



◀ Operations staff monitor processes from the Sacramento (Calif.) Regional Wastewater Treatment Plant control center. Joshua Nurmi

Daily flow and loading fluctuate continuously at the Sacramento (Calif.) Regional Wastewater Treatment Plant (SRWTP). These fluctuations exacerbate nocardioform blooms in the secondary process and can adversely affect effluent quality. A study team tested the best available instrumentation – on-line, total suspended solids (TSS) analyzers and solids retention time (SRT) control software – to automate activated sludge flow in real time. The team hoped these tools would enable operators to provide a more consistent SRT and food-to-microorganism ratio (F:M) than found in typical diurnal loadings.

The SRWTP, a high-purity-oxygen activated sludge (HPOAS) treatment plant owned and operated by the Sacramento Regional County Sanitation District, processes an average of approximately 570 ML/d (150 mgd) in dry weather. The plant has no hydraulic break between the influent pump station and secondary process. With no provision for flow equalization, the plant is subject to significant dry weather diurnal load fluctuations. During the wet weather season, SRWTP treats up to 1480 ML/d (390 mgd), partly because a portion of the sewer system is combined with the City of Sacramento's stormwater system.

This HPOAS facility consists of 12 carbonaceous oxidation tanks (COTs), 24 secondary clarifiers, and an onsite oxygen supply system. In the secondary treatment process, the main point of wasting is at the classifying selector that draws off surface flow from the return activated sludge (RAS) stream prior to re-entering the COTs. Dedicated variable speed pumps convey the waste activated sludge (WAS) from the classifying selector to the solids handling process. Additional wasting occurs from the mixed liquor stream. A sump at the end of each mixed liquor battery collects surface foam during warmer periods to remove *Nocardia*-related foam. Mixed liquor channel foam and scum from the secondary clarifiers tie into the waste sludge lines downstream of the RAS selector waste pumps. When the mixed liquor sumps operate, roughly 15% to 25% of the total wasted flow is mixed liquor.

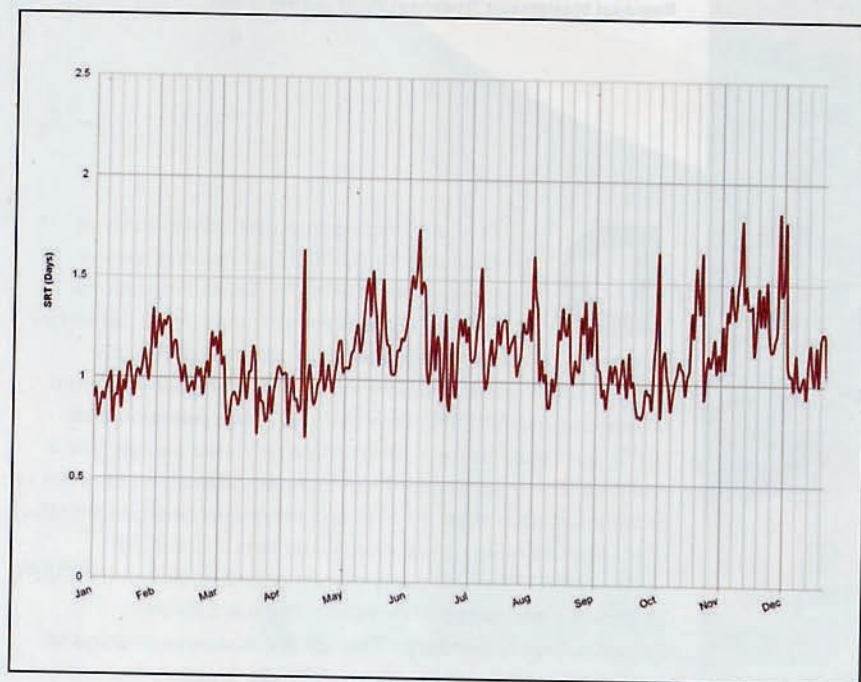
Pilot test shows that real-time control of solids retention time improved instantaneous SRT and F:M control at the Sacramento Regional Wastewater Treatment Plant

Jeremy Boyce and Joshua Nurmi

A control method that did not work

Nocardioform has been a major problem for SRWTP operations. Past studies have found that low F:M at influent temperatures greater than 27°C (80°F) intensify *Nocardioform* populations. The digesters are the first process affected by *Nocardia*-related foam because of the longer hydraulic detention time (more than 15 days). Foam accumulated there has led to overflows, digested sludge pump shutdowns, and heavy trash/debris sent to the biosolids recycling facility or solids storage basins. When *Nocardia* accumulates in the headspace of the COTs, plant operators cannot accurately quantify the solids inventory and effectively control the process. Lower-than-

Figure 1. Daily average SRT without SRT controller



actual F:M calculations could potentially lead to secondary performance problems. For example, a major *Nocardia* bloom developed in June 2008, and *Nocardia* remained in the system through November. For that entire year, the average daily mixed liquor suspended solids (MLSS) concentration ranged between 900 and 1900 mg/L because plant operators had difficulty controlling the secondary process, which had high levels of *Nocardia* in the COTs.

