

October 7, 2016

New Developments in BioWin 5.1

The primary focus of this release has been to improve both steady state and dynamic simulation speed, particularly for (a) large flowsheets incorporating many elements; and (b) systems incorporating biofilm elements (*e.g.* media bioreactors in MBBR and IFAS configurations, submerged aerated filters, trickling filters, *etc.*).

Speed Improvements - Steady State Simulation

The basic methodology for steady state simulations remains unchanged. That is, BioWin uses a “hybrid” solver that combines a Decoupled Linear Search (DLS) method and a Modified Newton-Raphson (MNR) method. The solver typically starts with a few iterations of DLS, and then switches to MNR to finish. The MNR is much more efficient at obtaining solutions, but it is computationally intensive. For example, in previous versions of BioWin, the MNR could take up to several minutes per iteration for systems with large, complex flowsheets. Given that several iterations often are required, this translated into steady state solution times of 20-30 minutes for very large systems.

In BioWin 5.1, the numerical engine underlying the MNR method has been replaced, resulting in huge gains for large flowsheets. **For example, in our internal testing we have systems that were taking ~200 seconds per iteration reduce to ~4 seconds per iteration, *i.e.* 50 times faster!**

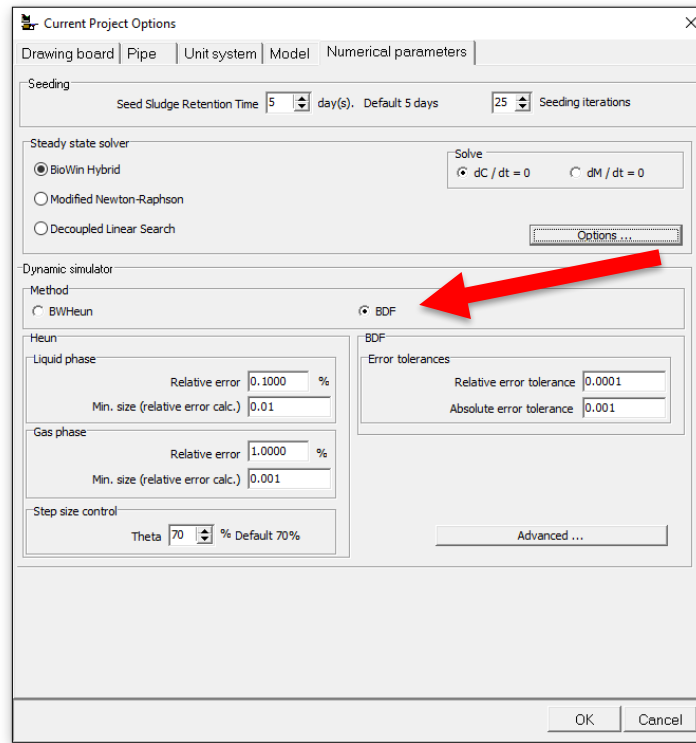
Speed Improvements - Dynamic Simulation

BioWin 5.1 uses a new dynamic integration method known as BDF (Backwards Differentiation Formula). The BDF method is faster than the previous method for large, complex flowsheets and flowsheets incorporating biofilm-based elements. Our BioWin 5.1 testing has indicated:

- **Large systems not incorporating biofilm reactors run 3 – 6 times faster**
- **Systems incorporating biofilm reactors run 10 – 50+ times faster**

