# Water Quality in the Freshwater Aquarium

**Curriculum for Science, Biology or Chemistry classes – (Grades 7-9)**

**Lesson objectives:** Students gain a comprehensive understanding of the chemistry involved in maintaining proper water quality in a freshwater aquarium, and how water quality affects the life that exists within, from micro to macro organisms.

**Materials:** aquarium, filter system, aquarium gravel, aquatic plants, tropical fish, tap water conditioner, fish food, thermometer, water test kit or test strips to measure: Ammonia, Nitrite, Nitrate, Acid/Base balance (pH), Alkalinity, Hardness.


**Introduction:** Aquarium water quality is an interaction between many different chemicals in the water that are produced by the aquatic organisms and influence their health. Without clean water, the fish will be stressed and more susceptible to diseases and parasites. This curriculum will explain why we test the various water chemistry characteristics and what the test results mean for the health of the aquarium inhabitants.

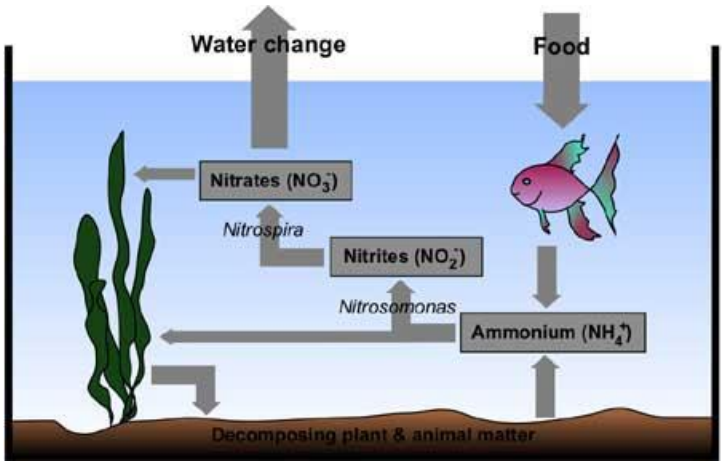
**Chlorine and Chloramine:**
Chlorine and chloramine are used by water municipalities to make the tap water supply safe for human consumption. These compounds are extremely toxic to aquatic organisms and no amount can be tolerated within an aquarium. They cause gill irritation and damage which prevents fish from breathing (absorbing oxygen from the water). Add water conditioner (sodium thiosulfate) to tap water whenever adding it to an aquarium.

**Ammonia:**
Ammonia is produced by heterotrophic bacteria that live in the aquarium and breakdown organic material in the aquarium (dead fish or plants, uneaten food, fish feces). Ammonia can become toxic very quickly if allowed to accumulate. The higher the pH and temperature of the water, the more toxic ammonia becomes. Ammonia in the water reduces the ability of the fish to excrete nitrogenous wastes from the blood through the gills. As ammonia increases in the water, so do the waste products increase in the fish's blood, causing toxicity, gill damage, and death. Properly operating filtration systems should keep the aquarium ammonia levels less than 0.2 mg/L.

**Nitrite:**
Nitrite is produced by the aerobic bacterial nitrification of ammonia. It takes time for the nitrifying bacteria to grow in a new aquarium, so if too many fish are added too soon, the ammonia will not be converted to nitrite and the fish can die. This is called "New Tank Syndrome." It can be prevented by adding fish over a several weeks' time to the aquarium and also by using a bacteria starter supplement

to help the nitrifying bacteria to grow more quickly in a new aquarium. Nitrite should be maintained at a level of less than 0.2 mg/L. Nitrite reduces the ability of the fish's blood to carry oxygen. Remove any nitrite from the aquarium by performing a partial water change. Other species of aerobic bacteria will convert nitrite to nitrate over time.

**Nitrate:**
Nitrate is produced by the aerobic bacterial conversion of nitrite. While high nitrate levels are dangerous to saltwater fish and invertebrates, freshwater fish are very tolerant of high nitrate levels. If nitrate levels exceed 20 mg/L, water changes can be used to lower the concentration.
High levels of nitrate also promote algae growth.




***Aquarium Nitrogen Cycle***
*Image Credit: Ilmari Karonen*
*Adapted from*
*http://www.fishlore.com/NitrogenCycle.htm*

**Acid/Base Balance (pH= power of Hydrogen):**
The pH is a measure of the Acid/Base balance of water, due to Hydrogen ions (H+) in the water, with a pH of a solution less than 7.0 being acidic, from an abundance of Hydrogen ions, and a pH of greater than 7.0 being basic, with a decrease of Hydrogen ions compared to Hydroxyl ions (OH-). A pH of 7.0 is neutral with an equal number of H+ and OH- ions. Most freshwater fish are highly adaptable to a wide range of pH values if changes in pH are made slowly. Rapid changes in pH are detrimental to fish, and it is very important that aquariums have a stable pH. The stability of the pH is related to water Alkalinity and Hardness.

