Albertville Municipal Wastewater Treatment Plant

Manual of Operations

Albertville, Maine

prepared by the

Albertville Wastewater Treatment Plant
and
Maine DEP

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INTRODUCTION

Activated sludge is a biological wastewater treatment process that brings together wastewater and a mixture of microorganisms under *aerobic* conditions.

The objective of activated sludge is to:

- Convert non-settleable, biodegradable materials to settleable solids and to produce a clarified effluent low in total suspended solids (TSS) and biochemical oxygen demand (BOD).

This objective is fundamentally accomplished by:

- reducing the organic materials using a complex biological community in the presence of oxygen and converting them to new cell mass, carbon dioxide and energy; and,

- producing solids that flocculate and are capable of settling in the clarifier.

It is the wastewater treatment plant operator's responsibility to ***control the treatment process by maintaining proper operating conditions so that the process meets effluent objectives in a cost-effective manner.***

In the activated sludge process, there are three basic controls:
- **waste sludge mass;**
- **return sludge mass; and,**
- **dissolved oxygen.**

There are many factors used as a basis for control of these variables. One of the first is knowing how much sludge is in the system, where the sludge is, how long it has been there, and how fast it is moving from one place to another.

1. pounds = concentration × volume × conversion factor, or
   pounds = mg/L × million of gallons × 8.34 lb/gal
2. Total Sludge, lbs = Aerator Sludge, lbs + Clarifier Sludge, lbs
3. Mean Cell Residence Time = Total Sludge, lbs/Waste Sludge, lbs, where
   Waste Sludge = Effluent TSS, lbs + Waste Sludge, lbs
4. Solids detention time in the clarifier = (clarifier sludge, lbs/return sludge, lbs/d) ×24 hrs/day
5. Solids detention time in the aerator = (Aerator Sludge, lbs/(Q + RSF) × MLSS) × 24 hrs/day

The purpose of this manual is to provide additional guidance to the wastewater treatment plant staff in order for them to make proper adjustment of the operational controls. Proper adjustment of operational controls leads to maintaining the proper "growth pressures" (or control variables). These guidelines will need to be used with <u>operator judgment</u> and updated as the process changes and new experience is gained over time.

STATISTICAL PROCESS CONTROL

Statistical Process Control is the name given to a system of process control that uses statistical analysis of operating data to set control limits for certain operating parameters such as MLSS or MCRT. If the operator can maintain the parameters within the control limits, a good quality effluent can be produced. The basic statistical process control techniques should always be tempered and enhanced by good operator judgment. Statistical process control can be used to analyze the process so that appropriate actions may be taken to achieve and maintain a state of control and to improve the overall capability of the process. Control charts are the primary statistical process control tool used by operators.

A control chart is a graph showing plotted values of some control parameter and one or two control limits. It is used to determine if a process is in control, and to provide information to adjust operational controls.

A control limit, for the purpose of this guidance manual, is a line on a control chart used to establish the maximum or minimum range of a control variable.

Statistical control is the condition describing a process from which all special causes of variation have been eliminated. Special causes result in points on a control chart outside of the control limits.

The information illustrated by the control charts can be used by the staff to make operational control adjustments. The staff may make control adjustments of the operational controls to meet established control variable targets. The staff should consider trends and remember not to "over adjust" operational controls. The staff should attempt to always stay within the established control limits. There are four operational controls for this facility:

1. Wasting
2. Recycle Sludge Flow
3. Aeration Rate
4. Recycle Chlorination

WASTE ACTIVATED SLUDGE FLOW RATE

Background:

Sludge wasting is one of the most important operational controls. Sludge wasting controls the following:

1 Effluent quality
2. The F:M ratio, the Sludge Age (MCRT or SRT), and the mixed liquor concentration (MLSS).
3. The oxygen consumption
4. The nutrients required
5. Aeration basin foaming
6. Mixed liquor settleability

Objectives for waste activated sludge flow rate control:

- Adjust the waste activated sludge flow rate to maintain a balance between the aeration basin solids and the incoming organic loading (BOD).
- Produce solids that flocculate and settle properly.

