The Biowin Advantage

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VSS/TSS Ratio Across A Primary Settling Tank

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Introduction

In this edition of The BioWin Advantage, we will deploy some of BioWin's less commonly used flowsheet elements to help us manipulate the VSS/TSS ratio across a primary settling tank.

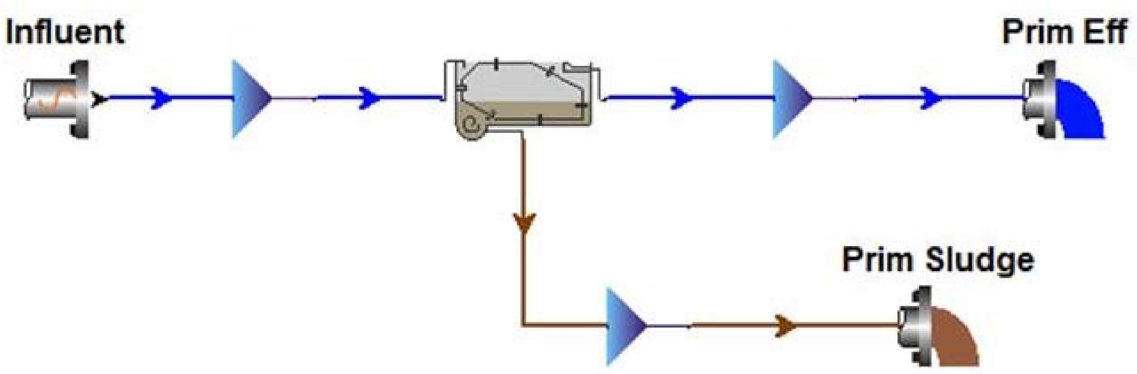
One Capture Rate for All Solids?

In recent editions of the BioWin Advantage, we've looked at using a one-dimensional flux-based model settling tank element to represent a primary settling tank (v2 n3). We've also looked at the relationship between influent wastewater characteristics and primary settling tank (PST) performance (v2 n4); we examined how setting the TSS removal in the PST influences other performance metrics such as BOD and TKN removal and how those relationships are influenced by the wastewater fractionation. For example, it is possible to achieve different COD and BOD removals for a specified TSS removal by changing the influent wastewater fraction F_{XSP} (the fraction that is particulate slowly biodegradable).

These concepts arise from the fact that BioWin PST elements apply the same capture rate to all of the particulate state variables. No distinction is made between the possible settling properties of say influent inorganic inert suspended solids (i.e. grit, which we might expect to settle more quickly) and particulate organic material. Therefore, when we use an ideal PST in our BioWin flowsheets, the influent wastewater VSS/TSS ratio sets the VSS/TSS ratio for the primary effluent and primary sludge streams – they will all have the same value.

However, under certain plant configurations and/or operating conditions, the actual data may not reflect this. It is possible that more ISS is captured across the PST compared to the lighter, less spherical particulate organic suspended material; this would be reflected in the data by a lower primary sludge VSS/TSS ratio and a higher primary effluent VSS/TSS ratio compared to the influent VSS/TSS ratio. In this edition of the BioWin advantage, we'll look at how we can use BioWin's cyclone elements in conjunction with an ideal PST to model this situation.

