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BASIC WATER QUALITY FOR FISH

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Fish health is profoundly affected by the environment in which fish live. Any deviation outside of an acceptable range may result in disease and even mortality; poor water quality is the most common cause of illness in fish. The astute veterinarian will make a basic water quality analysis part of every sick fish examination.

WATER SAMPLE COLLECTION

When requesting a water sample, explain to the client that the water from a bag of submitted fish is not an acceptable sample. At least 500 mL of water from the tank or pond, and a separate 500 mL sample of the source water (the water used to fill the tank or pond), should be submitted. Both samples should be collected in a manner to prevent air being trapped in the sample. This may require submerging and capping the clean sample container below the water surface. If the water samples cannot be directly analyzed, they should be immediately placed in a refrigerator for temporary storage. If the water samples must be shipped to a clinic or lab for analysis, the samples should be placed on ice in a cooler or styrofoam fish box and shipped for next day arrival.

Cooled water samples should be allowed to reach room temperature before analysis. Dissolved oxygen should be measured immediately after opening the container; the other parameters may then be measured.

TEST KITS

A variety of test kits are available, some as test strips, some use wet reagents and others dry reagents. While the test strips are handy for quick checks, they are not as reliable as those kits which use dry and wet reagents. Before purchasing a kit, make sure it contains reagents that have an expiry date. Some test kit manufacturers offer bulk reagents which are more affordable than buying an entire kit every time reagent supplies become depleted or go out of date.

WATER QUALITY PARAMETERS

While it is easy to focus on one parameter that is out of range, the thorough clinician will measure all parameters listed below, as each parameter is a piece of the whole. Some parameters, such as pH and temperature, have an important influence on others. To only measure one or a few of the parameters may result in a false impression and inadequate advice to the fish owner.

Table 1 lists typical water quality parameters and acceptable ranges for warmwater freshwater and marine fishes.

DISSOLVED OXYGEN (DO)

Dissolved oxygen is the most important limiting factor for in ponds.[1] Mortalities due to low DO are quite common in the summer. A low DO event may be triggered by several events. One, water temperature affects oxygen solubility in water; so as the temperature increases, oxygen solubility decreases. Two, phytoplankton blooms are common in ponds in the summer. These phytoplankton blooms, while producing oxygen during the day, consume oxygen after sunset. If a pond is heavily stocked, the DO level may be too low in the pre-dawn hours to support the fish. Typically, DO fish kills due to heavy phytoplankton blooms are discovered by the pond owner in the morning. Three, summer rainstorms may precipitate a DO crash, either due to phytoplankton loss (cloud cover) or a phenomenon called “turnover.”

Water in ponds tends to stratify during the summer, forming thermoclines. Turnover occurs when heavy rainfall mixes the thermoclines within a body of water. The lower cool anoxic water mixes with the upper warm layer of water, dramatically decreasing the DO.

Table 1. Water quality parameters and acceptable ranges for warmwater freshwater and marine fishes.

Parameter	Acceptable Range: Warmwater Freshwater Fish	Acceptable Range: Warmwater Marine Fish	Comments
Dissolved Oxygen	≥ 5 mg/L	≥ 5 mg/L	
Carbon Dioxide	< 20 mg/L	< 20 mg/L	
pH	6.0-9.0	7.8-8.4	Some fish require specific pH levels.
Alkalinity	≥ 100 mg/L	> 175 mg/L	
Ammonia, unionized (NH_3)	< 0.05 mg/L	< 0.05 mg/L	
Nitrite (NO_2^-)	< 0.10 mg/L	< 0.10 mg/L	Centrarchids are tolerant of higher levels.
Nitrate (NO_3^-)	< 100 mg/L	< 100 mg/L	Some marine invertebrates may be less tolerant
Hardness	50-200 mg/L	NA	High hardness can affect hatchability of the eggs of fishes such as tetras.
Chlorine, free or total	0	NA	
Temperature	22-28°C	22-28°C	

There are several means to manage low DO in ponds: supply supplemental aeration in the form of a fountain, paddlewheel aerator or other aeration device especially at night, flush the pond with well water that is directed into the air before the water hits the pond surface, reduce feeding, and reduce stocking density if pond is overstocked.

In recirculating systems or tanks, DO levels are rarely below the minimum level unless the life support system is not running (power failures, maintenance, etc.) or the system is overstocked. However, treatment chemicals containing formalin are frequently used in such systems, and formalin has a negative effect on the oxygen level. For each 5 mg/L of formalin, 1 mg/L of oxygen is removed.

The nitrifying bacteria that live in the biological filter are aerobic, as such they are also adversely affected by DO less than 2 mg/L.

CARBON DIOXIDE (CO_2)

Just as in terrestrial animals, excessive carbon dioxide can impact the erythrocyte's ability to deliver oxygen to the cell. Low DO exacerbates this effect. Carbon dioxide is more soluble in water than oxygen, however increasing water temperature decreases CO_2 solubility.[2]

Typically carbon dioxide is high in well water, and if not gassed off before entering a system, the carbon dioxide in well water can affect oxygen delivery and also decrease water pH.

