Notes on Achieving and Maintaining Water Quality

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Purpose and Summary

This document is to intended to augment the *AZ TIC Start-Up Instructions*, posted on the AZTIC.org web site. Its purpose is to provide TIC teachers, students, and volunteers with guidelines to better understand the interactions between water quality parameters, and to simplify the actions required to properly maintain them. When completed, our own AZ TIC Resource Manual will enable AZ teachers and volunteers to get the next level of detail from one document. Until then there are several good manuals from other states, posted on or linked to from the AZTIC.org website, for reference.

These sites and manuals represent volumes of very good background information, detailed descriptions, and specific recommended actions. To the first-time reader, however, there is a lot to read; and the guidelines, though usually quite good, of necessity, vary due to different fish raised (rainbow or brook trout, salmon) and different rules and regulations imposed by state fishery authorities.

Table 1 shows a quick summary, after reading many of these documents, of the key parameters in water quality for Trout-in-the-Classroom projects, their expected and desired ranges, their effects on each other and on the fish, and primary mechanisms controlling them to maintain water quality for our fish.

Table 1: Water Quality Parameters – Values, Effects, Control

Parameter	Possible Range	Desired Range	Effects	Control
pH	6.8 - 8.4	**Stability, 7.0 - 7.6 is good; 7.8 OK**	Bacteria activity produces acids which reduce pH a bit. pH affects toxicity of total ammonia (TAN) reading.*	Maintain consistency via water changes**, baking soda
NH_3 (ammonia)	0 - 5 ppm	**0, <0.5***	>1* may cause fish stress and Death; >5 can extend pre-cycle	Bacteria, water changes/ cleaning, less fish food
NO_2 (nitrites)	0 - 5 ppm	**0, <0.5**	>1 may cause fish stress and death; >5 inhibits bacteria***	Bacteria, water changes
NO_3 (nitrates)	0 - 50 ppm	**<40**	Less toxic to trout, but may feed other living organisms (e.g., algae) in tank.	Water changes
KH (carbonate hardness or carbonate alkalinity)	50-200 ppm	**150 or above initially, then 100-150**	Stabilizes (buffers) pH, generally reduces as it feeds bacteria.	Increase **17.9 ppm with 1 tsp baking soda** (sodium bicarbonate) for 55 gal.
GH (general hardness)	100-200 ppm	**Stability**	Can cause scale on glass. Will increase due to evaporation.	Water changes, cleaning glass
Temperature		**Stabilized at 52- 58° F**	Warmer water promotes bacteria. Colder reduces ammonia toxicity.*	Temperature Controller temp setting and interval
O_2 (oxygen)		**Plenty**	Fish and bacteria need it.	Air stones
Clarity		**Clear**	Cloudy can indicate excess food or other matter in tank.	Water changes, tank cleaning

*TAN (total ammonia) is the parameter that is tested, which is a combination of ammonia (NH_3) and ammonium (NH_4^+). The amount of ammonia (NH_3), the toxic component in TAN, is determined by pH and temperature. See separate chart for actual toxicity of TAN (in Chapter 7 of *Mid-Atlantic TIC Resource Manual*)

Water changes always must use **dechlorinated/conditioned water – e.g., 5 ml (1tsp) of NovAqua Plus for each 10 gallons of water.

***www.drtimsaquatics.org

Tables 2a and 2b, at the end of this document, summarize specific guidelines for water quality control actions, primarily bacteria dosing and water changes, taken from the *AZ TIC Start-Up Instructions* and *Mid-Atlantic TIC Resource Manual* from current and previous years. Recommended bacteria dosages tend to vary a bit across different manuals and states, but they are generally similar to each other and to the directions on the bottles. In point of fact, the development and health of the bacterial colonies in the tank and the filter are just as dependent on the other factors (such as pH and KH (discussed later), fish food, dead fish, hand washing, etc.) as they are on the precise bacteria dosages and timings. In addition, the specific dosage is often less important than the timing – which is what the rest of the paper is about.…

Background on Interactions and Effects – the Nitrogen Cycle

There are many good articles on the Nitrogen Cycle. A good recommendation is the one posted on the AZTIC.org website under Equipment, Troubleshooting, and "Water Chemistry and Nitrogen cycle". It is an article from Aqueon, titled, "Freshwater Aquarium Quality: the Nitrogen Cycle and Optimal Water Chemistry: https://www.aqueon.com/articles/freshwater-aquarium-water-quality. It's a short, 3-page article that introduces the Nitrogen Cycle in nature, and the interrelationships between the 6 parameters that we are testing: pH, Ammonia (NH_3), nitrites (NO_2), nitrates (NO_3), carbonate hardness (or carbonate alkalinity[1]) (KH), and general hardness (GH).

