SRTmaster^{TM} White Paper

Superior control method for maintaining an optimum food-to-mass (F/M) ratio

This paper explores problems associated with a non-optimum food-to-mass (F/M) ratio and with common methods used to maintain the F/M ratio. *SRTmaster*^{TM} is software that precisely and automatically maintains an optimum F/M ratio using the constant solids retention time (SRT) criterion.

The importance of food-to-mass ratio in an activated sludge system

F/M is one of the most important parameters of an activated sludge system. The F/M ratio is controlled by the amount of wasted sludge; an increase in wasted sludge mass decreases the F/M ratio, and vice versa. The best performance of activated sludge is only achieved when F/M is maintained at an optimum, constant value.

An F/M ratio above the optimum value may cause:

- low dissolved oxygen (DO) filamentous bulking
- energy waste due to reduced oxygen transfer efficiency and necessity of maintaining elevated DO concentration
- poor removal of pollutants (ammonia, nutrients) in an aeration basin
- dispersed growth of biomass
- flocculation problems
- overload of the thickening facility

An F/M ratio below the optimum value may cause:

- low F/M filamentous bulking and foaming
- increased oxygen demand by a conventional activated sludge process
- increased clarifier loading
- increased effluent turbidity

The use of SRT to maintain optimum F/M

Due to inherent difficulties in measuring the amount of incoming food (BOD) in a timely manner, wasting is usually done based on constant solids retention time (SRT), also known as sludge age. SRT is a ratio of the mass of solids in the activated sludge system to the mass of solids that have left the activated sludge system.

SRT is related to F/M by the following formula:

$$Y\,(F/M)-k=1/SRT$$

Y - yield coefficient
k - decay coefficient

According to this formula, if SRT is kept constant, F/M will also be constant. SRT is much easier to calculate than F/M because it uses the total suspended solids concentrations (TSS), which is easier to measure than the amount of incoming food. Therefore, *SRTmaster™* uses SRT to maintain an optimum F/M ratio.

Comparison of SRT control with other popular waste control methods

The advantages of wasting based on SRT control are recognized by practically every wastewater treatment professional, and this method of wasting is advocated in most publications discussing the design and operation of activated sludge systems. Other F/M control methods are less effective than *SRTmaster™* because they use less reliable methods to determine or control the F/M ratio.

SRT vs. MLSS

Using constant MLSS as the criterion does not guarantee that F/M is constant because when the amount of food changes, the mass stays the same. Because MLSS depends not only on food, but also on the ratio between influent and return sludge flows, wasting based on constant MLSS criterion may cause significant variability of the F/M, the flow and the mass of wasted sludge. Another problem with use of MLSS as a sole wasting criterion is the fact that increase of MLSS could be caused not by increase of biomass but by increase of the ratio of inorganic to organic matter in the influent.

At the same time it has been shown that sludge settleability is often affected by MLSS to a larger degree than by SRT. Thus, the combination of MLSS and SRT controls utilized by *SRTmaster™* is the best waste control strategy.

SRT vs. F/M

Using F/M as the wasting criterion requires surrogate of BOD measurements (usually COD or TOC). These measurements are more expensive to obtain than TSS, and are not as reliable.

SRT vs. constant sludge depth in the clarifiers

A change in sludge depth may be caused by reasons other than a change in F/M, such as variations in the return sludge flow to influent flow ratio, or a change in microbiological population. As a result, constant sludge depth in the clarifiers is not a good wasting criterion.

Drawbacks to common methods of SRT control

Because SRT is the most accurate, reliable, and easiest method for determining and controlling optimum F/M, many methods have been developed around its use – with varying degrees of success. The following are the most popular waste control methods aimed at maintaining a constant SRT:

Constant hydraulic wasting of mixed liquor

This is the simplest method of SRT waste control, as it does not require measuring the solids concentration. The SRT is held equal to the ratio between aeration tank volume and waste flow. This method, however, has two major problems:

- *Increased volume.* The volume of the required mixed liquor waste is several times greater than the volume of return activated sludge waste because of difference in suspended solids concentrations between mixed liquor and return sludge. This increase in wasted volume necessitates larger waste sludge and recycled transmission facilities (pumps, pipes), as well as larger sludge thickening facilities. The operating costs of waste sludge and recycled stream pumping and sludge thickening increase as well.

- *Variable mass of waste sludge.* It is difficult to maintain stable mass loading to the sludge thickening facility, and, as a result, the thickening process is not optimized.

Constant hydraulic wasting of return activated sludge
This method also does not require measuring the solids concentration. However, even a small unavoidable change in the ratio between return sludge flow and influent flow, or a small change in sludge settleability will drastically affect the SRT. It is also difficult to maintain mass loading to sludge thickening facility, and, as a result, the thickening process is not optimized.

Traditional (manual) control
Operators utilize the SRT control method that uses the regular SRT formula:

SRT= (Mass of solids under aeration)/(Mass of wasted solids)

Using this formula, the method of SRT control includes the following steps:

1. Sampling of mixed liquor and waste sludge
2. Lab processing of the samples
3. Determination of TSS
4. Calculation of solids under aeration based on the number of aeration basins in service
5. Calculation of waste flow
6. Changing the waste flow according to the SRT calculations

This routine is both labor-intensive and subject to various potential errors.