**Alkalinity:**
Alkalinity is a measurement of the negative ions (e.g., Hydroxide, Carbonate, Bicarbonate) in the water that buffer against pH shifts. Ideal alkalinity is in the 100-250 mg/L range. As the alkalinity falls, the water in aquariums may experience sudden, and deadly, pH shifts. Increase the buffering capacity of the water to stabilize the pH. This can be done by adding Sodium Bicarbonate or Calcium Carbonate to the water to raise the alkalinity. Alkalinity is also required by the bacteria in the Nitrogen Cycle, so low levels of alkalinity can inhibit the bacterial conversion of ammonia to nitrite to nitrate.

**Hardness:**
Hardness is the measurement of metallic positive ions (e.g., Calcium, Magnesium) in the water. It affects the pH similar to alkalinity. Water with high hardness usually also has a high pH. Hardness in aquatic systems is best at 100-250 mg/L, but some fish such as discus prefer softer water. African cichlids prefer hard water. Most fish will adapt to existing hardness if it is not too extreme of a change.

**Summary:**
Water testing is one of the most important aspects of aquarium maintenance. You should keep a log of your daily water test results in new aquariums, and weekly once the aquarium has been "cycled" (beneficial bacteria that regulate the nitrogen cycle have been established). Water testing is not something to be neglected.

**New Tank Syndrome – Establishing the Nitrogen Cycle:**

Many new aquarium keepers are frustrated with fish losses or even whole tank failures when they first start in the aquarium hobby. A big part of that failure is not understanding a few basic principles that are necessary for fish keeping success. This information is to help you get through that critical new tank stage after first setting up your aquarium.

All fish wastes, plus uneaten fish food, dead plant material, and any other organic debris in an aquarium contain nitrogen, which is broken down by heterotrophic bacteria in the aquarium to produce ammonia. This ammonia is very toxic to the fish, and will kill them if it accumulates. Fortunately, a different type of beneficial bacteria will convert the ammonia ($NH_3$) into nitrite ($NO_2^-$), which is slightly less toxic, and then into nitrate ($NO_3^-$), which is practically nontoxic. The problem is that these beneficial bacteria require many weeks to establish in a new aquarium. Often new aquarium hobbyists are reluctant to wait for this to occur, or are oblivious to the nitrogen cycle, and will add all the fish into a new aquarium immediately after setting it up. Unfortunately, this quickly leads to disaster – a tank full of dead fish – and often they give up keeping fish without ever knowing why they were unsuccessful.

To help prevent this "New Tank Syndrome" there are several rules that must be followed. First, start slowly – don't rush and purchase a bunch of fish right away – let the tank run at least a day after you have set it up before adding any fish. A good start might be to initially set up and decorate your tank, adding some live plants if you prefer, and check it to make sure the tank isn't leaking and the filter is working properly. Then add the fish gradually. Preferably no more than 3 fish per week! You should give the beneficial bacteria time to grow in your biofilter so the fish's waste can be detoxified sufficiently. Then each week you can add a few more fish until you reach the appropriate number of fish for your tank. Do not overcrowd your fish! You should have no more than one inch total length of fish per gallon of water. So, a 15-gallon tank can hold about 15 one-inch long fish, or 5 three-inch fish.

Do not over feed – this is one of the most common causes of fish loss. Uneaten food quickly breaks down into toxic ammonia. Only give the fish as much food as they can consume in 3-5 minutes, twice daily. There should never be any uneaten food left in the aquarium. Missing feedings for a few days won't hurt healthy fish when other factors in the aquarium are stable.

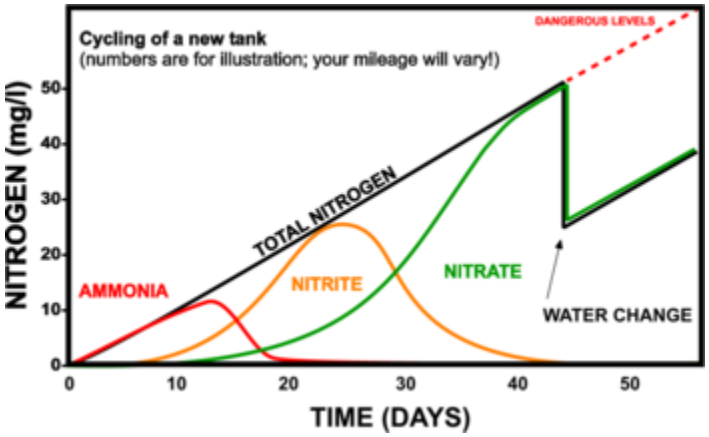
Test your water regularly for normal levels of pH (acid/base balance), ammonia, nitrite, and nitrate. If the levels are rising, change 10-25% of the tank water, then retest. Always use a water conditioner to remove chlorine from the tap water before adding it to your tank. Once the bacteria in the biofilter are established, you will no longer get elevated ammonia or nitrite levels, and you can keep the nitrate levels low by doing periodic partial water changes.