SRWTP previously controlled its sludge wasting based on a mean cell residence time (MCRT) target. In this control strategy, operators adjusted the flow set point of the WAS pumps once a day, based on a target MCRT calculated from process grab samples. Unfortunately, the strategy was flawed. For example, the set point only controlled the WAS pumps from the RAS classifying selector, not flow from the mixed liquor sumps, which could be as much as 25% of the total flow when in service. The daily adjustment did not account for diurnal loading changes. And finally, the MCRT calculation was based on multiple, manual grab samples for mixed liquor, WAS, RAS, secondary effluent and sludge level soundings that were not fully representative of the daily average.

Field testing TSS analyzers

The study team began by evaluating four self-cleaning TSS analyzers. Sensor 1 uses a continuous ultrasonic vibration system, shaking loose material that attaches to the sensor. A wiper blade cleans the light and sensor of Sensor 2 with an adjustable

system. Sensors 3 and 4 both use an air/water jet to keep clean. For Sensors 2, 3, and 4, these cleanings can be varied in frequency and duration. Based on manufacturer recommendations, the team cleaned Sensor 3 with a water jet and Sensor 4 with an air jet. In addition to the automated sensor cleaning, field staff performed manual cleanings and calibrated the devices based on manufacturer recommendations.

The testing focused on TSS analyzer performance in the areas of maintenance, reliability, and response time over a 6-month period. The TSS analyzers were submerged in the plant's mixed liquor and RAS process streams, having a typical range of solids concentrations between 800 mg/L and 1600 mg/L, and 4000 and 6000 mg/L, respectively. Each analyzer was placed in the Battery 3 mixed liquor channel and in the RAS channel.

For maintenance testing, the team assumed an analyzer needed recalibrating

when TSS data deviated between the sensor and grab sample readings by more than ± 100 mg/L for the mixed liquor and ± 300 mg/L for the RAS (approximately 7% deviation) for two consecutive data points. Grab samples taken in triplicate were analyzed in the lab and field using microwave ovens and compared to the TSS analyzer readings. For about 2 weeks, the team increased the cleaning frequency and tested the analyzer to determine the minimum interval required to provide accurate readings.