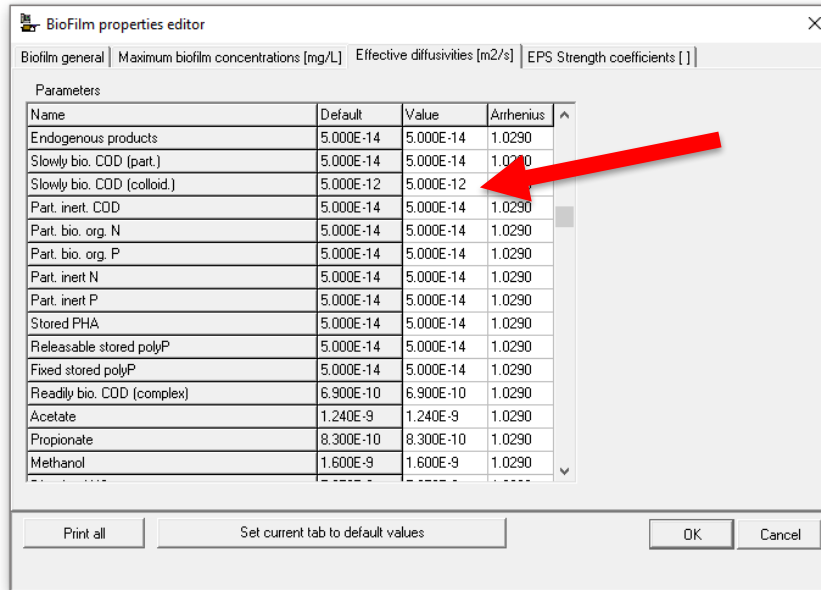
If you open the **Project > Current Project Options > Numerical parameters** tab shown below, the BDF method should be selected as the default method – even for a file you created in a

previous version of BioWin. The “old” BioWin method (BWHeun) is also still available because the new BDF method is not yet available for simulation of SBR systems.