Automated SRT control
Automating the SRT control process has proved to yield less labor and fewer errors. There are two automation methods, other than *SRTmaster*^{TM}, that use constant SRT control criterion:

- *Calculation of the waste flow using instantaneous SRT.* This method is easy to implement. However, due to high variability of MLSS and RASSS concentrations, waste flow will vary significantly and negatively affect the waste sludge thickening process. Additionally, instantaneous SRT is not equal to true Mean Cell Residence Time (MCRT), and SRT calculated based on instantaneous MLSS and RASSS values will vary significantly and will not reflect true MCRT.

- *Calculation of waste flow using the dynamic sludge age (DSA) formula.* Recognizing the shortcomings of instantaneous sludge age calculations, dynamic sludge age calculations were introduced in 1985. DSA calculations more accurately compute the true MCRT for an unsteady-state system. However, it has been shown that waste flow calculated based on the DSA formula is even more unstable than waste flow calculated based on the instantaneous SRT formula. This volatility becomes especially dangerous if one of the meters provides a faulty signal. Drastic changes in waste flow will have a significant negative impact on the thickening facility, similar to if the waste flow were calculated using instantaneous SRT formula. As a result, it is advisable to use extreme caution when the DSA formula is directly applied to automatic waste control calculations.

The benefits of automatic SRT control, as provided by *SRTmaster*^{TM}

SRTmaster^{TM} was introduced by Dr. Alex Ekster in 1992. Automation of the SRT control routine using on-line TSS measurements improves the accuracy of actual SRT measurement while significantly simplifying and improving the wasting process. Automation of the SRT control process using *SRTmaster*^{TM} has the following benefits compared to any of the above approaches:

- *Continuous monitoring and control.* Automatic SRT control takes into account all changes in solids under aeration and in the waste stream for an entire 24 hour period. This is in contrast to the traditional approach of taking a snapshot of TSS concentrations once a day and making a change in wasting only once a day.
- *Reduction in errors.* The negative effects of lab errors are significantly minimized and SRT calculation errors are avoided.
- *Reduction in TSS samples.* TSS sampling is reduced by 70- 90%.

The *SRTmaster*^{TM} control system requires only a controller and 2 TSS meters per treatment train (in some cases 1 TSS meter is enough).

Calculation of waste flow utilized in SRTmaster^{TM}

SRTmaster^{TM} uses a computerized model of the activated sludge process for tuning the SRT controller. The computer modeling consists of several steps.

First, the field data is collected and an activated sludge computer model (Fig.1) is calibrated using this data. Next, the time basis for SRT calculations is selected. Time basis is plant specific and depends on wastewater flow and characteristics, plant design, and etc. One criterion for time basis selection is closeness of calculated SRT and dynamic SRT. The computer model is used to simulate an effect of waste flow change on both dynamic SRT and calculated SRT. An example of simulation results is shown in Figure 2.

After the selection of the time basis for SRT calculations, PID tuning coefficients are found for the SRT controller with help of computer modeling. Finally, the behavior of the controller is modeled for "what if" situations. The final tuning coefficients for *SRTmaster*^{TM} are selected based on the modeling results.

The benefits of applying our approach to solving the "real world" problems of wastewater treatment are well documented. Software based on this approach is now successfully controlling activated sludge processes worldwide.

Fig.1 Picture of modeling software layout used for system modeling

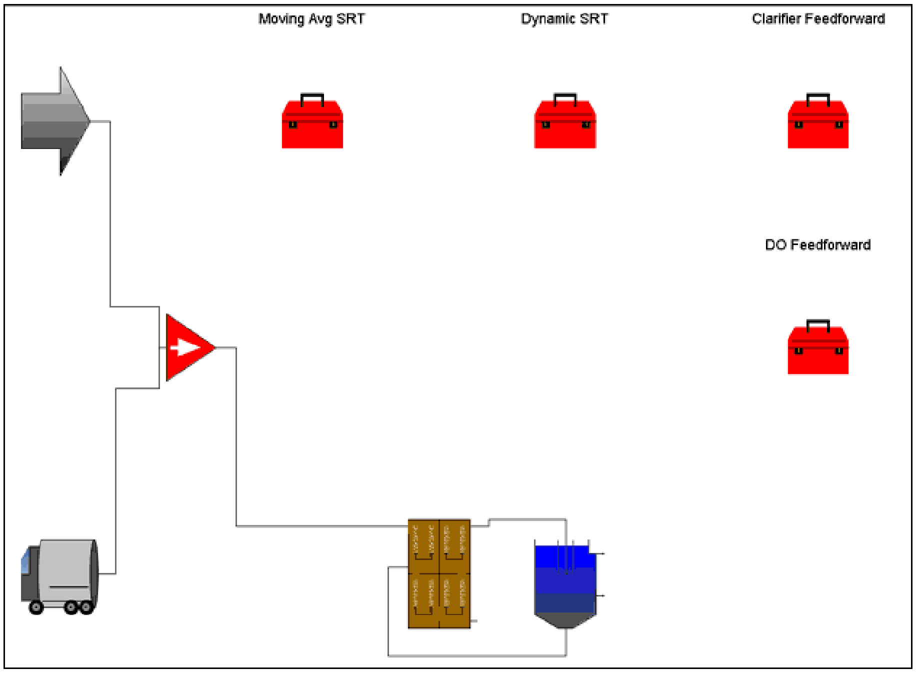

Fig.2 Results of computer simulation.