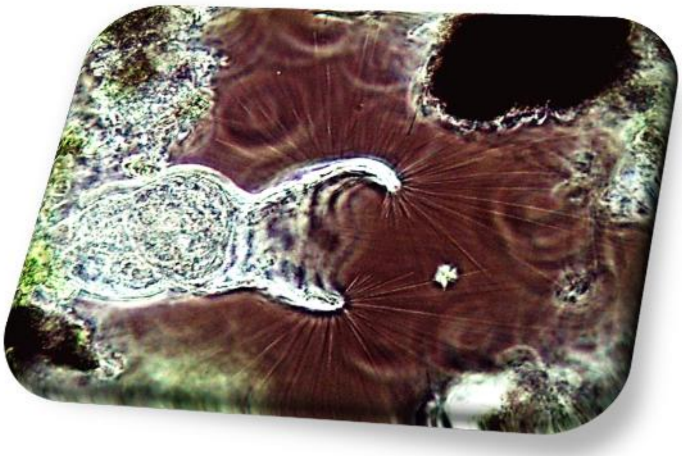


How Critical Are The "Critical 5 Plus One"?

In Various Locations

Ok, so what exactly are the "Critical 5 plus one"? I have never heard of that.

There are 5 critical measurements that should be monitored and controlled to effectively run a biological treatment plant efficiently;
Temperature, DO, Ammonia, Ortho-phosphate and pH.

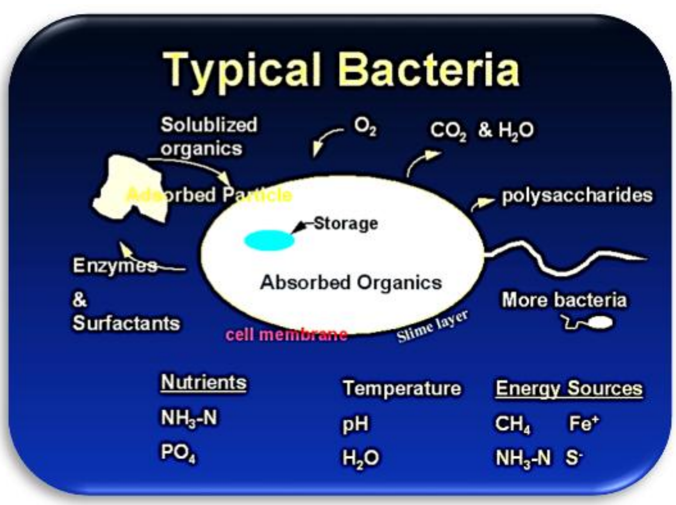
- **Acceptable Environmental Parameters for Biological Activity including:**

PARAMETER	ACCEPTABLE	OPTIMUM
Dissolved Oxygen	>0.5 mg/l	1.0 - 2.0 mg/l
Temperature	50 - 95° F	77 - 95 ° F
pH	7.0 - 9.0	7.5 - 8.5
Ammonia Residual	1.0 - 3.0 mg/l	2.0 - 3.0 mg/l
Ortho-phosphate Residual	0.5 - 2.0 mg/l	1.0 - 2.0 mg/l

- **Residual should be measured in the final effluent.**
- **Ammonia and ortho-phosphate if supplemented should be fed based upon front loading, not final effluent measurement. Use flow times loading, and use a ratio of 100 carbon- 5 parts nitrogen to 1 part phosphorus.**

As silly as these 5 variables may seem or appear to be just **general information**, they are extremely critical. 90% of all audits we conduct have at least one or more of these parameters in the wrong range. These are the easiest parameters to control at your wastewater treatment plant and some of the most critical ones. The bacteria do not care about any tests you perform, (i.e. sludge judge, MLSS, F/M etc.) parameters you measure or implement as long as these Critical 5 are in the correct range. Biomass quality and final effluent results will be impacted.