Base Case – Standard Ideal PST

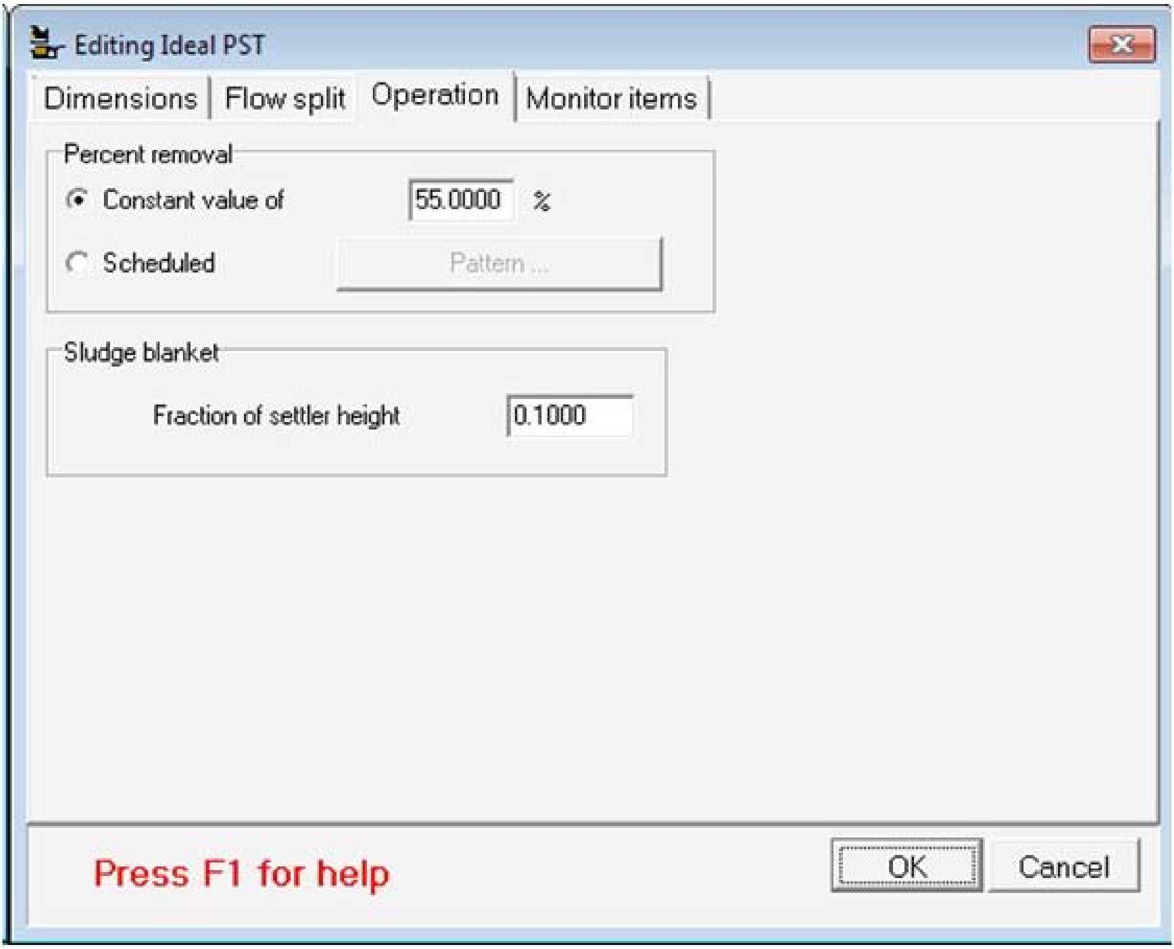


Four our base case, we'll use the simple ideal PST element shown above. The charts that are plotted in the Album of the BioWin file for our base case (Base Ideal PST #1-Base Case.bwc) have been generalized such that they rely on the mixing elements on the PST influent, underflow, and effluent streams. This means that it is very easy to modify the file that comes with this article and not disrupt the charts.

Some pertinent features of the system are listed in the following table:

ATTRIBUTE	VALUE
Average Influent Flow	6.34 mgd
Average Influent TSS Load	12,167 lb/d
Average Influent BOD Load	12,995 lb/d
Primary Settling Tank Volume	0.5 mil. gal.
Primary Settling Tank Area	6,684 ft^2
Primary Settling Tank Depth	10 ft
Primary Settling Tank Underflow	0.0316 mgd
Average SOR	944 $gal/ft^2/d$
Average HRT	1.9 hours

The ideal primary settling tank is set up with a 55% solids capture and a fixed sludge blanket height of 10% of the total depth, as shown below:



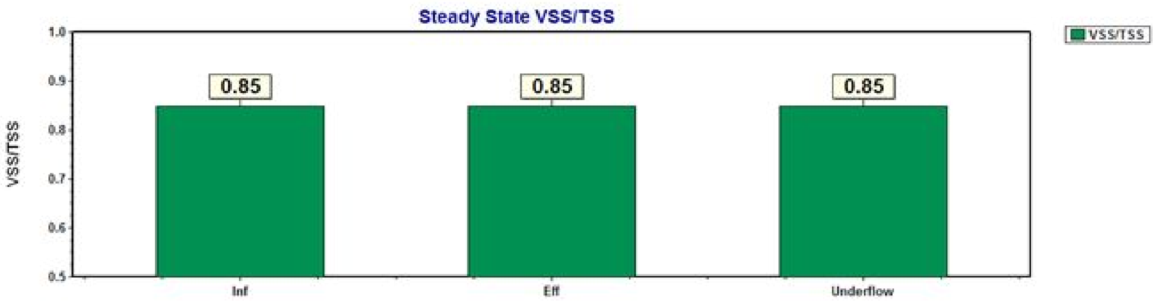
Important influent characteristics, in terms of both totals and fractions, are listed in the following table:

PARAMETER	VALUE
COD	500 mg/L
BOD	246 mg/L
TSS	230 mg/L
VSS	195 mg/L
TKN	40 mg/L
TP	6.5 mg/L
Unbiodegradable particulate COD fraction (F_{UP})	0.13 mgCOD/mgCOD
Readily biodegradable soluble COD fraction (F_{BS})	0.16 mgCOD/mgCOD
Unbiodegradable soluble COD fraction (F_{US})	0.05 mgCOD/mgCOD
Ammonia fraction of TKN (F_{NA})	0.66 mgN/mgN
Soluble PO_4 fraction of TP (F_{PO4})	0.50 mgP/mgP

The various wastewater fractions listed above, as well as others listed on the wastewater characteristics tab of the influent element in the accompanying BioWin file, represent default BioWin values which are representative of typical North American wastewaters. As such, several ratios for “total” parameters fall within expected ranges, e.g.:

- *The COD/BOD ratio is 2.03 mgCOD/mgBOD*
- *The TSS/BOD ratio is 0.94 mgTSS/mgBOD*
- *The VSS/TSS ratio is 0.85 mgVSS/mgTSS*

As discussed in the previous edition (v2 n4) we can use charts that employ "function series" to display more information about our system. Using this functionality to create a bar chart showing the VSS/TSS ratio for all streams illustrates the concept of that ratio being constant for all streams as discussed above.

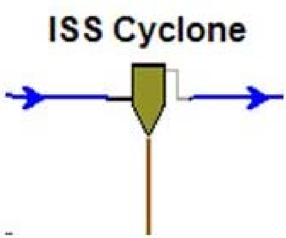


In the next section, we'll introduce BioWin's cyclone flowsheet elements, and following that show how we can use these to work around this "constant VSS/TSS" restriction.

