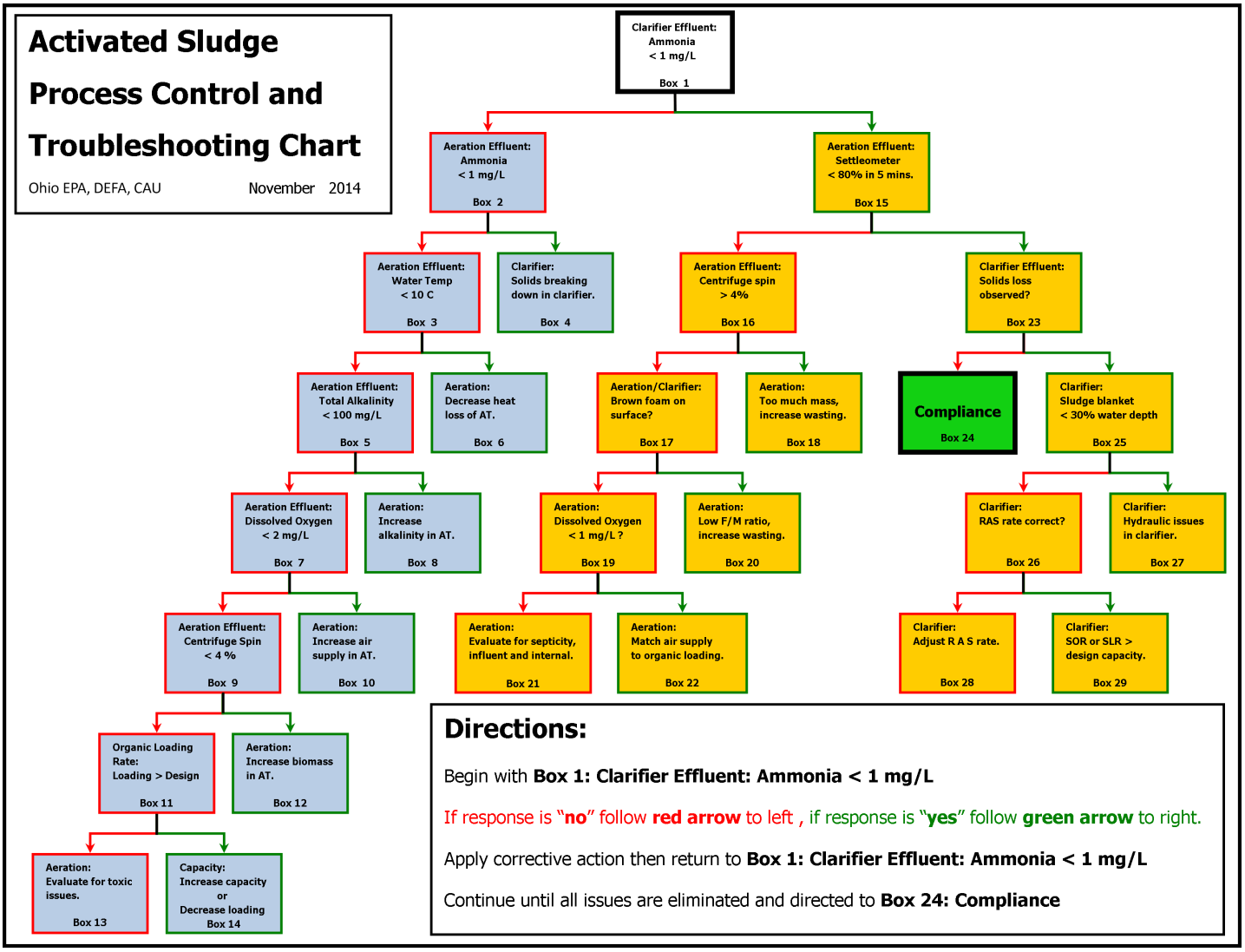
Activated Sludge Process Control and Troubleshooting Chart Methodology



Ohio EPA, Division of Environmental and Financial Assistance

Compliance Assistance Unit

Foreword

In the field of wastewater treatment, there comes a pivotal moment when most of us realize that the best way to advance in this profession is to learn the complexities of "how" wastewater is actually treated. But as wastewater veterans know, this goal can become a formidable and daunting task, especially when it comes to the activated sludge process.

Often a new wastewater trainee is faced with a myriad of potential training options that are well known to the more experienced operators. Over the years this training has taken many forms, typically revolving around correspondence courses, classroom instruction, workshops and seminars. These training options present a variety of process control theories, confusing terminology, an extensive list of acronyms and occasionally contradictory information. The new trainee can become vulnerable to this confusion and have difficulty formulating a comprehensive understanding of how all the puzzle pieces fit together.

To further complicate the learning process, the new employee's training is often driven by the desire to attain formal operator certification. It doesn't matter that the employee's original intent is to learn "how" to treat wastewater, it is the looming state certification exam that seems to ultimately take center stage. Unfortunately, this often creates a less than ideal training scenario in which the "need" to learn wastewater treatment is combined with the "desire" to become a certified wastewater operator. While these two goals appear to be compatible, the need to know all of the aspects of wastewater treatment needed to pass the exam can sometimes diminish the focus on "how" the basic activated sludge process actually works.

This phenomenon became evident while serving for 10 years on the Ohio EPA Advisory Council of Examiners. The Ohio EPA Class IV exam is a very valuable and unique process, in which the applicant is required to prepare a written document describing previous experience and details on the operation of each individual treatment process associated with their respective facility. Upon review of these Class IV exams, it became apparent that many operators did not possess an adequate understanding of the activated sludge process, even though they had successfully passed the multiple-choice exams required to obtain the prerequisite Class III operator certification. Somewhere along the line a training disconnect had occurred that left some operators without a comprehensive understanding of the many caveats that can be associated with activated sludge.

The current operator certification process is not to blame. The multiple-choice exam is the most frequently used method to evaluate the knowledge and skill level of an operator. Unfortunately, this type of evaluation can focus the operator's attention on merely passing the exam and consequently hinder the trainee's opportunity to understand the intricacies of the overall biological treatment processes.

I began searching for a better method to train new employees about activated sludge that would develop a more solid foundation that the new trainee could build upon over time. This training would have to be a logical and simplistic approach that can provide the operator with common sense explanations that mitigate and improve comprehension on a broader scope. This knowledge foundation should not only provide a basic understanding of the bio-chemical relations within the activated sludge process, but also provide a reliable and simplified method for the operator to troubleshoot the process.

In the early 1990's I become acquainted with the Ohio EPA staff members that were operating the agency's Compliance Assistance Unit (CAU). Their mission was to assist treatment plants that were experiencing process control difficulties within their facilities. Like many new programs, it started out small and has grown over the years.

During the earlier years of the CAU, I received an invitation to observe one of these troubleshooting events. I shared a day with them as they collected samples from various areas of a treatment plant to begin analyzing data for their troubleshooting venture. Over the years, the CAU was routinely exposed to a wide variety of conditions that might be contributing to treatment problems. This provided them with extremely valuable experience that would not have otherwise been possible to attain.

Over time and out of necessity, the CAU's troubleshooting methodology evolved into a simple and reliable method to quickly diagnose and troubleshoot the activated sludge process. The real beauty, however, is that this methodology can also be used for daily control of the activated sludge process. With their ***"Activated Sludge Process Control Troubleshooting Chart"*** and the supporting document, the necessary framework has now been developed for the "new" operator to easily understand the basics of operating and troubleshooting the activated sludge process without the need for expensive lab equipment, complicated formulas, or memorizing a wide variety of process control methods.

I personally experimented with the CAU's methods for one year at my 5 MGD treatment facility and soon realized that it makes no attempt to elevate the wastewater treatment field into the "rocket science" category. It simply utilizes many of the concepts that are already familiar to operators, but organizes them in a manner that is more straight forward and logical. The more familiar I became with the CAU process, the more confident I became with its efficacy. In 2006, I converted the operation of my activated sludge process to the CAU methodology and have had no regrets. At first the operators were tenuous about the change, but quickly and easily adapted to the new lab methods and data collection scheme. The daily monitoring and analytical tasks now consume less time, are very reliable, easier to understand and less expensive. In addition, I now have a very teachable and uncomplicated approach to train new employees on "how" to treat wastewater. It does not distract from an employee's ability to study for certification exams, but simply provides a solid foundation from which to extend their knowledge level.

This publication is an attempt to share this information in hopes that it will help new operator trainees to learn the essentials of the entire activated sludge process in a manner that is easier to comprehend. It is not intended to diminish the importance of conventional training methods or on-going research in the wastewater industry, but to simply provide a solid foundation from which to begin the training process.

This learning opportunity would not be possible without the commitment of the Ohio EPA and the employees of the CAU. I appreciate their patience, perseverance and willingness to make a difference.

Robert W. Brown

Ohio EPA Class IV Wastewater (1986)

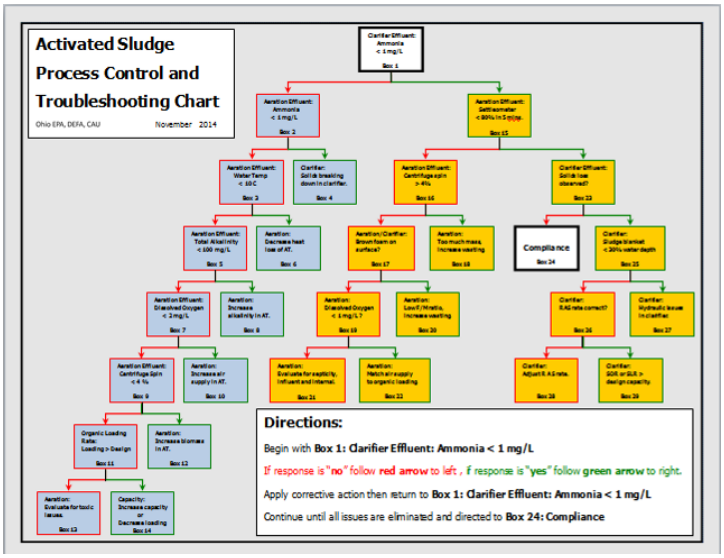
Activated Sludge Process Control and Troubleshooting Chart Methodology

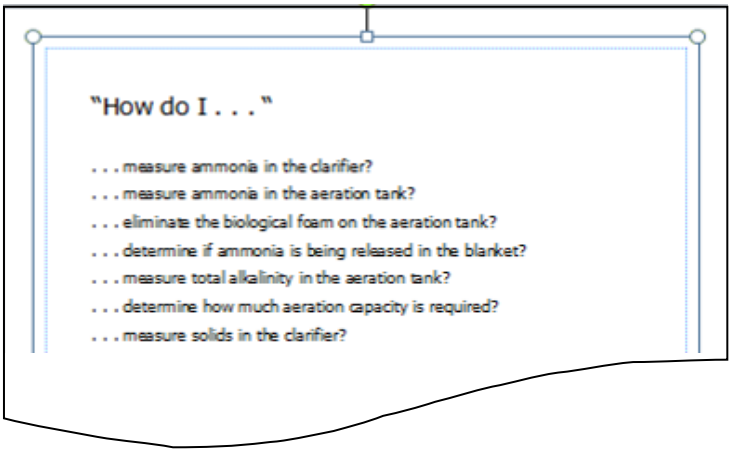
The following methodology was developed by the Ohio EPA Compliance Assistance Unit based on lessons learned from experienced operators and is intended to provide a streamlined approach to *"diagnose"* problems associated with the activated sludge process. The techniques employed offer the opportunity to incorporate these simplified methods into the daily *"control"* of the various activated sludge processes.

This methodology evolved from many years of field work and was developed out of the necessity to quickly diagnosis process control problems and return wastewater treatment facilities to NPDES permit compliance. It is designed to confirm and/or eliminate potential process control issues with the least amount of time, effort, sampling and analysis.

How to Use the "*Activated Sludge Process Control and Troubleshooting Chart*"

The reader is to begin at the top (Box #1) of the ***"Activated Sludge Process Control and Troubleshooting Chart"***. Respond to the statement with a "yes" or "no" and follow the directions provided at the bottom of the chart. If the response to the question asked in the box is "no", follow the red arrow to the left to be directed to collect additional information to continue the diagnoses of the situation. If the response to the question asked in the box is "yes", follow the green arrow to the right to be directed to the cause and solution to the issue. A copy of the chart is attached.





If further assistance is required, refer to the Appendix ***"How do I . . . "*** l This section provides details on how to perform the procedures requested in the individual boxes located in the chart. The following chart can be used to control the biological process to achieve complete conversion and desirable settling characteristics to maintain compliance. A full scale copy of this flow chart is located in the appendix.

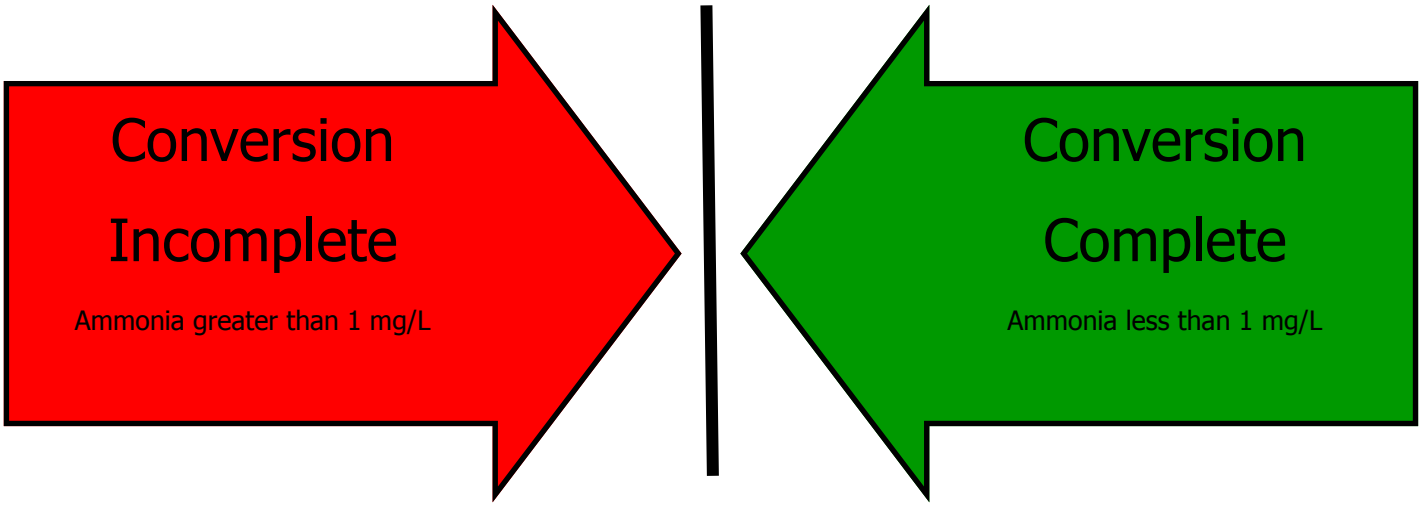
Activated Sludge Process Control and Troubleshooting Chart

Box # 1: Clarifier Effluent Ammonia < 1 mg/L

Wastewater contains pollutants in the form of carbon (cBOD) and ammonia nitrogen (NH_3). Bacteria in the aeration tank convert these pollutants into new bacterial cells (biomass) and more desirable forms of carbon (CO_2) and nitrogen (NO_3), thus preventing degradation of the receiving stream. Nitrifying bacteria in the aeration tank convert the incoming ammonia nitrogen to the less objectionable form of nitrogen called nitrate (NO_3).

These nitrifying bacteria are very sensitive to environmental conditions for growth. Due to this sensitivity, monitoring the conversion of ammonia to nitrate provides an "early warning" indicator of when an adjustment to the process is necessary. Anything which limits the effectiveness of the nitrifying bacteria to convert ammonia to nitrate will cause the aeration tank effluent ammonia concentrations to increase, an indication of loss of the conversion process (i.e. loss of control). Ammonia nitrogen is not removed in the clarifier therefore it will pass through to the Tertiary Stage.

Typically, if the ammonia nitrogen concentration from the aeration tank effluent is <1 mg/L, it is assumed that both of the major pollutants (cBOD and NH_3) have been successfully converted, therefore the treatment objective of the aeration tank (conversion) is now complete. If conditions are met, then the clarifier effluent will also have an ammonia concentration of < 1 mg/L.