Cold weather can sometimes be a problem for many plants due to permit restrictions and decreased biological activity. Many plants experience a significant drop in biological activity due to the temperature levels decreasing. Biological activity drops one log level for each 10-degree drop in temperature. This can significantly impact the amount of BOD loading that the biomass can handle effectively.



What is the "plus one"?
Alkalinity is sometimes considered the plus one but only for plants that require the additional step of Nitrification.

Nitrification
Nitrification is a sensitive process that must coexist with the carbonaceous BOD removal process. There are many stresses that can adversely impact nitrification before the

BOD or TSS removal efficiencies are affected. Biocides that are used in the cooling towers can contain chemicals that are toxic to nitrifiers. Gluteraldehyde is very toxic to nitrifiers and it tends to stay in the activated sludge. It is absorbed by the biomass. Zinc can also be toxic to nitrifiers. Alkalinity and pH were low at this time. Alkalinity is critical to Nitrification. Nitrifying bacteria

As ammonia is removed it is transformed-For each 1 gram of NH3-N oxidized to NO3, 0.15 grams of new bacteria cells are formed. Most of the NH3-N is used as an energy source. It is used in a non-assimilative way so only a small amount of biomass (sludge) is produced. Nitrification occurs 3-4 times slower than carbonaceous oxidation. Carbon dioxide (CO2) or carbonate is used as the carbon source in nitrification. 4.5 parts of O2 is needed for every part of NH3 to be degraded.

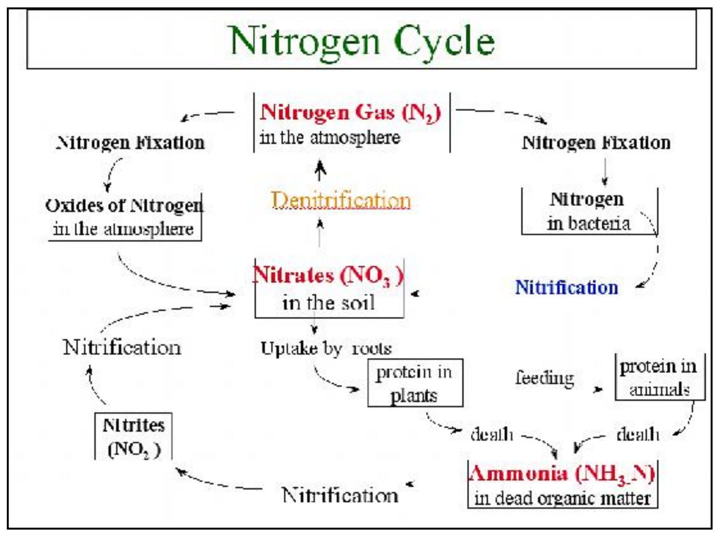
First Conversion (Ammonium to Nitrite)
Nitrosomonas bacteria oxidize ammonium to nitrite via hydroxylamine.

$$2NH_4^+ + O_2 \rightarrow 2NH_2OH + 2H^+$$
$$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

Second Conversion (Nitrite to Nitrate)
Nitrobacter bacteria convert nitrite to nitrate.

$$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$$

There is a wide range in the reported pH optima (PH 6.5 to 8.6). Typical refineries run in higher pH- `8.0-9.5. However, there is general agreement that as the pH shifts to the acid range, the rate of nitrification declines, thus, it is important that sufficient alkalinity is present in the wastewater to prevent a significant decline in the pH. It is recommended that a residual alkalinity of 50 mg/l for aeration and at least 150 mg/l for high purity oxygen systems be maintained for pH control during nitrification. Low pH conditions are only inhibitory and not toxic toward nitrifiers. Caustic or lime addition may be required to supplement low alkaline wastewaters.



Calculations on alkalinity must be considered using the fact that amines are also present in the water and will degrade down to release some of the ammonia for use in nitrification. Targeting alkalinity must include free ammonia as well as bound ammonia for final degradation rates to achieve below 1 in the system.

Critical 5 issues with various pieces of equipment associated with Wastewater.

