

AUTOMATIC WASTE CONTROL

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ABSTRACT

An intelligent automatic solids retention time (SRT) control system is discussed. The system utilizes non-parametric statistics for data filtering. It is shown that utilization of an SRT automatic control system helped to eliminate *Nocardia* foam and low F/M bulking, reduced variation in clarifier solids loading. The SRT control system also helped to improve operation of sludge thickening facility and to decrease polymer usage by as much as 50%. Laboratory TSS tests were reduced as much as 80%. The system required little maintenance and was very robust.

INTRODUCTION

Proper food-to-microorganism (F/M) population ratio is the single most important parameter affecting efficiency of an activated sludge system and health of biomass. Sludge wasting using solids retention time (SRT) criterion is based on the fact that constant SRT leads to constant F/M.

The waste flow is usually a small fraction of the influent flow, however, minimal variations of waste flow over time may have a profound effect on the performance of an activated sludge system. Inadequate wasting may cause clarifier overloading, low F/M bulking and foaming, and increased air demand for biomass endogenous respiration. Excessive wasting may cause poor removal of soluble pollutants, low D.O bulking, and in the case of nitrification -- excessive chlorine demand due to inadequate nitrite removal. Wasting also affects sludge thickening process not only because excessive wasting increases load on thickening facility, but, more importantly, because an increased daily variation in wasting biomass increases polymer consumption and reduces efficiency of all types of thickeners.

Adjustment of a waste activated sludge (WAS) flow is based on calculations that utilize mixed liquor (ML) and often return activated sludge (RAS) total suspended solids (TSS) concentrations. TSS concentration is conventionally measured by a gravimetric analytical method. Use of this routine for WAS determination has following problems:

- Due to influent and RAS flows variation TSS concentration in a grab sample can be 50 % different than a daily average. Daily waste calculations can be considerably off.
- Frequency of sampling is usually restricted to once or twice a day due to extensive time required for sampling and analytical tests. So, waste flow is calculated only once or twice a day, while solids

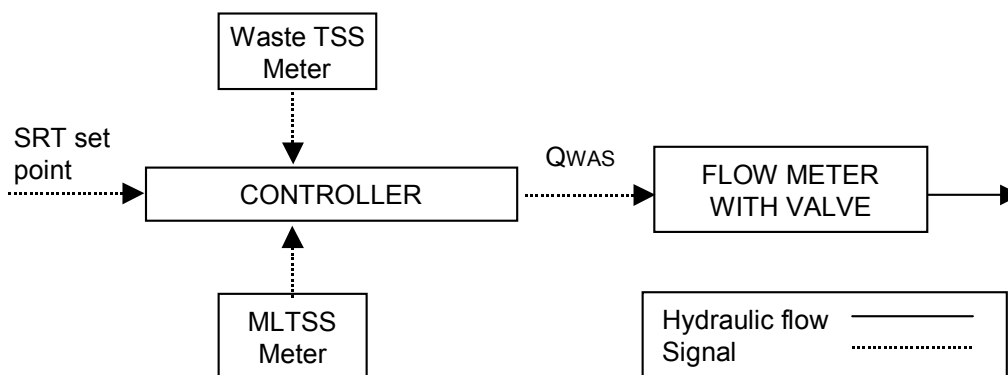
inventory is changing constantly. As a result, conditions for optimum performance of an activated sludge system are not met.

- A gravimetric test takes 2-4 hours to perform, consequently waste adjustment is always delayed for several hours and adversely affects system performance.
- The average test error for an individual sample is 5%, which can make waste calculation inaccurate.
- Solids loading on thickeners is not uniform

In addition, operators sometimes make errors in the tedious of waste calculations, and that causes significant problems in the activated sludge system.

An automatic waste control system can provide constant accurate control over solids inventory, reduce the time required for sampling and sample processing, and eliminate human errors associated with wastage calculations and lag time. In addition, the automatic waste control can stabilize sludge load to the sludge processing facilities. The system (see Figure 1) consists of two suspended solids meters, a controller (computer), and a waste flowmeter with a valve for adjustment. Information from the suspended solid meters is sent to the controller, the controller compares the operational criteria such as mixed liquor TSS or solids retention time (SRT) with the target value, calculates the necessary adjustment of the waste flow, and sends a signal to the control valve on the WAS line.

