Automatic Wasting & Activated Sludge
MANAGEMENT FOR SEWAGE TREATMENT WORKS

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WATER
Waste Water

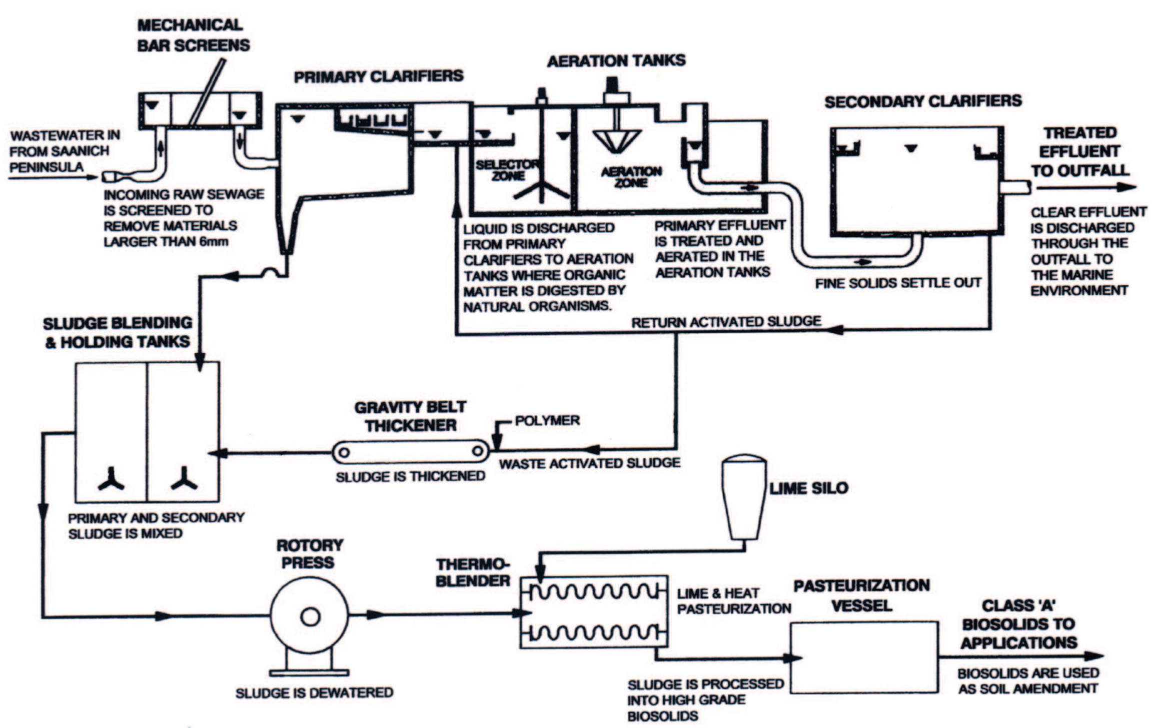
There are three key controllable processes in an activated sludge process:

1) Dissolved Oxygen in the aeration basins 2) Return Activated Solids flow rate 3) Waste Activated Solids flow rate
After discussing basic activated sludge treatment plant operation, this paper will present a proven method of reliably controlling the flow rate of the Waste Activated Solids thus effectively controlling the bacteria population to a value that gives the most efficient treatment of wastewater for minimal cost to treat.

Activated Sludge Treatment Plant Purpose and Operation

The purpose of a wastewater treatment plant is to remove biological oxygen demand (BOD) and reduce nitrates, nitrites, phosphorus, and total suspended solids prior to releasing the water back into the environment. If the wastewater is properly treated, then its release will not have a negative effect on the environment that it is released into.

An activated sludge treatment plant uses bacteria in suspension to treat the waste through consumption of the waste. Please refer to the diagram below. Raw wastewater enters the plant through mechanical bar screens to remove the large debris that would damage plant equipment. After that, easily settleable materials are removed from the wastewater by the primary clarifier so that they don't have to be biologically treated later in the aeration tanks, reducing treatment costs.