Lift Stations, Channels and Wet Wells
EQ tanks
Primary clarifiers
Aeration Basins
Secondary clarifiers
Digestors
Dewatering
Chlorination- UV
Sand Filters

What is growing in your Collection System, Lift stations, manholes or wet wells?

Anything and everything that is dumped down the drain winds up in the sewers and lift stations, from grease, garbage, toilet paper, human waste and food to industrial waste. Fast Food restaurants are adding significant loading to a collection system.

A collection system is not a sterile environment. As long as there is food for the bacteria to grow, they will grow in the collection systems. But as solids build up, the wrong conditions occur, and slime causing organisms can build up and cause blockages. The real control is in making sure the right types of bacteria grow in the collection system.

Basically, the collection systems can be thought of as one large holding tank or Equalization tank prior to the Wastewater Treatment Plant. Many municipalities have miles and miles of pipes, and numerous lift stations prior to a wet well, and then the actual wastewater treatment plant. Maintenance on these pipes can be costly and time consuming, as well as incur some safety concerns.

Bacteria, if given even the slightest chance, will grow anywhere there is sufficient food. Typically, there always is some type of small biofilm in all sewer collection pipes. Usually the growth is slow, due to low BOD loading and high flow of water causing enough movement or even pressure from the lift stations. The biofilm is relatively small, and sloughs off quickly with rain and normal flow. In effect, a miniature RBC unit can be created in the collections systems with the right conditions. Typically, the flow is enough to cause the biofilm to slough off without causing problems.

In cases where easily degradable organic compounds are discharged to a system, a very rapid biomass growth can occur. If the industrial or institutional discharger uses large amounts of rolling or cutting oils, Grease or sugars in the processes, has dipping baths where biofilms are allowed to grow, or septic water is allowed to collect in tanks onsite, and then this is discharged into the sewers, the bacteria in the system will quickly grow on these types of substrates. If the optimum environment is not present, such as sufficient N, P or lower pH, or sufficient mixing and Dissolved air, then a slimy biofilm will develop instead of floc.

Grease is one waste that the sewer system cannot handle and therefore needs to be kept out of the system, but most often is not. An additional concern is that since the government raised the temperature required by restaurants and food establishments from 180 F to ~210 F, grease traps are not working as designed and grease that used to be trapped onsite is now washing through the lines until the temperature of the water cools down and then hardening later on. This usually happens somewhere in the lines or in the lift station.

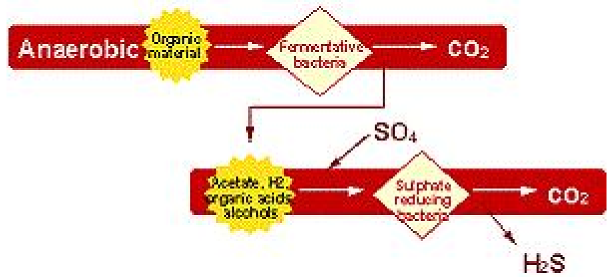
Wet wells at the plant can become septic and cause growth of filaments and spirillum. Septic influent can impact downstream processes, such as primaries and aeration basins.

Equalization Tanks and Wetwells

Equalization tanks or holding, equalization lagoons come in all sizes and shapes. They may be small or very large.
They can be above ground storage tanks, large lagoons, or covered sunken tanks. The can have slow mixing, large aerators or nothing at all. They can have covers, or be open to the air. What your equipment is like is not the main issue, the real issues are what you are trying to accomplish with the Equalization and how well you are doing it. Many plants, especially industrial facilities have large swings in influent loading. That may be either from BOD loading, pH or even toxicity. The purpose of an equalization holding area is to try to even out those swings before sending the wastewater on to the Biological portion of the system. Anytime you make more than a 10% change to the bacteria, which technically is major to them and can cause upsets, i.e., equalization is a good thing.