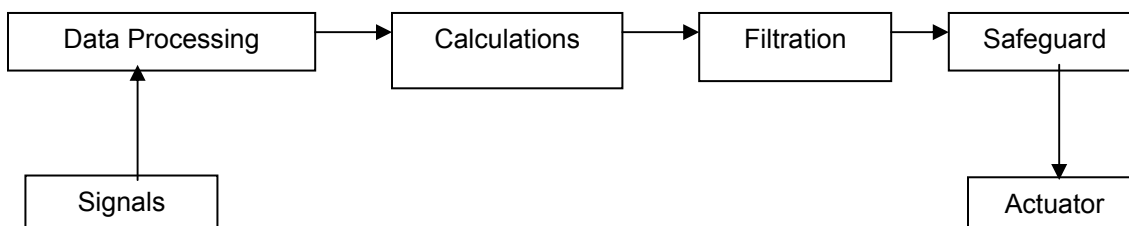
Figure 1. Automatic waste control system schematic



METHODOLOGY

The waste control algorithm consists of the following algorithm blocks: data processing, calculation, outcome filtration, and a safeguard (Figure 2).

Figure 2. Waste control algorithm.



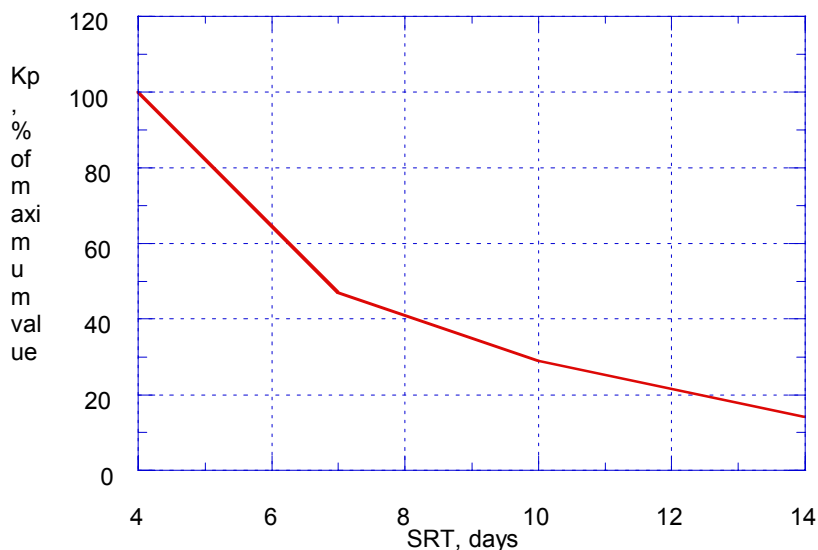
A data processing block filters the signals from the TSS meters and the waste flow meter. The filtering algorithm utilizes non-parametric statistics since TSS data usually are not normally distributed. It also detects malfunction of the TSS meters and waste flow meters, reports the malfunction to the operator, and prevents the utilization of a faulty signal in the control calculations.

A calculation block is the pivotal part of the algorithm. The calculation block utilizes the proportional-integral (PI) control law. Preliminary analysis of the waste control loop showed that it would require up to a year to tune the PI controller. To reduce the time of algorithm development and tuning, a computer IAWQ activated sludge model is utilized. The model is calibrated using field data. A match between calculated and factual wastage is used as a criterion for the modeling. After model calibration, computer simulated response of the system with SRT feed back is utilized for the selection of both reset time (T_i) and proportional gain (K_p). The following criteria are used for designing the SRT controller:

- At a proportional gain equal to twice the K_p design value, waste rate values shall not start to diverge.
- The magnitude of each successive oscillation peak of waste rate values during a change should not exceed one fourth of the previous peak.

K_p and T_i values are investigated for the range of potential SRT set points. Both upward and downward steps toward a target value are simulated. The selection of each pair of optimum K_p and T_i for each target value usually requires at least 10 simulations. Based on the simulation, the relationship between K_p and SRT is determined for each activated sludge system. Example of such relationship is shown on Fig.3. The calculation block is programmed with T_i value and the relationship between K_p and SRT.