The aeration tank "conversion" process must be completed first; therefore it is always the first measurement in the troubleshooting processes for activated sludge systems. If the ammonia nitrogen concentration from the clarifier effluent is greater than 1 mg/L, it indicates the aeration tank conversion process is incomplete or ammonia nitrogen is being generated downstream of the aeration tank in the clarifier. Ammonia nitrogen is only converted to nitrate in the aerobic environment of the aeration tank.

See "How do I . . . measure ammonia in the clarifier effluent?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 2: Aeration Effluent Ammonia: <1 mg/L

Ammonia nitrogen (NH_3) in the influent is converted to nitrate (NO_3) in the aeration tank. If this process is performing as designed, then the ammonia nitrogen should be < 1 mg/L in the aeration tank effluent. If the ammonia nitrogen is > 1 mg/L in the clarifier effluent, then one of two causes are possible. To determine the specific cause of the high ammonia, first measure the ammonia nitrogen in the aeration tank effluent.

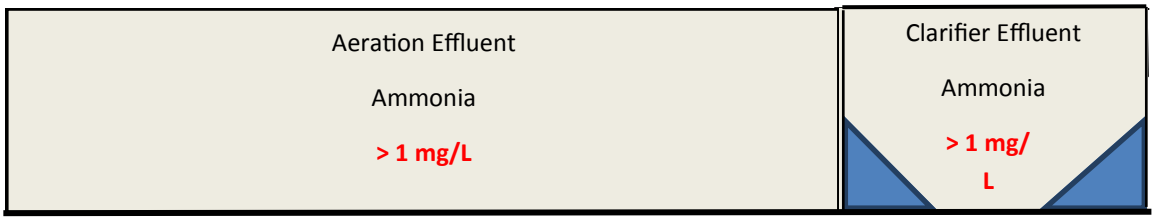


Figure 1: failure in aeration tank

If ammonia nitrogen is > 1 mg/L in the aeration tank effluent (Fig. 1), then the source (location) of the incomplete conversion is in the aeration tank. At this point the reason for the incomplete conversion must be identified and data will need to be collected from the aeration tank to identify the specific cause.

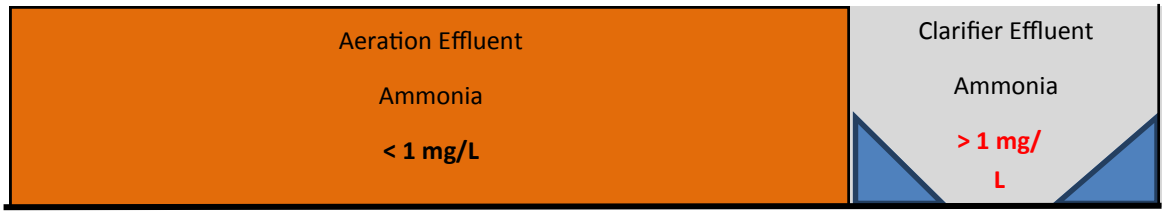


Figure 2: failure in clarifier

If ammonia nitrogen is < 1 mg/L in the aeration tank effluent, but > 1 mg/L in the clarifier effluent (Fig. 2), then the source (location) of the problem is in the clarifier. This situation indicates that all the ammonia was converted in the aeration tank, but is being generated in the clarifier. Data needs to be collected to identify the specific cause for the excessive ammonia nitrogen in the clarifier.

It is important to identify the location of the high ammonia value first, and then operational adjustments can be directed to the specific treatment unit of the activated sludge system causing the problem. Making adjustments to one unit of the treatment system when the issue is located in another unit is a common mistake in troubleshooting the activated sludge process.

See "How do I . . . measure ammonia in the aeration tank?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 3: Aeration Effluent: Water Temperature < 10 C

If the aeration tank effluent ammonia concentration is > 1 mg/L, then an environmental condition exists in the aeration tank that is limiting the complete conversion of the influent waste into bacterial cells.

Water temperature in the aeration tank has a direct impact on the growth rate of the nitrifying bacteria needed to convert the ammonia to nitrate. When aeration tank water temperatures decrease below 10 C, the nitrifying bacteria might not reproduce fast enough to maintain a sufficient population to convert all the influent ammonia nitrogen to nitrate.

As bacteria convert the waste in the influent to new bacterial cells in the aeration tank, heat is generated. This heat is transferred into the aeration tank environment and the water temperature typically maintains above 10 C. However, if the influent organic loading is low, less heat is generated. In addition, if more aeration is applied than necessary for the organic load, the aeration tank is being over-exposed to the colder ambient air, thereby causing heat loss. Over-aeration of low organically loaded systems can lead to aeration tank water temperatures decreasing below 10 C.

Measure the water temperature in the aeration tank effluent.

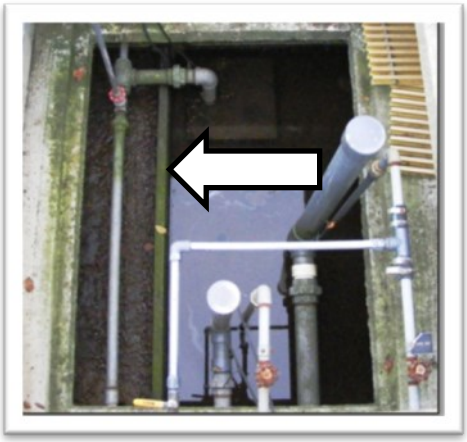
This dissolved oxygen meter is measuring over 2 mg/L of dissolved oxygen (DO) and a water temperature of 9.9 C. A reduction in the aeration would prevent heat loss and save on electrical expenses.

Aeration tank effluent DO concentrations of 2 mg/L should be sufficient to achieve complete conversion, however, if over aeration is lowering water temperature, a reduction in aeration run time would be required.

Activated Sludge Process Control and Troubleshooting Chart

Box # 4 Clarifier: Solids breaking down in clarifier (ammonia re-release)

Bacterial cells are made from carbon and nitrogen. When aerobic bacteria are in an environment without oxygen for an extended period of time, the bacteria die and break apart (lyse). When bacteria lyse, they release ammonia nitrogen back into the water column. If you measure higher ammonia in the clarifier effluent than the aeration tank effluent, the bacteria are likely breaking down in the clarifier. Dead bacteria typically turn black in color; therefore examine the clarifier sludge blanket for sources of decaying bacteria.



Possible Source: Scum Baffle

Biological foam can be generated in the aeration tank. These buoyant bacteria will migrate to the clarifier and accumulate behind the clarifier scum baffle. Eventually this biological foam begins to lyse and release ammonia nitrogen from the bacterial cells. Since the clarifier is not designed to remove ammonia, it passes through the clarifier to the plant effluent.

Solution: Clean the scum baffle area.

Possible Source: Clarifier Surface

If biological foam generation is excessive in the aeration tank, foam will eventually overload the scum baffle and migrate to cover the entire clarifier surface. Brown colored foam is typically associated with having more biomass in the aeration tank than necessary for the influent waste load (low F/M ratio).

Solution: See "How do I . . . eliminate the biological foam on the aeration tank?"

Possible Source: Clarifier Sludge Blanket

As the clarifier sludge blanket increases in depth, it becomes more likely for biomass to lyse and release ammonia in the sludge blanket. Since ammonia is soluble, it will release into the water column and pass through the clarifier to the effluent. A dark or black layer in the sludge blanket is a visual sign of potential ammonia release.

Solution: See "How do I . . . determine if ammonia is being released in the clarifier blanket?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 5 Aeration Effluent: total alkalinity <100 mg/L

If the aeration tank effluent ammonia concentration is > 1 mg/L, then a condition exists in the aeration tank that is limiting complete conversion of the influent waste into bacterial cells.

Nitrifying bacteria convert ammonia nitrogen (NH_3) in the influent to nitrate (NO_3) in the aeration tank. During this conversion of ammonia to nitrate, the nitrifying bacteria also generate acids. If sufficient acids are generated, the pH of the aeration tank will decrease and eventually inhibit the conversion process.

Alkalinity is naturally found in water and acts as a buffer to the acids that are generated by the nitrifying bacteria. If sufficient alkalinity is available, the pH remains within the desired range for the nitrifying bacteria and conversion is completed. However, if the influent waste stream contains a significantly higher concentration of ammonia nitrogen and/or the influent wastewater is low in natural alkalinity, a decrease in pH could occur and inhibit the conversion process.

Measure the total alkalinity in the aeration tank effluent using a field titration kit.

If the total alkalinity is > 100 mg/L, then the conversion process has not been limited by alkalinity.

Continue to evaluate other possible causes for the incomplete conversion.

If the total alkalinity is < 100 mg/L, then it is more likely alkalinity is the limiting factor.

It is not sufficient to measure total alkalinity only one time, or at the same time each day. To develop a true picture of the total alkalinity, it is important to measure the total alkalinity at different times and different days of the week.

Monitoring the total alkalinity (and not pH value) is critical to prevent upset conditions. The pH will drop quickly when alkalinity is consumed in the nitrification process. The goal is to provide sufficient alkalinity to prevent the pH from dropping and causing an upset condition.

See "How do I . . . measure total alkalinity in the aeration tank?"

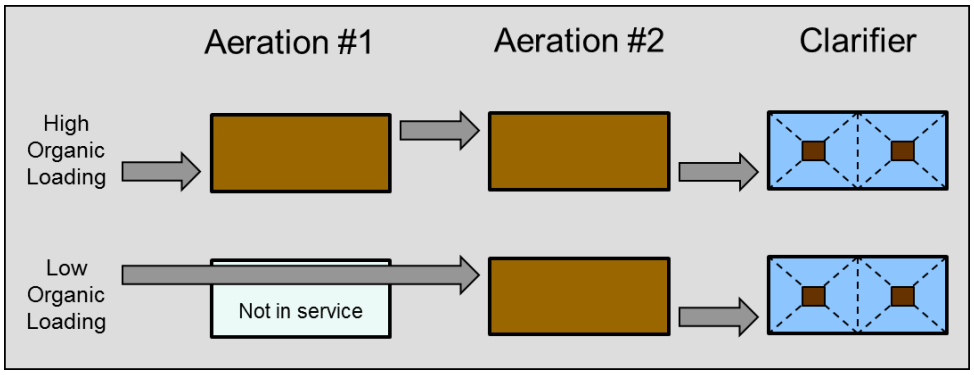
Activated Sludge Process Control and Troubleshooting Chart

Box # 6: Aeration: Decrease heat loss of aeration tank

To prevent heat loss, match the amount of aeration applied to the waste load being received.

Reduce Heat Loss: Aeration Tank Capacity

Systems that are subject to seasonal flow variations (i.e. campgrounds, schools on break) could experience significant decreases of influent organic loadings during the colder winter season. If influent loadings decrease, one option is to remove an aeration tank from service if the system is designed with this flexibility.



DON'T ADD DOG FOOD TO INCREASE ORGANIC LOADING—spending money to purchasing food to feed bacteria and then paying to remove it from the waste stream is illogical.

Solution: See "How do I . . . determine how much aeration capacity is required?"

Reduce Heat Loss: Timers

Applying more aeration than necessary over-exposes the warmer aeration tank contents to the colder ambient air temperature and uses more electricity than needed. Reduce aeration timing cycles to prevent over exposure. *(Caution: Airlift return systems (RAS) are controlled by aeration "on" cycles.)* Consider

Reduce Heat Loss: Covers

When colder ambient air comes in contact with the warmer aeration tank contents, the heat from the aeration tank water is lost to the atmosphere.

Solution: Prevent heat loss by covering the aeration tank with an insulating tarp or some other type of insulating material. In extreme cold situations, also protect exposure areas upstream of the aeration tank (i.e. flow EQ basin).

Activated Sludge Process Control and Troubleshooting Chart

Box # 7: Aeration Effluent: Dissolved Oxygen (D0) < 2 mg/L

If the aeration tank ammonia concentration is > 1 mg/L, then a condition exists in the aeration tank that is limiting the complete conversion of the influent waste into bacterial cells.

The nitrifying bacteria, which convert ammonia to nitrate, require adequate DO throughout the aeration tank environment. If insufficient DO is available, the conversion process is inhibited and aeration tank effluent ammonia may be > 1 mg/L.

Field monitoring of the DO concentration throughout the aeration tank is required to determine if insufficient oxygen is the cause for the incomplete conversion. The DO concentration is very dependent upon aeration tank loadings. Therefore a "true" picture of the available DO requires monitoring of the aeration tank at different times during the day and different days of the week to identify both the peaks and the valleys.

A data logging DO meter will assist the operator to trend the DO levels in the aeration tank environment over an extended period of time.

If your DO meter does not data log, measure aeration tank effluent periodically throughout the day, and throughout the week, to develop a DO profile.

Measuring DO levels at different depths and locations within the aeration tank provides the best overall picture of the oxidative condition within the tank. However, the most critical sampling location for data logging DO concentrations is the aeration tank effluent. This is typically the location of the highest aeration tank DO value.

Solution: Increase the dissolved oxygen concentration of the aeration tank. It could be as simple as increasing the blower run times, opening partially closed valves on diffusers drop pipes or may require cleaning of aeration tank diffusers. If available, additional aeration tanks can be brought into service to increase the aeration capacity if necessary.

Activated Sludge Process Control and Troubleshooting Chart

Box # 8: Aeration: Increase alkalinity in aeration tank to >100 mg/L

Measure the total alkalinity of the aeration tank effluent.

Field Measurement –"prevention" method

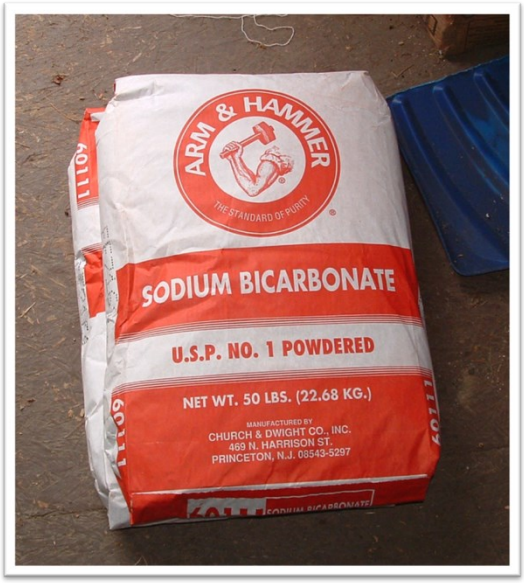
The nitrifying bacteria require more than seven times the alkalinity for each mg/L of ammonia nitrogen converted to nitrate. Thus, alkalinity concentrations can change rather quickly and adjustments need to be made without delay.

Use a simple titration method to estimate the total alkalinity on site. It is more important to measure the total alkalinity in the field, so adjustments can be made immediately.

Field Measurement – "post-mortem" method

When total alkalinity drops to < 100 mg/L, the biological environment is nearing a "cliff". When the alkalinity is consumed by the nitrifying bacteria, the pH can quickly drop off the "cliff". Since nitrifying bacteria cannot function at these lower pH environments, conversion is inhibited and ammonia concentration will increase. Monitoring total alkalinity allows time to correct the situation; monitoring pH informs you when it is too late. Aeration tank environments should not drop below 6.5 pH units.

Solution: Supplement Alkalinity



If the demand for alkalinity is greater than what is available, supplement with sodium bicarbonate.

If the influent ammonia load is excessive or if the natural alkalinity is insufficient, a stronger source of alkalinity than sodium bicarbonate may be required.

Activated Sludge Process Control and Troubleshooting Chart

Box # 9: Aeration Effluent: Centrifuge Spin < 4%

If the aeration tank effluent ammonia concentration is > 1 mg/L, then a condition exists in the aeration tank that is limiting complete conversion of the influent waste into bacterial cells.

The cBOD and ammonia nitrogen entering the aeration tank is considered "food" for the bacterial cells (biomass). The bacteria must consume or convert all these waste products into new bacteria or harmless by-products before it leaves the aeration tank. When influent loadings increase, the available biomass (bacterial population) in the aeration tank must be adequate to insure complete conversion of the ammonia to nitrate before leaving the tank.

Estimating the amount of biomass in the aeration tank can be performed with a centrifuge. It is more important to know the relative concentration of biomass and its trending pattern (increasing/decreasing) than to know the exact amount of biomass. A centrifuge can determine biomass concentrations in 15 minutes and is sufficiently accurate for process control.