While Equalization is a good thing, sometimes too much is not better. Many plants figure out that if a little is good, more is better. If you have just created a wide spot in the pipe, and are letting solids build up in the bottom of the holding tank, you can cause more problems than help. Solids building up can cause septicity, growth of filaments, organic acids, gassing and sometimes even H2S generation. This can mean safety issues, excess electricity costs, excess polymer or chemical consumption and excess solids handling costs.

What is septicity?



The presence of hydrogen sulfide (H2S) in waste water and sludge is defined as a septic condition. Septicity is a result of anaerobic bacterial activity in absence of oxygen or nitrate. By preventing septic conditions from arising, negative effects like odors, health hazards, corrosion and reduced efficiency of the treatment plant, can be eliminated or reduced.

Primary Clarifiers:

Septicity, low DO and low pH result when you hold solids too long in the primary clarifiers.

Many times operators often underestimate how much impact primary treatment can have on the secondary biological portion of the system. The whole purpose of primary treatment is to physically remove as much loading from the system as quickly and as cheaply as possibly without high tech equipment or excessive monitor and control. Often times, though small adjustment to the equipment can significantly improve solids removal as well as BOD and TSS removal or even prevent the growth of filamentous bacteria in the biological portion.

Primary systems are designed to be able to remove a significant portion of the BOD and TSS loading on a plant thus making it easier on the secondary biological portion of the system. Sometimes the addition of chemicals will improve efficiency. Coagulation and flocculation of fine suspended solids will convert some or all of the colloidal solids to settleable solids.

The purpose of a clarifier is to remove solids, produce a cleaner effluent and concentrate solids. Concentration of solids removed from the wastewater reduces the volume of sludge for dewatering and/or disposal. The smaller the volume of sludge removed results in lower capital and operating costs for dewatering equipment and/or sludge disposal. Sometimes existing dewatering equipment may not have enough capacity if the sludge is not concentrated.

Conditions Affecting Settling Factors:

Concentration of Solids- The larger and heavier the suspended solids, the faster they will settle. The more particles there are (within design), the better the settling.

Temperature- At higher temperatures, the water is less dense, therefore, the higher the temperature, the more rapid the settling.

Detention Time- About 50% of a municipal type suspended solids will settle out in 30 minutes, about 60% after 1 hour, and about 70% after 2 hours. Usually, clarifier design allows for detention times ranging between 2 to 3 hours, however, it may be as long as 4 to 5 hours. If necessary use a settleometer to check how long solids can be in the clarifier without floating to the surface.

Surface Loading-

Condition of Wastewater- Wastewater strength, freshness, temperature, and the density, shapes and sizes of particles all impact the efficiency of the unit. Septic wastewater settles slower because of smaller particle size or gas bubbles on particles that can cause floating.

Short Circuiting- Can be caused by uneven weirs, inadequate baffles, wave action or currents.

Problems can develop in settling tanks due to distribution of solids and flow. Basic trouble areas include short-circuiting, turbulent flow, and bottom scour.

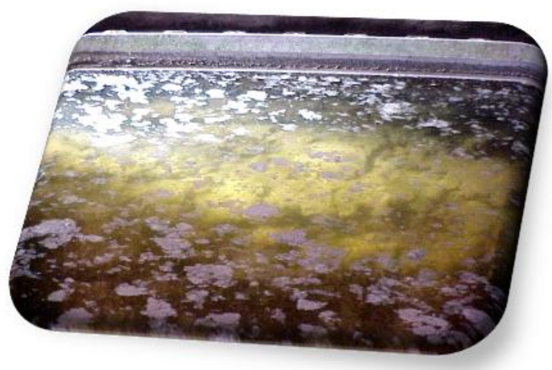
If Sludge is Held Too Long in the Clarifier it can create gasification by anaerobic decomposition. Gas bubbles can be seen breaking water surface. Re-suspension can occur of sludge solids. Floating black sludge can be seen. A strong hydrogen sulfide odor can be present in severe cases.

