Troubleshooting Activated Sludge Processes

Introduction

Review of the literature shows that the activated sludge process has experienced operational problems since its inception. Although they did not experience settling problems with their activated sludge, Ardern and Lockett (Ardern and Lockett, 1914a) did note increased turbidity and reduced nitrification with reduced temperatures. By the early 1920s continuous-flow systems were having to deal with the scourge of activated sludge, bulking (Ardem and Lockett, 1914b, Martin 1927) and effluent suspended solids problems. Martin (1927) also describes effluent quality problems due to toxic and/or high-organic-strength industrial wastes. Oxygen demanding materials would bleedthrough the process. More recently, Jenkins, Richard and Daigger (1993) discussed severe foaming problems in activated sludge systems.

Experience shows that controlling the activated sludge process is still difficult for many plants in the United States. However, improved process control can be obtained by systematically looking at the problems and their potential causes. Once the cause is defined, control actions can be initiated to eliminate the problem.

Problems associated with the activated sludge process can usually be related to four conditions (Schuyler, 1995). Any of these can occur by themselves or with any of the other conditions. The first is foam. So much foam can accumulate that it becomes a safety problem by spilling out onto walkways. It becomes a regulatory problem as it spills from clarifier surfaces into the effluent.

The second, high effluent suspended solids, can be caused by many things. It is the most common problem found in activated sludge systems. Sometimes a suspended solids problem carries with it a particulate-matter BOD problem if the effluent TSS gets quite high. Ordinarily, one mg/L of effluent TSS produces about 0.5 mglL BOD_5• At low values of BOD_5 plus TSS, the sum of the soluble BOD_5 and BOD from TSS values often equals the TSS value.

The third is high concentrations of soluble materials traveling through the system and not being properly treated. BOD bleed-through is rare in domestic treatment systems where

problems are usually related to particulate BOD contained in suspended solids. However, excess ammonia can often appear in domestic effluents. BOD bleed-through is much more common in industrial systems or combined domestic/industrial systems where slowlymetabolized compounds cannot be stabilized in a short detention-time activated sludge system.

The fourth general problem relates to low effluent pH. It is found most often in geographical areas with naturally low-alkalinity water supplies where extended aeration and/or nitrification processes are used. It is usually fairly easy to control. However, the problem can also be caused by low influent pH and control may be more difficult.

Schuyler (1995) has identified 32 different conditions for one of these four effluent problems to exist. These are shown in the following two-page troubleshooting guide. There are probably many other situations, but these represent the vast majority of the significant problems. The following discussion addresses each of those 32 conditions and the process control changes that should be made to eliminate the problem. While using this chart, it must be remembered that elimination of one problem may allow another problem to show up. Further, one condition may overshadow another such that the second condition cannot be observed until the first is eliminated. Finally, it is difficult to precisely defme control actions relative to specific numbers, such as an MCRT of 5 days or a return rate of 25 percent of Q. Therefore, most control actions are discussed relative to the direction iliat change is needed. For instance, for condition 23, the control action is to decrease wasting and return. The actual amount depends on actual conditions and cannot be specified here. A plastic laminated wall chart is available from Rothberg, Tamburini, & Winsor, Inc.

Excess Foam

Conditions 1 through 5 relate to excess foam in the system (Jenkins, et al., 1993). When considering foam problems the question must be asked, "Is the amount of foam that exists a problem?" If it is not a problem, the situation may be better left unresolved. Many people observe foam and consider it a problem when it is not. For instance, a dark leathery *Nocardia* foam may look bad on an aeration tank but may not be affecting effluent quality. However, the situation may arise where someone's boss or the public thinks it's a problem; then it becomes the operator's problem.

Condition 1- Pumice-Like Foam

This type of foam often appears gray but if one looks closely, they observe that the foam has a large number of dark specks. This foam is usually due to solids returned from sludge processing. It may be due to poor solids capture from a belt press or a centrifuge or from digester supernatant return that contains excess solids. The key to improvement of this condition is to improve the solids capture in the sludge processing scheme.