Another good reference is one of the articles with the Nitrogen Cycle graph, that is shown and discussed in several manuals, usually courtesy of the Michigan Department of Natural Resources, Salmon-in-the-Classroom Program. One reference is this one from the troutintheclassroom.org website: https://www.troutintheclassroom.org/technical-information/aquarium-maintenance/nitrogen-cycle/ . This drawing illustrates the stages of the Nitrogen cycle, in which ammonia, nitrites, and nitrates typically have their separate peaks in time. When looking at this graph, look at it primarily for relationships, not precise times and tested nitrogen values. For example, the time scale varies considerably with water temperature – faster in warm water, slower in cold water. But it does illustrate what teachers can expect to observe with their tested water quality parameters during a pre-cycle, or in the first few weeks with eggs if they have not pre-cycled.

Firsts Step: Test Your Tap Water and Start Your Observation and Actions Log

As the AZ TIC Start-Up Instructions specify, the first step is to test your tap water for all six quality parameters we test for regularly. This is where you are starting; and when you do water changes, it is important to know the characteristics of the water you are putting in. For example, if your nitrite reading gets to 2 ppm and you do a 20% water change (with 0 ppm nitrites in that water), you can expect the resulting tank reading to go down 20%, to 1.6 ppm, no more, with that water change.

Since the primary concern for pH and general hardness (for negative effects on our trout) is stability, these first test values are the values you will probably be maintaining to. The pH reading along with the tank temperature is needed to determine the relationship between ammonia (NH_3) and ammonium (NH_4^+) in the tank. From these numbers you can now determine the total ammonia (TAN) reading at which you can expect your fish to get stressed (using the TAN chart, referenced in Table 1). The general hardness (GH) normally changes more slowly, primarily due to evaporation, but it's good to check it once a month.

As you perform your first quality parameter tests, you need to create a log to record all your test results, along with temperature, equipment operation checks, observed fish behavior, and any control actions. The information you obtain when you begin water quality testing (pH, ammonia, nitrites, nitrates, and KH) along with

[1]Today, the terms KH, carbonate hardness, and carbonate alkalinity are generally used interchangeably for the measurement of bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}) in the water.

temperature, equipment operation checks, observed fish behavior, and any control actions, should be recorded on a data sheet.

This will allow you to observe, with your students, the chemical and biological interactions that are taking place in your fish tank. From those observations you will get a better idea of what is working for your tank. Also, importantly, if you call a TIC volunteer for advice on water quality or fish problems, he/she will first ask about your quality parameter test history. There are several log formats on our web site that you can use. We don't have a specific single recommendation. The methods teachers use in assigning their students specific water parameter testing and fish observation duties vary, depending on the school situation and student maturity. As a result, they often make their own log sheets to support that.

First Line of Defense is Bacteria

As you can see from Table 1, there are primarily two types of control actions – bacteria support, and water changes. We'll address bacteria first as it is the first line of defense against the toxicity of ammonia and nitrites. Interestingly, all the bacteria types we need are in the air. If we had several months before the eggs arrived and we were adding one fish at a time, we would not need to use our bacterial additives. But of course, we don't have that time, and our tanks are taken down each year, as it's not practical to keep them running over the summer. As a result, we need to boost the bacterial development with purchased additives.

Microbe Lift Special Blend contains bacteria that breaks down unused food and fish waste into ammonia. Nite-Out II contains bacteria that focus on the next two phases, converting ammonia to nitrites, and nitrites to nitrates. These are the substances that directly cause the most fish stress. Special Blend also includes bacteria for the fourth phase, decomposing nitrates, but those are anaerobic bacteria, which do not function well in our aerated tanks. Hence, water changes must be used to reduce excessive nitrates.

It's important to realize that it's not really the bacteria from the bottle that does the bulk of the work – it's the bacteria colonies established in the filter and in the gravel in your tank. (Probably 80% or more of the working bacteria are in the filter.) It takes a while for them to grow, feeding on the excess waste, ammonia, and nitrites. In addition, the bacteria that decompose organic waste into ammonia grow much faster than the other bacteria. The initial spikes, then, are the result of the temporary imbalance as the various bacteria colonies grow to their appropriate sizes. Once a tank has fully cycled, the bacteria colonies grow or decrease in size depending on the availably of their food sources. Also, bacteria growth happens much more slowly in the cold water that trout like to live in. This is another reason for the delay between the bacteria additive dosing and the resulting lowering of ammonia and nitrite counts. In some states, the temperature for raising rainbow trout has been raised from 54 to 58 to accelerate bacteria growth.