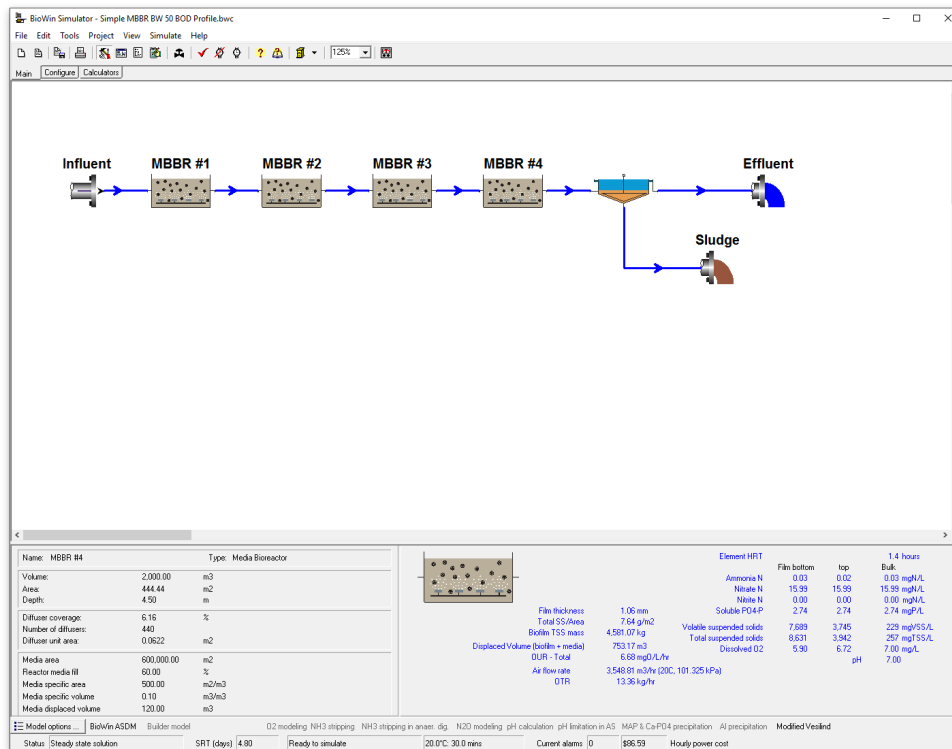


Model Change – Diffusion of Colloidal Material in Biofilms

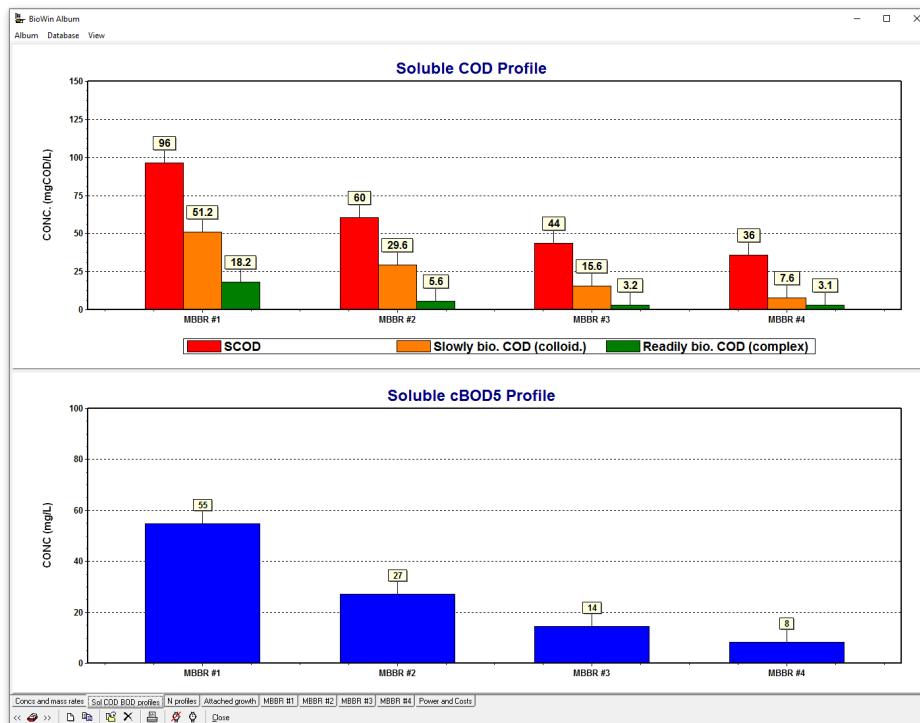
BioWin’s biofilm model has always incorporated a diffusion rate for colloidal material into the biofilm layers. This parameter can be found on the **Project > Parameters > Biofilm > Effective diffusivities** tab shown below:



In previous versions of BioWin, the default value assigned for the effective diffusivity of colloidal material was 5.0×10^{-12} . This value is greater than the one assigned to particulate material (e.g. particulate degradable COD has a value of 5.0×10^{-14}), but lower than soluble material (e.g. soluble readily biodegradable COD has a value of 6.9×10^{-10}). The fate of colloidal material in biofilm systems is directly impacted by this parameter value. For example, consider the system below consisting of four moving bed bioreactor (MBBR) units in series:

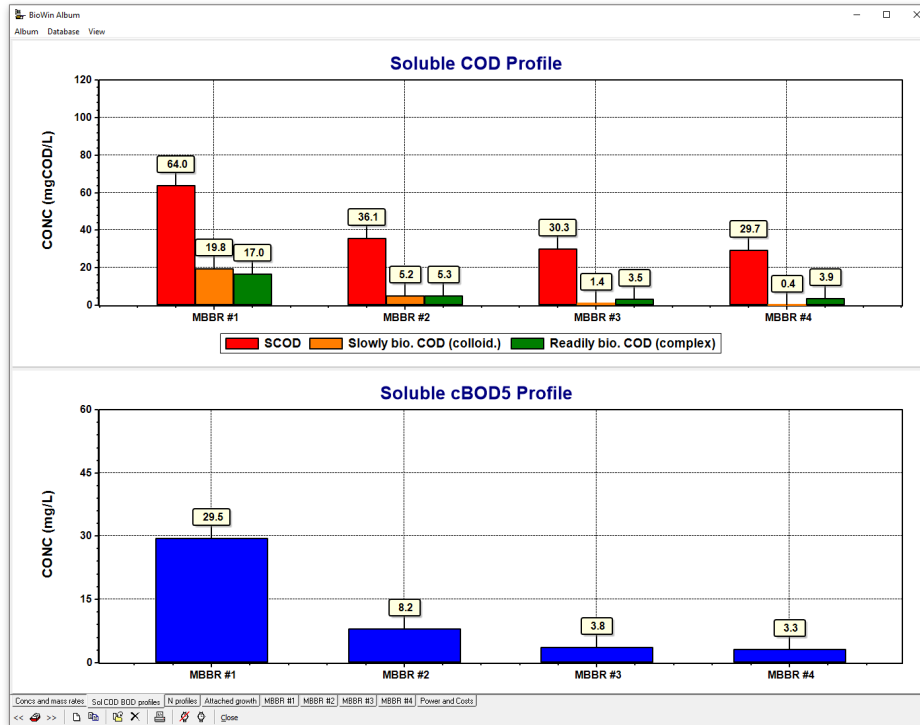


Using the default diffusivity parameters, the soluble COD and BOD profiles are as follows:



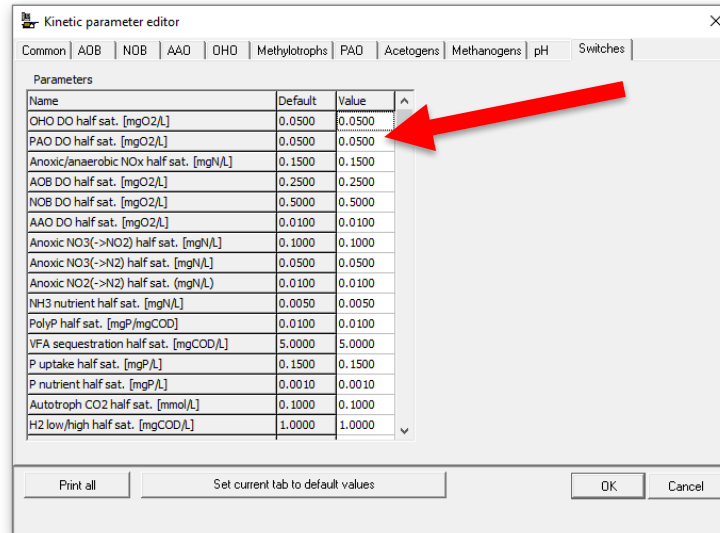
Note that soluble BOD is not significantly reduced until the end of the third MBBR unit (bottom chart). This can be explained by looking at the top chart. Although the uptake of soluble readily biodegradable material is nearly complete by the end of the second unit, the uptake of colloidal material is not as rapid and much of the soluble BOD leaving the second and third MBBR units is due to colloidal material.

Our investigations into performance of systems like the one pictured above suggests that the soluble BOD is removed to a greater extent by the end of the second stage. As a result, in BioWin 5.1 the default value assigned for the effective diffusivity of colloidal COD material has been **increased** to 5.0×10^{-10} . This value is closer to, but slightly less than, the value assigned to soluble material (recall that soluble readily biodegradable COD has a value of 6.9×10^{-10}). This results in more complete removal of colloidal material by the end of the second stage, and gives the soluble BOD profile shown below:



Model Change – Dissolved Oxygen Half-Saturation Constant for Phosphorus Accumulating Organisms

In previous versions of BioWin, the phosphorus accumulating organisms (PAO) used the same dissolved oxygen (DO) half-saturation model parameter as the ordinary heterotrophic organisms (OHO). This reflected conventional wisdom which suggested that PAOs did not take up phosphorus effectively at low DO concentrations. However, current research (Jimenez *et al.*, 2014) suggests that PAOs are in fact able to take up phosphorus effectively at very low DO concentrations. To reflect these findings, BioWin now incorporates a separate dissolved oxygen (DO) half-saturation model parameter for PAOs. This improves the model's ability to track biological phosphorus removal in systems operating under low DO / simultaneous nitrification-denitrification conditions. This parameter is found *via* the **Project > Parameters > Kinetic > Switches** tab shown below:



Model Change – Compression Settling of Solids

In BioWin users can define a solids concentration that represents the maximum compactability of solids in a model settling tank unit (*i.e.* a limit on underflow TSS concentration). In earlier versions, as the solids concentration in a layer of a model settling tank approached the maximum compactability value, that layer would “re-suspend” solids into the layer above; in this way the constraint on maximum compactability was maintained. This approach was not always satisfactory because (a) under certain conditions it resulted in unstable behavior, and (b) it did not properly reflect what physically occurs as solids transition from the hindered settling regime to compression settling.

In BioWin 5.1, the approach for modelling settling behavior at high solids concentrations and imposing a maximum compactability has changed. The following section discusses the new approach used at high solids concentrations, as well as the approach that has always been used to model settling at low concentrations.