Monitoring:

MLSS: Mixed Liquor Suspended Solids (MLSS) is the concentration of solids in the aeration basin as determined by standard total suspended solids laboratory analysis. The solids consist mostly of microorganisms; inert suspended matter and non-biodegradable suspended matter.

The target for aeration basin MLSS concentration is: **Target: 2,800 mg/L (summer)** **Target: 3,500 (winter)** Upper Control Limit: 3,800 mg/L Lower Control Limit: 2,400 mg/L

MLVSS: Mixed Liquor Volatile Suspended Solids (MLVSS) is the volatile or organic portion of the mixed liquor suspended solids, determined by the standard volatile suspended solids laboratory analysis.

The target for aeration basin MLVSS concentration is: **Target: 2,300 mg/L (summer)** **Target: 2,800 mg/L (winter)** Upper Control Limit: 3,200 mg/L Lower Control Limit: 2,000 mg/L

Solids Retention Time (SRT): A mathematical determination of the length of time activated sludge microorganisms spend in the aeration basin, expressed in days and calculated as:

$$SRT = \frac{(0.37\ MG)(MLSS,\ mg/L)(8.34\ lb/gal)}{WAS,\ lbs/day + EFF,\ lbs/day}$$

where, WAS is the waste activated sludge in pounds per day (concentration, mg/L)(WAS flow rate, mgd)(8.34) EFF is the effluent TSS in pounds per day (TSS, mg/L)(Effluent flow rate, mgd)(8.34)

The target for the solids retention time is: **Target: 12 days (summer)** **Target: 14 days (winter)** Upper Control Limit: 18 days Lower Control Limit: 8 days

Food to Microorganism Ratio (F:M): A mathematical calculation of the mass of food, measured as BOD, divided by the mass of biological solids under aeration or MLVSS.

$$F:M = \frac{(BOD,\ mg/L)(FLOW,\ mgd)(8.34)}{(0.37\ MG)(MLVSS,\ mg/L)(8.34)}$$

where, BOD is the primary effluent BOD concentration and MLVSS is the aeration tank mixed liquor volatile suspended solids concentration

The target for the F:M ratio is: **Target: 0.14 (winter)** **Target: 0.12 (summer)** Upper Control Limit: 0.17 Lower Control Limit: 0.09

Operational Relationship

WAS Rate Change	F:M Ratio	MLSS	SRT
Increase WAS	Increases	Decreases	Decreases
Decrease WAS	Decreases	Increases	Increases

The F:M Ratio compares the mass per day of food, measured as lbs. of BOD removed by the process with the pounds of microorganisms (measured as MLVSS) available to metabolize the food. The F:M Ratio increases as the SRT get shorter. The F:M Ratio decreases as the SRT gets longer.

Control Procedure:

Using information from the MLSS, MLVSS, SRT and F:M control charts, in combination with sludge quality information, the staff should adjust the wasting rate based on the targets and overall process status. Trends should be noted and knowledge of upcoming events should be used. The sludge wasting rate should not be changed more than ten to fifteen percent in one day. Wait one week or until observations and tests reveal a trend before making another change in the wasting rate.

1. Sample and analyze the mixed liquor to determine the MLSS concentration 3 times per week and the MLVSS concentration 1 time per week.
2. Calculate the SRT and F:M ratio.
3. Calculate the waste sludge required based on the following equation:

$$\frac{\text{Average pounds under aeration for the pervious week}}{\text{target SRT}} = \text{Waste sludge, pounds}$$

4. Evaluate the process based on sludge quality (microscopic, SVI, observations).
5. Determine the process status.
6. Plot the results of the MLSS, SRT, and F:M on control charts.
7. Evaluate the need to increase or decrease the waste activated sludge rate.
   a. Are the control variables (MLSS, SRT, and F:M) above or below targets?
   b. What is the process status based on sludge quality?
   c. Is there a trend upwards or downwards in the primary effluent BOD?
   d. Is there an anticipated increase or decrease in the primary effluent BOD?
   e. Are the control variables (MLSS, SRT, and F:M) within the range defined by the upper and lower control limits?
8. Do not make extreme changes in the waste activated sludge rate.