Once the team established the minimum cleaning and

Figure 2. Daily average SRT with SRT controller

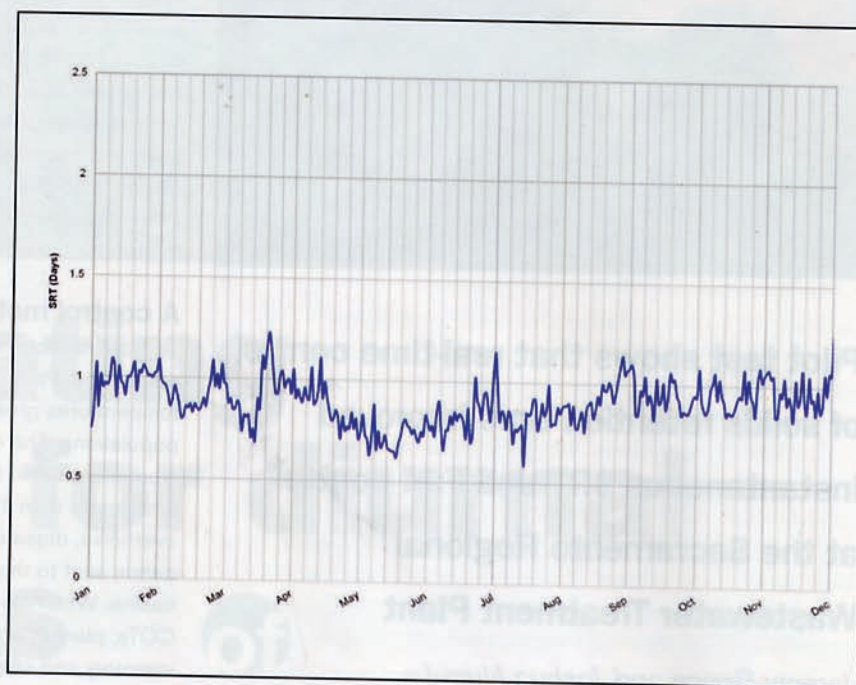
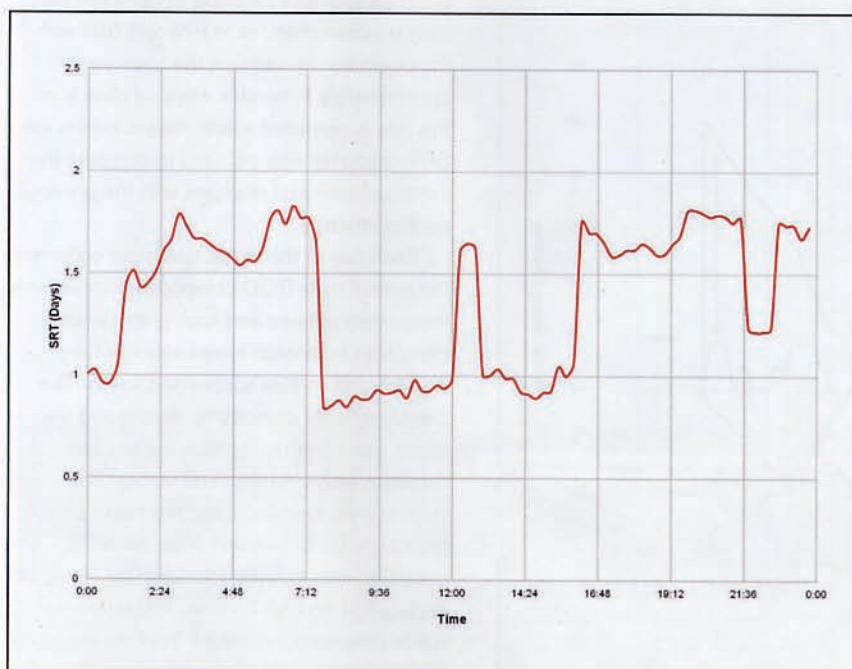


Figure 3. Intraday SRT without SRT controller



calibration requirements, they wanted to determine if optimal cleaning settings would reliably produce accurate readings over a longer duration. Operators cleaned and calibrated the sensors based on the intervals determined in the initial test. Analyzer and grab samples were measured and compared for approximately 2 months to evaluate the long-term performance reliability of the sensors.

The analyzers also had to be able to recognize immediate changes in the process (for example, a heavy load of solids or primary diversion) to alert operators of significant process changes. In the response test, sensors sampled deionized water in a bucket. Once the sensor established a zero reading, it was tested in a grab sample, with operators timing how long it took the sensor to read a stable TSS value. After the reading was recorded, operators returned the sensor to the bucket where they tracked the amount of time required for it to reach zero. Three testing sessions were repeated for each sensor.

Measuring maintenance, reliability, and response

The MLSS testing occurred from July through October 2008. In warm temperatures, a greater amount of biological growth attached to the sensors more quickly, requiring more frequent cleanings. The biological growth primarily consisted of epistylus and tubaflex worms. None of the analyzer self-cleaning mechanisms could completely remove the epistylus growth. The study team used a bleach solution to

fully clean the probes. Analyzers 1, 3, and 4 required less cleaning in the RAS than in the MLSS; however, this was likely due to a seasonal difference. The RAS testing occurred under colder temperature conditions when biological activity was lower.

Analyzers 1, 3, and 4 generally provided reliable readings. As long as they were cleaned and calibrated every 4 days, the analyzers were accurate within the specified range of $\pm 7\%$. The factory recommendation for the analyzers' self-cleaning function (30 seconds every 15 minutes) sufficiently maintained accurate data between cleanings.

Sensors 1, 3, and 4 performed adequately during the analyzer response test. All three analyzers took about 100 seconds to measure the complete cycle. These response times were well within the desired time frame to work with the SRT controller, which calculates 15-minute averages of data.

Pilot-testing SRT control software

Control of SRT is easier to maintain and less susceptible to error than MCRT because fewer samples and less volume are needed for its calculation. Because SRT is based on flow and TSS concentrations, it can be calculated instantaneously, unlike F:M, which requires measuring biochemical oxygen demand (BOD) and 5 days to measure. Being able to control SRT instantaneously can provide ancillary benefits, such as helping to control the F:M in the COTs.