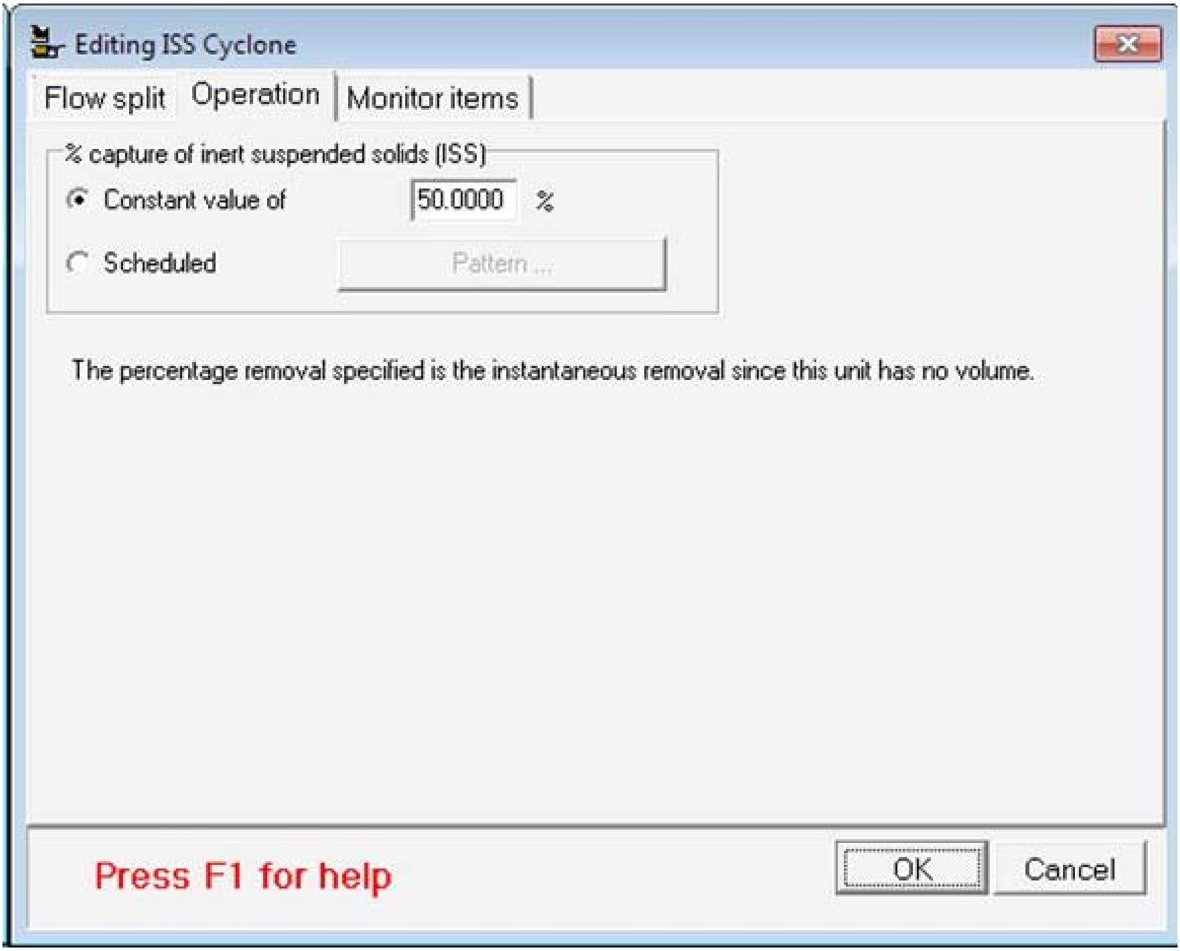
Introducing BioWin's Cyclones

There are two types of cyclone elements in BioWin: (1) a "standard" cyclone, and (2) a "dewatering" cyclone. These elements have slightly different functionality, but they share the common ability to selectively capture additional ISS. More detail on each is provided in the following sections.

Standard Cyclone Operation



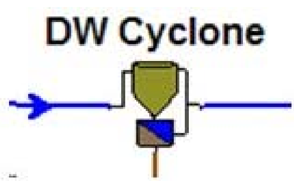
The "standard" cyclone is a volumeless unit that splits the incoming flow to an overflow and an underflow similar to other BioWin solid/liquid separators. However, the unique attributes of the cyclone become evident when looking at the Operations tab, shown below.



