle with math is to carry units through the problem. **Units show you how to do the problem**. In previous posts I discussed an article on the *TPO Magazine* website entitled, "5 Tips for Acing Wastewater Exam Math Questions" (http://www.tpomag.com/online_exclusives/2014/12/5_tips_for_acing_wastewater_exam_math_questions). There are multiple issues I have with the article, which, overall, I see as a disservice to the operations profession, but the most unforgiving is where the article express volume in MGD! **Gallons** is a unit of **volume** and **million gallons** is a unit of **volume**, but **MGD** is a unit of **flow**. While flow is volume per unit time, **volume and flow are not the same thing**. *TPO Magazine* should know better.

Primary clarification removes more organics for the least amount of money than any other process unit at a wastewater treatment plant. The process objective of primary clarification is the removal of settleable total suspended solids (TSS_{set}). Fortuitously, the BOD (or COD) associated with those solids also is removed and this is important. The reason it is important is because secondary treatment, where the remaining BOD is "removed" (I will explain "removed" in a subsequent post), is expensive, so the more BOD removed in the primary clarifiers, the better.

The influent to primary clarifiers is raw sewage. Raw sewage can go septic. It is for this reason that detention time in primary clarifiers is a very important consideration.

Problem of the Day

An average influent flow of 17.7 MGD is equally split between 4 primary clarifiers. Each primary clarifier is 175 ft long and 25 feet wide with an average water depth of 18 feet. Calculate the detention time in these primary clarifiers in hours. Based on typical operating practice, is this detention time too long or too short? You have noticed increasing odors around the primary clarifiers. Based on this observation and the primary clarifier detention time you have just calculated, what recommendation would you give to the chief plant operator?

Discussion

The equation for calculating detention time, fill time and empty time is always:

$$T = \frac{V}{Q}$$

where T is time (detention, fill or empty), V is volume, and Q is flow. Same equation over and over and over again.

Solution

The question asks specifically to express detention time in hours. These units, **hr**, are put between heavy vertical lines followed by the equals sign and the blank track.

Problem of the Day: An average influent flow of 17.7 MGD is equally split between 4 primary clarifiers. Each primary clarifier is 175 ft long and 25 feet wide with an average water depth of 18 feet. Calculate the detention time in these primary clarifiers in hours. Based on typical operating practice, is this detention time too long or too short? You have noticed increasing odors around the primary clarifiers. Based on this observation and the primary clarifier detention time you have just calculated, what recommendation would you give to the chief plant operator?

Information summary, specifically labeled:

- Plant flow = 17.7 Mgal/d
- Number of primary clarifiers = 4 PC
- Primary clarifier length = 175 ft
- Primary clarifier width = 25 ft
- Primary clarifier depth = 18 ft
- **Calculate: Primary clarifier detention time in hr**.

$$|\text{hr}| = \text{\_\_\_\_\_}$$

Hour (**hr**) is a unit of time. In the list of information given, the only other unit of time is the day in 17.7 Mgal/**d**. Because it is needed in the numerator of the answer, the only way the flow can be entered into the railroad track is so the d ends up in the numerator.

$$|\text{hr}| = \frac{\text{d}}{17.7\ \text{Mgal}}$$

But we don't need **d**, we need **hr**, so **d** is converted to **hr**.

$$|\textbf{hr}| = \frac{\cancel{\text{d}}}{17.7\ \text{Mgal}} \cdot \frac{24\ \textbf{hr}}{\cancel{\text{d}}}$$

We have the units in the railroad track that we need in the answer, **hr**, but we have to cancel the **Mgal**. **Mgal** is a unit of volume, so we now enter the total primary clarifier volume (length x width x depth x the number of primary clarifiers).

$$|\textbf{hr}| = \frac{\cancel{\text{d}}}{17.7\ \text{Mgal}} \cdot \frac{24\ \textbf{hr}}{\cancel{\text{d}}} \cdot \frac{175\ \text{ft} \cdot 25\ \text{ft} \cdot 18\ \text{ft} \cdot 4\ \cancel{\text{PC}}}{\cancel{\text{PC}}}$$

That didn't get rid of many units, in fact we now have more units to cancel. The good news is that we have units of volume in both the denominator (**Mgal**) and the numerator (**ft^3**). We have to convert one to the other so they will cancel. We start with a well-known conversion factor.

