POND WATER CHEMISTRY

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Pond Water Chemistry

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This is a composite of a series of articles dealing with the chemical makeup of pond water. How to measure what is in it, what is good, what is bad, and what to do about it. Before starting, I would like to discuss the name applied to what has typically been called the "bio-filter." A filter is defined as a porous device through which water (or gas) is passed to separate out matter in suspension. The biologic activity within the pond "filter" does not trap the matter in suspension but acts on dissolved components that could not be separated regardless of how fine the filter pores. Although this device may perform a dual role as a mechanical filter, to emphasize the processes of interest, you will see that I will often refer to it as the biologic converter or bio-converter, not as a filter.

By introducing fish into your pond, you have assumed the responsibility for the care of these creatures. This includes not only feeding them but also providing them with a healthy environment in which they can live and thrive. Partial determination of the quality of this liquid environment can be made through chemical measurements. It seems somewhat ludicrous that someone would spend hundreds or thousands of dollars to build a pond and then add hundreds or thousands of dollars of beautiful Koi but would not buy and learn how to use a ten dollar nitrite test kit. This doesn't mean that one must test the water every few minutes or even every few days. An established pond with the fish appearing healthy should be checked every month or so. It is only when something out of the ordinary is observed and possibly during seasonal changes when an additional test or two might be needed. A simple test at the right time may prevent a small problem from becoming a catastrophe. When starting up a new pond or bio-converter system, daily tests may be required until the converter comes on line, then weekly for a couple of months until the system has stabilized.

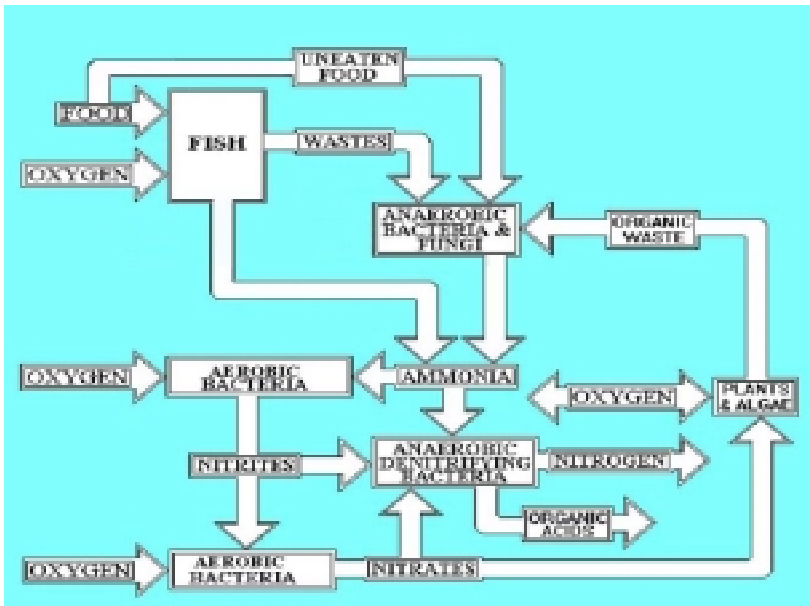
Just as when medicinally treating your pond, it is imperative to know the total amount of water in your pond and converter/filter system as accurately as possible. Over treatment or under treatment with chemicals can be equally disastrous. Don't guess on quantities, measure them!

Do not confuse the terms water quality and water clarity. Crystal clear water can contain compounds that are deadly to your fish. Green water, sometimes called an algae bloom and caused by excessive phyto plankton growth, can actually be beneficial to the fish although not very beneficial to the pond keeper who can't see them. Water clarity can give some indications as to mechanical filtration effectiveness.

A pond with a biologic converter and filled with Koi is a rather complex, somewhat self-contained ecological system. Each component of this system requires the other components to survive and prosper. The basic portion of the cycle is shown below. Fish waste and other organic waste is converted by bacteria and fungi to ammonia compounds. These compounds can be injurious to the fish, but a healthy biologic converter populated with families of bacteria consume these ammonia compounds and convert them to nitrite. Unfortunately, nitrite is just as toxic to the fish as the ammonia. Again, the biologic converter comes into play with another colony of bacteria that convert the nitrite to nitrate. The nitrate is basically inert to the fish but usable by plants and algae within the pond. As the plants and algae grow

and the Koi eat them, the cycle starts all over again. The bacterial colonies that do this conversion are called aerobic since they require oxygen to convert their "food" to energy just like the fish.