Note: Changes in waste rates will take 10 to 20 <u>days</u> to stabilize.

SLUDGE QUALITY

Background:

The overall behavior of the biological solids is referred to as "sludge quality". Using the sludge quality method means that the operator studies the aeration basin, mixed liquor solids and secondary clarifiers for informative physical characteristics that help identify sludge quality and process status. The inferences of these physical findings are used to supplement the results of other process control variables, i.e., MLSS and F:M ratio, to make control variable adjustments.

Objectives for sludge quality:

- Produce a mixed liquor that will form a strong floc and settles fairly rapidly as contrasted to a mixed liquor that settles very fast or very slow.
- Normally has a light brown color mixed liquor with a tan foam.
- Produce a mixed liquor that is active throughout the basin and stable at the end of the process as measured by the oxygen uptake rates.

Monitoring:

Microscopic Examination:

The operator should examine a wet mount slide to observe indicator organisms and determine the abundance of filaments on a weekly basis.

Relative Number of Microorganisms vs. Sludge Quality

The target for filament observation is: Target: b some Upper Control Limit: c common Lower Control Limit: a few Reference: D. Jenkins, M. G. Richard, and G.T. Daigger, *Manual on the Causes and Control of Activated Sludge Bulking and Foaming, 1986 (see Figure 13, page 35).*

Operational Relationship

Suggested Causative Condition	Indicative Filament Types
Low Dissolved Oxygen (for the applied organic loading)	Type 1701, *S. natans*, *H. hydrossis*, *M. parvicella*
Low Organic Loading (low F:M ratio)	*M. parvicella*, *Nocardia* spp., *H. hydrossis*, Types 021N, 0041, 0675, 0092, 0581, 0961, 1851 & 0803
Septic Waste/Sulfides	*Thiothrix* spp., *Beggiatoa spp.*, Type 021N
Nutrient Deficiency (N and/or P)	*Thiothrix* spp., Types 021N, 0041 and 0675
Low pH (<pH 6.5)	Fungi

Reference: Jenkins et al., *Manual on the Causes and Control of Activated Sludge Bulking and Foaming*, 1986, page 73.

Sludge Volume Index (SVI): The volume in milliliters occupied by one gram of activated sludge after 30 minutes of settling.

$$SVI = \frac{(\text{Settled Sludge Volume after 30 minutes}) \times 1000 mg/g}{MLSS, mg/L}$$

The target for aeration basin solids SVI is:
Target: 125
Upper Control Limit: 150
Lower Control Limit: 100

Controlling settling behavior of sludge is a challenge. It requires a very good understanding of - and control over - the growth pressures that influence the continually changing biomass.

Oxygen Uptake Rates:

The Oxygen Uptake Rate (OUR) test is a test procedure that determines the rate at which oxygen is removed from the mixed liquor by the activated sludge biomass. It is expressed as mg/L/hr oxygen uptake. The procedure is found in Standard Methods for the Examination of Water and Wastewater. The Specific Oxygen Uptake Rate or Respiration Rate relates OUR to biomass activity. This term gives the operator information related to the condition of the biomass. The unit expression is mg O_2/hr/gram of volatile suspended solids. It indicates an activity level because the rate relates to oxygen removed by a given amount of microbial mass as measured by VSS.

The target for aeration basin effluent end OUR is: **Target: 9 mg/L O_2/hr/gram MLVSS** Upper Control Limit: 12 mg/L O_2/hr/gram MLVSS Lower Control Limit: 6 mg/L O_2/hr/gram MLVSS

Activated sludge with an extremely high activity level (a young sludge) or extremely low activity level (old sludge) usually does not exhibit good flocculating characteristics. It is the flocculation that determines the way the sludge settles in the secondary clarifier.