In recirculating systems poorly designed for gas exchange, the carbon dioxide from respiration can accumulate to the point that toxicity occurs. A packed column (or degassing column) is an efficient and low cost method of providing gas exchange.

In ponds, the pH may vary as much as 2 units during the diurnal cycle due to the varying carbon dioxide levels produced by both fish and plant respiration. Phytoplankton is a significant contributor to overall carbon dioxide level.

High CO_2 commonly occurs during transport of fishes. Fishes transported in bags are subjected to high CO_2 level especially if packed in high density. Likewise, hauling tanks, if tightly closed, can prevent gas off of CO_2 even if the water is vigorously aerated with oxygen.

pH

pH is the logarithmic measure of hydrogen ions, in other words, the measure of acidity. Carbon dioxide is the most important influence on pH changes. Fish should be maintained within their optimum range. A low pH affects ion exchange, and below optimum pH can result in osmoregulatory failure. Low pH can also result in solubilization of heavy metal ions, if a source is present in the water. Fishes should be maintained within their optimum range. It is also important to note that the nitrifying bacteria also have an optimum range (6.5-9), and do not function below pH 6.5.[3]

ALKALINITY

Alkalinity is the measure of the buffering capacity or acid neutralizing capacity. In fish culture waters, alkalinity consists primarily of bicarbonate, carbonate, and hydroxide ions. High alkalinity buffers high pH swings due to phytoplankton respiration in ponds. Alkalinity is also used to determine productivity in ponds (the ability to support aquatic life). The nitrifying bacteria that reside in biological filters consume bicarbonate, at the rate of 7.14 g of alkalinity for each gram of TAN oxidized.[4] Alkalinity must be determined before using copper as a treatment in freshwater systems.

TOTAL AMMONIA NITROGEN (TAN)

Ammonia is the most important limiting factor for fish in kept in tanks and recirculating systems.[5] The primary source of ammonia is the protein metabolism of the fish. Ammonia is the primary waste product, and it is passively excreted across the gills.[6] A lesser amount is excreted in feces and urine. Uneaten food and decomposing organic matter are also sources of ammonia. Total ammonia nitrogen consists of two forms, ionized ammonia (NH_4^+) and unionized ammonia (NH_3). Unionized ammonia (UIA) is 100 times more toxic than ionized ammonia. At a pH of 7.0, most of the TAN is present as ionized ammonia. As pH and temperature increase, the percentage of TAN that is unionized ammonia increases. Since ammonia toxicity is primarily associated with UIA, the veterinarian must know pH and temperature of the water or pond to accurately determine how much TAN is unionized ammonia. Example: A submitted water sample has a TAN of 0.5 mg/L. The client states that the pH is 8.2 and the temperature is 82^{o}F. Using the pH and temperature, locate the percentage factor in Table 2 (0.0998). Multiply the percentage factor by the TAN to find how much UIA is present; 0.0998 x 0.5 = 0.0499. In this example, the UIA is at a dangerous level.

A UIA of 0.05 mg/L causes gill damage and reduced growth, and as UIA increases, mortality may result.

Total ammonia nitrogen may be measured by two methods, Ammonia Salicylate and Nessler's. Seawater may be analyzed using the Nessler's method by adding of 1.0 mL of mineral stabilizer to the sample before analysis. The mineral stabilizer complexes the high magnesium concentrations found in sea water, but the sensitivity of the test is reduced by 30 percent due to the high chloride concentration. The Ammonia Salicylate method is more reliable for marine samples.

Water treated with formalin or one of the ammonia locking compounds (e.g. AmQuel, AmmoLock, etc.) will have a falsely elevated TAN level when using Nessler's method. This reaction does not occur if the Ammonia Salicylate method is used.

It is important to note the Nessler's reagent contains mercury, and water samples treated with Nessler's reagent must be disposed as a hazardous material.

NITRITE

Nitrite is a byproduct of ammonia oxidation by the nitrifying bacteria. (See Figure 1 for an explanation of the nitrogen cycle.) It is colorless and odorless, and can result in signs of toxicity as low as 0.10 mg/L. Nitrite oxidizes the iron in hemoglobin, and the oxidized hemoglobin (methemoglobinemia or brown blood disease) is unable to bind oxygen and deliver it to cells. Channel catfish (*Ictalurus punctatus*) are especially sensitive to nitrite. On the other hand, the centrarchid family (bluegill, largemouth bass, etc.) are tolerant of nitrite levels that would be fatal to non-centrarchids. The uptake of nitrite at the gill can be blocked by addition of chloride, either as sodium chloride or calcium chloride, at the rate of 10 mg/L of chloride for each 1 mg/L of nitrite ion (Figure 1).