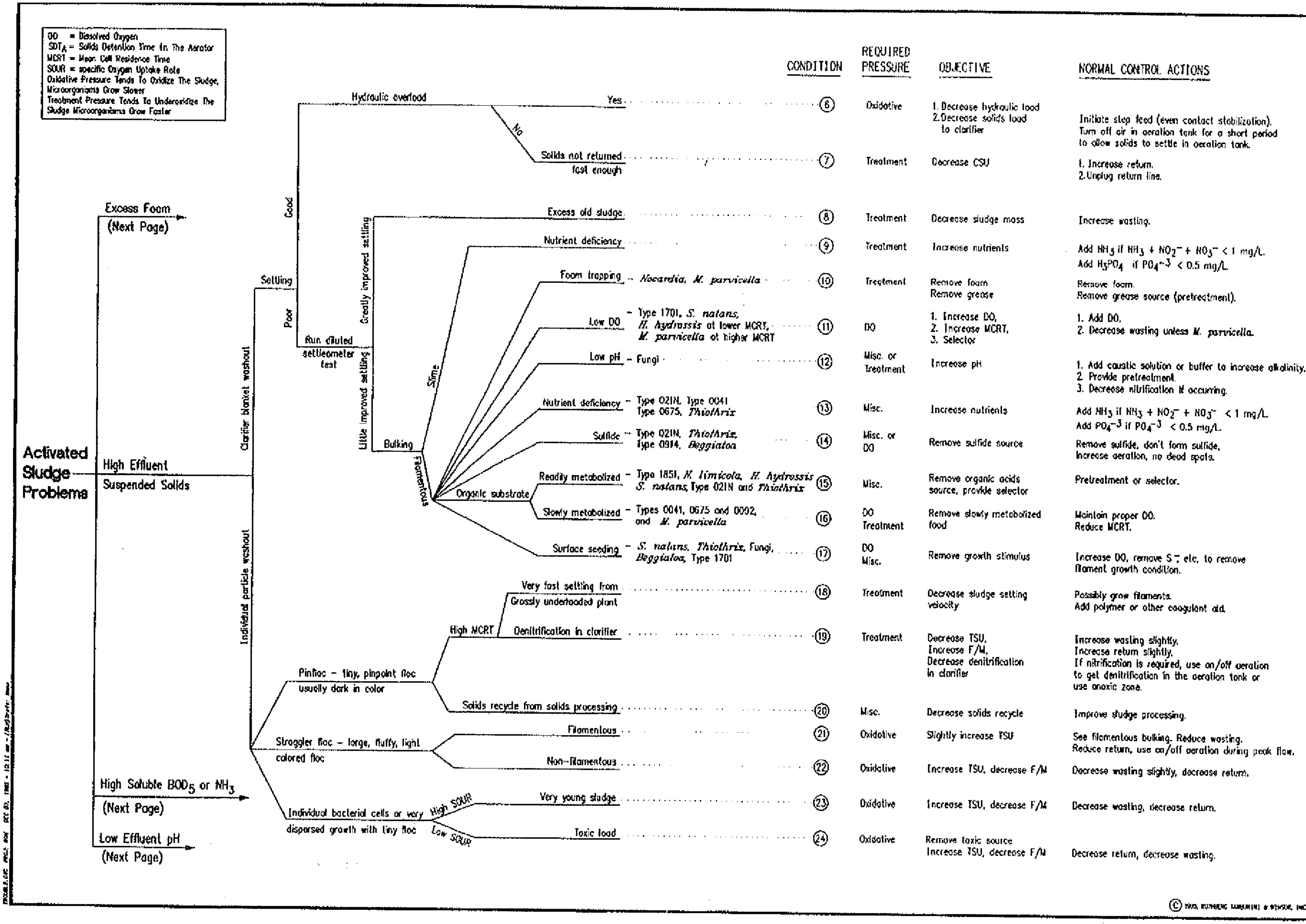

Figure 3A.1 Activated Sludge Process Control Troubleshooting Chart

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Figure 3.4.1 Activated Sludge Process Control Troubleshooting Chart