Pre-cycling a tank at room temperature before eggs arrive helps avoid these problems and is recommended when possible. Our recommended pre-cycle approach uses Tim's Ammonium Chloride, as documented in Chapter 4 of the *Mid-Atlantic TIC Reference Manual*, which can be done usually in two weeks. Another approach, documented in Chapter 6 of the PA TIC manual takes 4 to 6 weeks. Of course, there are many situations which preclude the ability to do either, and the cycling will occur with the eggs and/or fish in the tank. That's OK too, though you may lose a few more fish. Whichever method you choose, you'll want to be sure that the parameters in Table 1 (especially ammonia and nitrites) are within desired ranges before egg delivery. If outside the range, performing water changes (see below) is recommended.

The Importance of pH and Carbonate Alkalinity

It is always important to monitor the pH, and carbonate alkalinity (KH) readings. Bacteria activity consumes carbonates, which decreases the KH reading; and it creates more hydrogen ions, which decreases the pH, both of which slowdown bacteria growth. Increasing KH helps prevent this slowdown of bacteria growth and buffers decreases in pH. If the pH level of the tank were to decrease toward 6.0 bacteria reproduction would be significantly reduced, and below that reading, it would cease.

As Table 1 indicates, a KH reading of 150 ppm or above is recommended when the bacteria colonies are growing, i.e., whenever we are on the "primary" bacteria dosing (generally at least the first 4 weeks). Once the tank has cycled, KH readings between 100 and 150 ppm are recommended. As Table 1 indicates, the KH reading can be raised 17.9 ppm for each teaspoon of baking soda (sodium bicarbonate) added to a 55-gallon tank. It is best not to do it all at once if more than that increase is needed. The exception to this is when you first fill the tank and there are no eggs in it. The best way to add the baking soda is to dissolve it in a beaker of tank water before adding it. The pH of baking soda is 8.4 and it is possible to see a slight increase in the tank pH if several teaspoons are added at one time. This is normal and the pH should return to a value close to that of the tap water after a few days.

Bacteria Dosing

Regarding specific bacteria dosing, Table 2a gives recommendations for tanks that are being and have been pre-cycled, using the Mid-Atlantic TIC (Dr. Tim's) ammonium chloride method. Table 2b gives dosage recommendations for tanks that have not been pre-cycled. The recommendations generally, but not completely, follow the instructions on the bottles. Here are some general comments to consider, as occasionally, due to product availability, Special Blend and/or Nite-Out II may be replaced by other bacteria additives.

- All the bacteria additives have directions on the bottle for what could be called "primary" dosing, and another set of directions for "maintenance" dosing. Be sure to convert those dosages up to a 55-gallon tank (roughly 200 liters).
- If the tank has not been pre-cycled, the primary dosing of both Special Blend and Nite-Out II should begin on egg arrival.
- If the tank is being pre-cycled, bacteria dosing begins during pre-cycle according to instructions in the appropriate manual (Mid-Atlantic TIC manual, or PA TIC manual), and continues on egg arrival.
- In either case, maintenance dosing can usually begin a few weeks (often 4) after egg arrival, once the readings of ammonia and nitrites have been brought back to 0.5 ppm or lower. This will happen sooner in pre-cycled tanks. You may not get the readings all the way back to zero often.
- The maintenance dosing can even be reduced further if things are going well; but as trout grow, fish and food waste increase, so it's important to keep testing regularly.
- Then, if the desired values in the Table 1 are exceeded, primary dosing should be restarted.
- Important: Note that the shelf life of an opened bacteria additive is typically only 1 year or so, as usually noted on the bottle. So it is often best to start a new year with a fresh bottle.

Remember, all tanks and situations are different, so make your best guess for bacteria dosages and timing from this discussion and Tables 2a and 2b. Then it is most important to pay attention to the fish behavior and the water quality parameter tests, and adjust the bacteria dosages accordingly.

Water Changes, Water Changes

As you might expect from the above discussions, even after recommended bacteria additive dosing, we can expect to occasionally get ammonia and nitrite readings that will stress and even kill some trout. (E.g., over-feeding or leaving dead fish in the tank too long may cause an ammonia spike.) Water changes are the best solution for reducing the amplitude of the ammonia or nitrite spike while the bacteria colonies are still growing. It may not be a big reduction in the spike, but it is immediate, and it also (with cleaning) removes organic waste, which would feed the spike even more.