Sludge settling velocity is modeled according to the Vesilind equation for hindered settling. The settling velocity in a given layer is given by:

$$V_{S,i} = V_0 e^{-KX_i} \quad (1)$$

where V_0 = maximum settling velocity (m/d), K = hindered settling parameter (m³/kg TSS), and X_i = total suspended solids (TSS) concentration (kgTSS/m³) in layer i .

A criticism of Eq. 1 is that it over-predicts settling velocities at low concentrations. Furthermore, the standard Vesilind equation does not account for compression settling. BioWin employs switching functions to switch off the sludge settling velocity expression at very low solids concentrations, and also as the solids concentration approaches the maximum solids

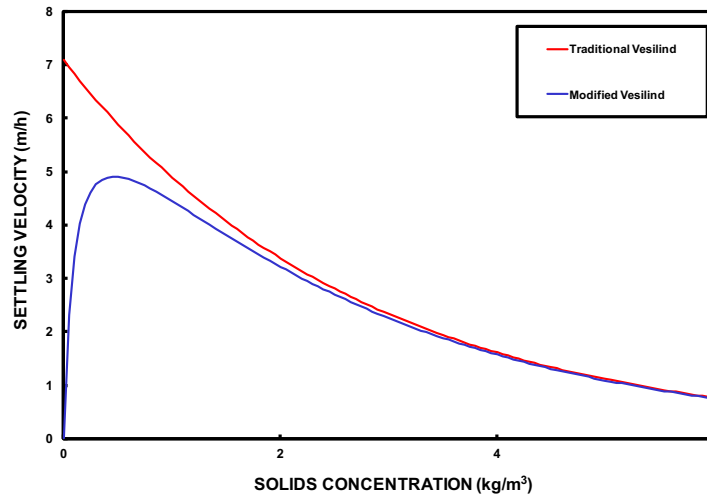
compactability in the lower layers of the settling tank. This provides a simplified method of modeling the poorly flocculating solids in the upper layers of the settling tank, and compression setting in the lower layers. As the solids concentration in the upper layers approaches a user-definable concentration (the upper layer settling velocity switch), the settling velocity approaches zero, and solids are carried upwards by the overflow stream (resulting in solids in the settling tank effluent). As the solids concentration in the lower layers approaches the user-definable maximum compactability, the settling velocity is quickly and smoothly reduced to zero.

The complete settling velocity equation used by BioWin is:

$$V_{S,i} = V_0 e^{-KX_i} \cdot \left(\frac{X_i}{K_S + X_i} \right) \cdot \left(\frac{1}{1 + e^{-\text{Compression Settling Transition Factor} \cdot (X_{MAX} - X_i)}} \right) \quad (2)$$

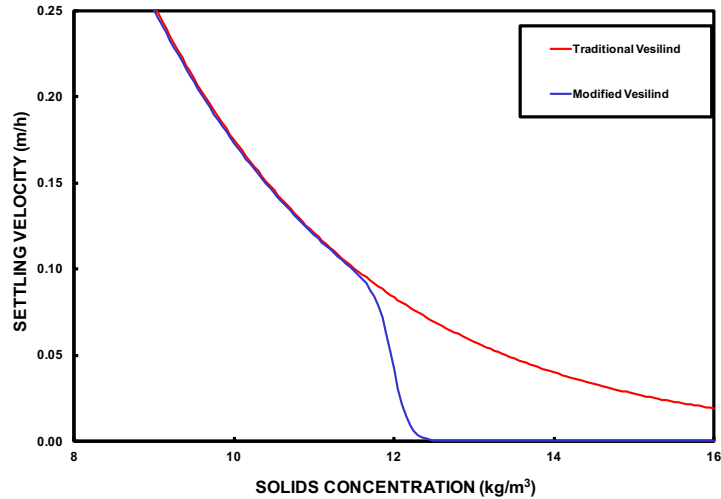
Where K_S is the upper layer settling velocity switch, X_{MAX} is the maximum compactability, and other variables are the same as in Eq. 1.

The switching function effect at low concentrations for a given combination of settling velocity parameters is shown in the figure below:



You can increase the suspended solids concentration at which settling velocity is decreased by increasing the K_S parameter. Varying the K_S parameter is a possible way to vary the predicted effluent suspended solids.