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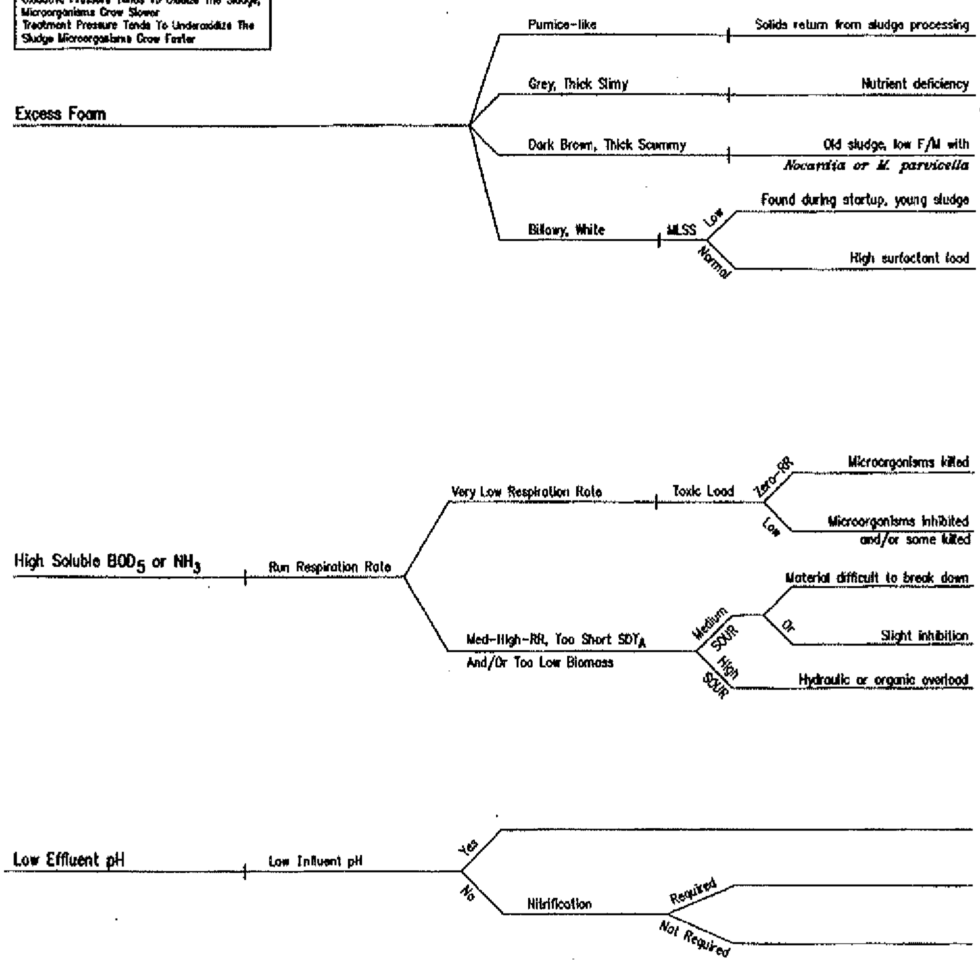
DO = Dissolved Oxygen
SDT_A = Solids Detention Time In The Aerator
MCRT = Mean Cell Residence Time
SOUR = specific Oxygen Uptake Rate
Oxidative Pressure Tends To Oxidize The Sludge, Microorganisms Grow Slower
Treatment Pressure Tends To Underoxidize The Sludge Microorganisms Grow Faster