As the concentration of biomass in the aeration tank increases, the aeration tank can theoretically treat an increase in influent organic loading. However when the biomass concentration (as determined by the centrifuge) increases above 4%, the proper settling rate of the biomass can be inhibited or slowed down. When this happens, the clarifier sludge blankets can begin to rise. If allowed to continue, the blankets can rise to the point where the biomass (sludge blanket) can exit over the clarifier weirs and consequently enter the final effluent.

If ammonia concentrations in the aeration tank are > 1 mg/L and centrifuge data indicates the biomass concentration is too low, then increase the biomass concentration in the aeration tank. This is accomplished by decreasing the sludge wasting rate

Solution: Track the solids in the aeration tank

The centrifuge is very useful in quickly identifying the amount of biomass in the aeration tank.

If the RAS pump is not functioning properly, solids could be collecting in the clarifier. First, core sample the clarifier to confirm solids are not "hiding" in the clarifier.)

See "How do I . . . measure the solids in the clarifier?"

Typical aeration tank concentrations range between 2% and 4% by volume. The trending of the biomass concentration is valuable in process control decisions.

See "How do I . . . determine how much to waste?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 10 Aeration: Increase air supply in aeration tank

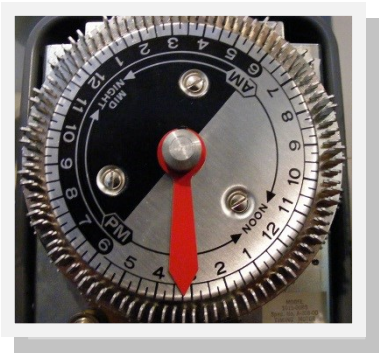
If insufficient aeration is being applied to the aeration tank, it can be an operational issue (increase blower run time) or a mechanical issue (evaluate blower output, restricted air flow).

Diagnosis

A snapshot picture of the DO (grab sample) in the aeration tank is not conclusive evidence that aeration is sufficient. Several measurements at different times and days of the week will provide a clearer picture. A data logging meter reveals all peaks and valleys of dissolved oxygen.

See "How do I . . . measure the DO in the aeration tank?"

Operational Issue: Timers



Aeration tank blowers are typically controlled by a timer. Increasing the aeration time can be achieved by either increasing the frequency of cycles and/or the duration of each cycle. Select a timer with more timer setting options for more flexibility.

See "How do I . . . determine how much aeration time is required?"

Mechanical Issue: Blowers/Motors/Diffusers

Mechanical equipment loses efficiency over time. In addition, influent organic loadings typically increase over time. Either of these situations can lead to insufficient aeration being applied to the aeration tank.

Items to evaluate:

1. Clogged valves/pipes/diffusers
2. Inadequate mixing can be caused by:
   - *diffusers installed along width and not length of tank
   - *course bubble diffusers replaced with fine bubble diffusers and not adjusted for full floor coverage
3. Blower discharge pressure

Activated Sludge Process Control and Troubleshooting Chart

Box # 11 System Loading Rate: Loading greater than design

Determine if the influent organic loading is greater than design loading of the treatment system.

To determine the influent loading rate, collect the following data; average influent flow and average influent BOD.

To calculate influent loading:

(Influent flow, MGD) x (influent BOD, mg/L) x 8.34 = pounds BOD/day

Example: Influent Flow = 15,000 gpd = 0.015 Million Gallons/day

Influent BOD = 200 mg/L

Actual Pounds of BOD/day = (0.015 MGD) x (200 mg/L) x (8.34) = 25 lbs BOD/day

Determine if the influent loading rate is greater than the design loading rate of the treatment system. Organic loading rates are calculated in pounds/day/1,000 ft^3 of aeration capacity. Once you have calculated the actual pounds of BOD per day being added to the aeration tank, you only need to divide this value by the 1,000 ft^3 of aeration tank capacity. For example:

Aeration Tank Dimensions: 12 ft. length, 6 ft. width, and 9 ft. water depth

Aeration Tank, ft^3 = (12′) x (6′) x (9′) = 648 ft^3

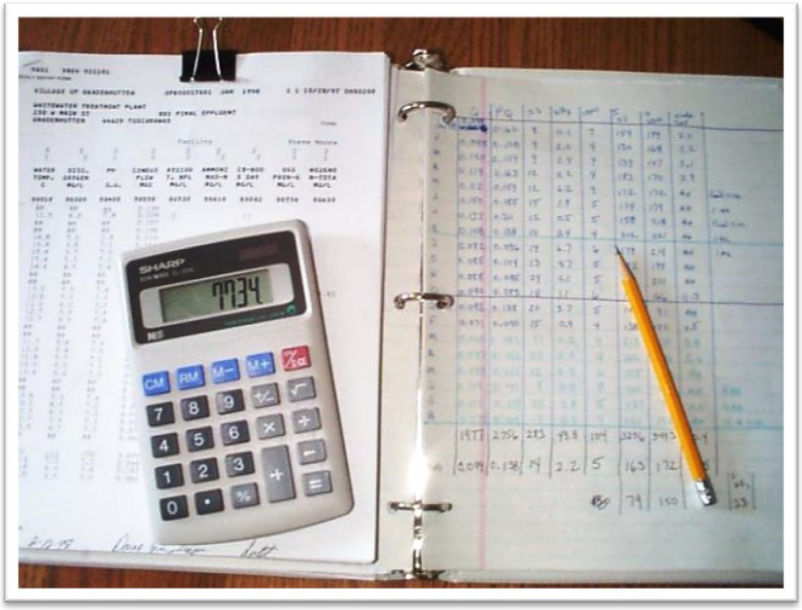
Aeration Tank 1,000 ft^3 = 648 ft^3/ 1,000 ft^3 = 0.648 / 1,000 ft^3 aeration capacity

Organic Loading Rate = 25 lbs BOD per day / 0.648 (1,000 ft^3) = 38 lbs/d/1,000 ft^3

A typical organic loading rate of an extended aeration package plant is 15 to 25 lbs BOD/day/1,000 ft^3 of aeration tank capacity. Review your design data to confirm your systems actual design organic loading rate.

Compare the actual organic loading rate to the design organic loading rate to determine if the treatment system is operating beyond its intended capability.

In our example, the actual organic loading rate is significantly higher than the design loading rate, which can result in incomplete "conversion" in the aeration tank.



Actual loading rate:

38 lbs BOD/day/1,000 ft^3

Design loading rate:

15 lbs BOD/day/1,000 ft^3

If actual loading exceeds the design loading conversion can be incomplete.

Activated Sludge Process Control and Troubleshooting Chart

Box # 12 Aeration: Increase biomass in aeration tank

If the aeration tank effluent ammonia concentration is >1 mg/L, then a condition exists in the aeration tank that is limiting complete conversion of the influent waste into bacterial cells.

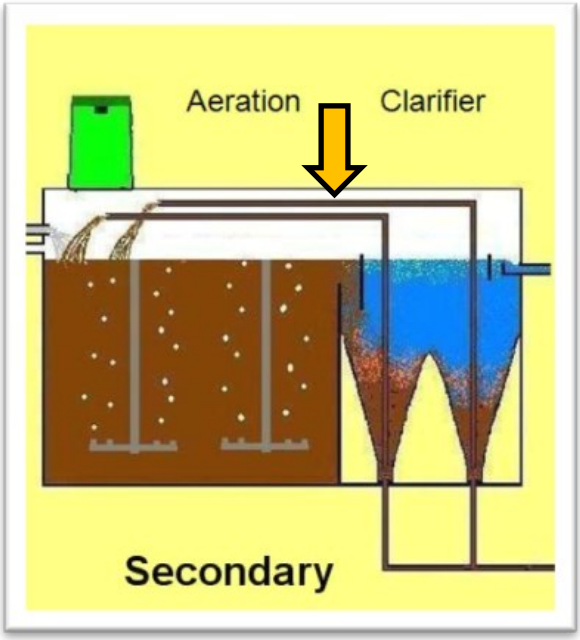
The concentration of biomass in the aeration tank is a function of the influent organic loading. The higher the organic loading in the influent, the more biomass is needed in the aeration tank.

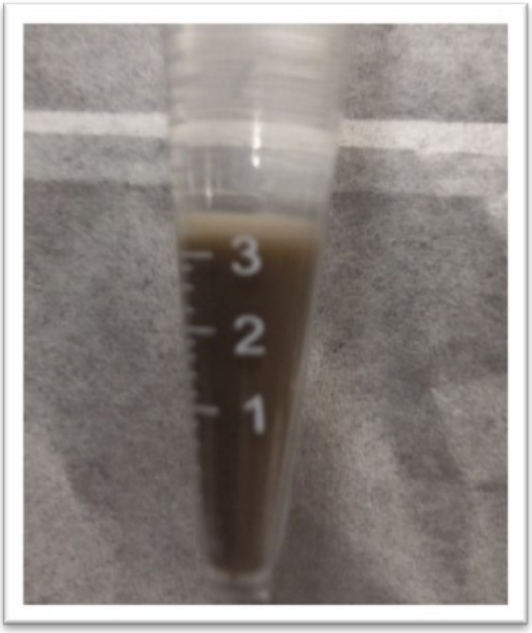
Sample Aeration Tank Effluent

Sample the aeration tank effluent and perform a centrifuge spin to determine concentration of biomass.

Sample Aeration Tank Effluent

If the aeration tank biomass concentration is less than 4%, then increase aeration tank biomass concentration. As concentration increases, continue to monitor the aeration tank effluent ammonia concentration. The ammonia concentration should decrease as the biomass concentration increases if this is the cause for incomplete conversion.





Aeration tank concentrations which exceed 4% typically causes the bacteria to settle slower due to the increased concentration.

Increasing the bacteria concentration in the aeration tank will provide more bacteria for conversion, but too many bacteria in the clarifier negatively affects the settling rate.

See "How do I . . . measure biomass in the aeration tank?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 13 Aeration: Evaluate for possible toxicity issues.

If the aeration tank effluent ammonia concentration is > 1 mg/L, then a condition exists in the aeration tank that is limiting complete conversion of the influent waste into bacterial cells.

If an activated sludge system which treats typical domestic waste is operating within its design organic and hydraulic loading capacity, and other operational limitations have been eliminated (i.e. temperature, DO, mass), then there are two probabilities for limited performance. In this situation there is either an internal side stream which is limiting conversion (i.e. digester supernatant containing high ammonia) or the possibility of a toxic or inhibitory substance in the influent which is impacting conversion.

Evaluate Potential Internal Recycle Streams

Aerobic digesters left un-aerated for extended periods of time can generate a high concentration of ammonia nitrogen. When this is decanted back to the head of the treatment system it can appear as if nitrification has been inhibited, when in actuality it was a slug loading from an internal side stream.

Evaluate internal recycle streams as potential sources of high ammonia concentrations. Check "inside the fence" first for internal recycles. A slug load of high ammonia could be a "self-inflicted wound" and appear as if the treatment system has experienced a toxic event.

See "How do I . . . identify internal side streams as sources?"

Inspect Collection System

Inspection of the collection system could provide an indication of an uncharacteristic (toxic) influent source.

Evaluate external sources (collection system) for potential sources. Evaluate conditions of manholes in the collection system. Examine for visual signs of corrosion, color, stains, or odors.

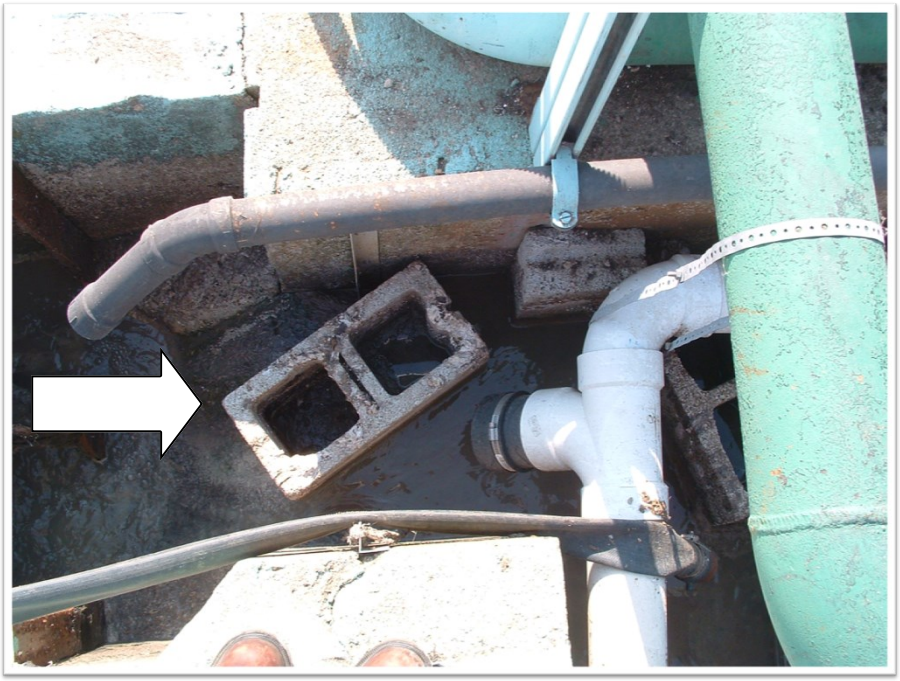
Other potential sources: septage receiving stations, and force mains with long detention times.

Activated Sludge Process Control and Troubleshooting Chart

Box # 14 Capacity: Increase capacity or decrease loading to aeration system

If the aeration tank effluent ammonia concentration is > 1 mg/L, then a condition exists in the aeration tank that is limiting complete conversion of the influent waste into bacterial cells.

It is possible that the average daily flow is within the system's design capacity, however the actual influent pumping rate could be in excess of the system's design. This issue can arise from at least two common problems. First, if the influent pumping rate is higher than the design flow rate of the system; and second, if the flow splitting device or flow equalization tank have an inferior design or are improperly adjusted. This causes the average daily flow to appear within design limits; however the system is actually exceeding its design flow rate each time the influent pump cycles on.



The "classic" flow splitting block operators use to equalize flow between parallel aeration tanks is not very effective. If influent flows are not split equally, then more treatment demand is placed on a the system. While the average daily flow may be within design, you could be only using 50% of the treatment capacity to treat a higher percentage of the flow.

If the influent pumping rate is exceeding the design flow:

Evaluate influent loading characteristics to determine if treatment modifications are necessary to achieve compliance with the discharge limits (i.e. improved flow splitting design, increased flow equalization capacity).

Evaluate pretreatment options to reduce potential high strength organic loadings from system dischargers.

Increase aeration efficiency by converting from course bubble diffusers to full floor fine bubble aeration diffusers.

Place additional aeration tanks into service to adequately process organic loadings.

Activated Sludge Process Control and Troubleshooting Chart

Box # 15 Aeration Effluent: Settleometer Analysis < 80% in 5 minutes

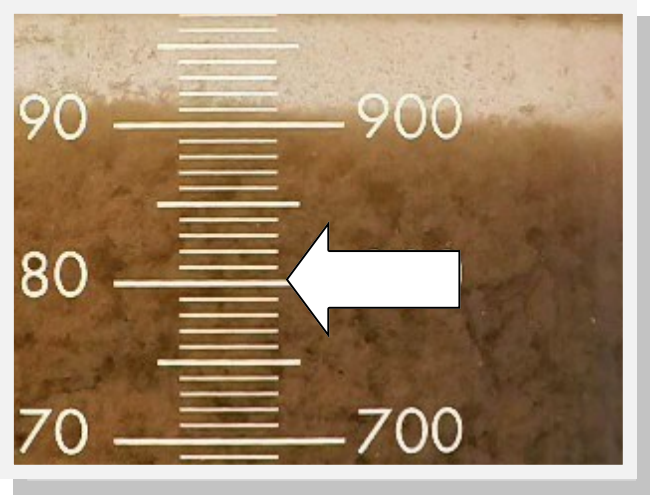
If the aeration tank effluent ammonia concentration is < 1 mg/L, the conversion of all influent organic waste into bacterial cells has been achieved. In short, the aeration tank has properly performed its function. The focus now moves towards separating the bacteria from the clean water in the clarifier. This is a function of the settling rate of the biomass, which must be maintained at the proper concentration to assist gravity settling in the clarifier. An evaluation of the settling rate is the first analysis to perform.

The settleometer test mimics the sludge setting characteristics within the clarifier. However, the settleometer represents a "perfect clarifier", meaning there are no hydraulic currents from influent or RAS flows, which can negatively affect the settling characteristics of the biomass.