Pond Nitrification Cycle



Test Kits in Estimated Order of Importance

Required

pH	**Ammonia**
Nitrite	**Thermometer**

Nice To Have

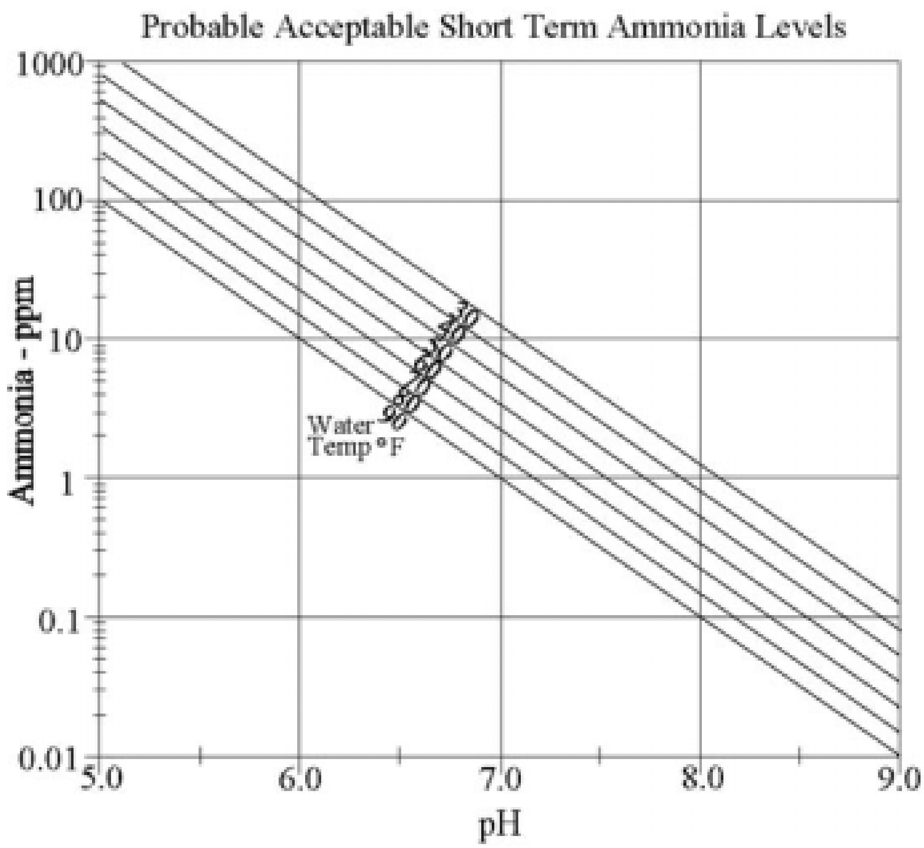
Alkalinity	**Salinity**
Nitrate	**Dissolved Oxygen**

Probably Not Necessary

Chlorine	**Hardness**

AMMONIA

Ammonia, NH_3, measured in parts per million (ppm), is the first measurement to determine the "health" of the biologic converter. Ammonia should not be detectable in a pond with a "healthy" bio-converter. The ideal and normal measurement of ammonia is zero. When ammonia is dissolved in water, it is partially ionized depending upon the pH and temperature. The ionized ammonia is called ammonium and is not particularly toxic to the fish. As the pH increases and the temperature drops, the ionization and ammonium decreases which increases the toxicity. As a general guideline for a water temperature of 70^{O}F, most Koi would be expected to tolerate an ammonia level of 1 ppm for a day or so if the pH was 7.0, or even as high as 10.0 if the pH was 6.0. At a pH of 8.0, just 0.1 ppm can be dangerous.