FIG.3 EFFECT OF SRT SET POINT ON PROPORTIONAL GAIN OF SRT CONTROLLER



The calculated waste flow signal is filtered using a low-pass filtration algorithm also utilizing non-parametric statistics, then the signal is sent into a safeguard block. A safeguard block is the most

sophisticated block in the algorithm. The purpose of this block is to check that the waste flow calculated by the controller will not have a negative effect on the Plant processes.

Before the output signal is sent to the actuator (valve or variable speed pump), the safeguard block checks whether new waste flow may cause one of the following problems: a) overload clarifiers b) overload sludge processing facility, c) underload sludge processing facility, d) excessive variation of waste flow (load), or e) excessive change in biomass inventory. If there are no negative effects of waste flow change, the new waste signal is sent to the actuator. In addition, the safeguard block informs operators about potential mass-disbalance problems that could be caused by a significant change of sludge depth level in the clarifiers, metering problems, or other operational problems.

RESULTS AND DISCUSSIONS

The following are three examples of process improvements associated with automatic SRT control.

1. 40,000m3/day Biological Nutrient Removal System

An SRT control system that includes a controller and two TSS meters was installed to control wastage from one of the treatment trains. Analysis of data from on-line MLSS and RASSS measurements showed that mixed liquor suspended solids concentration prior to automatic waste control was a highly variable parameter. Several problems caused significant variation of MLSS concentration. One of the causes was overflowing of a return activated sludge channel into a mixed liquor channel. Another cause was irregular wasting. The problems were resolved by maintaining lower water level in the mixed liquor channel and by implementing automatic wastage. In addition SRT value was optimized. During period of automatically controlled wastage both MLSS value and variability were greatly reduced (Fig.4). Drastic decrease in MLSS variability and its value improved clarification process as well as clarifiers ability to withhold storm flow. In addition reduction of MLSS reduced energy demand.

2. 667,000 m³/day conventional activated sludge system

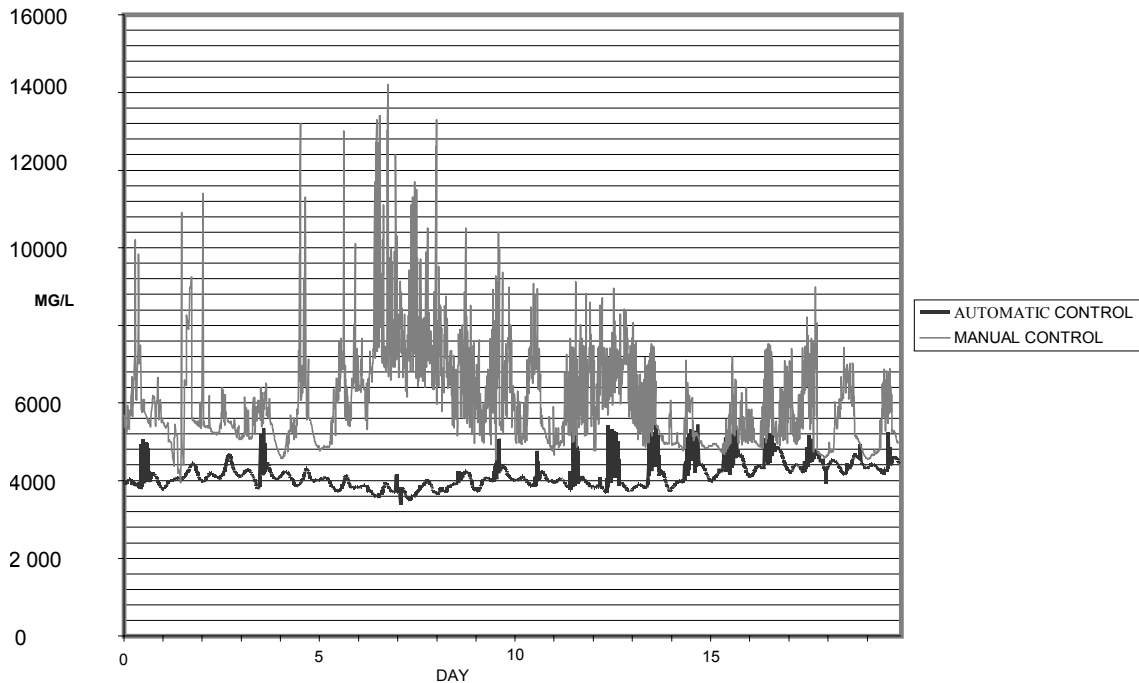
After installation of the same SRT control system significant reduction of TSS and wastemass were observed (Table1)