Establishing an adequate level of beneficial bacteria in your biological filter usually takes about 4-6 weeks. This time can be shortened considerably by using a beneficial bacteria starter product in the new aquarium. During this time, fish should be added gradually, with frequent monitoring of the water quality, and make partial water changes as needed to keep the ammonia, nitrite, and nitrate levels down. After the initial cycling period, water tests and water changes may only be necessary every few weeks. Understanding the precautions necessary when establishing a new aquarium will help you be more successful with your aquarium.


*Various beneficial nitrifying bacteria starting products are available commercially.*

**Student Activity: Chart the test results of the chemicals involved in the Nitrogen Cycle**

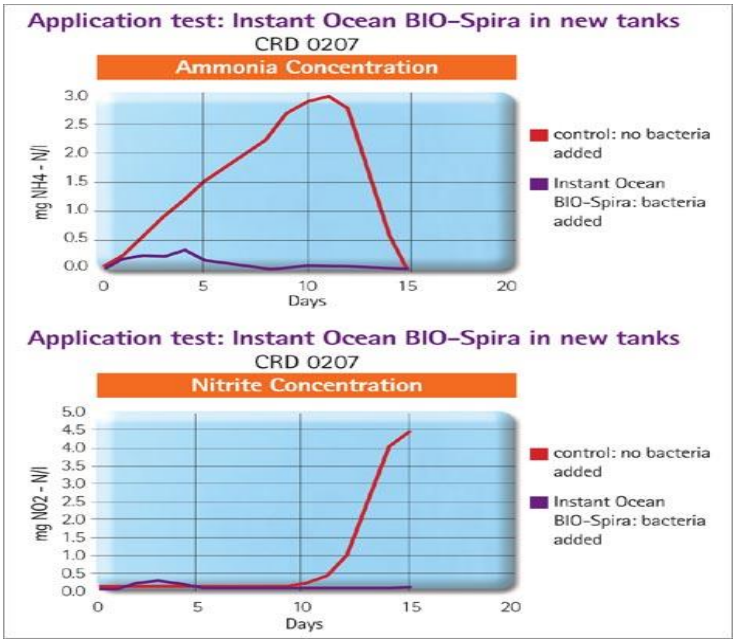
On the Water Test Results Log, record the results of the water quality tests each day until all the parameters are in the normal range. Then test the water quality weekly. Make a graph of the water test results over time to show how the values change. You may get a graph that looks similar to this one:




From:
http://www.theaquariumwiki.com/wiki/The_Nitrogen_Cycle

As the ammonia increases, nitrifying bacteria convert it to nitrite, which will then start to increase as the ammonia decreases. A different species of nitrifying bacteria then grows and will convert nitrite into nitrate, so the nitrite level will decrease and the nitrate will increase. Nitrate is removed from the aquarium through periodic water changes. All the nitrifying bacteria require oxygen (aeration) and the bacteria will colonize the surface of the gravel in the aquarium and the media in the aquarium filter. The different species of nitrifying bacteria are naturally found in water by are slow to grow. The time it takes to cycle the aquarium (getting all species of good bacteria that break down the fish wastes established) is usually 4-6 weeks.

When using a Beneficial Bacteria Starter product, such as BIO-Spira, the Nitrogen Cycle will take less time. This graph below shows that the ammonia and nitrite are reduce much more quickly in the aquarium that had BIO-Spira added (purple line) than in the control aquarium where no bacteria starter was added (red line).




*For more information about BIO-Spira:*
*http://www.instantocean.com/Products/aquarium-saltwater-care/salt-water-set-up/bio-spira-saltwater-aquarium-bacteria.aspx*

# Water Test Results Log

Monitoring the water quality in the aquarium is important for keeping the fish healthy. Any extremes or rapid changes in water quality or temperature can result in fish illness and death. When water test results are recorded, be sure to compare them to the normal range. If the water is outside the normal range, or has changed significantly from previous tests, action must be taken to stabilize the water and to keep the fish from being stressed. Refer to the Water Quality Corrective Actions Chart for proper steps to correct water quality.