Two types of ammonia test kits are commonly available. The first is based on the Nessler reagent. This kit normally uses drops in a water sample with an associated color chart. The second is a salicylate reagent test that may use drops, powders, or pills and is usually a two step process again followed by a color chart. The Nessler kit provides a faster test but is not compatible with any ammonia treatment chemicals that may be in the water (more about those later). One way to determine which type of test kit you have is that the Nessler kit color chart normally ranges from clear, meaning no ammonia, to yellow/yellowish-orange as ammonia levels increase. The salicylate based test kit ranges from a light yellow, meaning no ammonia, to green/bluish-green as ammonia levels increase. Both types read the total of ammonia and ammonium, so without knowing the temperature and pH, the toxicity cannot be determined. Suffice it to say that the only good ammonia reading is zero. But note that any pond containing fish will have some residual ammonia. The bio-converter does not remove all of it each pass and the fish continuously add it to the pond. The residual level will be determined by the fish load, the effectiveness of the bio-converter, and how often the water is passed through it. This residual level should not be detectable on the average test kit. The recommended test kit should be able to detect 0-1 ppm of ammonia. An ammonia test kit is considered to be a requirement for all pond keepers.

Effects:
Ammonia tends to block oxygen transfer from the gills to the blood and can cause both immediate and long term gill damage. The mucous producing membranes can be destroyed, reducing both the external slime coat and damaging the internal intestinal surfaces. Fish suffering from ammonia poisoning usually appear sluggish, often at the surface as if gasping for air.

Source:
Ammonia is a gas primarily released from the fish gills as a metabolic waste from protein breakdown, with some lesser secondary sources such as bacterial action on solid wastes and urea.

Control:
Ammonia is removed by bacterial action in the bio-converter and a small amount is directly assimilated by the algae and other plants in the pond. The bacteria consume the ammonia and produce nitrite as a waste product. A significant portion of this bacterial action can occur on the walls of the pond as well as in the pipes and bio-converter. Ammonia readings may increase with a sudden increase in bio-converter load until the bacterial colony grows to accept the added material. This can happen following the addition of a large number of new fish to a pond or during the spring as the water temperature increases. Fish activity can often increase faster following a temperature increase than the bacterial action does. A bio-converter that becomes partially obstructed with waste and/or develops channels through the media may operate at reduced effectiveness that can also cause the ammonia levels to increase.

Treatment:
Chemical treatments to counteract ammonia toxicity are available commercially under various trade names. These treatments, most of which are based on formaldehyde, chemically change the form of the ammonia into compounds that are not harmful to the fish. They do not actually remove it from the pond. The bio-converter bacteria still does the actual removal. Although most of these products use a dosage of 50 ml per 100 gallons to chemically bind up to 1 ppm of ammonia, be sure to check the manufacturer's directions before use as those containing formaldehyde can result in overdose conditions. Note that the Nessler type test kits may show false readings when any of these chemical treatments are in the water. If a pond has a healthy bio-converter, there is normally not only no need to treat with ammonia binding chemical agents, it is better not to use them at all.

When ammonia is detected (assuming a pH of about 7.5):

Increase aeration to maximum. Add supplemental air if possible.
2. Stop feeding the fish if detected in an established pond, reduce amount fed by half if starting up a new bio-converter/pond.

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3. Check an established pond bio-converter for probable clean out requirement
4. For an ammonia level of 0.1 ppm, conduct a 10% water change out. For a level of 1.0 ppm, conduct a 25% change out.
5. Chemically treat for twice the amount of ammonia measured.
6. Consider transferring fish if the ammonia level reaches 2.5 ppm.
7. If starting up a new bio-converter/pond, discontinue use of any UV Sterilizers, Ozone Generators, and Foam Fractionators (Protein Skimmers).
8. Retest in 12 to 24 hours.
9. Under Emergency conditions only, consider chemically lowering the pH one-half unit (but not below 6.5).

CAUTION: If the tap water has a higher pH than that of the pond or if the tap water contains Chloramine, adding the replacement water may make the situation worse.

NITRITE

Nitrite, NO_2-N, measured in parts per million (ppm), is the second chemical measurement made to determine the "health" of the biologic converter. Nitrite should not be detectable in a pond with a properly functioning bio-converter. Thus the ideal and normal measurement of nitrite is zero. A low nitrite reading combined with a significant ammonia reading indicates the ammonia-nitrite biologic converter action is not established, while a low ammonia reading with a detectable nitrite reading indicates that the nitrite-nitrate bacterial conversion activity is not yet working. Test kits are available in pill, powder, or droplet forms with color charts. Recommended test kit range 0 - 4 ppm. A nitrite test kit is considered to be a requirement for all pond keepers.