The aeration basin is where the food and oxygen are provided to the bacteria for them to consume the wastes in the water and not suffocate and die due to lack of oxygen in the water. Because raw wastewater containing food is always entering the aeration tanks, the bacteria that have finished eating get hydraulically pushed into the secondary clarifiers. In these clarifiers, the bacteria settle to the bottom and clean water is reintroduced into the environment. Most of the bacteria on the bottom of the clarifier are returned back into the aeration basin (Return Activated Sludge) so that they can continue to eat again. This forms a closed loop system of bacteria eating in the aeration basin, being separated from clean water in the secondary clarifiers, and returned back to the aeration basin to eat again. Also keep in mind that the bacteria, like any living organism that is provided a steady supply of food and a good environment to live in, will procreate and produce more bacteria.

Based on the previous discussion, two questions arise:

1) How do you measure the optimum bacteria population to give the best water treatment for minimal treatment cost?
2) How do you control the bacteria population to a manageable amount?

The optimum bacteria population is determined by matching the bacteria population to the amount of food coming into the system and is called the 'Food to Mass Ratio' (F/M ratio). Once you have determined what the F/M ratio is, plant Operations can adjust their biomass by adjusting the waste flow rate (see diagram above). Increasing the waste flow removes more bacteria from the process and reduces the bio-mass and vice versa. The waste flow is usually only a fraction of the influent flow into a wastewater treatment plant, but variations in waste flow have a profound effect on the performance of the entire plant over time. If waste flow, or wasting, cannot be adequately controlled, problems throughout the plant can be experienced.

If there is too little biomass, then there is not a large enough bacteria population to effectively treat the wastewater causing problems such as:

- Poor quality plant effluent – elevated values of TSS, nitrates, nitrates, & phosphorous which could potentially exceed effluent permits.
- Increased chlorine usage if chlorine is used for disinfection.
- Reduced ultraviolet disinfection effectiveness due to higher TSS if UV is used for disinfection.
- Secondary clarifier not settling due to solids 'bulking' (large chunks of solids floating to the surface due to nutrients being consumed in sludge blanket).
- Foaming problems in the aeration basin

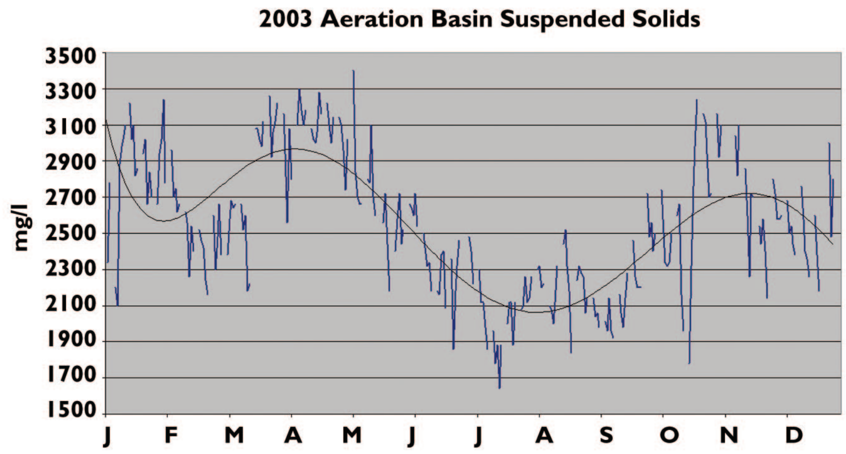
If there is too much biomass, then there is too large a bacteria population causing problems such as:

- Elevated aeration costs due to keeping excess bacteria alive.
- Promotion of 'cannibalistic' bacteria (nocardioform) that float on the surface and cause foaming problems in the aeration basin.
- Excessive Return Activated Solids pumping moving un-necessary bacteria.
- Greater mass loading on secondary clarifiers potentially causing settling problems.

If the biomass swings from too large to too small and back again, this allows the TSS concentration in the aeration basin to swing wildly creating problems such as:

- Bacteria are less efficient since the amount of food presented to them seems to change drastically, therefore you will have to have more bacteria in order to account for this loss of bacteria efficiency.
- The mass loading going to the clarifier is not constant, negatively affecting settleability.