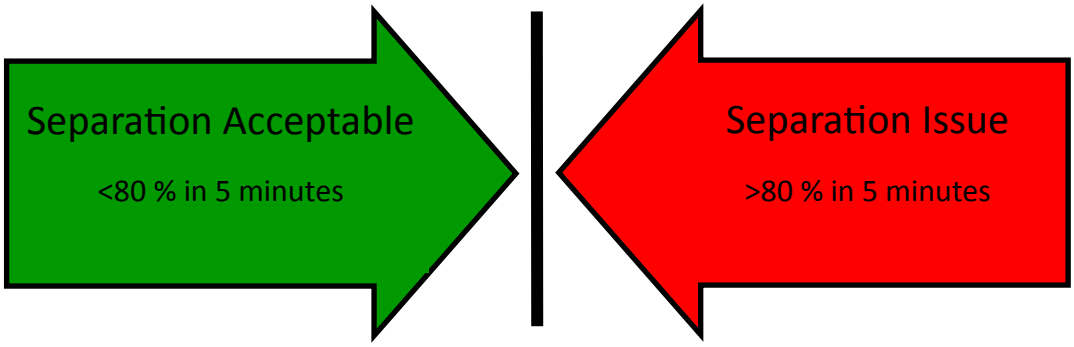
The settling characteristics are best reflected in the first five minutes of the settleometer test. As the biomass settles in the settleometer, the solids concentration increases in the settled sludge. As the settled sludge concentration increases, the settling rate decreases, therefore the first five minutes more accurately reflects the "true" settling characteristics of the biomass.

Settleometer Test

Within five minutes of the settleometer test, the settled biological mass should be below 80%. Biomass that settles slowly and cannot compact below this 80% mark is considered inhibited or "slow settling" and can be easily "carried" up and over the clarifier weir.



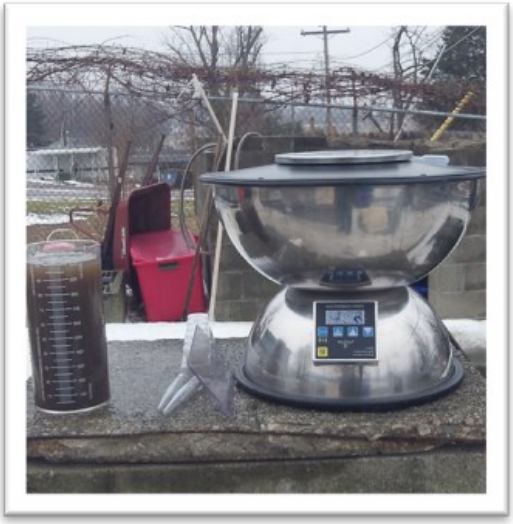
Settling rates of < 80% in 5 minutes should not cause solids loss in the clarifier, however this is a worst case scenario and can be adjusted to a lower percentage, (e.g. 70%), for a more conservative control parameter if desired. Maintaining a clarifier effluent ammonia concentration of < 1 mg/L is the first goal. Maintaining a sufficient settling rate is the second goal. Both are required for compliance.



Activated Sludge Process Control and Troubleshooting Chart

Box # 16 Aeration Effluent: Centrifuge Spin > 4%

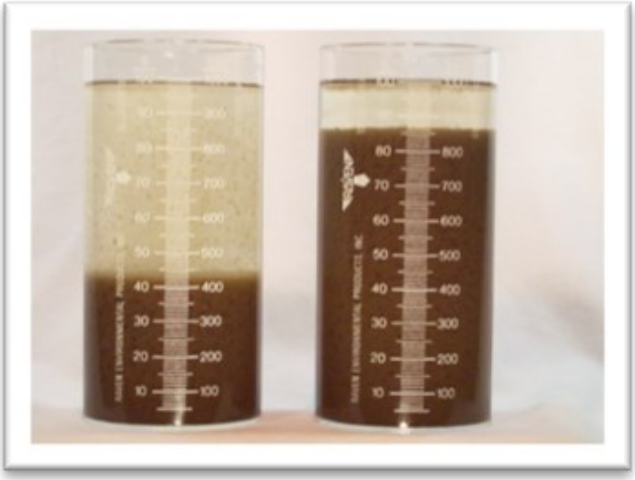
If the biomass does not settle below the 80% mark within five minutes, there is a problem with the settling characteristics. This condition can lead to a loss of biomass from the secondary clarifier. The first step is to identify the cause for the slower settling biomass. There are typically two main causes, (1) the concentration of the biomass is too high, or (2) the density of the biomass is too low.



Diagnosis

If the aeration tank biomass is too concentrated (i.e. high MLSS) then settling will be impaired. Typically when the aeration tank concentration exceeds 4% by centrifuge spin, slow settling is due to the high concentration of biomass.

The "two-minute diluted" settleometer test can also assist in identifying which of the two causes are at play.



Two-Minute Diluted Settleometer Analysis

Analysis: Concentration (left photo)

The diluted settleometer (on the left) settled significantly faster than the undiluted settleometer (on the right). The more significant the difference after two minutes indicates the slow settling is due to an excessive biomass in the aeration tank.

Analysis: Density (right photo)

The diluted settleometer (on the left) did not settle any differently than the undiluted settleometer (on the right). Concentration is not the issue here; however the biomass is "light weight" or of a low density. This is typical of a filamentous biomass.

See "How do I . . . evaluate settling with the two minute diluted settleometer analysis?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 17 Aeration or Clarifier: Brown foam on surface

If the five minute settleometer is > 80%, then the settling rate is too slow. If the aeration tank concentration is < 4%, or the two minute diluted settleometer analysis indicates slow settling then it is likely due to excessive filamentous bacteria growth in the aeration tank.

If there is excessive brown foam on the aeration tank and/or clarifier, this is a biological foam which grows in a low F/M aeration tank environment; high MLSS. Another possible indicator of low F/M growth conditions is very low effluent ammonia (< 0.3 mg/L), however this is not the most reliable indicator.

Aeration Tank Foam:

The observation of light brown/tan foam on the aeration tank is typical. If this foam is trapped in the aeration tank, it will accumulate and darken in color.

The foam can eventually become dried at the surface and resemble "floating soil".

Clarifier Foam:

If the foam is generated in the aeration tank, it can migrate to the clarifier, eventually covering the clarifier surface.

In this photo, the weir baffle is preventing the foam from escaping the clarifier.

Settleometer Test:

Another clue to an excessive filamentous growth condition is when the biomass develops a depression, or cone, in the center of the settleometer test after 30 to 60 minutes.

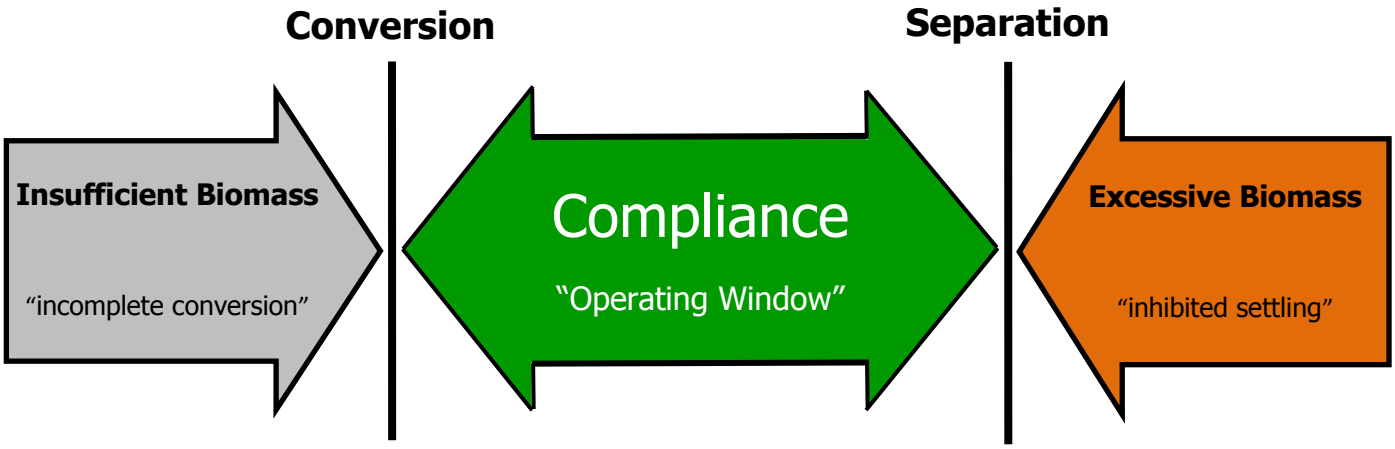
This cone develops because of the low density of the biomass caused by excessive filamentous bacteria. Also note the clarity of the supernatant in the settleometer. This clarity is also associated with a filamentous growth condition.

Activated Sludge Process Control and Troubleshooting Chart

Box # 18 Aeration: Too much biomass in system, increase wasting rate

Typically domestic activated sludge systems operate within a range of 2-4% concentration (v/v) based on a centrifuge analysis. Systems with aeration tank concentrations > 4% may begin to experience a slow settling rate due to a high concentration of biomass.

To correct, slowly increase the sludge wasting rate to reduce the aeration tank biomass. Continue to decrease the aeration tank biomass until the desired settling rate is achieved.



Establishing a wasting rate is simply a process of maintaining sufficient biomass to achieve complete conversion in the aeration tank (ammonia < 1 mg/L), while not maintaining an excessive amount of biomass to inhibit the settling rate in the clarifier (< 80% in 5 minutes).

The amount of biomass that provides complete conversion and does not inhibit settling is the target in which the treatment system performs the best. This aeration tank concentration typically ranges between 2% to 4% (v/v) based on a centrifuge analysis.

As the aeration tank concentration increases above the target value, increase the wasting rate to maintain the desired aeration tank concentration to remain within the proper operating window.

If the wasting rate is too excessive, the decreasing concentration of biomass in the aeration tank will be quickly identified by an increase in ammonia concentration leaving the aeration tank. Ammonia concentrations increase if too much biological mass is removed.

As influent organic loads increase or aeration tank water temperatures decrease, you may need to increase the target value by decreasing the wasting rate.

Activated Sludge Process Control and Troubleshooting Chart

Box # 19 **Aeration: Dissolved oxygen < 1 mg/L for extended period of time**

If the five minute settleometer is > 80%, then the settling rate is too slow. If the aeration tank concentration is < 4%, or the two minute diluted settleometer analysis indicates slow settling, then it is likely due to excessive filamentous bacteria growth in the aeration tank.

One of the more common aeration tank environments which generate filamentous bacteria is operating at a low DO concentration. Unlike the low F/M environment, which typically generates brown foam, low DO environments are typically absent of heavy brown foam.

Another indicator that the aeration tank is experiencing a low DO environment (and not a low F/M environment) is the aeration tank effluent could have ammonia values significantly greater than 1 mg/L.

To properly identify the DO concentration in the aeration tank, a data logging DO meter should be used to evaluate the DO concentrations and duration of time the system experiences concentrations of < 1 mg/L.

The aeration tank DO does not always need to be maintained above 2 mg/L. However, the lower and longer the DO concentration is maintained in the aeration tank, the more likely that low DO filamentous growth conditions exist.

Data logging the aeration tank DO will provide the best information to determine the possibility of a low DO growth environment. Measure daily diurnal swings and weekends/weekdays concentrations to obtain a complete DO profile picture.

See: "How do I . . . measure the DO in the aeration tank?

Activated Sludge Process Control and Troubleshooting Chart

Box # 20 Aeration: Low F/M ratio, increase wasting rate

If the five minute settleometer is > 80%, then the settling rate is too slow. If the aeration tank concentration is < 4%, or the two minute diluted settleometer analysis indicates slow settling, then it is likely due to excessive filamentous bacteria growth in the aeration tank.

One of the most common aeration tank environments that generate excessive filamentous bacteria is operating the aeration tank in a "starved" condition, which means having more bacteria (biomass) in the aeration tank than the influent food (BOD) source can support. This is commonly referred to as a low food to micro-organism ratio (low F/M).

Increase the sludge wasting rate (WAS) to reduce the aeration tank biomass concentration as measured by the centrifuge test. Continue to decrease the aeration tank biomass concentration until the desired settling rate is achieved. The settling rate will increase as the filamentous bacteria are wasted from the system and a more dense floc structure develops.

If the sludge wasting rate (WAS) is too excessive, the reduction in biomass in the aeration tank will be quickly identified by an increase in ammonia concentrations in the aeration tank effluent.

Remove accumulated foam from aeration tank and/or clarifiers after the aeration tank growth environment has been modified to the point where low F/M filamentous bacteria are no longer dominant. Stop the madness, then clean up the mess.

Activated Sludge Process Control and Troubleshooting Chart

Box # 21 **Aeration: Evaluate influent/internal side streams for septic sources**

If the five minute settleometer is > 80%, then the settling rate is too slow. If the aeration tank concentration is < 4%, or the two minute diluted settleometer analysis indicates slow settling, then it is likely due to excessive filamentous bacteria growth in the aeration tank.

Low F/M and low DO concentrations are common conditions for filamentous bacteria growth in activated sludge systems. However a third environmental condition, which could cause filament growth, is an influent loading or internal side streams containing by-products of septicity (i.e. organic acids, hydrogen sulfide).

Sources of influent septicity can originate from collection systems with long force mains, low flows resulting in solids deposition in the sewer pipe, industrial dischargers and/or internal flow streams (i.e. "anaerobic" digester supernatant).

Collection System:

Strong "rotten egg" odors in the influent can be an indication of septicity in the collection system. If you detect hydrogen sulfide odor in the influent, it is likely that products of septicity are being generated in the collection system. These by products of septicity can generate filaments.

Head works Condition:

Hydrogen sulfide is generated under septic conditions in the collection system. Significant corrosion could indicate products of septicity are contributing to filamentous growth in the aeration tank. Lift stations may also show signs of corrosion.

Influent Characteristics:

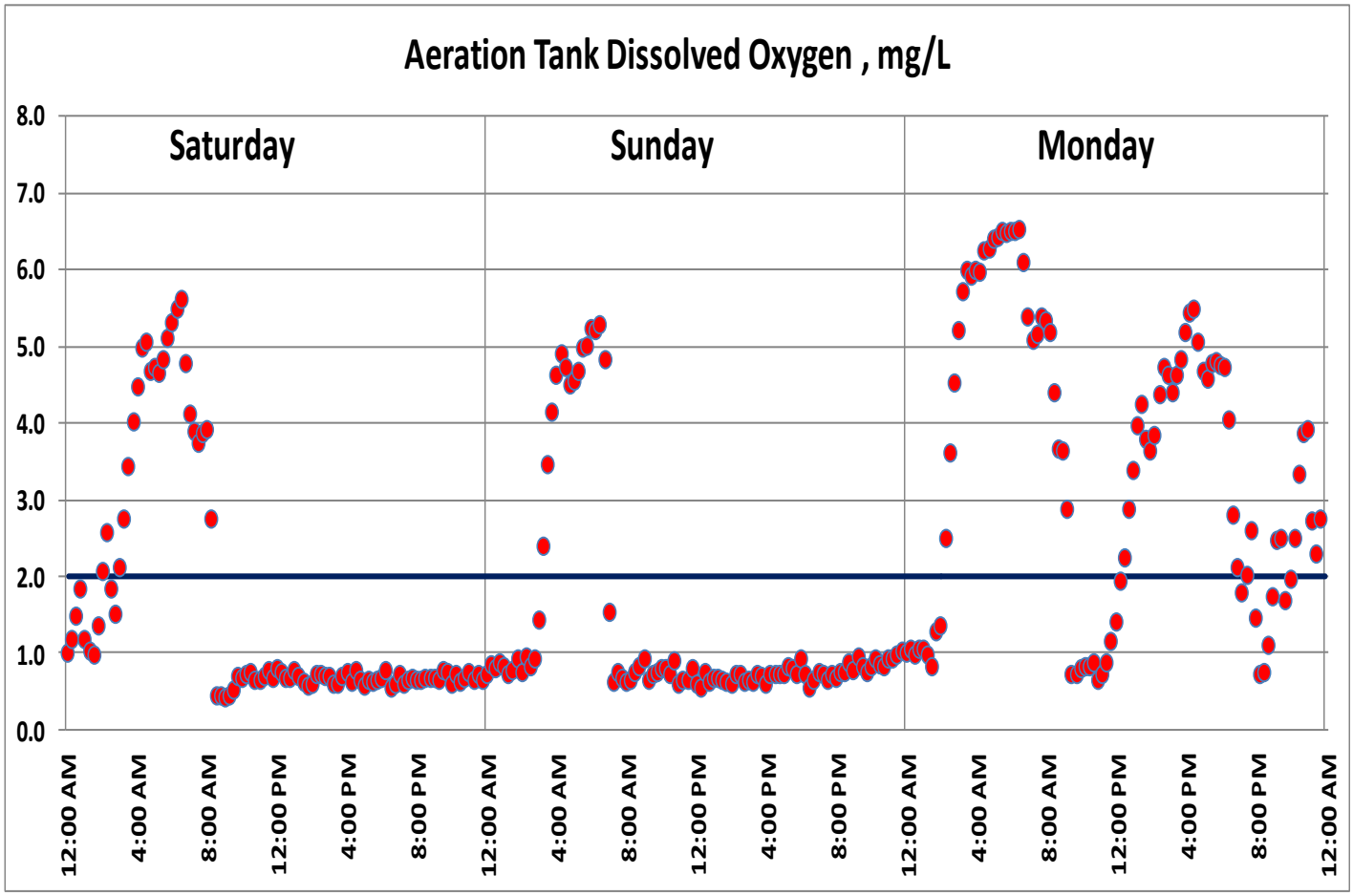
If you don't smell it, you still might see it. Influent domestic wastewater typically has a grey color. Influent flows which are more black in color are more likely to be from anaerobic environments or septic sources.