Source:
Nitrite is produced by autotrophic bacteria combining oxygen and ammonia in the bio-converter and to a lesser degree on the walls of the pond. Just as with ammonia, nitrite readings may increase with a sudden increase in bio-converter load until the bacterial colony grows to accept the added material. This can happen following the addition of a large number of new fish to a pond or during the spring as the water temperature increases. Fish activity can often increase faster following a temperature increase than the bacterial action does. A bio-converter that becomes partially obstructed with waste and/or develops channels through the media may operate at reduced effectiveness that can also cause the nitrite levels to increase.

Effects:
Nitrite has been termed the invisible killer. The pond water may look great, but nitrite cannot be seen. It can be deadly, particularly to the smaller fish, in concentrations as low as 0.25 ppm. Nitrite damages the nervous system, liver, spleen, and kidneys of the fish. Even lower concentrations over extended periods can cause long term damage. Short term, high intensity, "spikes" which often occur during a bio-converter startup or restart may go undetected yet cause problems to develop within the fish months later. A common indication of a fish that has endured a severe nitrite spike in the past is that the gill covers may be slightly rolled outward at the edges. They do not close flat against fish's body.

Control:
About the only control of nitrite is through the maintenance of a "healthy" bio-converter. Within the media, the bacteria combine oxygen with the nitrite to convert it to the relatively benign nitrate. These bacteria receive considerably less energy from this conversion process than do the bacteria carrying out the ammonia to nitrite conversion process. For this reason, they are not as hardy and tend to be the last to come and the first to go when a problem occurs within the bio-converter. Water change outs can reduce the levels temporarily by the same amount as the percentage of water changed. The addition of salt helps reduce the toxic effects significantly but should only be used as a interim measure, not as an ongoing treatment.

Whenever 0.25 ppm of nitrite or more is detected in a pond:

1. Increase aeration to maximum. For a nitrite level of 1 ppm or greater, add supplemental air, if possible.

2. Stop feeding the fish if detected in an established pond, reduce amount being fed by half if starting up a new bio-converter/pond.
3. Discontinue use of any UV Sterilizers, Ozone Generators, and Foam Fractionators (Protein Skimmers).
4. For a nitrite level less than 1 ppm, conduct a 10% water change out and add 1 pound of salt per hundred gallons of changed water.
5. For a level between 1 and 2 ppm, conduct a 25% water change out and add 2 pounds of salt per hundred gallons of changed water.
6.For a level greater than 2 ppm, conduct a 50% water change out and add 3 pounds of salt per hundred gallons of changed water.
7. Retest and repeat above in 24 hours.
8. For nitrite levels of 4.0 or greater, consider transferring fish.

> CAUTION: Again, if the added water contains Chloramine, the added ammonia after conversion to nitrite may make the situation worse.

NITRATE

Nitrate, NO_3-N, measured in ppm, is the third and last measurement used to determine the "health" of the bio-converter. Nitrate is produced by one of the autotrophic bacterial colonies by combining oxygen and nitrite. This occurs both in the bio-converter and to a lesser degree on the walls of the pond. A zero nitrate reading, combined with a non-zero nitrite reading, indicates the nitrite-nitrate bacterial converter action is not established. Test kits are available with dual droplet or pill form with color charts. The recommended test kit range 0 - 200 ppm. A nitrate test kit is considered nice to have but not required for the average pond. In an established pond with part of the routine maintenance including 5% to 10% water change outs every week or two, nitrate levels will normally stabilize in the 50-100 ppm range. Concentrations from zero to 200 ppm are acceptable but should normally be below 100.

Where ammonia and nitrite were toxic to the fish, nitrate is essentially harmless. There have been reports that high nitrate levels may weaken the colors in Koi, but there have also been reports that high nitrate levels can enhance the colors. Similarly, I have read reports, fortunately not in the same article, that high nitrate levels will both stimulate and suppress spawning activity. If the nitrate concentration gets too high, the nitrite-nitrate converting bacteria may not be able to do their job effectively resulting in a raised nitrite level. Nitrate is the end result of the nitrification cycle and is very important to plants in their life cycle. This is why the plants in your garden can flourish from being watered with the waste water from your pond (assuming you haven't added too much salt).