TABLE 1. AVERAGE PERCENT DEVIATION FROM 24HOUR MOVING AVERAGE (FACILITY 1)

	MANUAL CONTROL	AUTOMATIC CONTROL
MIXED LIQUOR TSS	12	4
RETURN SLUDGE TSS	14	5
MASS OF WASTE LOAD	23	3

Variation of waste (RASSS) and MLSS concentrations were reduced by almost a factor of 3, while the variation of mass waste stream was reduced by a factor of 7.

FIG.4 MLSS CONCENTRATION (FACILITY 1)



Average diurnal deviation of MLSS from 24 hour moving average (Fig.5) after implementation of SRT control was even less than in previous example (Fig.4). The difference (100mg/l vs.300mg/l) can be explained by difference in control of return sludge flow from the clarifiers: at facility 1 return flow was constant, at facility 2 return flow was proportional to influent flow.

FIG.5 MIXED LIQUOR SUSPENDED SOLIDS CONCENTRATION (FACILITY 2)

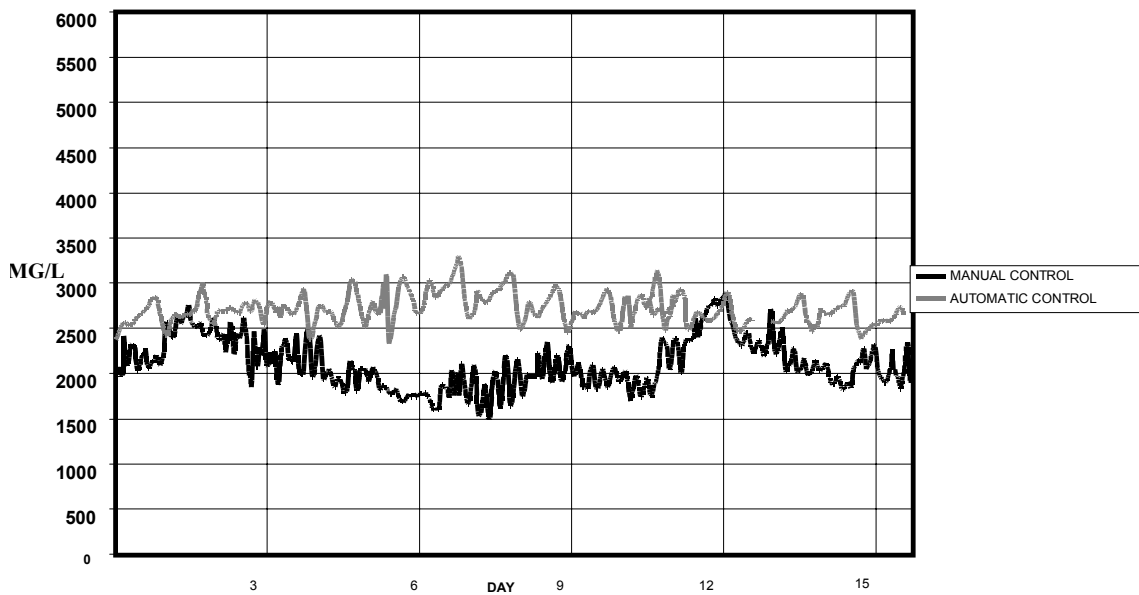
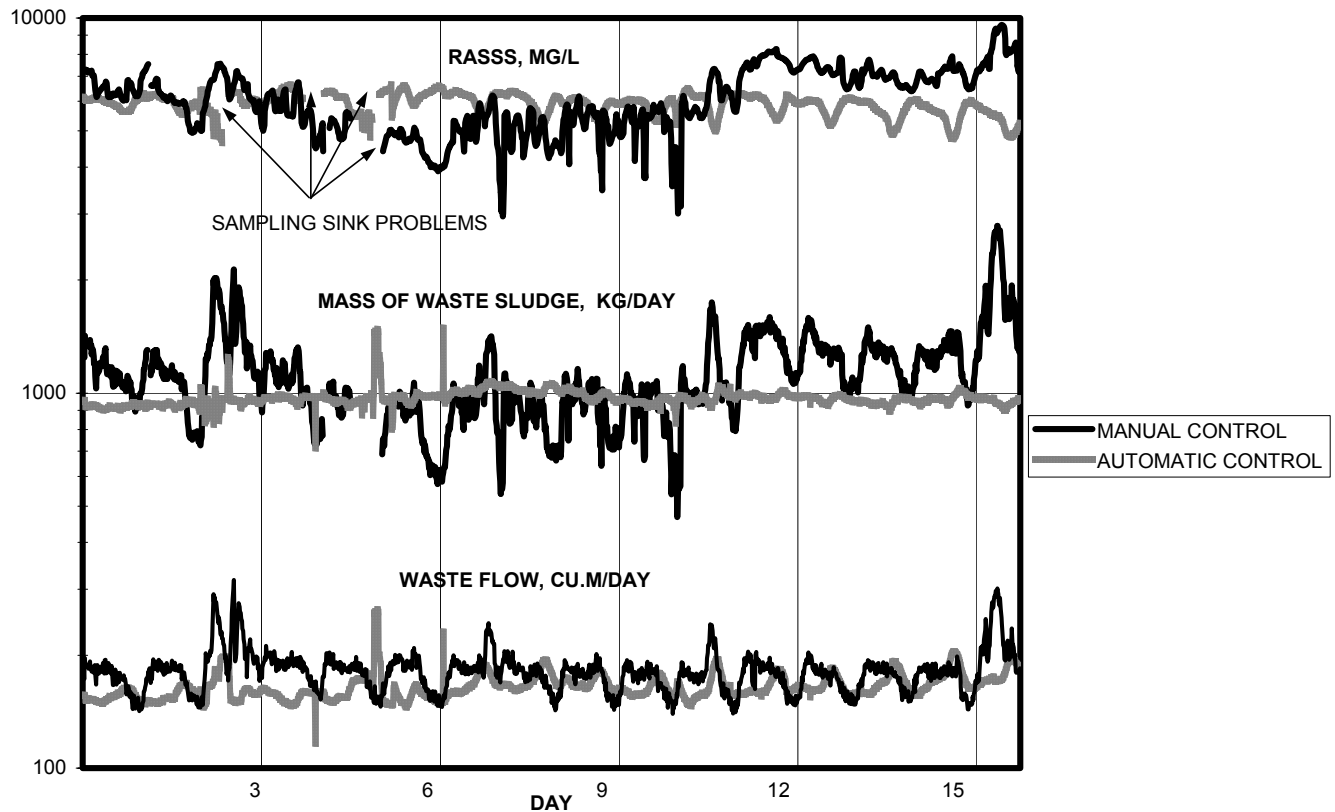