NITRATE

Nitrate is the byproduct of nitrite oxidation by nitrifying bacteria. Older literature states that nitrate is non-toxic. More recent work indicates that nitrate may alter hematologic factors in striped bass at levels as low as 200 mg/L. Nitrate is utilized by plants, and high levels may result in algae blooms. The easiest way to reduce nitrate is to do frequent, large water changes.

HARDNESS

Hardness is the measure of the divalent cations, primarily calcium and magnesium. Freshwater fish constantly lose electrolytes to the water column, and it is easy for them to take up calcium and magnesium as needed for osmoregulation. Hard water can have an adverse effect on hatchability of some fish eggs, especially the fish that originate from soft water, i.e. tetras. Water hardness greater than 150 mg/L minimizes toxicity of heavy metals.

The Environmental Protection Agency developed a guideline for hardness of natural water:

- Soft 0-75 mg/L
- Moderate 75-150 mg/L
- Hard 150-300 mg/L
- Very hard ≥300 mg/L

CHLORINE

Chlorine and chloramine are widely used by public municipal water suppliers to deliver safe drinking water to consumers. Typically chlorine arrives at the consumer's tap at 1.5-2.0 mg/L. However, chlorine at 0.05 mg/L can be toxic to many fish species. Chlorine is easily neutralized with sodium thiosulfate at 7.6 mg/L for each mg/L of chlorine. Activated carbon will also remove chlorine, but it requires frequent replacement. The practice of collecting the water for dissipation of chlorine is not reliable, as 20 hours is required for each 1 mg/L of chlorine.

Chloramine, a combination of chlorine and ammonia is also toxic to fish. To eliminate chlorine, the bond between chlorine and ammonia must first be broken, then each removed separately. There are products available, sodium hydroxymethanesulfonate and other similar products, that neutralize chloramine.

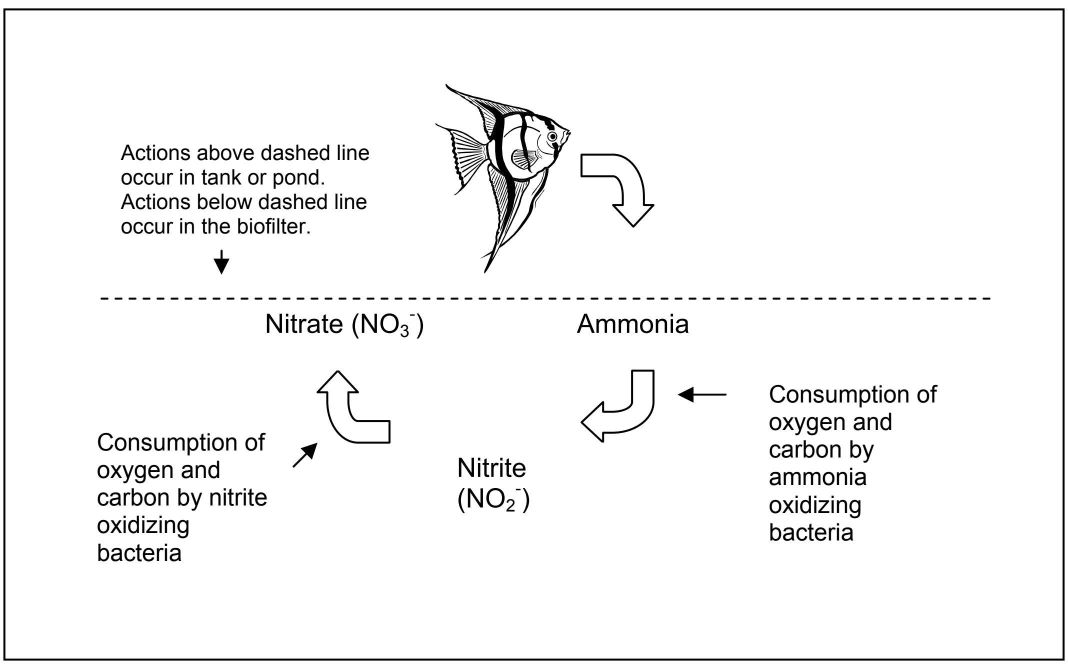

Figure 1. A simplified diagram of nitrification.

TEMPERATURE

Fish are ectothermic, so temperatures outside their optimal range have deleterious effects. Increases in temperature result in an increase in metabolism, thus an increased demand for oxygen. However, oxygen solubility decreases as temperature increases. Ammonia toxicity is increased by rising temperatures (Table 2). High temperatures also promote more rapid growth and reproduction of parasites and bacteria. At the other extreme, low temperatures slow metabolism and depress immune response, and digestion is impaired.[7] Temperature changes should be gradual, ideally no more than 2°C per hour.

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Table 2. Fraction of unionized ammonia in aqueous solution at different pH values and temperatures.

	Temperature														
	42.0	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6	(F°)
pH	6	8	10	12	14	16	18	20	22	24	26	28	30	32	(C°)
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093	
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150	
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236	
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369	
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572	
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877	
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322	
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948	
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768	
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776	
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902	
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038	
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072	