CONDITION	REQUIRED PRESSURE	OBJECTIVE	NORMAL CONTROL ACTIONS
1	Misc.	Reduce solids return	Improve solids capture in sludge processing.
2	Misc.	Add nutrients	Add NH_3 or NO_3^- if $NH_3 + NO_2^- + NO_3^- < 1$ mg/L. Add H_3PO_4 if $PO_4^{-3} < 0.5$ mg/L.
3	Treatment	Decrease TSU	Increase waste, remove foam from system.
4	Oxidative	Increase TSU	Decrease waste.
5	Oxidative	Increase TSU and SDT_A	Decrease waste and return.
25	Oxidative	Remove toxic material Increase TSU, decrease F/M	Decrease wasting.
26	Oxidative	Remove toxic material	Decrease wasting, decrease return.
27	Oxidative	Increase SDT_A, decrease F/M	Decrease wasting, decrease return.
28	Oxidative	Increase SDT_A, decrease F/M	Decrease wasting, decrease return.
29	Oxidative	Increase SDT_A, decrease F/M	Decrease wasting, decrease return. Initiate step feed.
30	Misc.	Increase pH	Chemically adjust pH. Enforce pretreatment code.
31	Oxidative	Denitrify	Use on/off aeration or anoxic selector. Chemically adjust pH.
32	Oxidative	Stop nitrification	Increase wasting, reduce TSU. If not possible, see #31.

Condition 2 - Slimy Foam

A grayish slimy foam that is very thick is commonly caused by nutrient deficiencies. It is often noted with a slime bulking condition. Those deficiencies may be either nitrogen or phosphorus. The solution usually involves addition of the limiting nutrient, such as ammonia to provide nitrogen, or phosphoric acid to provide phosphorus. There is usually enough nutrient if the ammonia plus nitrate in filtered (0.45 μm) effluent is greater than 1 mg/L and the soluble orthophosphate is greater than 0.5 mg/L (Jenkins, et al., 1993). However, in certain cases where easily degradable, soluble BOD is available, higher N and P concentrations may be necessary.

Condition 3 - Dark Brown, Thick, Scummy Foam

Old sludge conditions usually cause a dark brown, thick, scummy foam. It is usually caused by the growth of *Nocardia* or *Microthrix parvicella*, both of which grow at the high MCRT/low F/M condition associated with old sludge. A treatment pressure is required to decrease the total sludge units in the system. Thus, one must increase wasting and try to remove foam from the system. Once *Nocardia* has started to grow profusely, it is difficult to eliminate through increased wasting. Therefore, removal of foam from the system becomes more important. Foaming due to *M. parvicella* appears to occur more during colder temperature conditions while *Nocardia* can bloom profusely under higher temperature conditions. Both also appear to like oils and grease in their diets.

Conditions 4 and 5 - White Billowy Foam

White billowy foam is caused by high concentrations of surfactants such as detergents. It is not nearly the problem today that it was before biodegradable detergents were used. Condition 4 occurs at start-up of a system where a young sludge exists due to low mixed liquor suspended solids concentrations. In this condition there are just not enough solids present to break the surface tension of the surfactant bubbles that form. Thus, billowy white foam can accumulate on the aeration tank and can even be blown around by the wind. The condition is usually short-lived since at start-up the operator is usually applying oxidative pressure by increasing the total sludge units in the system. If the condition occurs due to previous excessive wasting, the solution is still to decrease wasting and increase the total sludge units in the system.

Condition 5 is found when there are higher concentrations of suspended solids. The cause is usually a very high surfactant load such as may be found when certain industrial processes are cleaned. Although there is a higher suspended solids concentration, it is still not high enough to break the surface tension of the surfactant bubbles. Again, an oxidative pressure is required to increase the total sludge units by decreased wasting and it is also worthwhile to increase the solids detention time in the aerator by decreasing the return flow rate.