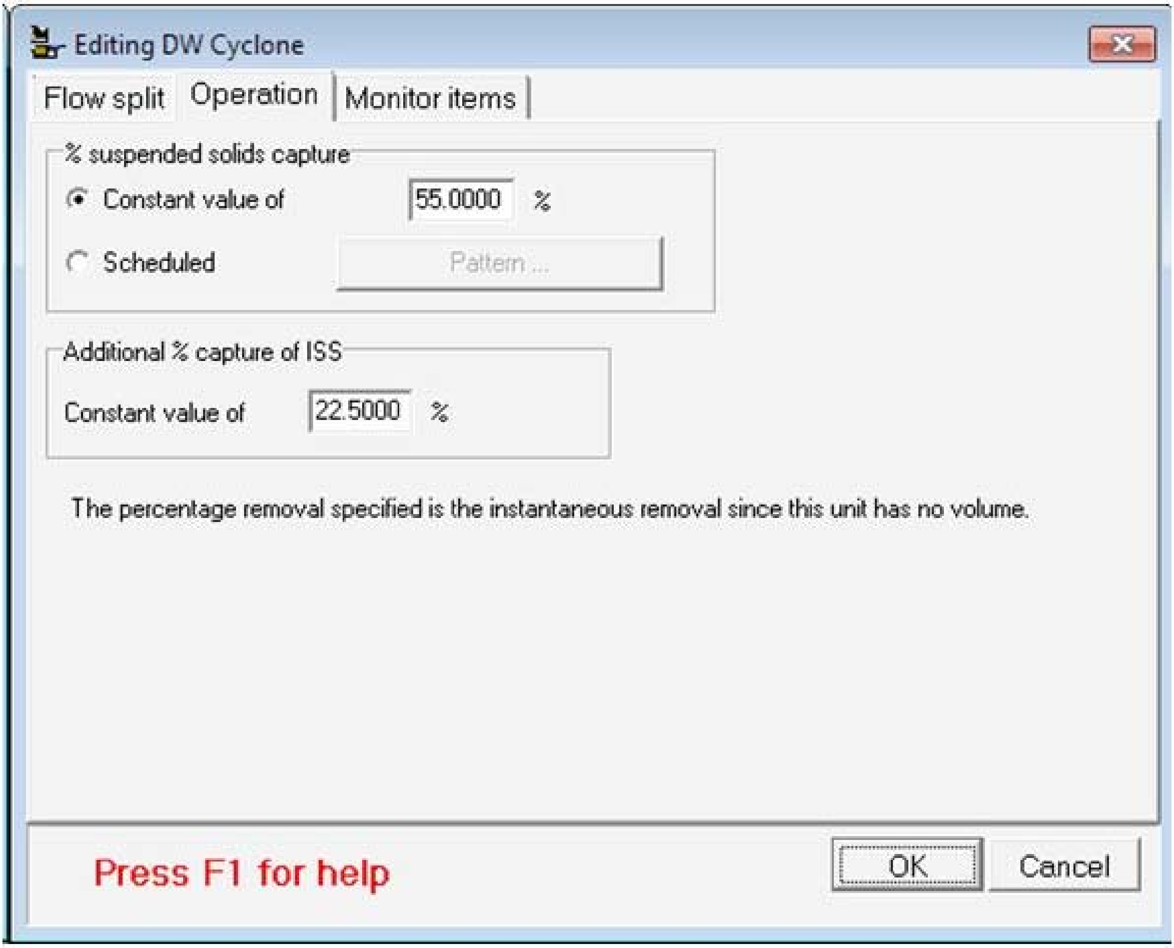
In a "normal" BioWin solid/liquid separation element, we specify a % solids capture, and this capture rate is applied to the incoming mass rate for *all* particulate state variables. The captured solids are directed to the underflow stream, and the remainder report to the overflow stream.

In a cyclone, the specified % solids capture rate is applied *only* to the incoming mass rate of ISS. The captured ISS is directed to the underflow stream, and the remainder reports to the overflow stream. *All other* particulate state variables are split according to the flow split that is specified on the Flow split tab. That is, the mass rates for all other particulate state variables in the overflow and underflow streams are set by the flow split.

Dewatering Cyclone Operation



The dewatering cyclone is a volumeless unit that splits the incoming flow to an overflow and an underflow in a similar fashion to other BioWin solid/liquid separators. However, the unique attributes of the cyclone become evident when looking at the Operations tab, shown below.