FIG.6 PARAMETERS OF WASTE STREAM (FACILITY 2)



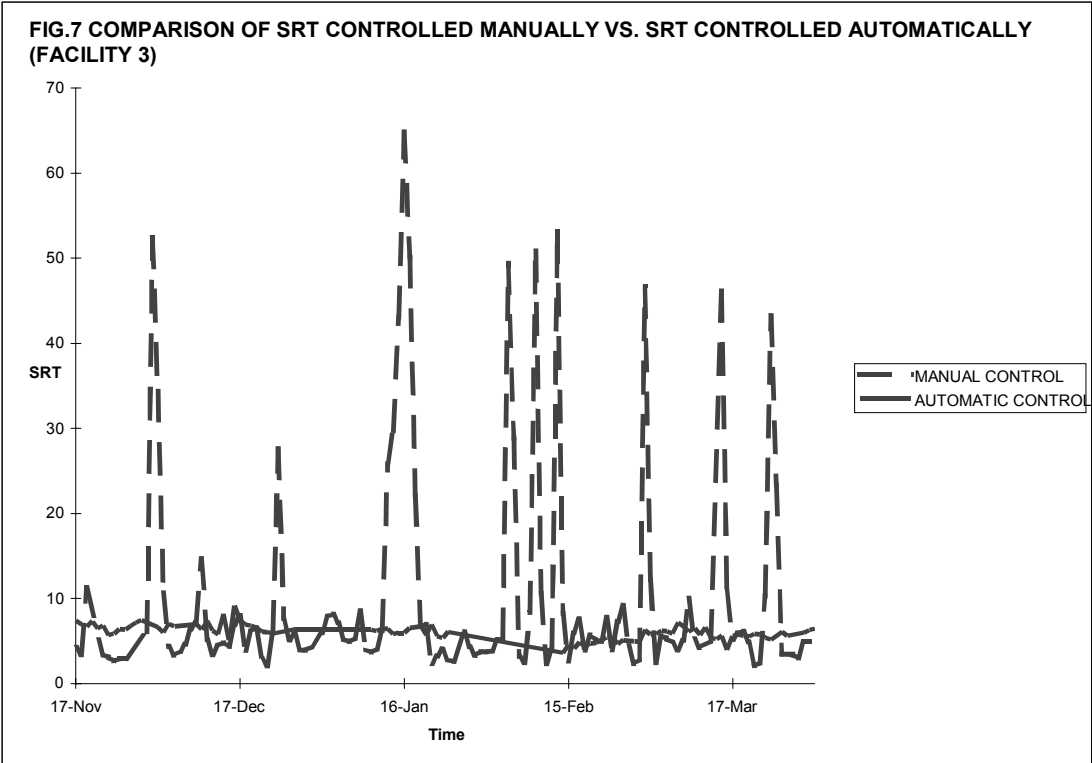
Significant reduction of variation in the waste stream mass (Fig.6) improved the operation of the thickening facility and the earlier practice of bypassing caused by facility overload became unnecessary. Significant (up to 50%) reduction of polymer usage was also observed.