Figure 4. Intraday SRT with SRT controller online

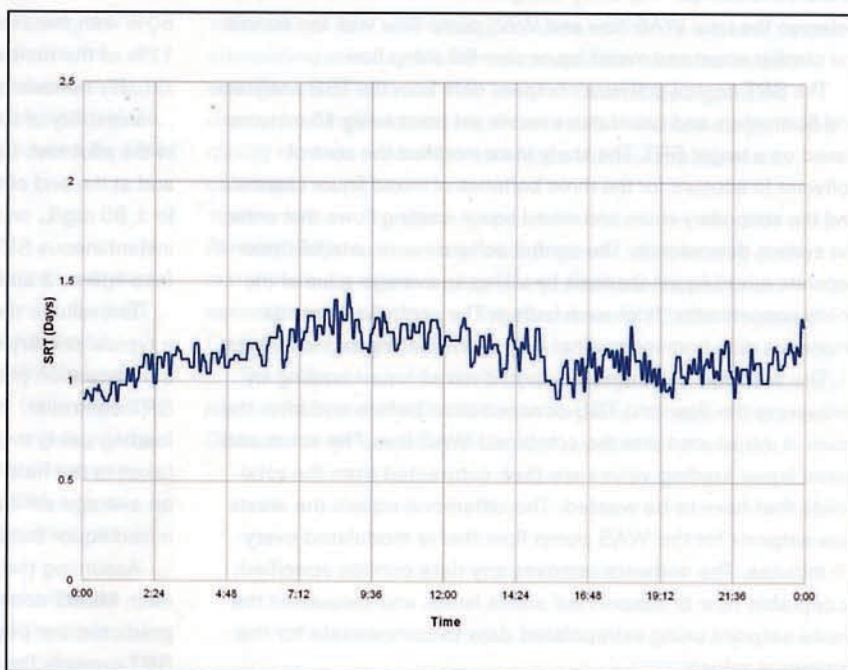
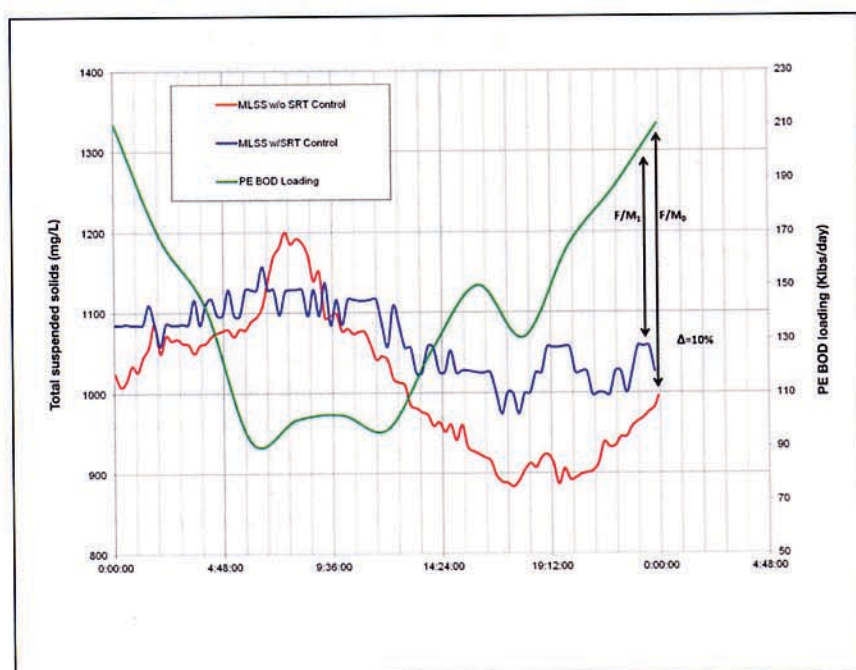


Figure 5. Intraday mixed liquor suspended solids ranges



The plant's SRT control system comprises multiple solids analyzers and flowmeters that output a waste setpoint based on a target SRT. In all, five TSS meters and eight flowmeters send data to the controller. The TSS analyzers are in all three mixed liquor channels, the RAS channel, and in the WAS line. Flowmeters stationed at each of the solids thickeners (two at the gravity belt thickeners and four on the dissolved air flotation thickeners) measure the total WAS flow leaving the system, including secondary clarifier scum and flow from the mixed liquor channel sumps. The study team added two flowmeters on each of the waste lines directly off the WAS pumps to account for the mixed liquor and scum flow that ties into the waste system downstream of the WAS pumps. The study design assumed that the difference between the total WAS flow and WAS pump flow was the sum of the clarifier scum and mixed liquor channel sump flow.

