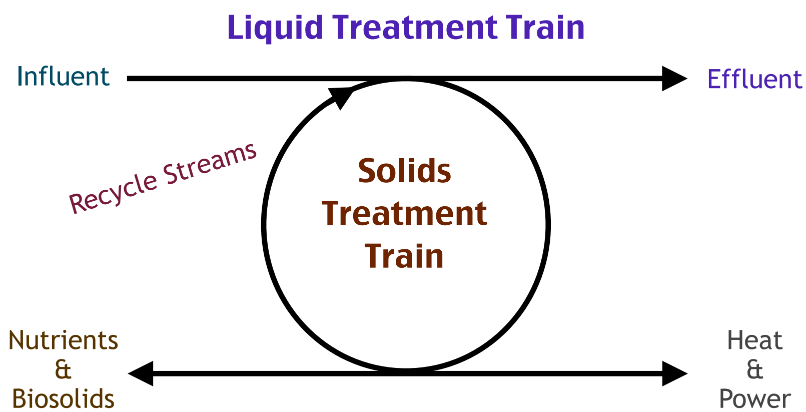
Problem of the Day

2014.Oct.21

Discussion

WWTT uses the following graphic to establish the relationship between the **Liquid and Solids Treatment Trains** at wastewater treatment plants (WWTPs). Also shown in the graphic is the potential for resource recovery from WWTPs at the arrows labeled **Effluent** (think reclaimed water and how precious water is), **Heat and Power** in cogeneration facilities, and **Nutrients and Biosolids**. This graphic also highlights an often overlooked component in wastewater treatment: **Recycle Streams**. Depending on the size of the plant, recycle streams can be 24/7. On this account, the **quality** and **quantity** of recycle streams are hugely important as they can impact both the capacity and performance of the liquid treatment train.



Generic WWTP graphic showing interaction between liquid and solids treatment trains, potential for resource recovery in the effluent, heat and power, and nutrients and biosolids outputs, and the potential impacts of recycle streams.

One calculation operators do that addresses the quality of recycle streams is the percent solids recovery (PSR) of thickening and dewatering process units in the solids treatment train. It is calculated simply:

$$PSR = \frac{\text{lb TS in output}}{\text{lb TS in input}}$$

The PSR is always reported as a percent, so this equation has to be multiplied by 100. Percent solids recovery is also known as solids capture efficiency. In order to return the best quality recycle flows to the liquid treatment train, we like to see PSRs greater than 90-95%.

Problem

Problem of the Day: Over the last 30 days of operation, the dewatering centrifuge at the Greenfield WWTP has produced an average of 15,500 pounds of dry cake solids per day. The density of the cake averaged 68 lb/ft^3. The anaerobically digested sludge fed to the centrifuge averaged 3.6% TS. The centrifuge, on average, was operated 7.5 hours per day at 120 gpm. Calculate the PSR.

Solution

The equation for calculating PSR is repeated here in more of a railroad track format, specific to the current problem:

PSR, %	=	lb TS_c	100
		lb TS_s	

It is very important to understand how this equation has been setup. The reader should first understand that the TS in the **output**, in this case **cake**, are the same TS in the **input**, in this case **sludge**. However, WWTT uses the little "accounting trick" to distinguish between the two: **lb TS_c = pounds of TS in the cake** coming out of the centrifuge and **lb TS_s = pounds of TS in the sludge** going into the centrifuge. Again, the TS in the cake (TS_c) are the same TS in the sludge (TS_s), we're just using the subscripts c and s to account for where we're calculating the pounds of TS. This little accounting trick really helps to keep track of where the solids are, either coming into the unit or going out. It also makes the railroad track almost failsafe.

WWTT thinks "dry" and "wet" sludge are downright confusing, and the current problem exemplifies the confusion. To be clear, keep in mind that a sample—liquid, semi liquid or semi solid—of known volume or mass is placed in an evaporating dish and the sample is **dried to dryness** in a 103-degC oven. The material left in the evaporating dish after the sample has been completely dried is the TS. If a problem talks about "TS," then it is understood to be "dry," because that is how the TS test is performed. On the other hand, if the problem talks about "sludge" or "cake," then it is understood to be "wet." The current problem, not unlike a problem recently on a State of California certification exam, tries to confuse you with the reference to "dry cake solids per day." Without specifically saying so, this is referring to the TS in the cake, TS_c. The subterfuge is made all the worse when the problem statement gives the density of the cake because it is completely unnecessary to do the problem.