In order to calculate your F/M ratio, operations needs to measure their Biological Oxygen Demand (BOD), but this is a 5 day test and operations needs to know how to adjust their wasting



rate now. The F/M ratio can be inferred from the calculation of Solids Retention Time (SRT). This is a measure of the number of days 'typical' bacteria is recirculated back into the aeration basin from the clarifier before it is wasted or removed from the closed loop system. The SRT is calculated by the simple formula below:

SRT = Mass Under Aeration / Mass Wasted per day

Otherwise written as:

$$SRT = \frac{\text{(Aeration Basin Solids Density) * (Basin Volume)}}{\text{(Wasted Solids Density) * (Waste Flow Rate)}}$$

Both of the solids densities from the aeration basin and the wasted solids are usually determined through gravimetric analysis of grab samples collected from the field. This measurement, which takes a minimum of 2 hours to perform, is typically performed once per day, thus waste flow rates are adjusted once per day based upon information that is 2 hours old. Combine potential wasting adjustment errors with the fact that wasting is controlled based on manual laboratory tests, usually performed only once or twice per eight hour shift, and it is understandable why many activated sludge plants seldom have responsible control of their wasting process. In fact, the normal SRT control process utilised in most plants today is strictly reactive, with over 2 hours between sample gathering and waste flow adjustment, almost worthless in maintaining true wasting control.

Improvements To Plant Operation provided by Automatic SRT Control

Based upon process information supplied by the plant, we are able to make a few forecasts on the improvements that will be realised through the use of Automatic SRT Control.

1. Stabilised mixed liquor in the aeration process. By automatically controlling waste flows, we are able to reduce the large daily/weekly swings in MLSS concentrations. Controlling the suspended solids in the aeration basin has a direct relationship to controlling the F/M ratio, thus effectively improving treatment capability. The graph shows the actual Mixed Liquor Suspended Solids (MLSS) in the aeration basin at a Western Canadian Wastewater Treatment Plant. On average, the MLSS within one month can swing 600 mg/l. After the implementation of automatic waste control, the MLSS will more closely approximate the black trend line that has been superimposed on the plant data.
2. Reduced laboratory testing requirements, often by over a 75% reduction. Most customers find that the information provided by the continuous TSS analyzers are 'close enough' (+/- 50mg/l) to the daily laboratory readings and reduce their grab samples from 7+ times per week to once per week. Approximate savings of 12 man-hours per day.
3. Improved and stable Food to Mass ratios in the aeration process leading to better treatment of raw influent and the promotion of a more efficient biomass in the aeration basin. This benefit is related to achieving a more stable MLSS value.
4. Elimination of foaming in aeration basins. By properly maintaining a correct F/M ratio, foaming due to too little or too much biomass is eliminated.

Product Information

The SRT Control System consists of a Royce Technologies Model 7700 Controller, two 7011A TSS analyzers, a 73B TSS sensor, a 74A sensor, and a 711 portable TSS analyzer. The 73B is normally installed in the reactor or mixed liquor channel, and the 74A (pipe insertion sensor) is normally installed in the RAS pipe. Depending on how the plant is designed, the system can be supplied with more than one 73B, or if RAS is in a channel (rather than a pipe) a 73B can be used instead of a 74A.

The controller needs to know the mass of solids under aeration and the mass of solids being wasted. The former is calculated by knowing the solids in the reactor or mixed liquor channel (7011A/73B) and the size of the tank(s). The later is calculated by knowing the solids in the waste pipe (WAS) and the waste flow. The 7011A/74A analyzer is usually installed in the RAS line rather than the WAS line as it is easier to get to and solids are always flowing in the RAS line. Of course, the solids concentrations (as opposed to flows) in the RAS and WAS lines are identical. The 7700 requires an input (4-20mA) from a waste flow meter to compute mass wasted solids. Royce can supply this flow meter, but it is more often already installed at the plant or on the P&I drawings for a new plant.

Both solids sensors require air or water supply of 50psig to keep them clean. Royce can supply air compressor systems (Model JCT-1), or just a solenoid, which can be connected to existing air or water services at the plant. The 7011A analyzers control the frequency and duration of the cleaning system.

The 7011A analyzers are connected to the 7700 controller via RS 485 daisy chain loop. The 7011A analyzers also have a 4-20mA output, which can be fed directly to a monitoring or SCADA system.

The 7700 can control wasting either directly or indirectly, continuously or intermittently. In direct control, the control output signal can be 4-20mA for a control valve or contact closures for a waste pump. In indirect control mode (most plants use this method), the 7700 sends a 4-20mA signal representing the target waste flow to a SCADA system, which then controls waste to that target (cascade control).

Royce Technologies has over 20 control systems installed throughout the world on new plants as well as existing plants.

