Water Quality Basics in the Typical Koi Pond

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Alkalinity: Alkalinity is also referred to as KH in the hobbyist world. Alkalinity is defined as the acid-neutralizing capacity of water. For most practical purposes this is comprised of hydroxyl, bicarbonate, and carbonate anions that can bond with hydrogen ions to affect pH. In a typical fish system in a normal pH range, the primary constituent at play is the bicarbonate anion. Bicarbonate is consumed by nitrifying bacteria as their carbon source. Bicarbonate is consumed at a rate of roughly the equivalent of 1 lb of sodium bicarbonate per every 4 lbs of food given to the fish. Bicarbonate is also lost in water that is removed from a system. Bicarbonate can enter the system from several sources; 1) incoming water during water changes, 2) addition of baking soda, or 3) the breakdown of calcium carbonate materials (e.g. limestone). Number 3 is a very slow process because it involves the acidic decomposition of the calcium carbonate. The carbonate must then shift to bicarbonate upon uptake of a hydrogen ion. In lightly loaded systems, the use of limestone or oyster shell may suffice, but it should not be relied on to provide a regular supply of bicarbonate. Incoming water with sufficient alkalinity may provide all the system needs, but this needs to be confirmed with testing. If those sources are not sufficient, then the best method for raising alkalinity is the addition of baking soda. There is no magic number at which to keep a system's alkalinity, regardless of the type of filtration. All that really matters is that you have enough for filtration to occur properly, and to keep the filtration supplied with bicarbonate. Anything over about 50-80 mg/l is sufficient for the filtration, but it doesn't leave a lot of room should something change suddenly. I usually recommend keeping it above 100 mg/l and preferably above 150 mg/l, but that's up to the individual to decide. Upon addition, baking soda will tend to try to stabilize the pH at about 8.5 regardless of whether the pH starts out above or below. In time, the reactions occurring in the system will cause the pH to move away from that. Typically the pH will move down in time, but leaching from concrete or blooms of cyanobacteria or some algae can cause it to go up.

Hardness: Hardness is also referred to as GH in the hobbyist world. Hardness originated as a measure of the ability of water to precipitate soap. This has been updated to essentially become a measure of the quantity of calcium and magnesium in the water. In the typical fish system magnesium is not usually an issue (unless you have dolomite present), so the primary component here is calcium. Hardness can come from incoming water, breakdown of limestone or oyster shell, or addition of chemicals such as calcium chloride. Alkalinity and hardness are related, but they are not directly dependent on each other. Alkalinity can be high with low hardness, low with high hardness, or they may be equally high or low. It all depends on which constituents you are dealing with. For the most part, hardness does not affect the health of koi, so it is a low priority parameter.

pH: pH is pretty straight forward. It is just a measure of the acidity of the water, or in more technical terms it is the negative log of the concentration of hydrogen ions. In terms of health, most fish will be fine in water ranging from about 7 to 8.5. They can survive outside of this range, but they will likely get stressed as a result. Sufficiently maintaining alkalinity and avoiding heavy algae blooms will help assure the pH does not get outside of that range.

Total Dissolved Solids (TDS): This is a measure of all of the constituents dissolved in the water (smaller than 0.45 microns is considered dissolved). If you boil away a sample of 0.45-micron filtered water, what you are left with is the TDS. Hardness and alkalinity play a small role, but the primary one here is going to be plain old salt (sodium chloride). If you add salt to treat the fish, the only way it is going anywhere is with water changes. Don't continuously add salt without water changes unless you test to see where you're at, otherwise you're just causing the salt to build up.