High Effluent Suspended Solids

High effluent suspended solids are usually caused by one of two conditions: either individual particles that will not settle are discharged or the sludge blanket in the clarifier washes out. Either of these can cause conditions 6 through 24 to occur. Look first at clarifier blanket washout related to conditions 6 through 17. In this situation, the sludge blanket in the clarifier actually rises close enough to the surface so that it washes over the effluent weir. To learn the reason for the clarifier-blanket washout, the first thing to do is to look at the sludge settleability. If the problem is not a blanket wash-out, it is individualparticle washout. The individual particles may be tiny pin-floc, large straggler-floc or individual, dispersed cells. Physical observation of the effluent and microscopic observation of the mixed liquor or effluent will show which type or combination of types of individual particles is involved.

Hydraulic Overload ~ Conditions 6 and 7

If the settling test or diluted settling test shows that the sludge settles well, then the blanket washout is usually due to too many solids in the clarifier.

Condition 6 is caused by hydraulic overload of the clarifier. It results when too many solids are pushedinto the clarifier and they are not physically returned fast enough to the aeration tank. There are just too many solids applied to the clarifier. The required pressure to eliminate the problem is oxidative. The objective is to decrease the solids load to the clarifier by initiating step feed or even going to contact stabilization. If step feed or contact stabilization are not available, a short-term decrease in solids load to the clarifier can be accomplished by turning the air off in the aeration tank for a short time. This allows the solids to settle in the aeration tank. This reduces the solids load on the aeration tank while at the same time allows the sludge return system to return solids from the clarifier to the aeration tank. The same approach can be used to manage short-duration daily peak flows or other short-term peaks such as storm inflows or things like weekends at ski areas. However, the on-off approach will not work if the aeration basin discharge is from the bottom of the tank.

Condition 7 occurs due to an overload of the return system, not a hydraulic overload. The actual solids loading to the clarifier is not excessive, but the solids are just not returned fast enough. A treatment pressure is usually required, decreasing the clarifier sludge units. However, the problem may be caused by something much simpler and can be handled by an increase in the return rate. If there is a physical problem such as a clogged return line, clean the line.

Problems with Poor Settling

Before the reason for poor sludge settleability can be pinpointed, a diluted settleometer test must be run. A simple old-sludge condition, with just too much sludge in the system, will show greatly improved settling in the diluted test. However, a bulking situation, even though it shows some improved settling, will not show large improvement.

Condition 8 - Excessive Old Sludge

As mentioned above, this is pinpointed through the diluted settleometer test, which shows a great improvement in sludge settling. The required pressure is a decrease in the total system sludge mass. Increased wasting is required to accomplish that objective. This problem is very common.

Conditions 9 through 17 ~ Bulking

Bulking has been the scourge of activated sludge ever since flow-through systems began being used in the 1920s. It can be caused either by production of slime or growth of filamentous organisms.

Condition 9 - Slime Bulking

Slime bulking (Jenkins, et al., 1993) is usually caused by a nutrient deficiency. As in Condition 2, ammonia or nitrate must be added if the ammonia plus nitrite plus nitrate is less than 1 mg/L. Phosphate must be added if the phosphate is less than 0.5 mgIL in the effluent. Slime bulking is usually associated with industrial waste, but may be found in municipal systems that have high concentrations of industrial wastes discharged to them. Even higher concentrations of N & P may be required with certain industrial wastes. This is true if the organic loading comes from easily metabolized materials, such as simple sugars, short-chain organic acids, or alcohols. These may be metabolized so rapidly that excess N and P are required in the system to ensure that the local concentrations are high enough. Complete mixing may also help in this situation.

Condition 10 – Foam Trapping

Systems can trap foam as in Condition 3 where *Nocardia* and *Microthrix parvicella* float to the surface. The key to removing the problem is to remove the foam from the system. Increased wasting will help some, but this will often have negligible benefit. A short-term solution includes some facilities using a vacuum truck to remove the foam from the·· surface. A long term solution includes eliminating grease from the influent.