Record water quality test results daily for first week or more. Once Ammonia and Nitrite levels are low, test weekly.

| | | Date | Date | Date | Date | Date | Date | Date |
|---|---|---|---|---|---|---|---|---|
| **Water Test** | **Normal Range** | | | | | | | |
| Temperature | 71-78 F / 22-26 C | | | | | | | |
| Chlorine | 0 mg/L | | | | | | | |
| Ammonia | 0 - 0.2 mg/L | | | | | | | |
| Nitrite | 0 - 0.2 mg/L | | | | | | | |
| Nitrate | 0 - 20 mg/L | | | | | | | |
| Hardness | 75 - 200 mg/L | | | | | | | |
| Alkalinity | 75 - 200 mg/L | | | | | | | |
| pH | 6.8 - 8.4 | | | | | | | |

1 milligram per liter (mg/L) is the same as 1 part per million (ppm)

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Copy this page to produce more Water Test Result Logs to keep track of the aquarium water quality.

# Water Quality Corrective Actions Chart

| | | Corrective Actions: | | |
|---|---|---|---|---|
| **WATER TEST** | **NORMAL RESULT for Aquarium** | **TEST RESULT IS TOO HIGH** | **TEST RESULT IS TOO LOW** | **Products needed:** |
| **Temperature** | Tropical Fish: 71-78 F Goldfish: 65-75 F | Make 25% water change with cooler tap water (add dechlorinator) | Adjust Aquarium Heater; Make 25% water change with warmer tap water (add dechlorinator) | Water Conditioner (Sodium Thiosulfate Dechlorinator) |
| **Chlorine** | 0 mg/L | Add Water Conditioner (Sodium Thiosulfate Dechlorinator) | No action needed | Water Conditioner (Sodium Thiosulfate Dechlorinator) |
| **Ammonia** | < 0.2 mg/L | Make 25% water change with dechlorinated tap water; Add Ammonia neutralizer; Follow label instructions. | No action needed | Ammonia Neutralizer |
| **Nitrite** | < 0.2 mg/L | Make 25% water change with dechlorinated tap water | No action needed | Water Conditioner (Sodium Thiosulfate Dechlorinator) |
| **Nitrate** | 0 - 20 mg/L | Make 25% water change with dechlorinated tap water | No action needed | Water Conditioner (Sodium Thiosulfate Dechlorinator) |
| **pH** | 6.8 - 8.2 [Compare to local tap water pH] | Make 25% water change with dechlorinated tap water | Make 25% water change with dechlorinated tap water | Water Conditioner (Sodium Thiosulfate Dechlorinator) |
| **Hardness** | 75 - 250 mg/L [Compare to local tap water Hardness] | Make 25% water change with dechlorinated tap water | Make 25% water change with dechlorinated tap water | Water Conditioner (Sodium Thiosulfate Dechlorinator) |
| **Alkalinity** | 80 - 250 mg/L | Make 25% water change with dechlorinated tap water | Add Alkalinity Booster (available from Pet Store) | Alkalinity Booster |

Retest water after taking corrective actions to be sure it is in normal range. Repeat corrective actions as needed.

Student Review - Answer the following questions:

1. What pattern do you notice between the ammonia levels and the nitrite levels?

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2. What does it mean when bacteria are said to be aerobic?

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3. Where do you think the bacteria came from in your initial tank setup?

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4. How do you know when the complete nitrogen cycle is occurring in the fish tank?

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5. What measures could be used to ensure the water in the aquarium remains safe for the fish?

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6. Draw a version of the Nitrogen Cycle, including all the chemical components and show where bacterial activity occurs.

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Answers:

1. As the ammonia increases, it allows *Nitrosomonas* bacteria to grow and produce nitrite, and then the ammonia level decreases.

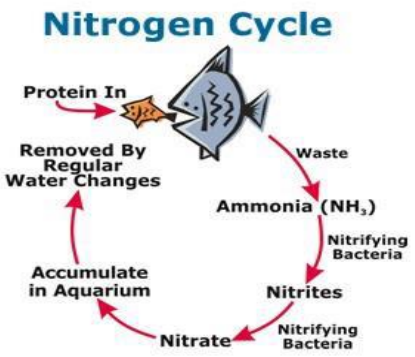
2. Aerobic bacteria require oxygen to grow. If the oxygen level in the aquarium water decreases (such as if the filter shuts off and the water stops flowing) the bacteria will begin to die.

3. The bacteria are naturally present in water, and can also come into the aquarium on the fish and plants.

4. When the ammonia and nitrite levels decrease and the nitrate level is increasing, then the Nitrogen Cycle is complete.

5. To ensure the aquarium water stays safe for the fish, one could do partial water changes as needed to keep the ammonia, nitrite and nitrate levels low, add beneficial bacteria starter to speed up the time it takes for the Nitrogen Cycle to establish, add Ammonia Binder to the aquarium if the ammonia level was increasing, and use a water conditioner to remove chlorine from tap water added to the aquarium.

6.




Prepared by Dr. Nick Saint-Erne, Certified Aquatic Veterinarian, for *Pets in the Classroom*, 2017.