Activated Sludge Process Control and Troubleshooting Chart

Box # 22 Aeration: Increase air supply to match organic loading

If a low DO concentration is the cause of filamentous growth, the aeration being applied must be adjusted to more accurately reflect the influent organic loading.

Data logging will identify the aeration cycle periods that need to be adjusted. In the chart below, if low DO filament growth conditions exist in the aeration tank, they are most likely being generated during low DO conditions (< 1 mg/L) on Saturday and Sunday due to the extended, low DO environment.



Increase the aeration cycle periods or bring additional blowers on line during low DO conditions.

Evaluate the aeration distribution system for clogged diffusers, pipes and valves which could be restricting flow.

Evaluate the mixing intensity of the aeration pattern. Diffusers which are designed along the width of the aeration tank are more likely to experience mixing issues than diffusers which are designed along the length of the aeration tank.

The color of a healthy aerobic biomass is typically light to dark brown depending on concentration. Aeration tanks limited by DO and sufficient mixing intensity will appear more grey in color.

Activated Sludge Process Control and Troubleshooting Chart

Box # 23 Clarifier Effluent: Biomass observed leaving the clarifier

If the biomass settles below the 80% mark in five minutes, there is typically no problem with the settling characteristics (not a biological issue). However biomass can still be lost from the clarifier due to a hydraulic issue.

Observed Biomass Loss:

The most obvious sign is solids deposition in the receiving stream. Depending on the effluent sampling criteria (grab vs. flow composite), effluent sampling data may not identify the solids loss.

Biomass deposition in the clarifier trough is another indicator.

Another evaluation method is to use the clarifier core sampler to measure solids deposition in the dosing tank prior to sand filtration or solids deposition in the disinfection unit.

Life Expectancy of a Sand Filter

Systems with slow sand filters provide an obvious method to evaluate solids loss over time. The more biomass lost through the clarifier effluent, the shorter the life expectancy of the sand filter. Package plants using slow sand filters typically experience 2-3 months of operation. They must then be taken out of service and cleaned. If the sand filter is operating on less than 2-3 months of service, then loss of biomass from the clarifier is probably occurring.

Left Photo: Youthful - water filters through sand before reaching walls.

Center Photo: Aging - water reaching side walls, begins to cover entire floor.

Right Photo: Deceased - water ponding on surface

Does the sand filter survive at least 2 to 3 months?

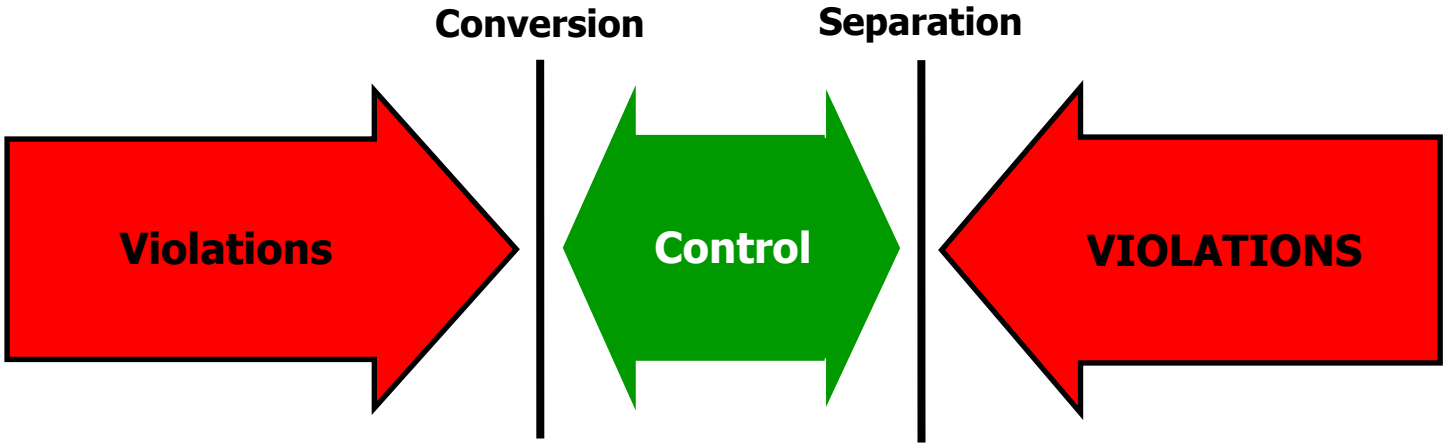
Activated Sludge Process Control and Troubleshooting Chart

Box # 24 Compliance

If clarifier effluent ammonia values are <1 mg/L, then conversion is complete. If the biomass will settle below the 80% mark in the settleometer in five minutes then separation is adequate. The area between these two process control criteria is the "operating window" in which the treatment system will perform most effectively and efficiently.

The ammonia and settleometer analysis establishes the "operating window". Maintaining the process between these two criteria provides the best effluent with the least amount of expense and effort. As organic and hydraulic loadings change, the operating window will also change. As more pressure is applied to the treatment system the window becomes smaller, but by measuring and adjusting the process you can maintain in the safest location; the "middle of the window".

As water temperatures change, the operating window will also change. Warmer temperatures typically expand the window, while colder temperatures contract the size of the window. Good operations begin with locating the system's current location and then adjusting the process to maintain a position in the middle.



Lack of monitoring the system leads to a smaller operating window. This results in an increase in violations and the system becomes more labor intensive to "correct" something which could have been prevented. Don't create more work for yourself. Small adjustments can prevent most upset conditions.

Activated Sludge Process Control and Troubleshooting Chart

Box # 25 Clarifier: Sludge blanket < 30% of clarifier water depth

As the biomass settles in the clarifier, a concentrated sludge layer or "blanket" develops on the bottom.

As this sludge blanket increases in depth, clarifier capacity decreases. The closer the blanket is to the clarifier surface, the more likely biomass will be carried over the clarifier weir.

Sludge blankets can increase and/or decrease in depth based on high influent flows, return pumping rates and settling characteristics of the biomass.

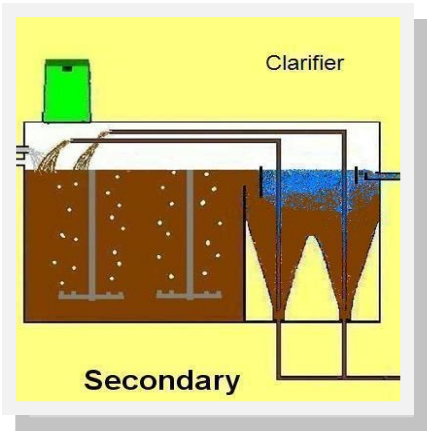
Measure the sludge blanket depth with a "core sampler".

See: "How do I . . . measure solids in the clarifier?"

High Sludge Blanket Depth

The blanket is too close to the effluent weir.

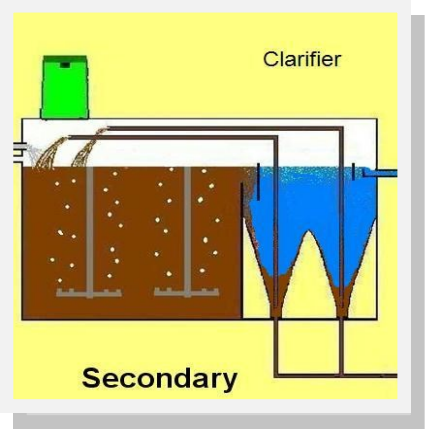
Biomass entering the clarifier will travel across the top of the sludge blanket and be drawn out over the effluent weir.



Normal Sludge Blanket Depth

The blanket is less than 30% of the clarifier water depth.

Biomass entering the clarifier has room to settle out and should not be drawn over the effluent weir.



Eliminating the sludge blanket depth as a cause for solids loss is easy to confirm with a clarifier core sampler.

See "How do I . . . interpret the core sampler results?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 26 Clarifier: Return Activated Sludge rate

Ideally, the return activated sludge pumping rate (RAS) needs to match the settling rate of the biomass coming from the aeration tank. A slow settling biomass requires a slower RAS rate and a fast settling biomass requires a faster RAS rate. Failing to match the RAS pumping rate to the biomass settling rate may cause solids to overflow the clarifier weir. Basing RAS rates on a percentage of influent flow is a common, but faulty, method.

The return sludge pump can only remove biomass that has already settled to the bottom of the clarifier. The biomass cannot be "drawn" to the bottom of the clarifier by increasing the RAS pumping rate.

An RAS pumping rate that is slower than the settling rate of the biomass creates a condition where more biomass is entering the clarifier than is being pumped out. This results in an accumulation of sludge (increased sludge blanket) in the clarifier. An increasing sludge blanket can result in decreasing clarifier efficiency and increasing solids loss.

An RAS pumping rate that is faster than the settling rate of the biomass creates a condition where excess water is being returned to the aeration tank. This results in additional hydraulic pressures (more flow) within the clarifier. Increased hydraulic pressures within the clarifier results in the biomass being unable to properly settle and concentrate into a sludge blanket. Biomass remaining in suspension in the clarifier will be more likely to be push out over the clarifier weir. This is exaggerated when filamentous bacteria (slow settling biomass) dominate in the secondary system.

Evaluate the RAS rate and then adjust the pumping rate to match the biomass settling rate.

If the biomass is settling well, but solids are observed leaving the clarifier, then there is a problem within the clarifier itself. A high sludge blanket (> 30%) will be the primary cause for potential solids loss. If the RAS pumping rate needs to be increased, then the loss of biomass from the clarifier should decrease. However if the RAS pumping rate is correct, then typically too much biomass is in the system and the sludge wasting rate should be increased.

See "How do I . . . determine the correct RAS pumping rate?"

Activated Sludge Process Control and Troubleshooting Chart

Box # 27 Clarifier: Hydraulic issues in clarifier.

If clarifier biomass loss is observed, but is not caused by a slow settling biomass (> 80% in 5 minutes in settleometer) or a sludge blanket which is > 30% of the clarifier water depth, it is possible there are unique hydraulic pressures within the clarifier "carrying" solids over the clarifier weir.

There are three common design features that can possibly lead to the loss of biomass in the clarifier; uneven flow splitting into the clarifiers, density currents within the clarifier, and weir locations/ elevation removing flow from the clarifier.

Flow Splitting

Devices that are designed to split the flow horizontally are incapable of equalizing loadings to downstream tanks. In this design, flow splitting is impacted as hydraulic flow rates change. That is why the strategically place "flow splitting brick" only performs well at certain flow rates.

See "How do I . . . correct a flow splitting issue into the clarifier?"

Internal Density Currents

Even if the flow is split evenly among the clarifiers, internal density currents can short circuit through a clarifier and cause solids loss.

See "How do I . . . eliminate a density current within a clarifier?"

Weir Location/Elevation

Effluent weirs located next to the back wall of a rectangular clarifier; or weirs which are uneven, will allow biomass to be drawn out of the clarifier. Weirs designed too close to a wall can be removed from operation by sealing off the weir area.

See "How do I . . . correct effluent weirs which are causing solids loss?

Activated Sludge Process Control and Troubleshooting Chart

Box # 28 Clarifier: Adjust return activated sludge (RAS) rate.

A quick and simple method to evaluate the proper RAS rate is to perform a centrifuge analysis of the aeration tank effluent and the RAS.

The aeration tank biomass concentration is typically between 2% and 4%. As the biomass settles in the clarifier, it will increase in concentration. A "rule of thumb" is that the RAS concentration should be at least 1.5 to 2 times the concentration of the aeration tank biomass. If the RAS is less than 1.5 times the aeration tank biomass, then the RAS rate is probably set too fast.

If the RAS concentration is twice the aeration tank concentration, then theoretically biomass is being returned at a rate which is slow enough to allow a 50% reduction in volume. A fast settling biomass can actually produce a RAS concentration 3 times the aeration tank concentration. RAS concentrations greater than 2 times the aeration tank concentration can be a very effective way to operate, resulting in reduced WAS volumes and longer biomass detention times in the aeration tank. However, RAS concentrations greater than 2 times the aeration tank concentration approach a condition which may allow an excessive sludge blanket to accumulate, resulting in reduced clarifier efficiency. Always use a "core sampler" to determine if the RAS flow rate is too slow for the biomass settling characteristics.

RAS Rates

A centrifuge is used to measure the aeration tank and return sludge concentrations. This data used with the results of a settleometer analysis can identify what the current RAS rate is and if it needs to be adjusted.

See "How do I . . . determine the correct RAS pumping rate?

Activated Sludge Process Control and Troubleshooting Chart

Box # 29 Clarifier: SOR or SLR in excess of clarifier design capacity

Clarifiers are designed to allow adequate detention time for the biomass to separate and concentrate by gravity. This separation process can be affected by either hydraulic pressure within the clarifier and/or biomass loading into the clarifier.

Surface Overflow Rate (SOR) is a measurement of the "overflow velocity" per square foot of the clarifier surface. As the upward, overflow velocity increases, it is more difficult for the biomass to settle to the clarifier bottom.

SOR

If only one clarifier is available, determine if it is exceeding its designed SOR during peak flows.

If more than one clarifier is in service, each clarifier should receive equal flow. Don't allow 50% of the clarifiers to handle more than 50% of the flow.

See "How do I . . . calculate the SOR in the clarifier?"

Solids Loading Rate (SLR) is a measurement of the "settling velocity" of the biomass per square foot of the clarifier surface. As the biomass loading rate increases, it is more difficult for biomass to settle to the clarifier bottom.