In addition, you can see from Table 1 that water changes are also useful for maintaining stability of pH, KH, and nitrates. Nitrates are generally not as toxic to fish, but, as they are a major component in fertilizers, they promote growth of other living things that we may not want in the tanks

Many TIC resource manuals recommend 10% (5 gal) - 20% (10 gal) water changes weekly, often with two 5% - 10% water changes each week (e.g., Monday and Thursday) as a general practice, and greater amounts as

needed, generally not exceeding 25% to 30% changes. Combining water changes with tank cleaning, it's good to clean only half the gravel on each change so you don't remove too much bacteria.

Here are some tips for water changes, from experience:

- Leave 1/4 to 1/3 of the tank bottom clean of gravel so you can see more clearly when cleaning is needed.
- Wash hands with soap and water and dry them before the water change. (Hand sanitizer will be harmful to the fish.) It is still best to keep hands out of the tank water at all times. E.g., when drawing up water to be tested use the turkey baster to partially fill a clean beaker.
- Start small and increase cleaning and water amounts as necessary – to 5%, 10%, etc.
    - The first water change may be determined by an ammonia spike. Then another jump when the nitrite spike occurs.
- Putting water back into the tank, it is normally recommended to use cold water from the tap, and treat it with water conditioner/dechlorinator, like NovaAqua Plus, which dechlorinates, and also removes or neutralizes chloramines and heavy metals. It becomes effective immediately with a little stirring. (Water left in an open container for 48 hours or more will be dechlorinated, but may still contain chloramines and heavy metals – Not Recommended. Also, it will be warmer and create a bigger temperature change for the fish in the tank.)
- When combining water change with bacteria dosing, be sure to dose after the water change.
- For scooping water into and out of the tank, cut off the top of a gallon milk jug, but do not remove the handle.
- (Not really water change, but…) to be prepared in case of a chiller failure, freeze two 2-liter or quart bottles filled with dechlorinated water. Placed in the tank, these can generally keep the temperature cold enough for the trout while you're awaiting a replacement

Reference for Bacteria Actions and Water Changes

A good reference with more detailed information (but not too much) on bacteria actions and water changes is Chapter 7, "Caring for the Tank," of the *Mid-Atlantic TIC Resource Manual*. A link to the manual is on the AZTIC.org website under "Teacher Tools" – https://test-troutintheclassroom.pantheonsite.io/wp-content/uploads/2022/03/MD-TIC-MANUAL-REVISED-2022.pdf. This chapter also contains the TAN (Total Ammonia Nitrogen) table referenced in Table 1, which shows the TAN value (the result of our "ammonia" test) at which the ammonia becomes toxic to fish, as a function of pH and temperature.

Reading this chapter, you can get a good general feel for the mechanics of doing the cleaning and water changes, as well as more background on bacteria dosing. There is a discussion on cleaning your filter, although it does say that cleaning the filter or changing its media during the school year is not normally necessary. Also, there's a nice daily and weekly checklist for caring for your tank.

Watch the Fish, Take Observation and Action Logs, Have Fun

As Chapter 7 of the Mid-Atlantic manual says, the most important thing is to watch the fish. Particularly after the first few weeks (and your tank has cycled), they are your first indicator that something is wrong. If the fish are OK, you may not need to react with a control action. Watch your fish, log your observations and control actions for knowledge retention, learn about the interactions in nature, and enjoy watching them grow.

Editorial Note: Table 1 is duplicated at the end of this paper on a single page for easy printout if desired.

Acknowledgments: Thanks to Chuck Dinkel for editing help and for providing experience and wisdom to improve the quality of this paper.

Table 2a: Water Quality Control – Guidelines for Pre-Cycled Tanks (using ammonium chloride method)[1]

Taken from the *Mid-Atlantic TIC Resource Manual*

Nite-Out II	**Pre-Cycle**	**Weeks 1-4 after egg arrival**	**After Week 4**
	25 ml every other day	25 ml 2x per week. Double to 50 ml on egg delivery (with lower temp).	15 ml 2x per week. If doing a water change, dose after.
Water Changes	**Pre-Cycle**	**After Week 4**	**Later Weeks**
	Recommended only if NH_3> or NO_2 > 5	As necessary, clean 2x per week, half of stones each time to remove fish/food waste. Remove only water necessary to clean tank bottom.	As necessary, increase water removed with each cleaning to 2-3 gal (5%), then to 5 gal (10%).[2] More as needed. Watch water temperature.
NovaAqua Plus	**First Fill of Tank**	**Afterwards**	
(water conditioner/ dechlorinator)	5 ml (1 tsp) per 10 gal of water added	1 ml per 2 gal of water added	
Baking Soda	**KH = 150 at Tank Setup**	**KH > 100 after Week 4**	
	1 tsp/55gal = KH increase of 17.9 ppm	1 tsp/55gal = KH increase of 17.9 ppm	

[1]If the ammonium chloride method is used for pre-cycle, Special Blend is not required. Otherwise see guidelines in the PA TIC manual for use of Special Blend and Nite-Out II, in the PA TIC pre-cycle method.