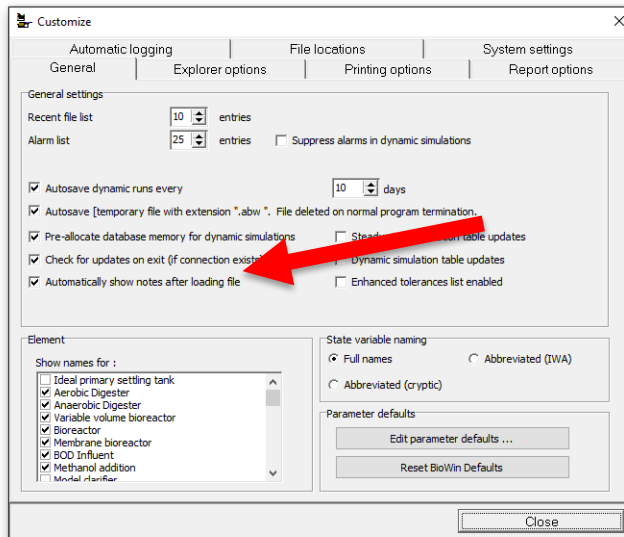
The switching function effect at high concentrations in the lower layers of the settling tank for a given combination of settling velocity parameters is shown in the figure below. Lowering the X_{MAX} parameter is a way to simulate poorly compressible bulking sludge.



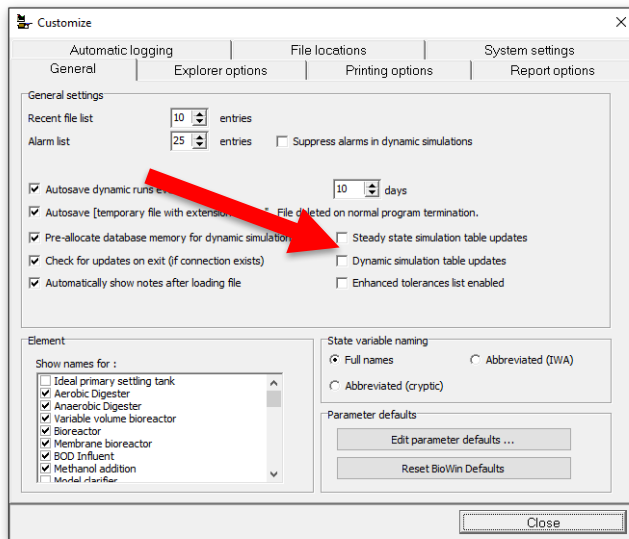
Other Usability Improvements

The following minor fixes have also been implemented in BioWin 5.1:

- You can choose whether or not the Notes window is displayed when you open a BioWin file, by checking or unchecking the **Automatically show notes after loading file** box under **Tools > Customize > General**



- Users of previous versions of BioWin reported a “sluggish” behavior in BioWin files that incorporated very large tables in the BioWin Album. This is no longer the case, so long as the user does not set BioWin to update tables continually during simulations. The **Steady state simulation table updates** and **Dynamic simulation table updates** checkboxes *should remain at the default unchecked state*.



- A progress bar now shows at the bottom of the simulation control box while BioWin places numerical seed values in all flowsheet elements. This will only be readily evident on large flowsheets with many elements.
- Improved plotting series naming for multi-layer elements (e.g. SAF).
- It is now possible to display a Rates window for a SAF element.
- Tighter numerical adherence to splitters with “zero” fractions and rates specified for a stream.
- Anaerobic digesters and variable volume bioreactors may now be set to “constant” volume.
- Biofilm details tables in the Album may now be copied to the clipboard for exporting to Excel.
- The software package that BioWin uses for its charting engine (TeeChart) has updated to a new version. The functionality is similar to what it was in previous BioWin versions, but the interface has changed somewhat.

Reference

Mainstream Nitrite-Shunt with Biological Phosphorus Removal at the City of St. Petersburg Southwest WRF. Jimenez, J., Wise, G., Burger, G., Du, W. and Dold, P. **Proceedings of the Water Environment Federation 86th Annual Technical Exhibition & Conference, New Orleans, Louisiana, USA, September 27 to October 1, 2014.**