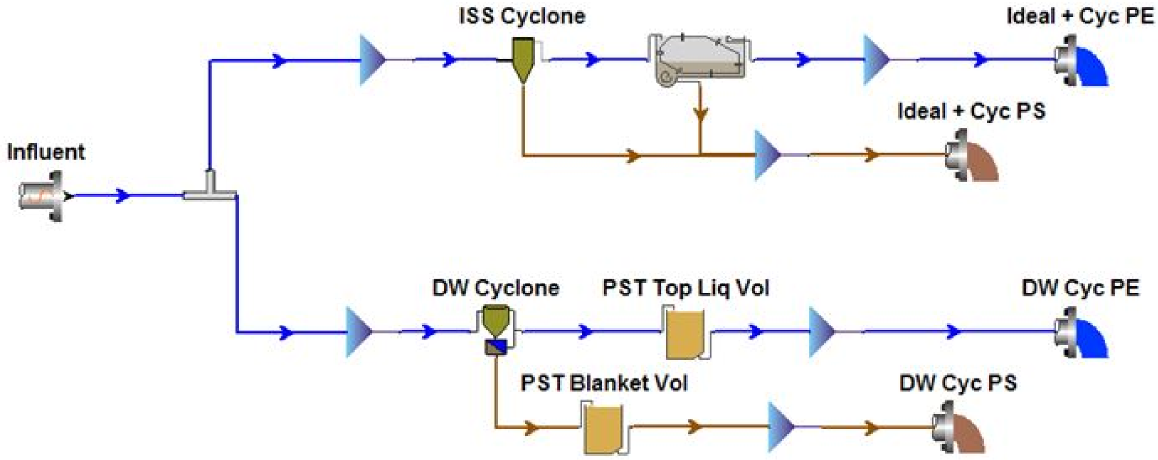
A dewatering cyclone applies the specified % solids capture rate to the incoming mass rate for *all* particulate state variables (including ISS) in the same way of a "normal" solid/liquid separation element. The captured solids are directed to the underflow stream, and the remainder report to the overflow stream.

Furthermore, an additional specified % solids capture rate is applied *only* to the incoming mass rate of ISS. The additional captured ISS is directed to the underflow stream, and the remainder reports to the overflow stream. For example, in the screenshot above, we have specified a base solids capture rate of 55%, and an additional ISS capture rate of 22.5%. This means that 55% of the influent mass rate for all particulate state variables will be captured and report to the underflow, and 77.5% of the influent ISS mass rate will be captured and report to the underflow.

Now that we've explored BioWin's cyclone elements in more detail, let's use them to change the wastewater VSS/TSS ratio across a PST.

Using Cyclones to Manipulate VSS/TSS Ratio

The screenshots below show how we can use either of BioWin's cyclone elements to change the VSS/TSS ratio across a primary settling tank. This is illustrated by splitting an influent flow evenly between two process flowsheet branches that accomplish additional ISS removal using a cyclone-type element. (DW Cyclone (with vol) vs Ideal PST(with ISS cyc) #1.bwc)



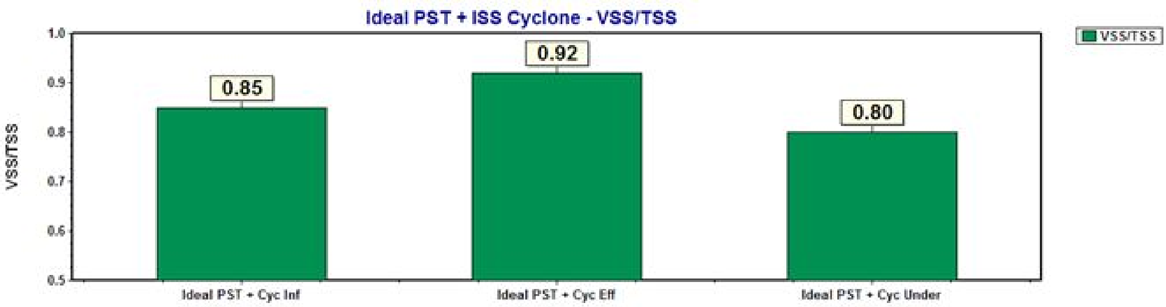
Explanation of Top Flowsheet Branch – Standard Cyclone Approach

In the top flowsheet branch, the influent wastewater is passed through a "standard" cyclone which has the ISS capture set at 50%. The underflow of the cyclone is set to a small value (0.0001 mgd) so that the solids in its underflow primarily is ISS (recall that other particulate state variables must report to the underflow simply based on the flow split). The overflow of the cyclone then passes through a standard ideal PST with the solids capture rate set at 55%.