Ammonia: Ammonia is of course the first and foremost waste product that needs to be taken care of. Ammonia is excreted by the fish primarily through the gills and secondarily as urea from the urogenital tract (pee). If allowed to build up it becomes toxic. It is less toxic at lower pH, so systems with pH above about 8 are at greater risk should the ammonia spike. The only significant methods of removal are nitrification and flushing of water. Zeolite and Amquel can be used short term or in an emergency, but they are only binding the ammonia within limitations and if left unchecked will result in unbound ammonia that can still cause problems. Ammonia can evaporate or volatilize, but the evaporation is at a proportional rate to that of the water that it's in, so you would have to evaporate off such a significant quantity of water that it's not an option. Nitrification is of course the primary method of removal by converting the ammonia to nitrite and then to nitrate. The process requires oxygen and a carbon source (alkalinity). For those that wish for 0 ammonia, "be careful what you wish for". The bacteria need ammonia to survive. If you have no ammonia, the bacteria can't survive. Without a significant population of bacteria, the system is that much more susceptible to sudden changes (such as addition of fish). In reality, though, most handheld test kits are likely showing 0 when in fact there's just a very low amount (0.05-0.1 mg/l-ish). Ammonia levels below 0.5-1 mg/l will be safe for the fish but keeping ammonia around 0.1-0.2 mg/l is better for the fish and still providing some food for the bacteria.

Nitrite: Nitrite is very similar to ammonia, except that it is the more toxic chemical of the two. Again, the only significant methods of removal are nitrification and flushing of water. Ozone can be used to convert nitrite quickly into nitrate, but the use of ozone presents other problems that require careful handling. Salt does counteract the toxicity to some extent, but this is for emergency situations only, and if there is a spike in nitrite, the source needs to be found. Denitrification does remove nitrite also, but it’s a tricky reaction to control properly. Just as with ammonia, the bacteria need some nitrite available to be able to survive. Nitrite levels below 0.5-0.75 mg/l will be safe for fish, but again keeping nitrite down to around 0.1-0.2 mg/l will be better for the fish and still provide food for the bacteria.

Nitrate: Nitrate is certainly much less toxic than ammonia or nitrite, but it does become toxic at some point. The toxic level is more on the order of 50-100 mg/l or even greater instead of the 1 mg/l of ammonia and nitrite. Removal of nitrate is by one of several methods; 1) plant uptake, 2) flushing, or 3) denitrification. Denitrification is done under anaerobic conditions where bacteria will convert nitrate back to nitrite, and then nitrite to nitrogen gas where it bubbles off to the atmosphere. It is a very tricky reaction to control and can result in hydrogen sulfide or even sulfuric acid development if not properly controlled. Plants will take up a certain amount, but it may not be enough to remove everything that's being produced. Water changes are the primary method of removal. Keeping levels below 50 mg/l will be safe for the fish, but less than 10 mg/l is preferred.

Oxygen: Pretty straight forward here as well. Fish need oxygen and so do the bacteria in the filter. Keeping it at or near saturation is preferred (6-8 mg/l or so depending on temperature), and is generally not that difficult with some minimal aeration via waterfalls, air pumps, blowers, etc.

Carbon dioxide: The product of respiration. It is consumed by algae, but the green water necessary to have sufficient removal is not generally desirable. If you have enough aeration to keep the oxygen at or near saturation, then the carbon dioxide will automatically be degassed, so it's not really of major concern. As nitrification occurs and removes alkalinity, the pH may decrease as a result of the introduction of carbon dioxide, but this is easily fixed by replenishing the alkalinity.

Water: Well, duh, the fish need water. You'd think it's a no-brainer, but you'd be surprised how many stories I hear of someone accidentally pumping down a system, or having a pipe break, etc. When designing the system, try to add fail safes to make the sure the system can't drain if something happens while you're not around. I'll include the obvious chlorine in this one. Chlorine and fish don't get along. Make sure you dechlorinate when adding water, and unless you have dechlorinated water such as well water, DON'T LEAVE THE HOSE RUNNING ALL NIGHT!!!

Now to a few of the questions that don't necessarily have an answer right now. Most of the above is based on keeping healthy fish, but as we all know with koi, it's not all about health, but also quality. I've heard lots of stories by people claiming that pH, hardness, and food additives can affect colors. Until recently I'd never heard of alkalinity playing a role, but you never know. I'm not aware of any definitive scientific evidence that any of these factors affect the quality of the fish to any greater degree than having good genetics, good health, and plain old good luck. Your mileage may vary on this topic. I've seen good looking fish under all types of conditions, and I've seen not so good looking fish under all types of conditions, so I'm inclined to believe it has more to do with the genetics, health, and luck, but "to each his own" on this issue. Experimenting with this one is probably part of the fun of the hobby anyway.