Condition 11 - Low DO Bulking

Type 1701, *Sphaerotilus natans*, and *Haliscomenobacter hydrossis* have all been known to grow profusely under low dissolved oxygen conditions. In recent years, it came to light that *Microthrix parvicella* also grew well under low DO conditions at high MCRT. Also, it was not known until recently that as the food-to-microorganism ratio increases, aeration basin dissolved oxygen also needs to increase, otherwise low DO bulking can occur. For instance, to protect a system with an F/M of approximately 1.0, almost 5 mg/L DO is required (watch potential denitrification problems). That F/M is defined as pounds of COD removed per pound of ML VSS in the aeration tank (Jenkins, et aI., 1993).

Objective number one is to increase the DO, but in certain cases that is impossible. Objective number two would be to increase the MCRT, which in turn would decrease the F/M ratio. An MCRT increase would be accomplished with a decrease in wasting. Finally, a third objective would be to develop a selector section that could operate anaerobically, anoxic ally, or aerobically. Jenkins, *et aI.* (1993), indicate that any of the three types of selectors will work on low DO filaments.

Condition 12 - Low pH

Growth of fungi is common in the fruit processing industry where a low pH exists along with a high sugar concentration. To get rid of low pH bulking, the objective is to increase the pH by adding either a caustic solution or a buffer solution to increase the alkalinity. A possibly better alternative is to provide pretreatment to eliminate the low pH initially. A third process control change would involve decreasing any nitrification that is occurring, since nitrification tends to depress aeration tank pH. Or as a related solution, increase denitrification in the aeration tank to increase alkalinity and pH.

Condition 13 - Nutrient Deficiency Bulking

Types 021N, 0041, 0675, and *Thiothrix* have been known to cause bulking when deficient in either nitrogen or phosphorus (Jenkins, et aI., 1993). The control objective is to increase nutrients so the ammonia plus nitrite plus nitrate is greater than 1 mg/L in the effluent, and phosphate is greater than 0.5 mglL in the effluent.

Condition 14 - Sulfide Bulking

Thiothrix, *Beggiatoa*, and types 02IN and 0914 oxidize sulfide into elemental sulfur, depositing sulfur granules within the cell (Jenkins, et aI., 1993). The control objective is to remove the source of the sulfide. Preaeration oxidizes the sulfide so it is not available to the filaments. Better aeration and mixing help if the sulfide is being formed in the treatment process itself. There is also the possibility that addition of iron compounds such as ferric chloride or ferrous sulfate would chemically bind the sulfide, making it unavailable for the microorganisms.

Condition 15 - Readily Metabolized Substrate Bulking

Types 1851, 021N, *Nostocoida limicola*, *H. hydrossis*, S. *natans*, and *Thiothrix* species all can rapidly metabolize short-chain organic acids (Jenkins, et al., 1993). Industrial systems may receive organic acids directly in the influent and biological nutrient removal (BNR) systems may produce those acids, as do anaerobic selectors. The control objective is to remove the organic acid source either through pretreatment or installation of an appropriate selector (aerated, anoxic, or anaerobic).

Condition 16 - Slowly Metabolized Substrate

Types 0041, 0675, and 0092 along with *M. parvicellaare* known to grow well on slowly metabolized food. There are no real answers to controlling this growth to date, but it appears that maintaining good mixing and proper dissolved oxygen throughout the aeration process helps. These are also associated with older sludges. Therefore, reducing MCRT often reduces their growth.

Condition 17 - Surface Seeding

Organisms such as *Sphaerotilus natans, Thiothrix, Beggiatoa,* fungi, and type 1701 can grow on upstream surfaces such as pipes or attached growth pretreatment systems. As these organisms slough off, they provide a large population of filaments for the aeration tank. If the environment in the aeration tank is not conducive to growth of these filaments, they will die out without proliferating. However, if they find a suitable environment in the aeration tank, they will proliferate accordingly. Therefore, the answer to control is to make sure that the aeration system provides enough DO, removes sulfide, or does whatever else is necessary to remove good filament growth conditions in the aeration tank.