Aeration Basin and Clarifier Observations:

The operator should note the following aeration basin observations:

- Spray patterns
- Turbulence
- Color
- Foam

The operator should make the following secondary clarifier observations:

- Clarity
- Bulking
- Washout
- Clumping/Ashing
- Straggler Floc
- Pin Floc
- Secondary Clarifier Effluent Turbidity:

RECYCLE SLUDGE FLOW RATE:

Background:

Objectives for recycle sludge flow rate control:

- Adjust the recycle sludge flow rate to maintain a balance of solids between the secondary clarifiers and the aeration basin.
- Adjust the recycle sludge flow rate to obtain the maximum recycle solids concentration while preventing sludge septicity from developing.

Monitoring:

Mass balance flow rate:

$$Q_r = \frac{(MLSS_{mg/L}) \times (Q_{MGD})}{RASSS_{mg/L} - MLSS_{mg/L}}$$

where,

Q = Influent flow, mgd
Qr = Recycle flow, mgd
MLSS = Aeration basin mixed liquor suspended solids concentration, mg/L

Depth of Blanket (DOB): The distance from the clarifier water surface to the top of the sludge blanket. When subtracted from the total clarifier depth, this is the equal to the blanket thickness (BLT).

The target for the blanket thickness is: **Target: 1.5 feet** Upper Control Limit 2.5 feet Lower Control Limit 0.5 feet

Recycle secondary solids concentration:

The target for the recycle secondary solids concentration is: **Target: 7,500 mg/L** Upper Control Limit 10,000 mg/L Lower Control Limit 5,000 mg/L

Control Procedure:

The operator will use the information from the depth of blanket and recycle solids concentration in combination with judgment to establish the recycle rate.

Recycle sludge flow can be thought of as a solids balancing process in which sludge is recycled from the clarifier to the aerator.

Operational relationship

	Depth of Blanket	Recycle Concentration
Increase RAS	Increases	Decreases
Decrease RAS	Decreases	Increases

Too high or low recycle sludge flow rates can create problems with sludge quality and clarifier operation. High return rates increase the turbulence in the clarifier, decrease the aeration detention time for the biomass, and cause a billowing sludge blanket in the clarifier.

Too low return rates allow sludge to accumulate in the clarifier. This degrades sludge quality when anaerobic conditions in the sludge blanket occur.

In a properly balanced system, recycle sludge flow rate adjustments should not significantly change the F:M ratio. **F:M is controlled by wasting. Good sludge quality results from a proper sludge wasting strategy. Recycle redistributes sludge.**

The strategy of adjusting recycle flow rates does not work when there is a high blanket level in the clarifier caused by sludge bulking. In this case, the high blanket level would call for increasing the recycle sludge flow rate to lower the blanket. Increasing the recycle flow rate when the sludge is bulking will make the problem worse. A bulking sludge requires more settling time.

1. Determine the sludge blanket level for each clarifier.
2. Determine the recycle sludge concentration.
3. Calculate the minimum recycle rate based on the mass balance calculation.
4. Evaluate the need to increase or decrease the recycle rate for each clarifier.
    a. Are the control variables (BLT and recycle concentration) above or below targets?
    b. Is the recycle at least the minimum required by the mass balance calculation?
    c. Is filamentous bulking a problem?
5. Based on the evaluation, increase or decrease the recycle flow rates by less than +/- 25 percent per day.

Note: Changes in recycle rate will take 12 to 24 hours to stabilize.

AERATION AND DISSOLVED OXYGEN:

Background:

Oxygen is required by the microorganisms to satisfy the oxygen demand exerted by BOD conversion and endogenous respiration. The contents of the aeration basin must also be sufficiently mixed to keep the mixed liquor solids in suspension and to uniformly mix the solids with the wastewater. In addition, oxygen must be dissolved in the liquid to maintain D.O. at the center of the floc and result in a residual D.O. concentration that doesn't promote excessive filamentous bacteria.