Note the large difference in the ranges of the test kits being used to measure nitrate (200 ppm) as opposed to those for ammonia and nitrite (1-4 ppm). Assuming our the bio-converter was converting the equivalent of 1 ppm of ammonia to the equivalent of 1 ppm of nitrite to the equivalent of 1 ppm of nitrate per day, it would take 100 days or over three months, (longer with any water change outs), for the nitrate levels to build up to the 100 ppm level. The nitrate concentration is controlled naturally through routine water change outs and to a lesser degree through plant/algae consumption.

pH

For the record, pH is technically defined as the negative base 10 logarithm of the effective hydrogen ion concentration in gram equivalents per liter (whatever that means, and why is it spelled so pHunny?) We are going to skip many of the technical details since it is not really necessary that a pond keeper knows exactly what pH is. What is important is to know how to make pH measurements, to routinely make the measurements, and how to interpret their results. The discussion below is not intended for chemistry majors nor for anyone who desires a technically accurate description of our subjects. It is provided for the average pond owner to visualize what is going on in his or her pond.

Various substances exhibit similar characteristics in how they react with other substances. A broad range of these characteristics has been divided into the two categories, acid and base, where the pH measurement is related to a ratio of the base components to the acid components. (We aren't going into what these components actually are.) If a substance has one acid component for each base component, it is said to be neutral and has a pH value of 7. Greater than 7 is less acid, more base, and less than 7 is more acid and less base. Each unit is 10 times the previous, i.e., a pH of 9 is 10 times more base than 8, a pH of 5 is 10 times more acid than 6. Some examples of more acid like things are vinegar, orange juice, and the liquid in your car battery that makes holes in your clothes. Bases include lye, antacids for your stomach, and brushing your teeth with baking soda. When acid like substances are mixed with base like substances, they react with each other producing some byproducts and leaving the resulting solution with a pH somewhere between the two original values. The further apart the pH of the two substances, the more energy is released in the reaction. Put a teaspoon of baking soda in a half glass of vinegar and see what happens.

We are familiar enough with the extremes of acids and bases to know it is not a good idea to place a bare hand in either battery acid or caustic lye, and we can assume that neither would be a good place to put our fish. A pH measurement will help us determine if our water is a proper place to put the fish. For our Koi ponds, the pH should normally be between 7.0 and 8.5, but it is probably acceptable to be anywhere between 6.0 and 9.0. Although most of the fish could tolerate a pH as low as 5.0, bio-converter bacteria are subject to damage. Long term conditions above 9.0 can cause kidney damage to the Koi.

Test kits are available that use drops, pills, or powders with a color chart to show various ranges of pH. A wide range pH test kit (Range 5.0 - 10.0) is considered as a requirement for all ponds. If higher accuracy is desired, one or more limited range test kits are nice to have for the ranges most often encountered. Battery operated, digital electronic pH meters are available that measure from 1-14 in 0.1 increments. Most of the inexpensive versions of these ($100 or less) provide readings that are both temperature and battery condition dependent. All require periodic calibration and the less expensive ones usually require calibration prior to each use. Since doing this calibration and maintenance of the meters with probe cleaning and storage solutions is more involved than making a chemical reading of the pH, an electronic pH meter is not considered appropriate for most pond keepers. Those who have difficulty distinguishing the small color differences of the chemical test color charts find them wonderful.

ALKALINITY

Just knowing the pH doesn't give us the complete picture. A pH test of distilled water can show almost any value since just a tiny amount of residual impurities, either acid or base, can have a major effect on the ratio of the two.

For example: assume we have the equivalent of 1 acid component and 1 base component in our water (equal amounts means the pH is a neutral 7). Adding 100 more base components will cause a change of over 100 in the ratio (101 divided by 1) and cause the pH to go to just over 9. Now let's start with 1000 acid components and 1000 base components in our water; again equal amounts so the pH is still 7. If we now add the same 100 base components, the ratio changes only slightly (1100 divided by 1000) and the pH goes up just a little bit (to about 7.04). The Alkalinity (often called the total alkalinity) of our water is related to the actual number of base components and can be thought of as the "intensity" of the pH. (There is also a similar measurement called acidity related to the number of acid components but since we are normally concerned with slightly base water, it is easier to measure the larger number of base components than the smaller number of acid components.)