Conditions 18, 19, and 20 - Pin-floc

Pin-floc is tiny, usually dark, pinpoint-sized floc associated with very old sludge. Three different problems, specifically numbers 18, 19, and 20, are associated with pin-floc.

Condition 18. Pin-floc is often found in situations where the treatment plant is grossly underloaded and the mixed liquor suspended solids cannot be reduced any further than the present value. If it is reduced, the concentration gets so low that effective settling is impossible. Normally, one would try to reduce the MCRT, but this requires wasting and a reduced MLSS and it seldom works in this case. It may be worth trying to grow some filaments, such as low DO filaments, that would slow the settling and improve the capture of solids. Maintaining a DO between 0.1 and 0.5 in the aeration tank will usually allow low DO filaments to grow. Be careful!

Condition 19. Pin-floc is also associated with denitrification in the clarifier. Bacteria convert the nitrate to nitrogen gas and the resulting bubbles buoy floc particles to the surface. Ashing or clumping is often seen. A treatment pressure is required by reducing the total sludge units in the system. A slight increase in wasting usually eliminates the problem, however increased returns may also be required. If an increased return rate is used, be sure the other process demands, e.g., SDT A are met. Too-high return rates are very common. The use of on/off aeration or an anoxic zone in the aeration tank may also be helpful. It allows the denitrification to occur in the aeration tank where it is not a problem rather than in the clarifier where it is a problem.

Condition 20. Pin-floc also occurs in systems where solids are unintentionally being returned from solids processing. Excessive solids in anaerobic or aerobic digester supernatant or improper solids capture from sludge dewatering systems can all cause excessive loads of tiny sludge particles that will show up as pin-floc. They mayor may not be associated with denitrification, so one has to be careful to decide which is causing the problem.

Conditions 21 and 22 - Straggler Floc

Straggler floc is large, light colored, very fluffy floc that mayor may not be filamentous. Microscopic observation will quickly show if it is filamentous or nonfilamentous. The effects of straggler floc are made worse by poor clarifier design and by high influent or return flows. Reducing return rates often helps.

Condition 21. All of the filamentous growth conditions, Conditions 11 through 17, can cause fIlamentous straggler floc development and the control actions associated with those should be followed. With severe cases during peak flows, try on/off aeration or step-feed. If that does not work, clarifier modification may be required.

Condition 22. NonfIlamentous straggler floc may be observed where changes in organic loading have caused certain floes to grow very quickly. An oxidative pressure is needed, which increases the total sludge units and decreases the food-to-microorganism ratio. Thus, a slight decrease in wasting and a slight decrease in returns often solves the problem.

Conditions 23 and 24 - Dispersed Growth

Dispersed growth is growth of individual bacterial cells or very tiny floc. The specific oxygen uptake rate (SOUR) will help identify the cause for the dispersed growth.

Condition 23. Very fast growth conditions, such as those seen at start-up can exhibit dispersed growth. It is shown by extremely high SOURs. An oxidative pressure is required that increases the total sludge units and decreases the F/M ratio. Again, as in

Condition 22, a decrease in wasting and a decrease in return will usually help the condition.

Condition 24. A toxic load can also cause dispersed growth. This case is shown by a very low OUR or SOUR Once the toxic load has passed, an oxidative pressure is needed to increase the total sludge units and decrease the food-to-microorganism ratio. Thus, a decrease in wasting and decrease in return is appropriate. Remember, excessive cWorination of return sludge for bulking control can cause dispersion of cells.

High Effluent Soluble BOD or Ammonia

Conditions 25 through 29 all relate to high soluble BOD or ammonia in the effluent. It is important to determine the respiration rate because the specific cause of the problem can easily be determined with the respiration rate, or SOUR.