If we call the mass rate of ISS in the top flowsheet ISS Cyclone influent "X", then we can work out what the overall ISS removal will be based on the different unit process capture rates:

- *Mass Rate of ISS in Cyclone Underflow=0.5X*
- *Mass Rate of ISS in Cyclone Overflow=0.5X*
- *Mass Rate of ISS in PST Underflow=0.5X·0.55=0.275X*
- *Combined Mass Rate of ISS in PST & Cyclone Underflows=0.5X+0.275X=0.775X*

That is, the overall ISS capture for this configuration is 77.5%. The impact of this additional ISS capture across the PST can be seen by looking at the chart for the VSS/TSS ratio:

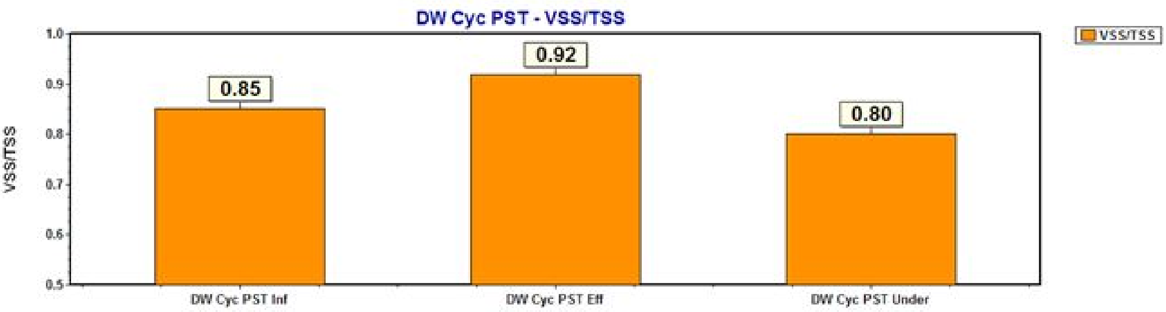


The VSS/TSS ratio of the primary effluent has *increased* to 0.92 and the primary sludge ratio has *decreased* to 0.80 due to the additional ISS capture.

Explanation of Bottom Flowsheet Branch – Dewatering Cyclone Approach

In the bottom flowsheet branch, the influent wastewater is passed through a dewatering cyclone that has the capture for all particulate state variables (including ISS) set at 55%, and the additional capture of ISS set to 22.5%. With this combination, the overall capture of ISS will be 77.5%, just like the top flowsheet branch. The dewatering cyclone has the advantage that it is straightforward to know what the overall capture of the ISS will be because it is input directly.

One disadvantage of using a dewatering cyclone on its own is that it has no volume; therefore, proper attenuation and lag of concentration peaks would not be achieved in the case of dynamic simulations. However, this is easily overcome by incorporating two non-reactive tank elements. The tanks represent the volumes of the primary sludge blanket and the clarified liquid. In the top flowsheet branch, the PST has been set up to have the sludge blanket fixed at 10% of the PST volume. Knowing this, we can set up the two tanks in the bottom flowsheet branch to have equivalent volumes, and this will ensure that proper attenuation and lag of concentration peaks will be achieved for the dewatering cyclone approach. Finally, the underflow rate from the dewatering cyclone is set to the sum of the underflow rates of the standard cyclone and the PST from the top flowsheet branch in order to have the same overall flow and mass balance (0.0001 mgd + 0.0316 mgd). The impact on the VSS/TSS ratio is identical to that of the top flowsheet branch, as seen by the following plot:



Conclusion

In this edition of the BioWin Advantage, we've introduced a few of BioWin's less commonly used flowsheet elements – cyclones – and shown how we can use those to change the VSS/TSS of a wastewater stream across a PST. Note that this concept also could be used in other situations where some differential settling of materials may occur! We trust that you found this technical topic both interesting and informative. Please feel free to contact us at info@envirosim.com (Subject: The BioWin Advantage) with your comments on this article or suggestions for future articles.

Thank you, and good modeling.

The EnviroSim Team

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