If the alkalinity is low, it indicates that even a small amount of acid can cause a large change in our pH. Consider the pond owner whose pH was 8.0. He was told that 7.0 was better so he puts in chemicals to lower it. The next day, it is back to 8.0 so he adds more chemicals. The following day it tests at 7.5. He feels good because it is finally starting to come down and dumps in some more stuff. All of a sudden he finds that the pH is 5.0. His bio-converter bacteria were destroyed and his fish are dying. Each treatment kept reducing the alkalinity until it was so low that the final addition caused a major pH transition.

Alkalinity is related to the amount of dissolved calcium, magnesium, and other compounds in the water and as such, alkalinity tends to be higher in "harder" water. Lime leaching out of concrete ponds is a primary source of alkalinity but it is also slowly increased by evaporation which concentrates the source compounds. Alkalinity is naturally decreased over time through bacterial action which produces acidic compounds that combine with and reduce the alkalinity components.

Alkalinity is most often measured in ppm (referred to as calcium carbonate equivalents). A measurement is normally made by pretreating the water sample with a pill, powder, or droplet solution which results in the sample turning blue. The alkalinity is then determined by measuring (from a calibrated pipette or by counting drops) the amount of a second acidic reagent required to change the color to pink. A recommended test kit should measure a range of 0 - 200 ppm. An Alkalinity test kit is recommended but not considered to be a requirement for the average pond keeper. In an established pond, the ideal Alkalinity measurement should be around 100 ppm. Readings from 50 to 200 are acceptable.

Treatment:
Much more important than either the actual pH and alkalinity measurements, assuming they are both in the acceptable ranges, are **CHANGES** to them. A typical established pond will normally settle down into an equilibrium state with a pH of about one half unit above or below the pH of the tap water used for replenishment. Over time (months), all of the inhabitants (bacteria, plants, and the fish) become acclimated to their environmental conditions. Stress occurs in all of them if they must adjust to any

changes. Rapid changes in pH can cause extreme stress to the fish similar to shock in humans. A sudden change of a half or more pH unit in an established pond is an indication that something happened and the cause should be determined. Slow, longer term, changes provide other indications. Increasing pH and/or alkalinity trends in a pond are normally caused by lime leaching out of concrete and to a lesser degree by concentration due to evaporation. Decreasing pH and alkalinity tendencies are primarily due to bacterial action that release acidic compounds. Concrete ponds usually stabilize at a slightly higher pH value than ponds with liners.

High alkalinity is normally prevented by routine water change outs (assuming the tap water has a lower alkalinity than the pond water). Increasing pH trends can be minimized by an initial pretreatment or curing of a new concrete pond. Fill the pond with water (no fish), add Muriatic acid (swimming pool acid) as necessary to adjust the pH to about 5. Circulate continuously and test daily, adding additional Muriatic acid to maintain the pH level until no additional acid is needed. This normally takes 2-3 days. After draining, the pretreatment cure is complete and the pond is ready to be filled for use (now you can put in a few test fish). A properly treated concrete pond will usually reach an equilibrium state where the production of compounds which reduce the alkalinity is matched by the components being leached out of the concrete.

Ponds with vinyl liners or of fibre glass construction tend to show a decrease in alkalinity over time and may need supplements to maintain an acceptable level. Raise alkalinity by adding Calcium Carbonate, concrete blocks, oyster shells, limestone, or even egg shells. To raise the alkalinity by 40 ppm, add 1/2 oz of Calcium Carbonate (precipitate powder) per 100 gallons of water. A bag of oyster shells or even a concrete block or two (not cinder block) submerged in the pond or filter area may be all that is needed. Keep a close eye on the pH while adjusting Alkalinity levels. An alkalinity stabilization Apill@ can be made from plaster of paris. Just mix water with the plaster of paris, let it harden, and put it in an area that receives good water flow across the surface. A one pound plaster of paris Apill@ for each 500 gallons should suffice. Periodic replacement is necessary as they dissolve.