Conditions 25 and 26, very low SOUR

Condition 25 is shown by a zero SOUR and is caused by the fact that all of the microorganisms have been killed. They cannot use the oxygen. Once the toxic material is removed, it is imperative that the total sludge units are increased and the food-tomicroorganism ratio is decreased, thus a decrease in wasting is required. If the SOUR is low, then Condition 26 is shown. The microorganisms were either inhibited, or a certain number, but not all, of the microorganisms were killed. In either case, an oxidative . pressure is needed again once the toxic material is removed. A decrease in wasting and a decrease in return is effective until the mass of live microorganisms has been increased to the level needed for proper treatment.

Conditions 27 through 29, medium to high SOUR

If the respiration rate or SOUR is medium to high, then a non-toxic situation exists. Condition 27. A medium SOUR can be due to the material in the influent being extremely hard for the microorganisms to break down. If this is the case, an oxidative pressure is needed and an increase in the solids detention time in the aerator and decrease in F/M is required. Thus, decreased wasting and decreased return will help. This supplies more microorganisms and more SDT A for the microorganisms to do the job.

Condition 28. A medium SOUR can also be found with slight inhibition, a condition very similar to Condition 26 and decreased wasting and decreased return should help.

Condition 29. A high SOUR or high effluent NH_3 relates to a hydraulic or organic overload. In this case, there are not enough microorganisms or enough time in the aeration tank. to adequately treat the BOD or remove the ammonia. In this case, an oxidative pressure is needed to increase the solids detention time in the aerator and to decrease the food-to-microorganism ratio. Decreased wasting and decreased return will help.

Step Feeding or contact stabilization can also be very effective with condition 29. This reduces the solids loading on the clarifier, while allowing maintenance of a larger mass of microorganisms.

Low Effluent pH

The last general condition that requires consideration is low effluent pH, conditions 30-32. It is usually caused by one of two reasons, low influent pH or *low* alkalinity water with nitrification. Either can cause regulatory noncompliance.

Condition 30. If the influent pH is low (acidic), there is a good chance that the condition will go through the plant and show-up in the effluent. Chemical addition to raise the pH is the immediate solution. Lime, soda ash, or sodium bicarbonate are normally used for pH adjustment. However, the ultimate solution is to eliminate the low pH source from the collection system by enforcing pretreatment requirements. An industrial system may have to live with pH adjustment.

Condition 31. If the influent pH is satisfactory, then the low effluent pH is usually caused by nitrification in combination with low natural alkalinity in the wastewater. If ammonia removal is required, then nitrification must continue. Use of on/off aeration or provision for an anoxic zone often returns enough alkalinity to satisfactorily raise the pH. However, if neither of these is possible, then pH adjustment similar to Condition 30 may be required.

Condition 32. With satisfactory influent pH near 7.0 and nitrification not required, the MCRT or DO can often be reduced enough to inhibit nitrification. With no nitrification, there is no alkalinity reduction through the aeration process and the pH remains stable. However, in systems that naturally nitrify, such as extended aeration, a solution for Condition 31 may have to be applied, if MCRT and DO control cannot provide a solution.

References

Ardem, E. and W. T. Lockett. 1914a. Experiments on the oxidation of sewage without the aid of filters. *J. Soc. 01 Chemical Industry (England), 33:523-539.*

Ardem, E. and W. T. Lockett. 1914b. The oxidation of sewage without the aid of filters. Part II. *J. Soc. of Chern Industry (England),* 33: 1122-1124.

Martin, A. J. 1927. *The Activated Sludge Process.* MacDonald and Evans, London.

Jenkins, D., M. G. Richard and G. T. Daigger. 1993. *Manual on the Causes and Control of Activated Sludge Bulking and Foaming.* Lewis Publishers, Inc., Chelsea, MI.

Schuyler, R.G. 1995. *Activated Sludge Process Control Troubleshooting Chart.* Rothberg, Tamburini and Winsor, Inc., 1600 Stout Street, Suite 1800, Denver, CO 80202-3126.