Several times robustness of the control system was challenged when RAS flow to the sampling sink was interrupted, and as a result, the RASSS meters produced invalid readings. The control system automatically detected problems with RASSS readings and not only initiated alarms but also changed the control algorithm to disregard the faulty readings. Once conditions returned to normal, the controller automatically changed the control algorithm back to the one used prior to the encountered problems.

3. 600,000 m³/day Biological Nutrient Removal Facility

Prior to implementation of automatic SRT control the facility has experienced significant foaming problems. Following the installation of automated sludge wasting no incidents of nocardioform foaming have occurred. It is suggested that the reason for the absence of nocardioform foaming is that SRT control with automatic sludge wasting allows much less variation in discrete calculated SRT values than manually controlled wasting based on laboratory TSS analyses does. This point is illustrated by SRT data in Figure 7. During manually controlled sludge wasting based on daily laboratory TSS analyses there are many incidents of very long calculated SRT. These may have been caused by errors in analyses or operation because of the

relatively infrequent data collection and waste flow adjustments. Of course, biological SRT change did not exceed 1 day per day. But even a change in 1 day/day represents 15%-20% instantaneous increase in SRT and several fold decreases in waste flow. Long SRT and drastic reduction in waste flow increase nocardioforms population in aeration tanks. These organisms concentrate in the foam layer and are retained in the activated sludge system by the surface-foam-trapping features of the aeration basin even when the SRT is lowered. With continuous TSS measurements and automatic sludge wasting control, there were no incidents of drastic decrease of waste flow and no nocardioform growth. It is interesting to note that with automatic SRT control it was possible to operate in a nocardioform foam-free condition with a longer average SRT (6.3 days) than with manual activated sludge wasting based on daily laboratory TSS analyses (5.1 days).



An attempt was made to reduce diurnal variation of MLSS by maintaining constant MLSS instead of constant SRT. Results (Table 2) showed that MLSS deviation from moving average was reduced by 1%. Mass of waste load however, was increased in more than 15 times and such increase significantly deteriorated sludge thickening process. Automatic SRT waste control was chosen as an ultimate wasting strategy.

TABLE 2. PERCENT DEVIATION FROM 24HOUR MOVING AVERAGE (FACILITY 3)

	MLSS CONTROL	SRT CONTROL
MIXED LIQUOR TSS	2	3
RETURN SLUDGE TSS	5	3
MASS OF WASTE LOAD	50	3

CONCLUSIONS

- Automatic monitoring of mixed liquor suspended solids and return activated sludge suspended solids reduces number of laboratory TSS tests by as much as 80%.
- Automatic SRT control considerably improves performance of activated sludge process by providing stable environment for microorganisms and suppresses nocardioform foaming.
- Implementation of automatic SRT control improves sludge thickening by providing stable mass load to the thickening facility.