The SRT control software compiles data from the TSS analyzers and flowmeters and calculates a waste set point every 15 minutes based on a target SRT. The study team modified the control software to account for the three batteries of mixed liquor channels and the secondary scum and mixed liquor wasting flows that enter the system downstream. The control software accounts for three separate mixed liquor channels by taking an average value of the solids concentration from each battery. The controller discards erroneous data from meters that may need cleaning and calibration.

The software calculates scum and mixed liquor loading by measuring the flow and TSS concentration before and after the scum is introduced into the combined WAS line. The scum and mixed liquor loading values are then subtracted from the total solids that have to be wasted. The difference equals the waste flow setpoint for the WAS pump flow that is modulated every 15 minutes. The software removes any data outside specified, acceptable flow or suspended solids limits, and calculates the waste setpoint using extrapolated data to compensate for the erroneous values.

The study team used data from the previous year as a baseline to compare the daily process changes in F:M and SRT with the controller. In addition, the team used approximately 1 month's worth of data from the new suspended solids meters before the SRT controller was installed to compare the intraday (real-time) changes with the previous control strategy.

Each day of the study, operators collected the normal daily BOD composite sample from the primary effluent and took grab samples every shift from each mixed liquor battery for TSS and volatile suspended solids. The primary effluent composite sample and the mixed liquor grab samples were used to calculate daily F:M and SRT values. For consistency, the team used the same daily grab samples before and after the SRT controller was activated to compare changes in daily F:M and SRT values. Instantaneous solids concentration values from the analyzers provided data needed to evaluate the intraday activated sludge process changes.

Controlling swings and lowering variability

Prior to bringing the SRT controller on-line, SRT could swing between 0.75 and 1.7 days. Not only were there fewer major daily swings, but the SRT range was consistently tighter with the controller, reducing the daily average from 0.6 to 1.2 days (see figures 1 and 2, p. 46).

The SRT control software strategy of adjusting the set point every 15 minutes effectively controlled daily SRT variability and helped reduce daily F:M variability. Compared to baseline data, the daily F:M improved from a range of 0.8 to 2.6 to between 1.2 and 2.0. Fifty percent of the time, daily F:M ratio swings were within ± 0.2 before the SRT controller and improved to 80% with the controller. High F:M swings (0.6 to 1.0) occurred 17% of the time with the previous control strategy but were virtually nonexistent with the SRT controller.

Variability of the intraday MLSS concentrations also improved in the pilot test. Based on data from the solids analyzers before and at the end of the test, the MLSS range improved from ± 160 to ± 80 mg/L, on average. With the SRT control software, the instantaneous SRT variability dropped from $+0.5$ to $+0.15$ days (see figures 3 and 4, p. 47).

To evaluate the intraday F:M, the study team superimposed a typical primary effluent organic loading on real-time MLSS concentration profiles from before and after the activation of the SRT controller. The team calculated the diurnal primary effluent loading using the influent flow and hourly BOD grab samples taken in the field. The MLSS concentration profiles were based on average solids concentrations from the TSS analyzers in each mixed liquor battery (see Figure 5, above).

Assuming the same diurnal loading was applied to each MLSS concentration profile simultaneously, the team predicted the peak instantaneous F:M would be higher without SRT control. The MLSS concentration reaction would be



View of the high-purity oxygen activated sludge process from the Sacramento Regional Wastewater Treatment Plant control center. Joshua Nurmi

more pronounced when the loading drops, creating higher instantaneous F:M when the loading increased later in the day. Attenuating the solids concentrations with the controller minimizes the instantaneous peak F:M. Based on typical values, the team estimated that the peak F:M could be reduced by 10% with SRT control.

Learning the limits of automation

A few unexpected events affected the SRT control software performance. Occasionally, flowmeter failures caused the SRT controller to waste incorrectly. Over the course of the pilot, dissolved-air flotation, gravity belt thickener, and WAS pump flowmeters failed at least once. Flowmeters used for process control should be routinely checked for accuracy and regularly maintained. The influent BOD load also affected performance. Although rare, high loadings can cause elevated F:M with or without the SRT controller, because the controller does not directly measure influent BOD.

According to this pilot study, using SRT control software for the activated sludge process greatly improved the daily variability in SRT and F:M. It also decreased the intraday

variability of SRT and MLSS concentrations. To a lesser extent, attenuating intraday MLSS concentrations has also helped equalize instantaneous F:M "peaks" caused by significant diurnal loading fluctuations. As a result, the secondary effluent quality is more consistent and *Nocardia* blooms are more contained.

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