Objectives for oxygen addition are:

- Provide oxygen in proportion to the organic (BOD) loading for proper biological metabolism.
  - If necessary, provide adequate oxygen for metabolism of nitrogen compounds
- Provide sufficient mixing.
- Optimize oxygen feed rates through D.O. aeration basin residual monitoring and management.

Monitoring:

Dissolved oxygen: The amount of oxygen dissolved in the aeration basin liquid, expressed in mg/L.

The target for aeration basin dissolved oxygen (D.O.) residual is: **Target: 1.0 mg/L** Upper Control Limit 2.0 mg/L Lower Control Limit 0.5 mg/L

Dissolved oxygen is monitored at the effluent end of each basin before it discharges over the weir.

Control Procedure:

1. When the D.O. exceeds 3.5 mg/L, shut the aerators at the effluent end off.

2. The weirs are adjustable (with some difficulty) to either increase or decrease the aerator submergence.

RECYCLE SOLIDS CHLORINATION

Background:

Recycle solids chlorination is a short-term measure in response to filamentous bulking. Other short-term measures include:

- "sludge juggling"
- polymer addition to the secondary clarifiers

Long-term measures to correct chronic filamentous bulking include:

- aeration basin pH control
- control of influent waste septicity
- nutrient addition
- changes in aeration rate
- changes in biomass concentration
- changes in waste feeding patterns

Objectives for recycle sludge chlorination:

- Expose activated sludge to sufficient chlorine to damage filaments extending from the floc surface while leaving organisms within the floc largely untouched.

The chlorine dosage is adjusted such that its concentration is lethal at the floc surface but is sublethal within the floc.

Monitoring:

SVI:

The target SVI to <u>begin</u> recycle solids chlorination is: **SVI = 135 (5 day moving average)** The target SVI to <u>end</u> recycle solids chlorination is: **SVI = 135**

Microscopic examination:

The target for filament observation is: Target: 2 some Upper Control Limit: 3 common Lower Control Limit: 1 few Reference: D. Jenkins, M. G. Richard, and G.T. Daigger, *Manual on the Causes and Control of Activated Sludge Bulking and Foaming*.

Chlorine effects on filaments include, in order: • a loss of intracellular sulfur granules • cell deformity and cytoplasm shrinkage • finally filament breakup and lysis

Control Procedure:

Chlorine dosage should be started low and increased until effective. Sludge settleability usually improves within 1-3 days if an adequate chlorine dosage is applied.

1. SVI: _________

2. Filamentous Bacteria Amount: ___________
(Enter: Few, Some, Common, Very Common, Abundant, or Excessive)

3. Enter chlorine dosage: ____________ lbs Cl_2/1,000 lbs MLVSS in aeration
(Enter: Few or Some = 0, Common = 4; Very Common = 6; Abundant = 8; Excessive = 10)

4. Enter MLSS concentration: __________ mg/L

5. Enter the most recent MLVSS analysis: __________ % MLVSS

6. Calculate the pounds of MLVSS:

0.37 MG × 8.34 × _____________ (MLSS, mg/L) × _____ % MLVSS = __________

7. Calculate chorination rate:

____________ lbs MLVSS X 1/1000 × ______ Cl_2 Dosage = ____ lb Cl_2/ 1000 lb MLVSS/day

8. Round off result of #7 to nearest lb: ______ lb Cl_2/day

9. Determine gallons of Sodium Hypocholrite required to deliver dosage calculated in #8.

$$\text{gallons NaOCl} = \frac{\text{pounds } Cl_2\text{/day}}{\text{Z pounds available } CL_2\text{/gal}} = \_\_\_\_\_\_\_\_ \text{ gal /day}$$

where: Z = 0.44 for 5.25% NaOCl (common Chlorox bleach)
Z = 0.83 for 10.0% NaOCl
Z = 1.0 for 12.5% NaOCl
Z = 1.25 for 15.0% NaOCl

10. Set chlorination and record time of adjustment

11. Observe filaments and note SVI

12. Dosage should not exceed 10 lb Cl_2/day per 1000 lb MLVSS.