Here is what we know from the problem statement, labeled the way WWTT recommends:

- Averaged over 30 days of operation
- Average cake TS produced = 15,500 lb TS_c/d
- Average cake density = 68 lb cake/ft^3 cake (information not needed for problem)
- Average centrifuge feed rate = 120 gal sldg/min
- Average operating time = 7.5 hr/d
- Average sludge TS concentration = 3.6% TS = 3.6 lb TS_s/100 lb sldg
- Average sludge density = 8.34 lb sldg/gal sldg (assumed since not given)

Using the equation above, the railroad track is started with the average production rate of cake TS, as shown.

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PSR, %	=	15,500 lb TS_c	
		d	

The equation above tells us that we have to divide lb TS_c by lb TS_s. This latter unit shows up in only one other place in the list above. **Note lb TS_c cancel with lb TS_s because they are the same TS.**

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PSR, %	=	15,500 ~~lb TS_s~~	100 lb sldg
		d	3.6 ~~lb TS_s~~

It is helpful to remember that **whenever calculating percent, all the units must cancel out**. With this in mind, we work our way down the railroad track canceling units as we go. The unit, lb sldg, shows up in only one other place in the list above.

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PSR, %	=	15,500 ~~lb TS_s~~	100 ~~lb sldg~~	gal sldg
		d	3.6 ~~lb TS_s~~	8.34 ~~lb sldg~~

The unit, gal sldg, only shows up in one other place in the list above, so it is entered next to cancel units.

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PSR, %	=	15,500 ~~lb TS_s~~	100 ~~lb sldg~~	~~gal sldg~~	min
		d	3.6 ~~lb TS_s~~	8.34 ~~lb sldg~~	120 ~~gal sldg~~

We're making good progress working our way down the railroad track. We notice that min and d are on opposite sides of the railroad track, so we might think about canceling them both out with one conversion factor. But before we do that, we have to ask the question, "Is the centrifuge operated all day?"

The answer is no; it is only operated 7.5 hours per day. The unit, min, currently in the railroad track, then, has to be converted to hours.

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PSR, %	=	15,500 ~~lb TS_s~~	100 ~~lb sldg~~	~~gal sldg~~	~~min~~	hr
		d	3.6 ~~lb TS_s~~	8.34 ~~lb sldg~~	120 ~~gal sldg~~	60 ~~min~~

Now the actual run time can be entered so units cancel.

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PSR, %	=	15,500 ~~lb TS$_c$~~	100 ~~lb sldg~~	~~gal sldg~~	~~min~~	~~hr~~	~~d~~	
		~~d~~	3.6 ~~lb TS$_s$~~	8.34 ~~lb sldg~~	120 ~~gal sldg~~	60 ~~min~~	7.5 ~~hr~~	

Finally, we have to multiply by 100 to get percent.

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PSR, %	=	15,500 ~~lb TS$_c$~~	100 ~~lb sldg~~	~~gal sldg~~	~~min~~	~~hr~~	~~d~~	100
		~~d~~	3.6 ~~lb TS$_s$~~	8.34 ~~lb sldg~~	120 ~~gal sldg~~	60 ~~min~~	7.5 ~~hr~~	

Since all the units have canceled except the ones needed in the answer and we've multiplied by 100 to get %, the math is done and the arithmetic gives the answer:

15,500 x 100 x 100 ÷ 3.6 ÷ 8.34 ÷ 120 ÷ 60 ÷ 7.5 = **95.6%**.

There are several different questions around PSR that can be asked. A lot of the time, the PSR is given and something else has to be calculated. So we have to ask ourselves the question, **what does PSR mean**? It is very, very helpful in other solids thickening and dewatering problems that PSR, if given, is expressed the following way (using the PSR just calculated):

95.6% PSR	=	95.6 lb TS$_c$
		100 lb TS$_s$

Saying in words what was just written as a railroad track equation: **95.6% PSR means that 95.6 lb of TS end up in the cake for every 100 lb of TS applied or fed to the centrifuge**.

So for every 100 pounds of TS applied to the centrifuge, 95.6 pounds of TS end up in the cake. Where do the other 4.4 pounds of TS go?

Yes, back to the liquid treatment treatment train. This is why we want to see PSRs greater than 90 to 95%.

Happy calculating and good operating. If you see any mistakes or have any questions, leave us a comment!