Ashing and gassing can occur in primary clarifiers just as well as secondary clarifiers. Are you holding the solids too long in the clarifier? This is a very common practice that causes septicity and promotes growth of filaments. Check for pin floc, air bubbles rising or clumps of floc floating - these all indicate solids held too long.

What you do in the primary impacts your secondary aeration basin, as well as your digestor or dewatering, since that is usually where the solids are sent from the primary. Septic solids sent to a digestor can create a huge filamentous growth, as well as

fungi. Both take up a large volume, thus defeating the purpose of a digestor and reducing the amount of solids. Septic influent sent to the aeration basin, immediately put a huge demand on the aeration requirements, thus depriving the floc forming bacteria of the oxygen they might need. Again, promoting the growth of filamentous bacteria.

Aeration Basin - Obviously the critical 5 plus one are very important in the aeration basin. Usually this is the only place an operator focuses on these critical parameters. Often they are overlooked in other parts of the plant, but if you have any recycle of sludge, influent, supernatant, that wind up back at the front of the plant, all these can impact the activity in the aeration basin~ Filaments and Zooglea can grow due to major changes in these Critical 5.





Secondary Clarifiers: How long do I hold the solids in the clarifier? One good way to judge how long the solids can be held in your clarifier is to run a settleometer test. You cannot physically see into the bottom of the clarifier, so by using your settleometer, you are basically running a clarifier test. How long does it take for the solids to settle, how much of a bed is created, how much bulking, is there a rag layer, how long does it take for gassing? ashing? How long before the whole thing pops to the surface? These are all things you look at when running a settleometer. Do not just run it for the normal 30 minutes. Check to see how long it takes before there is small pin floc on the surface. Time it, check to see how long it takes for the whole bed to pop. These will give you an idea of how long you have in your clarifier before it will happen in your plant.

One thing that can be done is a dilute 50/50 test. In this test a normal settleometer is run, and then one with 50% water and 50% sludge run. This is used along with your microscope to tell if you just have too much MLSS or you have a case of filamentous bulking. If you have filamentous, and your sludge only settles to 900, then in a 50/50 dilute with just too much MLSS, theoretically, it should settle to around 450. It you have filamentous bulking though, it may settle in the 50/50 at 700 or 800, but definitely not at the halfway point.

Operators tend to think that all biological activity occurs only in the aeration basin. Wrong, it occurs all throughout your system. It is not a sterile environment. There will be biological activity even in your clarifier, especially if you still have some BOD left, otherwise there will be endogenous respiration. The rule of thumb is to have 1-2 ppm of DO in your residual leaving the aeration system. Not because it means you need more air in the aerated system, but so that you have enough air for respiration in the clarifier. Think about it, you probably are carrying at least 1/3 to 1/2 of your solids inventory in your clarifier. That is a lot of bacteria. They still require oxygen, especially your nitrifiers. If you starve them of oxygen in the clarifier, and then return them back to the front of the system, it takes time for them to activate again. If you have more than enough oxygen in the clarifier, everything will settle, you will have clear supernatant, your bacteria will be ready to work the instant they are back in the aeration basin and you will not grow filaments.

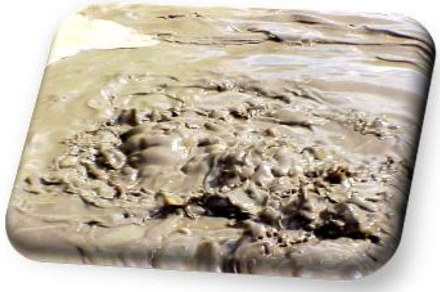
Ashing and Gassing, what is this?

Gassing is the first sign that the bacteria are running out of air in the clarifier. You can call it an early warning system. Bacteria first will go for free oxygen, then nitrates, then sulfates. One way or another they will find a source. If you run out of air in the clarifier, and they have to use nitrates, they give off N2 gas. This will show up as gassing or air bubbles rising to the surface. Same with sulfates, H2S gas is generated, which if too high, can cause serious health problems.