Installations include cities of Mesa, AZ; New York City; Camden Utilities New Jersey, Highland Creek Ontario, Canada and many others. Cities that are considering our SRT controller include Boise ID, Seattle WA, Santa Barbara CA, Surprise AZ, Toronto, Canada, Orange County FL, South West Water UK, and Kansas City KS.

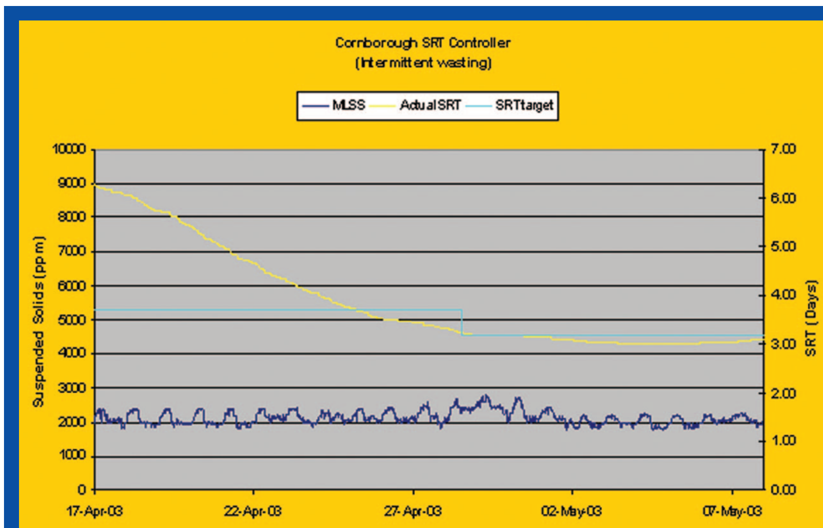
Additional papers, articles and references are available from a local Royce Technologies representative on request

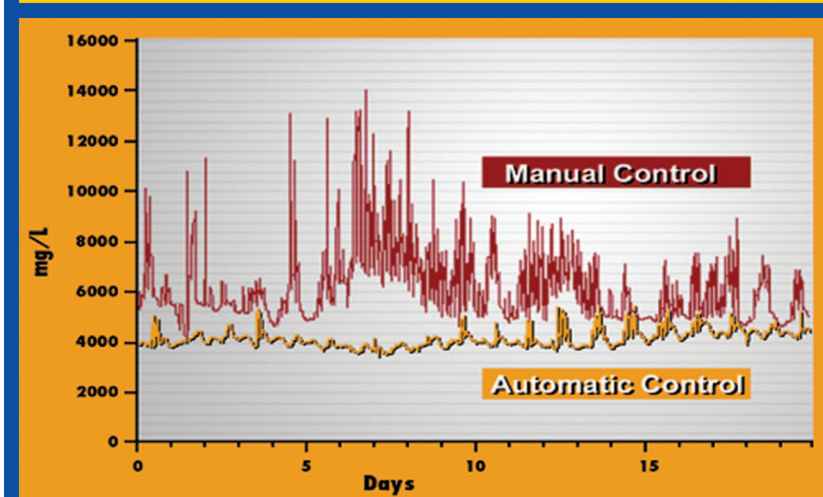
Benefit Examples

- In the graph below taken from the Cornborough WWTP, it shows that there is no significant change in MLSS values (blue line) even though the Solids Retention Time (yellow line) is automatically adjusted from a maximum of 6.25 days down to the target value (aqua line) of 3 days during a period for almost a month.

The daily change in the MLSS values are due to the fact that this plant wastes intermittently once per day rather than continuously.

- At the Alafaya Trail WWTP in Orlando, Florida; there was a significant improvement in their aeration basin suspended solids. There are two differences between the manual control data and the automatic control data that must be pointed out.





Conclusion

There are numerous process advantages gained by automatically controlling the waste activated sludge flow rate. Some of these advantages provide an immediate return on investment such as reduced grab sampling time, laboratory time, reduced aeration demands, and reduced return activated sludge pumping costs. Other advantages provide a general process improvement, but don't immediately contribute to the return on investment such as reduction of foaming, improvement of plant effluent quality, and improved clarifier settling.

With this paper, we have hoped to provide the process benefits, reduction of operation costs, and return on investment associated with the implementation of the Automatic Waste Valve controller provided by Royce Technologies.