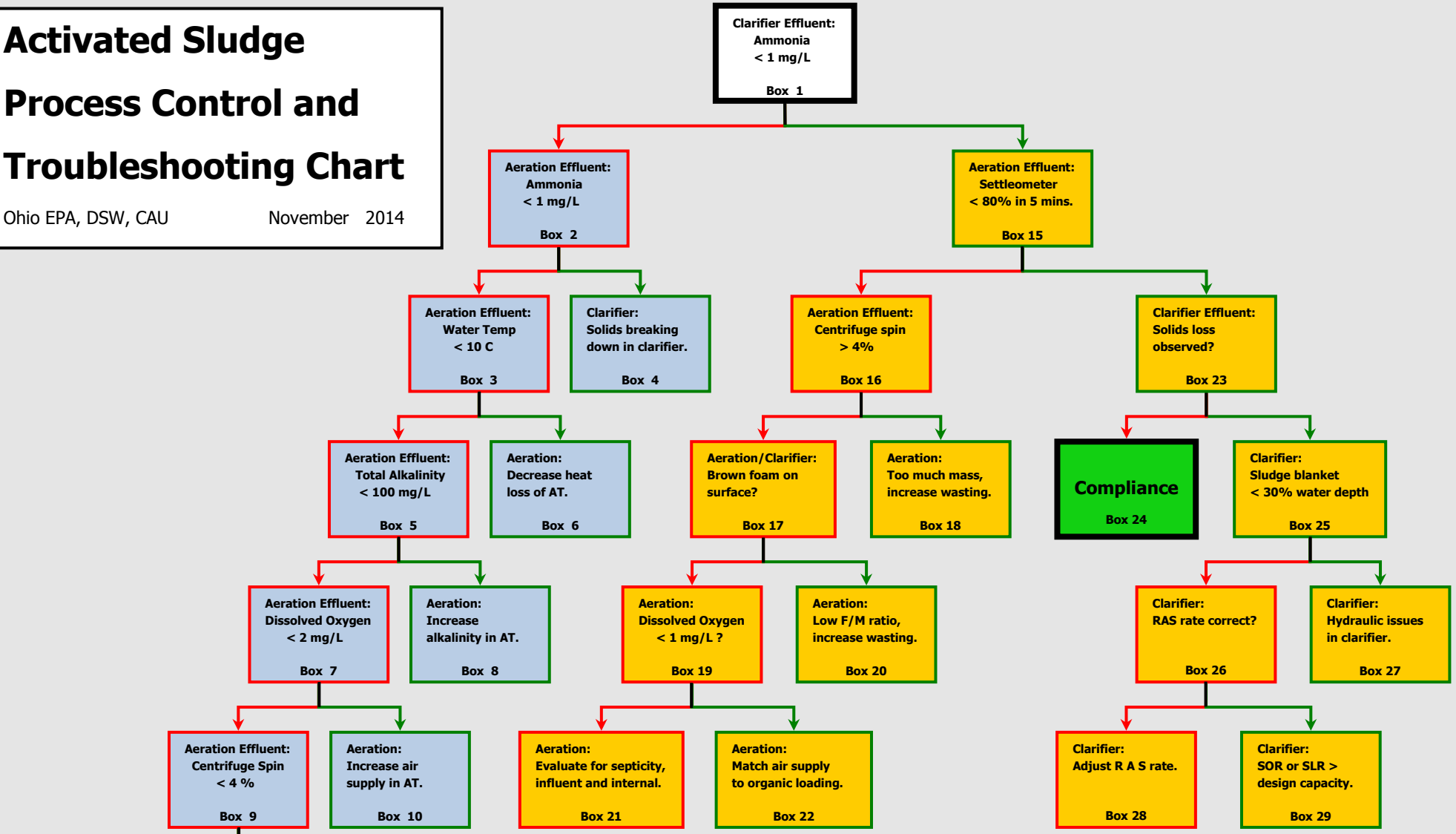
SLR

As biomass concentration increases, it will settle slower in the clarifier. Reducing the aeration tank biomass concentration or placing another clarifier in service will lower the SLR to the clarifier(s).

See "How do I . . . calculate the SLR in the clarifier?"

Activated Sludge Process Control and Troubleshooting Chart

Ohio EPA, DSW, CAU November 2014



Directions:

Begin with **Box 1: Clarifier Effluent: Ammonia < 1 mg/L**

If response is "**no**" follow **red arrow** to left , if response is "**yes**" follow **green arrow** to right.

Apply corrective action then return to **Box 1: Clarifier Effluent: Ammonia < 1 mg/L**

Continue until all issues are eliminated and directed to **Box 24: Compliance**

How do I . . .

. . . measure ammonia in the clarifier effluent?

. . . measure ammonia in the aeration tank?

. . . eliminate the biological foam on the aeration tank?

. . . determine if ammonia is being released in the clarifier sludge blanket?

. . . measure total alkalinity in the aeration tank?

. . . determine how much aeration capacity is required?

. . . measure solids in the clarifier?

. . . determine how much to waste?

. . . measure the DO in the aeration tank?

. . . determine how much aeration time is required?

. . . measure biomass in the aeration tank?

. . . identify internal side streams as additional pollution sources?

. . . evaluate settling with the two-minute diluted settleometer analysis?

. . . interpret the clarifier core sampler results?

. . . determine the correct RAS pumping rate?

. . . correct a flow splitting issue into a clarifier?

. . . eliminate a density current within a clarifier?

. . . correct effluent weirs which are causing solids loss?

. . . calculate the SOR in the clarifier?

. . . calculate the SLR in the clarifier?

How do I measure ammonia in the clarifier?

If the clarifier effluent is low in suspended solids, a sample can be collected from the clarifier surface to perform an ammonia analysis. If the clarifier effluent is high in suspended solids, such that it would affect the ammonia analysis, use a centrifuge to separate the suspended solids and perform an analysis on the centrate of the centrifuge tube.

There are several methods for analyzing the sample. The degree of accuracy of the method is not as critical as the ability to measure the ammonia concentration, monitor the trending of the ammonia concentration, and make timely process control decisions on-site. Small, single parameter colorimeters are available for accurate ammonia analysis. This method provides a digital readout of the ammonia concentration of the sample. The initial cost for the meter is more than an aquarium kit, however, the colorimeter does provide a more accurate analysis, especially when ammonia concentrations are high. However, it will likely require you to dilute the sample so the results are within the range of the meter.

A less expensive method is to purchase a test kit for ammonia nitrogen, commonly sold at aquarium stores. While this type of test kit can be accurate enough for process control testing, you will need to verify its accuracy. When collecting a final effluent sample for submitting to a lab for reporting purposes, draw off some of the sample and perform an ammonia analysis with your field test kit. Record this data and compare it to the ammonia value that your contract laboratory reports. If the ammonia values determined by your field test kit is close to the ammonia value reported from your approved lab, you will have confidence in using the field test kit for operational decisions. Performing this "split-sampling" procedure periodically can also indicate when the chemical reagents in the field test kit are becoming ineffective and the data is unreliable. Once you have determined which field kit provides accurate data, you can begin evaluating the treatment system for complete conversion.

There are two different methodologies for measuring ammonia nitrogen. The Nessler method offers a higher detection range than the Salicylate method, however, the Nessler method contains a mercury compound in the reagents. The waste products from the Nessler analysis are considered hazardous waste and need to be disposed of in an approved manner.

How do I measure ammonia in the aeration tank?

The difference between measuring ammonia in the aeration tank and in the clarifier is that the suspended solids concentration in the aeration tank will invalidate the results. Use the centrifuge to quickly separate the suspended solids and obtain a sufficient sample for ammonia analysis.

Collect a sample from the aeration tank effluent. Fill two centrifuge tubes to the 100% mark and spin the sample for two minutes. After centrifuging, the clear liquid on top will be of sufficient volume to analyze for ammonia.

Another method is to draw a sample for ammonia analysis from the supernatant of a settleometer analysis after it has had time to allow for bacteria separation from the clear water. Collect a fresh sample from the aeration tank but don't allow the settleometer to sit for more than a few minutes before a sample is collected for analysis.

Once a clear sample of the aeration tank effluent is collected, analyze with the same ammonia test methodology you use for process control.

How do I eliminate the biological foam on the aeration tank?

As the dissolved and suspended pollutants continue to flow into the aeration tank, more bacteria are generated. If excess bacteria are not removed or "wasted" from the Secondary Stage, the bacteria concentration increases to a point where competition for the in coming "food" becomes extreme.

There are certain bacteria which can naturally out-compete for the food source when the food becomes more scarce. These types of bacteria are also known to generate a brown foam on the aeration tank's surface. This "starved growth" condition is commonly referred to as a low F/M ratio environment (low food to microorganism ratio). A low F/M ratio in the aeration tank can promote biological foam which may migrate to the clarifier surface. To prevent this low F/M ratio in the aeration tank, an operator must either increase the food (influent cBOD) coming into the aeration tank or decrease the oxidative pressure within the aeration tank.

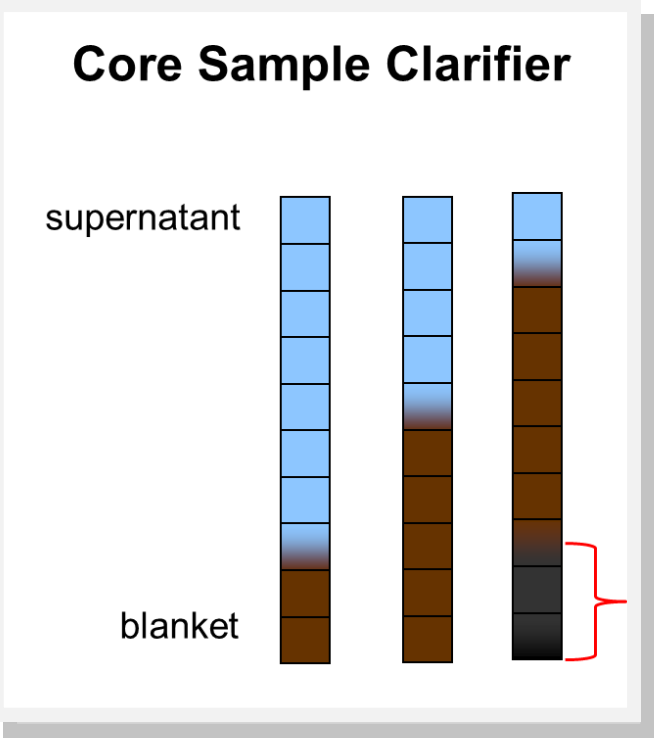
Operators have little control of the organic load coming into the treatment system. However, operators have several methods to control the "oxidative pressure" which is applied to treat the influent organic loading. Oxidative pressure is defined as anything which allows the treatment system to move closer to complete conversion of the influent organic loading. An example of adding oxidative pressure would be to bring more aeration tanks into service and thereby increasing the available detention time for treatment. Other examples include increasing the run-time of the blowers to provide longer aeration cycles, or increasing the concentration of bacteria in the aeration tank. Oxidative pressures are operational modifications which apply more "pressure" to completely oxidize the waste and reach complete conversion.

If an aeration tank is experiencing a low F/M ratio, which in turn is generating a biological foam, the operator needs to reduce the oxidative pressure to prevent this foam generating environment. Operational controls which reduce oxidative pressure on the aeration tank are to reduce the blower run -time (reduce timer settings), reduce the concentration of the bacteria in the aeration tank (increase wasting rate) or, if necessary, reduce the aeration tank capacity (take aeration tanks off line).

If the aeration tank effluent ammonia concentrations are < 1 mg/L, you have sufficient aeration tank detention time, sufficient volume of mass in the aeration tank, and/or sufficient aeration being applied. Start reducing these sources of oxidative pressure until you detect an increase in aeration tank effluent ammonia concentrations. An increase in aeration tank effluent ammonia will indicate you have reduced the oxidative pressure too much.

Instead of reducing oxidative pressure some operators will attempt to increase the influent organic loading to increase the aeration tank F/M ratio. Attempts include adding a waste load to the influent to change the aeration tank environment. Typically this is done by supplementing the influent with an inexpensive dog/rabbit food. This method is strongly discouraged because you are spending time and money to add waste to the treatment system, which costs you time and money to remove again. By reducing oxidative pressure you eliminate the generation of the biological foam, reduce your operational cost (reduced pumping, electrical costs) and avoid increasing cost by purchasing a supplemental organic loading. There are just too many starving dogs in the world to waste dog food! Focus on reducing oxidative pressures in the treatment system, which will save you money.

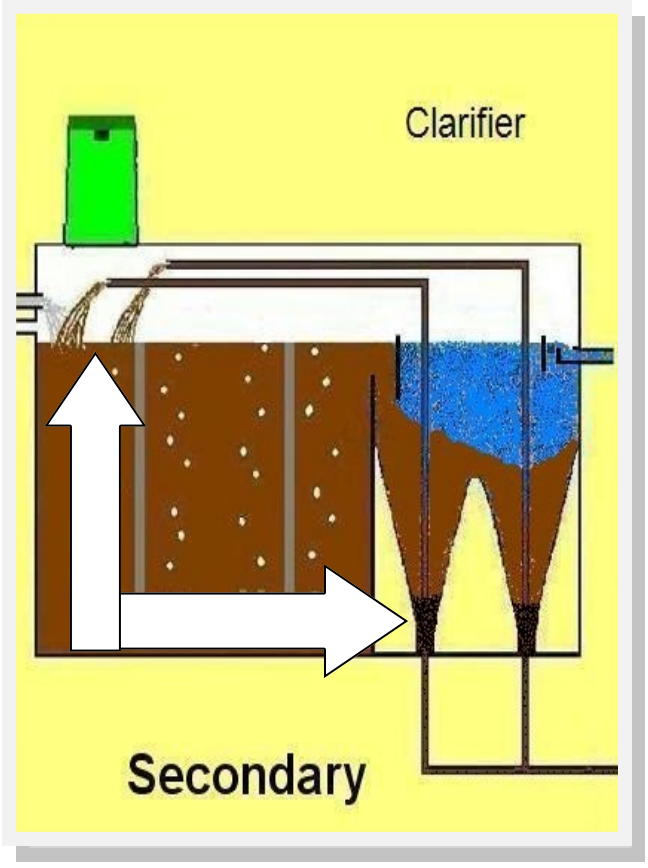
How do I determine if ammonia is being released in the clarifier blanket?



If clarifier effluent ammonia values are greater than the aeration tank effluent ammonia values, then aerobic bacteria are breaking down and releasing ammonia nitrogen in the clarifier. As the sludge blanket increases in depth it is more likely for the sludge blanket to release ammonia nitrogen. If the situation is severe you may notice a darker color to the sludge layer in the bottom of the clarifier when using the clarifier core sampler.

If the problem is just starting to become an issue, you might not notice a darker color to the sludge blanket. To stay ahead of this problem, you could monitor the ammonia concentration in the clarifier's Return Activated Sludge (RAS).

Collect a sample of the clarifier RAS and centrifuge it to obtain a clear liquid sample (centrate) at the top of the centrifuge tube. Use this sample to chemically measure the ammonia concentration. If the RAS is starting to release ammonia nitrogen, you should see an increase in ammonia nitrogen in the RAS when compared to the aeration tank effluent.



If ammonia nitrogen is being released from the sludge blanket, an operational adjustment is required. Ammonia is released in the clarifier sludge blanket because the aerobic bacteria are without dissolved oxygen for too long.

If the RAS ammonia nitrogen is greater than aeration tank effluent ammonia nitrogen then bacteria are breaking down in the clarifier and need to be brought back into an aerobic environment in the aeration tank to prevent ammonia release.

It could be that the RAS pumping rate is too slow, which causes bacteria to remain in the clarifier too long. If the RAS pumping rate has been measured and found to be acceptable, then typically the entire system contains too much bacteria and an increase in wasting would be indicated.

How do I measure total alkalinity in the aeration tank?

Collect a sample from the aeration tank effluent. Fill two centrifuge tubes to the 100% mark and spin the sample for two minutes. The clear liquid left on top after centrifuging is of sufficient volume to analyze using most field test kits.

It is recommended that you do not use "test strips" as a methodology to determine total alkalinity because it is too subjective. There are inexpensive titration test kits which use eye droppers to apply the acid reagent. Simply count the drops of acid that is added to the sample until you observe an obvious color change. Multiply the number of drops by the test kit multiplication factor to determine the total alkalinity in the aeration tank.

The test kits typically allow you to measure both phenolphthalein alkalinity and total alkalinity, depending on which indicator reagent is used in the analysis. It is the total alkalinity that is required to be greater than 100 mg/L in the aeration tank effluent to prevent lowering of the pH and inhibition of the nitrification or conversion process. The phenolphthalein alkalinity is not used in making process control decisions.

Measure the total alkalinity in the aeration tank effluent. Since the nitrification process (conversion of ammonia to nitrate) occurs in the aeration tank, it is critical to the treatment process to monitor total alkalinity in the aeration tank. Total alkalinity values can change as the water passes through downstream treatment stages. Values measured at locations downstream of the aeration tank (i.e., final effluent) might not accurately reflect the total alkalinity situation in the aeration tank.

When total alkalinity concentrations decrease below 100 mg/L, the system could quickly consume the remaining alkalinity depending on the remaining ammonia nitrogen to be converted. Ammonia nitrogen requires 7.14 mg/L of alkalinity for every 1.0 mg/L of ammonia present in the aeration tank that is converted to nitrate nitrogen. For example, having 100 mg/L of total alkalinity while still needing to convert 10 mg/L of ammonia is not sufficient. Although the system is nitrifying well, the alkalinity demand will require an additional 71.4 mg/L of the available alkalinity leaving less than the desired target of 100 mg/L of alkalinity.

Monitoring with pH is ineffective if your desire is to prevent a process upset. When alkalinity is depleted the pH will drop rapidly after it is too late to make an adjustment. Monitoring total alkalinity will provide an early warning to prevent an upset.

How do I determine how much aeration capacity is required?

The treatment system is designed for an influent cBOD concentration and average daily flow rate. The total organic loading to the system is a function of both of these values. If influent cBOD concentrations remain the same but the influent flows decrease, then less aeration or "oxidative pressure" is required because the total organic loading will be less at lower flow rates.