Ashing is when tiny particles of floc trap that gas, and rise to the surface. Pay attention to those signs. First you will see small tiny pin floc that looks like cigarette ash and then clumps. Then larger clumps finally the entire bed can burp and rise up.
Did you know that the solids that go over the weirs could impact your final effluent BOD results along with the TSS?

False high BOD readings can occur if biological material or algae are present in a BOD sample. These will increase the final BOD reading and potentially increase your final effluent values, which, in turn can mean permit violations or surcharge increases.. Obviously clarifiers are a major part of operations in a wastewater treatment plant!





Digestors: The biggest thing that many plants do wrong with aerobic digestors is pH control and D.O. levels.

Digestors still need the basic "Critical 5" components in the same range as the aeration basin if you really intend to reduce solids and save on your handling costs! The goal is to save money on handling and hauling costs, yet balance the time and electricity factor! Many small plants that have farms nearby need to calculate how much they save on solids hauling or polymers, vs. how much they spend on electricity and how much nutrients they return to the front end that add to ammonia and phosphate removal. If new regulations come into effect for nutrient removal, a serious look at solids reduction vs. nutrient removal will need to be examined. There is a lot of nutrient value in the solids that can be used for farmers for beneficial reuse to help them and save them costs on nutrients. Also the nutrient value in biosolids is more stable and environmental friendlier than chemical addition. Less run off occurs, more is given to the plants and less erosion occurs. Look into this option near your area!

Ok, so back to pH and D.O. control. Some plants try to turn off the air in the digestor for numerous reasons. One reason is to decant the solids so they can be dewatered and return some of the supernatant back to the front of the plant. While this is necessary, the amount of time you decant is critical. The longer you have the air off, the lower the D.O. goes. This impacts numerous things. It can turn the system septic and cause filamentous bacteria to grow in the digestor. This makes it harder and harder to decant and dewater. Also, the septic supernatant goes back to the front of the plant, places more demands on the oxygen in the aeration basin and can lower available DO to the bacteria that need it for growth.
The septic water can also cause the growth of filaments in the aeration basin, cause more settling problems in the clarifier and digestor, which makes you leave the air off longer and longer and the cycle continues and conditions worsen. This is a bad cycle that needs to be broken.

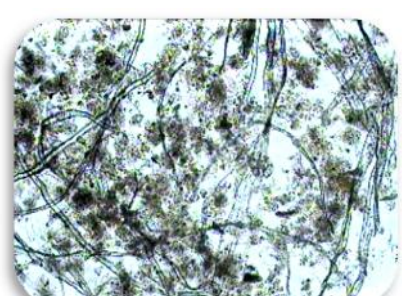
We have worked with numerous plants that had this type of cycle in their systems. Low pH and not enough DO to start with, and then turning off the air too long during the decant cycle.

How do you break this cycle?
Short term, you can hit the system with chlorine and use polymers to settle out the filaments. Long term, change the process, do not turn the air off as long, increase pH, and /or D.O. or any of the Critical 5 parameters you have out of control and start running the system optimally! You would be surprised at how small changes can impact the system significantly!

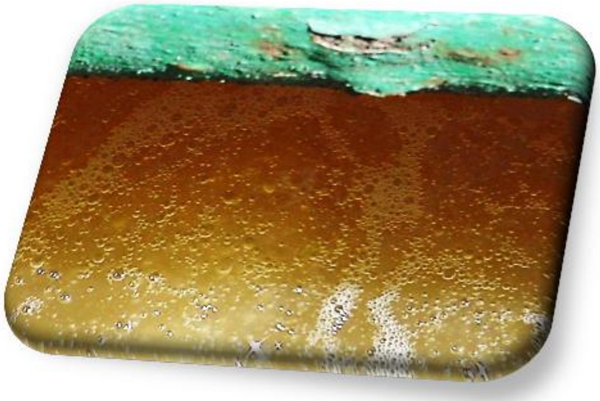
Have you ever pulled a sample and looked under the microscope at your digestor sample? Here is how we finally were able to solve the problem at two different plants - they both had tons of filaments and we could not get rid of the problems. Note: The images below left and right. NO wonder, they were constantly reseeding the front of the system with filaments, depleting all the D.O., using large amounts of polymer in dewatering and hauling off more solids than necessary. Floating solids on the clarifier were a problem, foaming in the system was present and dewatering was hard. Decanting in the digestors was next to impossible. It's amazing though with just minor changes to a few areas in the process, how completely different the system could be! See digestor newsletter- 12-05