$$\mathbf{hr} = \frac{\cancel{\text{d}}}{17.7\ \text{Mgal}} \cdot \frac{24\ \mathbf{hr}}{\cancel{\text{d}}} \cdot \frac{175\ \cancel{\text{ft}}}{\cancel{\text{PC}}} \cdot \frac{25\ \cancel{\text{ft}}}{\cancel{\text{PC}}} \cdot \frac{18\ \cancel{\text{ft}}}{} \cdot \frac{4\ \cancel{\text{PC}}}{} \cdot \frac{7.48\ \text{gal}}{\cancel{\text{ft}}^3}$$

The conversion factor WWTT uses that basically says, "There's a million gallons in a million gallons," or **10^6 gal/Mgal**, seems kind of silly but under the pressure of an exam, it will take the thinking out of "should I divide or multiply by 1,000,000?" You won't make a mistake if you use it as shown.

$$\mathbf{hr} = \frac{\cancel{\text{d}}}{17.7\ \cancel{\text{Mgal}}} \cdot \frac{24\ \mathbf{hr}}{\cancel{\text{d}}} \cdot \frac{175\ \cancel{\text{ft}}}{\cancel{\text{PC}}} \cdot \frac{25\ \cancel{\text{ft}}}{\cancel{\text{PC}}} \cdot \frac{18\ \cancel{\text{ft}}}{} \cdot \frac{4\ \cancel{\text{PC}}}{} \cdot \frac{7.48\ \cancel{\text{gal}}}{\cancel{\text{ft}}^3} \cdot \frac{\cancel{\text{Mgal}}}{10^6\ \cancel{\text{gal}}}$$

Because all the units have canceled in the railroad track except those needed in the answer, **hr**, we **know** the math is done.

Problem of the Day: An average influent flow of 17.7 MGD is equally split between 4 primary clarifiers. Each primary clarifier is 175 ft long and 25 feet wide with an average water depth of 18 feet. Calculate the detention time in these primary clarifiers in hours. Based on typical operating practice, is this detention time too long or too short? You have noticed increasing odors around the primary clarifiers. Based on this observation and the primary clarifier detention time you have just calculated, what recommendation would you give to the chief plant operator?

Information summary, specifically labeled:

- Plant flow = 17.7 Mgal/d
- Number of primary clarifiers = 4 PC
- Primary clarifier length = 175 ft
- Primary clarifier width = 25 ft
- Primary clarifier depth = 18 ft
- **Calculate: Primary clarifier detention time in hr**.

$$\mathbf{hr} = \frac{\cancel{\text{d}}}{17.7\ \cancel{\text{Mgal}}} \cdot \frac{24\ \mathbf{hr}}{\cancel{\text{d}}} \cdot \frac{175\ \cancel{\text{ft}}}{\cancel{\text{PC}}} \cdot \frac{25\ \cancel{\text{ft}}}{\cancel{\text{PC}}} \cdot \frac{18\ \cancel{\text{ft}}}{} \cdot \frac{4\ \cancel{\text{PC}}}{} \cdot \frac{7.48\ \cancel{\text{gal}}}{\cancel{\text{ft}}^3} \cdot \frac{\cancel{\text{Mgal}}}{10^6\ \cancel{\text{gal}}}$$

The arithmetic gives the answer:

24 x 175 x 25 x 18 x 4 x 7.48 ÷ 17.7 ÷ 1,000,000 = **3.2 hr**.

Math is not random. Use units and you will succeed.

But we're not quite done with the problem. Typical design values and expected removal percentages for primary clarifiers are:

Hydraulic loading	600 to 1,200 gal/d·ft^2
Weir overflow rate	10,000 to 15,000 gal/d·ft
Detention time	**1.5 to 2.5 hours**
BOD removal	25 to 40%
TSS removal	40 to 60%
Settleable solids removal	> 95%

From this list, we see that the detention time we just calculated, **3.2 hr**, is outside the range given; it's too long. Because of the odors, we recommend the CPO consider taking one of the primary clarifiers off line.

Happy calculating. Let us know, by leaving a comment, if you want us to do a specific problem.