As the bacteria convert influent pollutants into more bacteria, they generate heat that will assist in keeping the aeration tank water temperature above 10 C. However, when the influent organic loading is low, less heat is generated. When this situation is compounded with cold ambient air and excessive aeration, the water temperature can drop well below 10 C.

A simple calculation can be used to estimate how much aeration capacity is required. One parameter used to design treatment systems is the organic loading rate. Compare the actual organic loading rate that is received at the treatment system to the design organic loading capacity to determine the percent of capacity in use. If the system is not using all of its design organic loading capacity, it may be possible to reduce the oxidative pressure being applied (i.e., take aeration tanks out of service, reduce aeration blower run-time).

For example:

A treatment system is designed for a flow of 10,000 gallon per day and an influent cBOD concentration of 200 mg/L. This system actually receives only 4,000 gpd with an influent cBOD concentration of 175 mg/L. What is the percent oxidative capacity being used?

Design Organic Loading =

(10,000 gpd x 200 mg/L cBOD x 8.34 lbs/gallon)/1,000,000 = 16.7 lbs cBOD/day

Actual Organic Loading =

(4,000 gpd x 175 mg/L cBOD x 8.34 lbs/gallon)/1,000,000 = 5.8 lbs cBOD/day

Percent Oxidative Pressure =

(5.8 lbs cBOD/d actual loading / 16.7 lbs cBOD/d design loading) x 100 = 35%

Since the treatment system is receiving only 35% of its design organic loading, in theory, you should be able to reduce the aeration to match this lower loading. Begin by reducing blower run-time and monitor the aeration tank water temperature and effluent ammonia. Reduction in the aeration should increase water temperature, which will eventually lead to a reduction in effluent ammonia. If less than half of the design organic loading is being used then taking half of the aeration tanks out of service would move the system closer to its design aeration requirement.

Taking half the aeration capacity out of service could prove to be too much of a reduction of oxidative pressure and periodic ammonia spikes may occur. If so, increase the biomass concentration in the aeration tank in service until you reach a centrifuge spin which will consistently produce an ammonia concentration less than 1 mg/L but does not impact the settling characteristics (such as an aeration tank centrifuge spin of 4% or greater that would typically impact settling).

How do I measure solids in the clarifier?

A simple method to identify if bacteria are "hiding" in the clarifier is to use the core sampler and measure the compacted sludge blanket in the clarifier. If the sludge blankets are less than 30% of the clarifier water depth, then the majority of solids are in the aeration tank. If the sludge blanket in the clarifier is greater than 30%, the bacteria are "hanging out" in the clarifier too long. For clarifiers designed with multiple hoppers, measure the blanket depth of each hopper and average the values. It is common to see the first hopper in a multiple hopper clarifier maintain a higher blanket level than downstream hoppers.

Lower the core sampler slowly into the middle of the hopper clarifier, carefully avoiding submerged piping. "Dropping" the core sampler into the clarifier will provide inaccurate sludge blanket depths. Also lower the core sampler vertically and do not collect a sample as if you were "spear fishing".

If the sludge blanket is less than 20% to 30% of the clarifier water depth, then the majority of the bacteria are in the aeration tank.

One way to quantify, or measure, the amount of bacteria in the clarifier is to discharge the clarifier core sample into a bucket and use the centrifuge to determine the amount of bacteria in this clarifier "profile" sample.

If there is a two-hopper clarifier, core each hopper and mix both core samples in a bucket before centrifuging. Neither hopper should have a sludge blanket greater than 30% of the clarifier water depth, however, the first hopper sludge blanket depth is typically higher than the second hopper.

The centrifuge values of clarifier core samples should be less than the aeration tank centrifuge values. If the clarifier core samples are similar in value to aeration tank values, then there is too much mass in the clarifier.

How do I determine how much sludge to waste?

Knowing how much mass is enough for complete conversion and when too much mass affects the separation process are the keys to maintaining the biological process of the treatment system. We can easily determine when sufficient mass is available by maintaining aeration tank ammonia nitrogen concentrations at less than 1 mg/L. By using the centrifuge you can measure or quantify how much mass is needed to convert all the waste into bacteria. Typically, small activated sludge package plant will achieve complete conversion with aeration tank concentrations between 2% and 4% when measured with the centrifuge. The minimum aeration tank centrifuge spin concentration which provides ammonia nitrogen concentrations less than 1 mg/L is the minimum target concentration. Simply maintain an aeration tank concentration which achieves ammonia nitrogen concentrations less than 1 mg/L. As the aeration tank centrifuge concentration increases, bacteria settling rates slow down. Typically the settling rate is not significantly impacted until the aeration tank concentrations begin to exceed 4% or unless the filamentous bacteria are dominating the treatment system.

Build up sufficient biomass to reduce effluent ammonia below 1 mg/L. When the settling rate is greater than 80% in the settleometer after 5 minutes, reduce the aeration tank centrifuge spin by increasing the wasting rate. This is the target aeration tank centrifuge spin you should maintain.

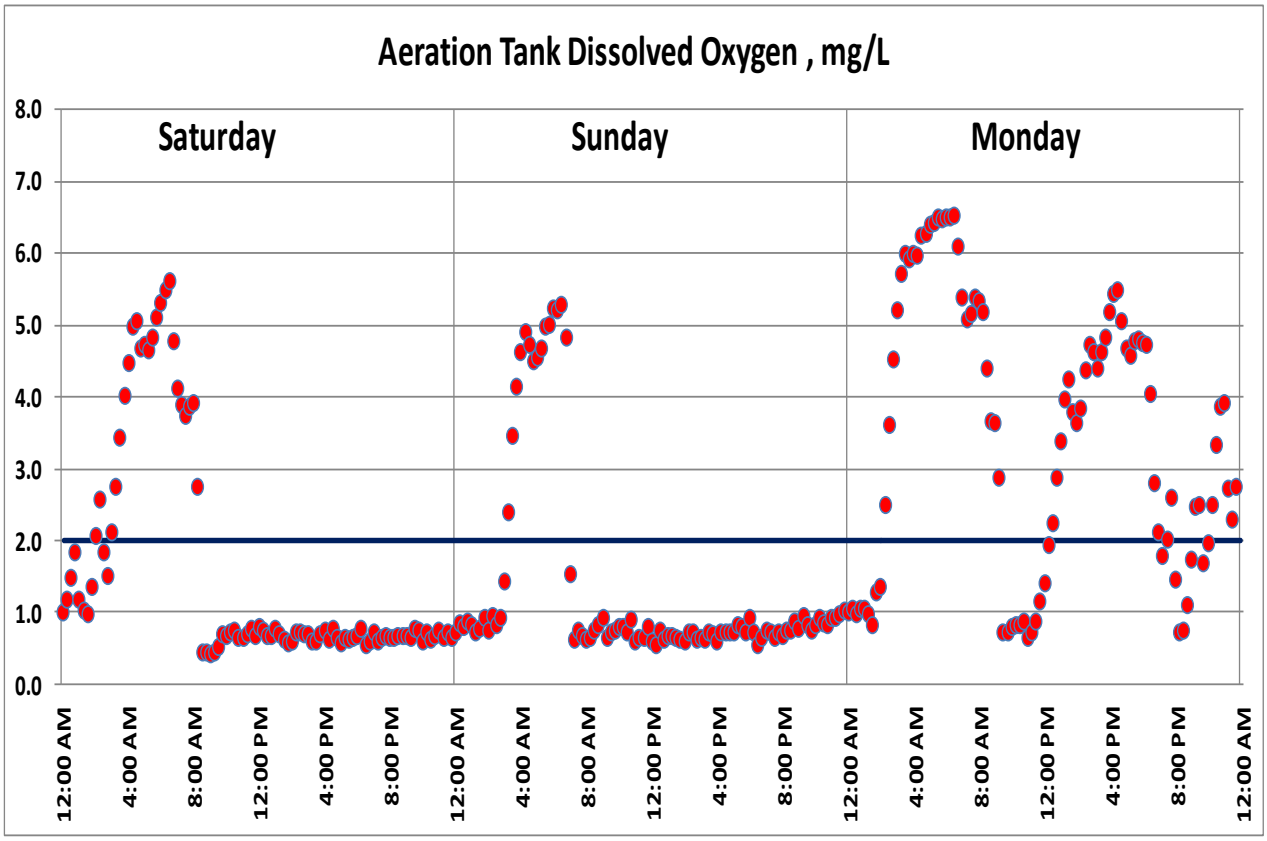
There are many ways operators "calculate" how much mass to waste. This method does work to provide a bacteria concentration which achieves complete conversion but does not inhibit separation. However, there is a simpler way. If you measure ammonia concentrations of less than 1 mg/L, you have sufficient bacteria mass. As long as it is settling well (less than 80% in 5 minutes), there is not an excessive amount of biomass. By simply measuring the concentration of mass in the aeration tank by centrifuge, you can maintain this target centrifuge spin, which provides complete conversion and adequate separation. A 15 minute centrifuge spins will indicate if you need to increase or decrease the wasting rate to bring balance back to the process. (No math involved!)

How do I measure DO in the aeration tank?

Begin by monitoring the DO concentration near the discharge of the aeration tank into the clarifier. Place the DO probe within 1-2 feet of the surface of the water and record the data. Use this same location as a reference point so all the dissolved oxygen data collected will be related to this same location. The data loses significance if you measure the aeration tank effluent one day and then measure a different location the next time in the aeration tank.

In a small treatment system, which has only one aeration tank, this should be sufficient since these smaller aeration tanks exhibit a complete mix environment. In a larger treatment system, which has multiple aeration tanks, monitoring the DO at the effluent of each aeration tank will provide valuable insight of the oxygen demand as it travels through the treatment process.

The DO concentrations which provide sufficient conversion of ammonia nitrogen will be your targeted DO values. DO residuals of 2 mg/L typically are sufficient for complete conversion.



A data logging DO meter can provide the detail necessary to determine if the DO being applied is sufficient. If you are measuring dissolved oxygen one time during the day it would be like picking just one data point on the chart and basing your operational decision on that one event.

If a data logging DO meter is not available, a more complete DO profile can be obtained by measuring aeration tank DO at different times during the day and different days of the week. Once a more complete DO profile has been determined, adjustments to the aeration blower cycles can be made to maintain adequate dissolved oxygen in the treatment system.

How do I determine how much aeration time is required?

Matching the aeration being applied to the waste load being received provides for optimal treatment conditions and saves operational costs by reducing blower/motor runtimes. However, not meeting the aeration requirements will lead to upsets and permit violations. A simple way to "estimate" blower runtime is to calculate the actual organic loading being received and compare it to the design organic loading of the system.

For example: A treatment system is designed for a flow of 10,000 gallon per day and an influent cBOD concentration of 200 mg/L. This system actually receives only 4,000 gpd with an influent cBOD concentration of 175 mg/L. What is the percent oxidative capacity being used?

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Percent Oxidative Pressure =

(5.8 lbs cBOD/d actual loading / 16.7 lbs cBOD/d design loading) x 100 = 35%

If the treatment system is operating at one-half or less of its design loading rate, then you might be able to operate the aeration at one-half its design (12 hours in a 24 hour period).

Begin by spreading the blower run time to a total of 12 hours of on-time, but avoid excessive periods of off-times. More aeration on-time should be programed into the timer when the organic loading is being received and more blower off-time during periods of low flows and/or loadings (i.e., typically midnight to 5 am). Since the RAS is also controlled by the blower run times, extended blower off-times could allow settled solids to remain too long in the clarifier and denitrify. If the system does not receive sufficient aeration, the aeration tank effluent ammonia concentrations will increase.

If you are not sure of the actual influent loading or the intended design loading you can start by aerating continuously and measuring the aeration tank effluent ammonia nitrogen concentration. If the aeration tank effluent ammonia concentration is less than 1 mg/L you can begin decreasing blower runtime.

Important issues to consider:

The air-lift return activated sludge (RAS) pumps operate using the same aeration source as the aeration tank. Reducing blower runtime affects both the aeration tank and the RAS. A decrease in the air being supplied to the RAS pump will allow bacteria to remain in the clarifier too long. Solids which remain in the clarifier too long can denitrify and float to the clarifier's surface, which leads to solids loss or solids break down resulting in ammonia nitrogen release in the clarifier effluent. To prevent either of these situations in the clarifier, limit the duration of the blower off-time.

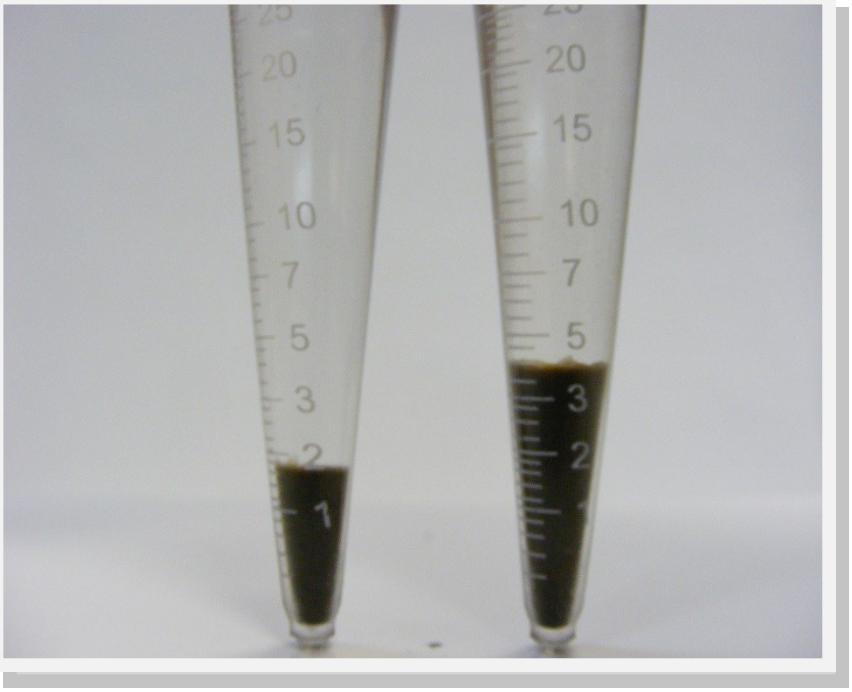
If the treatment system receives the majority of the organic loading during a specific time of the day (i.e. morning) the blowers should be operate more frequently during this period. If influent organic loadings decrease (i.e. school on summer break) longer aeration off-time can be used.

How do I measure biomass in the aeration tank?

Collect a sample of the aeration tank effluent and perform a centrifuge analysis to determine the concentration of bacteria by percent volume (v/v%). It is best to begin the analysis within 15 minutes of sample collection. Collect sufficient aeration tank effluent volume to fill 2 centrifuge tubes. This allows the centrifuge to be balanced and sample results should not differ significantly. If values are too varied, resample and perform another centrifuge analysis.

Fill each centrifuge tube to the 100% mark on the tube. Load the centrifuge tubes opposite each other in the centrifuge to prevent an unbalanced load. Typical sampling locations are the aeration tank effluent (to determine the amount of biomass in the aeration system); the return activated sludge (RAS) (to determine the compaction of the biomass in the clarifier and also to evaluate RAS pumping rates); and the core sample of the volume of solids in the clarifier (which is used in evaluating improper RAS rates or excessive biomass in the treatment system).

Aeration tanks usually operate well when spins range from 2 to 4%. Aeration tanks with spins less than 2% sometimes flocculate insufficiently to filter out suspended solids as it settles in the clarifier. If the system can achieve ammonia nitrogen values below 1 mg/L with aeration tank centrifuge concentrations less than 2%, then less oxidative pressure needs to be applied to prevent over oxidation of the biomass. This is best achieved by taking aeration tanks out of service, if possible, or by reducing the aeration runtime in order to limit the oxidative pressure.



Treatment systems which are consistently over-oxidized could experience an extremely fast settling biomass which does not filter out suspended solids. This may result in more frequent binding of slow sand filters due to solids loss. If tertiary treatment is not available, there may even be a possibility of exceeding effluent total suspended solids limits.

Another possibility with an over-oxidized treatment system is that the aeration tank will experience a low food to microorganism ratio (low F:M) environment. Low F:M aeration tank environments can produce excessive filamentous bacteria which settle slow and are susceptible to hydraulic washout, even under design flow conditions. An increase in the wasting rate will address both of these situations. By increasing wasting, the aeration tank centrifuge concentration will decrease from its previous concentration.