Dewatering: Ok, how can I possibly have to worry about the critical 5 when I am dewatering solids?
You would be surprised. Do you hold solids in a tank prior to dewatering? If you hold them too long, DO will drop and pH will drop. Supernatant from dewatering is returned to the front of the system and this can impact your biological activity.

Another big thing is the supernatant from dewatered solids may have very high N and P values. This is returned to the front of the system. If you are adding nutrients, make sure to add this amount to your calculations. It might save you some money on the cost of nutrients. If you are worried about nutrient removal, this again, needs to be factored. Make sure to calculate the amount of alkalinity needed based upon the extra loading of N in the supernatant.



Chlorination: I have to worry about some of the Critical 5 in my final effluent treatment? Really, why?



Septicity and gassing: Here is gassing in a chlorine contact chamber, and the next photo is gassing in a channel leading up to the UV treatment. Both show signs of biological activity, gassing and septicity. Floating solids also indicate growth and lack of DO so the solids float to the surface. Both conditions will impact either treatment. Clean out channels for both types of treatment periodically, making sure that solids do not grow or settle into the bottom of the system. These can seriously impact your treatment efficiency.

Floating solids and plant growth can impact the treatment results. Reduced compounds such as sulfide, ferrous iron, BOD, nitrite, and ammonia react with free chlorine to reduce the effective amount of chemical available for disinfection purposes

Table 2
Chlorine demand and dose guidelines for domestic wastewaters [a]

Wastewater source	Typical chlorine demand, mg/L	Recommended chlorine dose, mg/L, at given pH 6	7	8
Septic tank effluent	30 to 45	35 to 50	40 to 55	50 to 65
Activated sludge type treatment effluent	10 to 25	15 to 30	30 to 35	30 to 45
Packed bed (e.g., sand) filter effluent	1 to 5	2 to 10	10 to 20	20 to 35

[a] From U.S. EPA (1980)

Ammonia residuals: Many plants have to nitrify, especially municipalities. If full nitrification does not occur, and high ammonia residuals exist, this could interfere with the disinfection program, since chloramines may form.
Chlorine disinfection involves a very complex series of events and is influenced by the kind and extent of reactions with chlorine-reactive materials, temperature, pH, suspended solids concentrations, and the viability of test organisms.

Chloramines are used for disinfection of surface water in potable systems to prevent the formation of THM's and HAA's, and to extend the disinfection residual. However, chloramines are only about 1/100th the disinfection power of free chlorine. The form of chloramine formed is strictly pH dependent.

Chloramines can impact disinfection and chlorine demand. Most plants run with free chlorine as the disinfectant.

1. Chlorine is added to a wastewater effluent and first combines with any reducing agents (H2S, etc.) to neutralize them.
2. Chlorine then reacts with any ammonia to form chloramines
3. Then if you keep adding more free chlorine, it will destroy (oxidize) the chloramines.
4. When nothing remains to react with, you've reached "breakpoint chlorination" and will establish free chlorine residual.

If you do not have high enough residuals, poor coliform control is the result.
See full newsletter on UV and chlorination 7-08

Table 17–1. Typical chlorine dosages required for sewage disinfection.