[2]Water changes will move quality parameters proportionally toward initial tap water readings

Table 2b: Water Quality Control – Guidelines for Tanks Not Pre-Cycled

Special Blend	**Day 1 – Egg Arrival**	**Day 8, 15, 22, 29**	**Every Week Thereafter**
	60 ml[1]	40 ml[1]	15 ml every 2 wks[1]
Nite-Out II	**Weeks 1 - 4**	**After Week 4[2]**	
	25 ml daily[3], Or M-W-F 40 ml[4]	25 ml 2x per week[3]; after gravel cleaning, when it is done.[3,4]	
Water Changes	**Weeks 1 - 4**	**After Week 4[2]**	**Later Weeks**
	Consider when NH_3 or NO_2 > 1.	As necessary, clean 2x per week, half of stones each time to remove fish/food waste. Remove only water necessary to clean tank bottom.	As necessary, increase water (with each cleaning) to 2-3 gal (5%), then to 5 gal (10%).[5] Monitor water temperature.
NovaAqua Plus	**First Fill of Tank**	**Afterwards**	
(water conditioner/ dechlorinator)	5 ml (1 tsp) per 10 gal of water added	1 ml per 2 gal of water added	
Baking Soda	**KH to 150 at Tank Setup**	**KH > 100 after Week 4[2]**	
	1 tsp/55 gal = KH increase of 17.9 ppm	1 tsp/55 gal = KH increase of 17.9 ppm	

[1] *AZ-TIC Startup Instructions* (also directions on Special Blend bottle)

[2] After tank has cycled – NH_3 & NO_2 near zero, usually around 4 weeks. Go back to previous dosage if NH_3 or NO_2 spike again.

[3] Nite-Out II directions on bottle

[4] From *Mid-Atlantic TIC Resource Manual*, (bottle says dose after cleaning; manual says dose always 2x per week, even if you don't clean)

[5] Water changes will move quality parameters proportionally toward initial tap water readings

Table 1: Water Quality Parameters – Values, Effects, Control

Parameter	Possible Range	Desired Range	Effects	Control
pH	6.8 - 8.4	**Stability, 7.0 - 7.6 is good; 7.8 OK**	Bacteria activity produces acids which reduce pH a bit. pH affects toxicity of total ammonia (TAN) reading.*	Maintain consistency via water changes**, baking soda
NH_3 (ammonia)	0 - 5 ppm	**0, <0.5***	>1* may cause fish stress and Death; >5 can extend pre-cycle	Bacteria, water changes/ cleaning, less fish food
NO_2 (nitrites)	0 - 5 ppm	**0, <0.5**	>1 may cause fish stress and death; >5 inhibits bacteria***	Bacteria, water changes
NO_3 (nitrates)	0 - 50 ppm	**<40**	Less toxic to trout, but may feed other living organisms (e.g., algae) in tank.	Water changes
KH (carbonate hardness or carbonate alkalinity)	50-200 ppm	**150 or above initially, then 100-150**	Stabilizes (buffers) pH, generally reduces as it feeds bacteria.	Increase **17.9 ppm with 1 tsp baking soda** (sodium bicarbonate) for 55 gal.
GH (general hardness)	100-200 ppm	**Stability**	Can cause scale on glass. Will increase due to evaporation.	Water changes, cleaning glass
Temperature		**Stabilized at 52- 58° F**	Warmer water promotes bacteria. Colder reduces ammonia toxicity.*	Temperature Controller temp setting and interval
O_2 (oxygen)		**Plenty**	Fish and bacteria need it.	Air stones
Clarity		**Clear**	Cloudy can indicate excess food or other matter in tank.	Water changes, tank cleaning

*TAN (total ammonia) is the parameter that is tested, which is a combination of ammonia (NH_3) and ammonium (NH_4^+). The amount of ammonia (NH_3), the toxic component in TAN, is determined by pH and temperature. See separate chart for actual toxicity of TAN (in Chapter 7 of *Mid-Atlantic TIC Resource Manual*)

Water changes always must use **dechlorinated/conditioned water – e.g., 5 ml (1tsp) of NovAqua Plus for each 10 gallons of water.

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