How do I identify internal side streams as additional pollution sources?

Aerobic digesters are designed to store excess bacteria from the Secondary Stage. As the digester becomes full, the air can be turned off to allow the settling of solids. The clear water on top, the supernatant, can then be decanted off the top to recover additional digester capacity.

The decanted water should not cause a problem with the treatment system unless the aerobic digester has turned into an anaerobic digester by having the air off too long during solids separation. This becomes an even more important issue when the ambient air temperature is warmer. Digester supernatant can be a major source of addition ammonia to the treatment system.

A simple method to determine if the aerobic digester contains a high concentration of ammonia nitrogen is to sample the decant for ammonia nitrogen with the field test kit prior to decanting back to the aeration tank or to the head works of the treatment system.

If the decant is high in ammonia nitrogen, a "slug" load of high ammonia supernatant could pass through the secondary system not completely converted. The ammonia nitrogen is not necessarily toxic, but rather it may provide a load that exceeds the design capacity. A high ammonia slug load could cause a "toxic" effect if the total alkalinity is depleted and the aeration tank pH drops too low impacting the conversion process.

If the decant is high in suspended solids use the centrifuge to separate solids from the water and perform an ammonia analysis on the centrate of the centrifuge tube.

How do I evaluate settling with the two-minute diluted settleometer analysis?

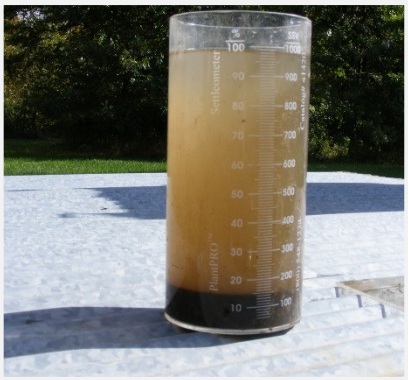
Slow settling of the biomass (> 80% in 5 minutes) is usually caused by one of two situations: either the density of the biomass is low (bacteria wearing floatation devices) or the concentration of the biomass is too high (too crowded in the settleometer). The correct operational response depends on the situation, a density problem or a concentration problem.

To determine which situation is inhibiting settling, a two-minute diluted settleometer analysis is performed. Collect a sample of aeration tank effluent. Fill one settleometer to the 100% mark and a second settleometer to the 50% mark. To the second settleometer, which is one-half full, add clarifier effluent to bring the total volume to the 100% mark.

The two settleometers will have the exact same biomass but one is only 50% of the concentration of the other settleometer. Since there are no internal or external hydraulic pressures (density currents, RAS pumping rates), these settleometers reflect the "true" settling characteristics of the biomass.

Diluted and Undiluted Settleometers of Dense Biomasss

Gently stir both settleometers and then hold the paddle still a few seconds to eliminate and water movement in the settleometers. Pull the paddles out and begin timing the settleometers. Record the values after 2 minutes to determine the cause for the slow settling.



Diluted Settleometer of Dense Biomass

If the diluted settleometer settles significantly faster (photo above) than the undiluted, then the cause of the slow settling is that the concentration of the biomass is too high. If wasting is increased, reducing the concentration, the biomass should settle faster.

Another indicator of a dense biomass is if the bacteria settle so fast they do not provide any "filtering" of suspended solids as it settles (photo to the left). This is indicated initially by a cloudy, turbid supernatant which will clear up as time goes on.

If after 2 minutes the diluted settleometer is not significantly different than the undiluted settleometer (photo to the right), this indicates a density issue. Density issues point to excessive growth of filamentous bacteria. The photo below illustrates "coning" which is another indicator of excessive fil-

Coning Effect of Filamentous Biomass

Diluted and Undiluted of Filamentous Biomass

How do I interpret the clarifier core sampler results?

The Core Sampler provides a window into clarifier operation. While the settleometer test reveals the settling characteristics of mixed liquor, the core sampler will show the actual settling characteristics of the mixed liquor in the clarifier.

In a clarifier core sample, look for three distinct zones: the Supernatant Zone, the Interface Zone, and the Blanket Zone. The Supernatant Zone will be at the top of the core sample and should be clear with little or no solids present. The Interface Zone will be in the middle of the core sample. These are uncompacted solids and usually indicate that the solids are still settling. The Interface Zone can also be due to the presence of an over abundance of filamentous bacteria. The Blanket Zone is at the bottom of the core sample and represents the amount of fully compacted solids.

One, two or all three zones may be present in a core sample. Ideally, a large fraction of the core sample would be clear supernatant with a small amount of interface and a blanket of less than 30% of the clarifier depth. This would represent a good settling sludge that separates well and compacts adequately. If the core sample is mostly blanket with little supernatant or interface, then it is likely that the RAS rate is too slow or that there are too many solids in the entire system (i.e., aeration tank spin is greater than a 4.0% centrifuge spin). If the core sample is mostly interface with little supernatant or blanket, then it is likely that excessive amounts of filamentous bacteria are present in the mixed liquor or the RAS rate is too fast. If the supernatant is cloudy or turbid, then the RAS rate is probably too fast.

By tracking the day to day variations in core sampler results, an operator can gain insights into the onset of settling problems. If the interface begins to increase over time, then an operator would expect that filamentous bacteria are beginning to dominate the mixed liquor in the aeration tank. Another filament indicator is that the supernatant will be very clear, a result of the filtering effect that filamentous bacteria provide by capturing small flocs and debris incorporating them into the flocs.

If the blanket begins to increase over time, the RAS rate should be checked and readjusted if necessary. Also, if the sludge at the bottom of the blanket is black or much darker than the rest of the blanket, the clarifier hopper walls may need to be scraped or possibly the RAS riser pipe is too far from the bottom of the sludge hopper and may need to be extended.

How do I determine the correct RAS pumping rate?

The target RAS pumping rate can be determined with the results of the settleometer test and the centrifuge test. To find the target RAS rate, first prepare a settleometer test with aeration tank effluent and record the settled sludge volume every 5 minutes for 30 minutes if the mixed liquor settles well, or every 5 minutes for 45 to 60 minutes if the settleometer settles slowly. While the settleometer test continues, prepare the centrifuge test with multiple samples from the aeration tank effluent and the RAS being returned to the aeration tank. Average the results from each sample location.

Once the test data is completed, set up a table to analyze the data. In the first line (Time =0) the settleometer test just begins and the Settled Sludge Spin is the aeration tank spin. The calculation column divides the aeration tank spin by the Settled sludge volume percentage (as a decimal). Once the table is complete, compare the theoretical settled sludge spin to the actual RAS centrifuge spin. For instance, if the actual RAS spin is 5.2, then the solids retention time in the clarifier is just over 10 minutes. But the sludge does not stop settling until about 25 minutes indicated by very little settling in the time interval.

Settled Sludge Time	Settle Sludge Volume Percentage	Theoretical Settled Sludge Spin	Calculation
0	100	3.2	3.2 / 1.00 = 3.2
5	78	4.1	3.2 / 0.78 = 4.1
10	64	5.0	3.2 / 0.64= 5.0
15	51	6.3	3.2 / 0.51 = 6.3
20	42	7.6	3.2 / 0.42 = 7.6
25	39	8.2	3.2 / 0.39 = 8.3
30	38	8.4	3.2 / 0.38 = 8.4
35	37	8.6	3.2 / 0.37= 8.6
40	37	8.6	3.2 / 0.37= 8.6
45	36	8.9	3.2 / 0.36 = 8.9

Determine the target RAS rate with settleometer and centrifuge by finding where the settleometer begins to "flatten out." In the example that would be between 20 and 25 minutes with a theoretical settled sludge spin between 7.6 and 8.2. Choosing 7.8 for the target RAS spin, adjust the telescoping valve upward until the RAS spin reaches the desired concentration. If the actual RAS spin would have been 8.8, then the telescoping valve would have to be lowered to increase the RAS rate to the desired spin.

How do I correct a flow splitting issue into a clarifier?

Splitting flow equally between two parallel clarifiers is essential to optimizing treatment. If one unit receives more flow than another parallel unit, then that unit could likely fail under peak flow conditions, unable to perform beyond its design capabilities. Meanwhile the unit receiving less flow will be under utilized, performing well below its design capacity. The net result will be a less efficient treatment system and potential permit violations for suspended solids.

The best way to split any flow is to utilize a flow splitter box. In a properly designed flow splitter box, the flow is directed upward to neutralize any horizontal momentum of the flow and then allow the flow to proceed over equal length weirs that are at equal elevations. If the flow is not directed upward, the forward horizontal momentum of the water could cause a turbulent environment in the flow splitter box that may direct more flow over an individual weir. If the weirs are not level, or are at different elevations, then flows will definitely be unequal. If there are no overflow weirs, then the flow splitting would be random.

Poor flow splitting between clarifiers can be difficult to retrofit due to buried pipes and insufficient available head between the aeration tank and the clarifier to build a splitter box. However, if the flow can be equally split upstream of the clarifier, then the flows should be equal all the way through the parallel treatment trains.

Random Flow Splitter: No weirs, no flow control.

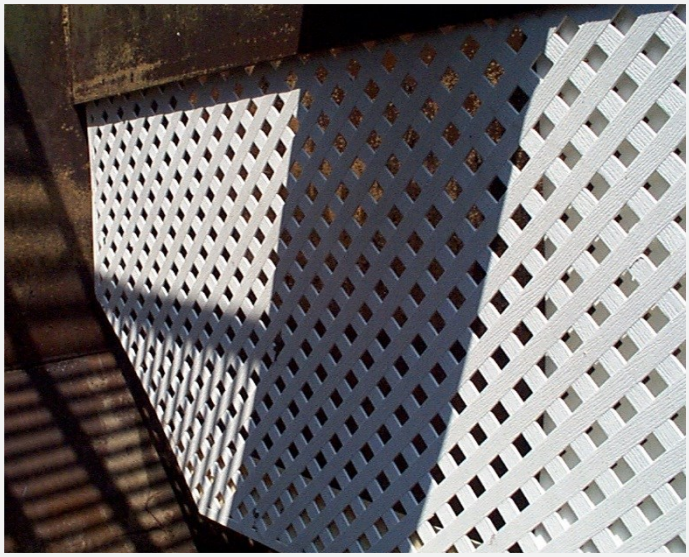
Proper Flow Splitter: Overflow weirs of equal length.

How do I eliminate a density current within a clarifier?

A clarifier density current occurs when mixed liquor enters a clarifier and flows between the higher density sludge blanket and the lower density clarifier supernatant. The mixed liquor has momentum and will continue in the direction of flow until it encounters the clarifier wall. Upon hitting the end wall of the clarifier, the momentum is disrupted and some of the mixed liquor can surface and flow over the weirs into the clarifier effluent. This loss of solids can impact sand filters by clogging them or be discharged into the receiving stream resulting in a permit violation. The installation of properly located baffles can break up a density current thus preventing solids loss and can also improve flocculation of the mixed liquor.

There are two locations in a hopper type clarifier where baffles can improve performance. A flocculation baffle can be installed at the influent end of a clarifier where the scum baffle is located. A mid-tank baffle can be constructed at the peak of a two-hopper clarifier where the side walls of the hoppers come together.

To install a flocculation baffle, the scum baffle can be extended downward to within 1-2 feet of the hopper slant. Rigid plastic sheeting or landscape lattice can be fixed to the existing scum baffle to make the baffle. When mixed liquor enters this baffled region, the flow is gently mixed. This mixing increases collisions between bacterial flocs which promotes bigger, heavier flocs that will settle well. In addition, influent flows will "hit" the baffle and are redirected back into the influent flow. This rebound effect will help to disrupt currents which can persist through the length of the clarifier and carry solids to the effluent weir.



Installing a mid tank baffles is a little trickier. There is usually nothing for a mid-tank baffle to be anchored upon, the baffle will need to be fixed to the side walls of the clarifier. Typically, metal angle is attached to the clarifier side walls and wood boards or plastic sheets are then bolted to the angle. Care must be given to keep the top of the baffle below the water surface so that scum and other floatables are not trapped on the "wrong side of the skimmer.

How do I correct effluent weirs which are causing solids loss?

Clarifier effluent weirs can contribute to solids loss in two ways. Weirs that are not level can establish a current in the clarifier that leads directly to the lower end of the weir. Also weirs that are not optimally located in the clarifier can collect solids that are influenced by clarifier end wall current effects and flow over the weirs.

Clarifier weirs usually have some adjustments so that a weir can be re-leveled should the clarifier settle unevenly or shift slightly. To level a weir, fill the clarifier, block off the influent flow to the clarifier, and shut off the RAS. Since water will seek its own level, just loosen the adjustments and reposition the weir until the water level is even all around the weir. Then retighten the adjustments.

An example of a poorly located weir would be one that is perpendicular to the clarifier end wall or even too close to the end wall. If there is a density current of mixed liquor flowing across the clarifier (see How Do I Eliminate a Density Current Inside a Clarifier), it will continue uninterrupted until it encounters an obstacle, the end wall. Because there is a current flowing over the weir, solids will be carried along with that current over the weir. A simple method to reduce this effect is to block off the portions of the weirs that are close to the end wall. For a weir that is perpendicular to the end wall, taking the 2-3 feet of weir out of service by clamping wood or plastic to the weir. This will allow solids to resettle to the bottom of the clarifier rather than escape over the weirs. For a weir parallel to the end wall, taking the back side weir (the one closest to the end wall on a double sided weir) out of service can also reduce solids loss.

How do I calculate the SOR in the clarifier?

The Surface Overflow Rate (SOR) is a design criteria for clarifiers. The number is calculated by determining the peak flow rate into the clarifier (gallons per day) and then dividing that number by the clarifier surface area (square feet).

The significance of the surface overflow rate is that it provides a numeric value for the hydraulic capacity of a clarifier. In a clarifier, suspended solids settle with a downward velocity. But clear water is flowing upward toward the effluent weir at the same velocity that the mixed liquor enters the clarifier. This results in opposing flows. If the upward flow rate of the clear water is greater than the settling sludge flow rate of the mixed liquor, then solids can be carried over the weir into the effluent trough. If the settling sludge velocity is greater that the upward velocity of the effluent, then there should be no solids loss.

For example, a package plant clarifier may have surface dimension of 6 feet wide by 15 feet long. The clarifier surface area would be:

$$\mathbf{6\ ft \times 15\ ft = 90\ ft^2}$$

If the design peak flow to the clarifier is **40,000 gallons per day**, then:

$$\mathbf{SOR} = \frac{\mathbf{40{,}000\ gpd}}{\mathbf{90\ ft^2}} = \mathbf{444\ gpd/ft^2}$$

For small package plant clarifiers the maximum design surface overflow rate is typically 600 — 800 gpd/ft^2. For larger clarifiers with active sludge scrapers, the design surface overflow rate is usually 1000 gpd/ft^2**.**

How do I calculate the solids loading rate in the clarifier?

The Solids Loading Rate (SLR) is a design criteria for clarifiers. The number is calculated by determining the mass of mixed liquor (in pounds) into the clarifier and then dividing that number by the surface area of the clarifier.

The significance of the solids loading rate is that it provides a numeric value, not to be exceeded, for the amount of the solids entering a clarifier. In a clarifier, suspended solids settle, compact and only then will be pumped back to the aeration tank. A high solids loading rate to a clarifier can lead to a slower sludge settling condition, due to the high concentration and/or a sludge blanket that is greater than desired. Either condition can lead to solids loss.

For example, a package plant clarifier may have surface dimension of 6 feet wide by 15 feet long. The clarifier surface area would be:

$$\mathbf{6\ ft \times 15\ ft = 90\ ft^2}$$

The design mass into the clarifier can be calculated by multiplying the mixed liquor suspended solids concentration by design peak influent flow rate plus the peak design return sludge flow rate and then multiplying by the conversion factor of 8.34.

For example:

MLSS = 3000 mg/L

Clarifier Influent Flow = 0.040 MGD

RAS Flow = 0.040 MGD

$$\textbf{lb/d of solids} = \textbf{3000 mg/L MLSS} \times \textbf{0.080 MGD} \times \textbf{8.34} = \textbf{2002 lb/d}$$

$$\textbf{SLR} = \frac{\textbf{2002 lb}}{\textbf{90 ft}^2} = \textbf{22.2 lbs/d/ ft}^2$$

For small package plant clarifiers the limiting design solids loading rate is 25 lbs/day/ft^2. For larger clarifiers with active sludge scrapers, the design solids loading rate is usually 35 lbs/day/ft^2.