Type of effluent to be disinfected	Dosage mg/L	Dosage lb/mil gal
Raw wastewater	20	167
Raw wastewater (septic)	50	420
Settled wastewater	20	167
Settled wastewater (septic)	40	354
Chemical precipitated effluent	15	126
Trickling filter effluent	15	127
Activated sludge effluent	8	67
Sand filter effluent	6	50

Backwash from Sand Filters in a Wastewater Treatment Plant; How They Can Impact The Process

Many wastewater plants have a sand filter for their own plants. This is used as a final polishing step in the process to remove any TSS in the final effluent most often times. Sometimes additional BOD and nitrification occur, depending on the type of filter, the holding time in the units and the design criteria.

There are many types of sand filters: recirculating sand filters, intermittent, slow and rapid and some that also have additional filters such as carbon for final polishing. Sand filtration is a relatively old technology. Intermittent sand filtration has been used more widely than have recirculating sand filters.

Properly designed and functioning recirculating sand filters can provide for enhanced BOD5 and TSS removal, pathogen reduction, and both nitrification and denitrification of wastewater effluent to some extent, depending upon the design and operation of the unit.

How efficiently you run the sand filter can impact the amount of backwash you send back to the front of the plant. Remember, that additional flow decreases the amount of holding time you have in your system. Too much backwashing can cause hydraulic overload on a plant or shorten the time in the system and decrease BOD removal and nitrification. Backwash is usually determined by Volume, Pressure drop over the filter or a Time schedule.

If you get carryover of sand and fine particles back to the front of the plant, this can impact pumps, increase wear and tear on machinery and add to maintenance and repairs or replacement costs also.

Wash troughs are used to collect and remove backwash water. Wash troughs are usually located 3.5 - 4 feet above the bed, 6 - 10 feet apart. Correct spacing and height of troughs ensures the dirty wash water is efficiently skimmed off, without washing out any of the filter media. Check your weirs on your wash troughs and make sure they are not clogged and the flow is even.

The under drain must be maintenance and corrosion free. Uniform collection and distribution of water is important to the integrity of the filter bed. Short-circuiting or stagnation caused by the under drain can greatly reduce the effectiveness of the filter.

Temperature is a big one in the Critical 5 and that can be related to all areas in the plant, whether spring, summer, fall or winter:

Wastewater in the Winter- Problems and Solutions

Wastewater treatment in itself can have many ups and downs. So many things can impact how successful the wastewater process is at removing the critical components of BOD, TSS and nutrients.

Winter, with its fluctuating temperature changes can have a significant impact on the wastewater treatment process. Snow, icing, and freezing rain can cause huge problems for some wastewater treatment plants.

Remember that temperature is one of the critical 5 components in a wastewater treatment plant. Temperature can significantly impact whether you are winning the time and numbers game. Wastewater treatment is always a time and numbers game. Since you really are limited by the time component- (in reality this is the size of the treatment plant) the only thing you can play with and change is the numbers factor. That means adjusting the numbers of bacteria or MLSS in the aeration basin.

Another thing to consider, for every ten degree °F change in the weather, the bacteria loses one logs growth of activity. If your outside weather drops 20 to 30 degrees in one day that can significantly impact the activity in your system, if you do not have a high temperature influent consistently. That means you have to adjust the amount of RAS and WAS in your system to reflect the temperature changes. You can only adjust the MLSS as quickly as your pumping capabilities allow. Another thing to remember, the bacteria are finicky. They do not like significant changes. Any time a change of more than 10 percent is made, on any variable that is critical to them, they get temperamental

1.) Snow, Freezing rain
2.) Hydraulic washout due to excessive freezing rains from storms or melting snows
3.) Changes in BOD loading
4.) Sludge Age changes due to activity changes
5.) Loss in removal efficiency.
6.) Icing problems for equipment or freezing pipes.

Well, I guess those Critical 5 Parameters are more important than you thought!
Walk through your plant and look carefully at each piece of equipment you are operating.
Make sure that you try to optimize all pieces.

***Environmental Leverage* carries a full line of bacterial bioaugmentation products. Along with the products comes a full staff of professionals that will guide or assist you through your situation.**
"Let Us Simplify Your Solution".


1-lb. Water Soluble Bio-Pouch