Established ponds will normally maintain their equilibrium pH value if sludge and decaying organic material is routinely removed from the pond, mechanical filter, and biological converter. Scheduled water change outs (10% per week for a small pond, less for larger ponds) are also helpful. Monitoring the pH by recording weekly readings (before the water change outs) can provide an excellent indication of any developing problems. pH values do change somewhat during each 24 hours, depending upon the temperature, quantity of plants (algae and others), and the size of the pond, so try to take the measurements at about the same time of day. Alkalinity measurements can provide a warning that a pH problem may be imminent.

If the pH gets out of control on the high side, conduct daily water change outs to bring it back into range. Recheck after each water change out and again in 24 hours. Don=t forget to check the pH of the water being added, it may be part of the problem. At a pH of 9, do daily 10% to 25% water change outs. For a pH of 10, do 25% to 50% water change outs. At pH extremes over 10, remove any remaining fish. Only under **EMERGENCY** conditions should chemical means be used to lower the pH in a pond. Any attempt to lower the pH chemically can be particularly hazardous to you, the biologic converter, and the fish (not necessarily in that order).

A low pH problem, below 7, is normally only observed in a liner based or an older concrete based pond. It is usually the result of a ApH crash@. This is when the total alkalinity has been consumed by the biologic activity in the converter and the pH suddenly drops. This has been observed to go as low as 4.5. Again, start water changeouts and increase aeration. Sodium bicarbonate (plain old pure baking soda, Arm & Hammer or generic store brand) will raise the pH and also increase the total alkalinity.

> **CAUTION**: Be sure to check and treat for any ammonia presence **BEFORE** attempting to raise pH through either chemical or water change out means.

Repeating for emphasis, the value of the pH measurement, within the acceptable limits, is of little importance. A change, whether sudden or a slow trend, to the pH of an established pond, indicates action may be required and is why periodic pH measurements are important. Further, if your pH is reasonably stable and is anywhere between 7.0 and 8.5, not only is there no need to attempt to adjust it. You probably will do more harm than good by trying to change it.

TEMPERATURE

Whether you measure your pond's temperature in degrees Centigrade or degrees Fahrenheit or both, a thermometer is considered a requirement for all ponds. A floating pool or spa thermometer is good. It is recommended that it be floated in the filter/converter system or tied to an easy access point at the edge of the pond. At a slightly higher cost, the electronic indoor/outdoor thermometers on the market (i.e. Radio Shack) provide a continuous digital readout. Just drop the end of the waterproof outdoor probe into the water. (Note: Small floating glass aquarium thermometers have been swallowed by Koi.)

Temperature Ideal Range 65^{O} F-75^{O}F (20^{O}C-25^{O}C)

Acceptable 35^{O}F-85^{O}F (2^{O}C-30^{O}C)

The temperature of the pond normally follows that of its surroundings although with a delay related to the size of the pond. Direct exposure of the pond to open sky can cause larger swings in temperature. Direct sunlight during the day can cause the temperature to rise higher, and heat loss on clear nights can cause the temperature to drop lower than shaded ponds. A clear night sky can absorb a large amount of heat from a small pond and actually drive the pond temperature below air temperature.

Events generally happen faster at higher temperatures and in smaller ponds. Over normal temperature ranges, biologic activity doubles for each 10^{O} rise in temperature. The toxicity of ammonia increases as the temperature rises and the amount of dissolved oxygen that the water can hold decreases. Although Koi have been known to survive for limited periods at 100^{O}F and even higher, the mortality rate of fish conditioned to 75^{O}F water increases rapidly above 85^{O}F. Above 80^{O}F, supplemental air may be required. Below 55^{O}F (12^{O}C), Koi stop producing antibodies and at about 45^{O}F (7^{O}C) enter a state similar to hibernation. Bio-converter bacteria activity ceases at about 40^{O}F (5^{O}C).

Feeding fish versus Temperature:

Less than 50^{O}F Do Not Feed
50^{O}F-60^{O}F 2-4 times weekly
60^{O}F-85^{O}F 2-4 times daily
Above 85^{O}F Do Not Feed

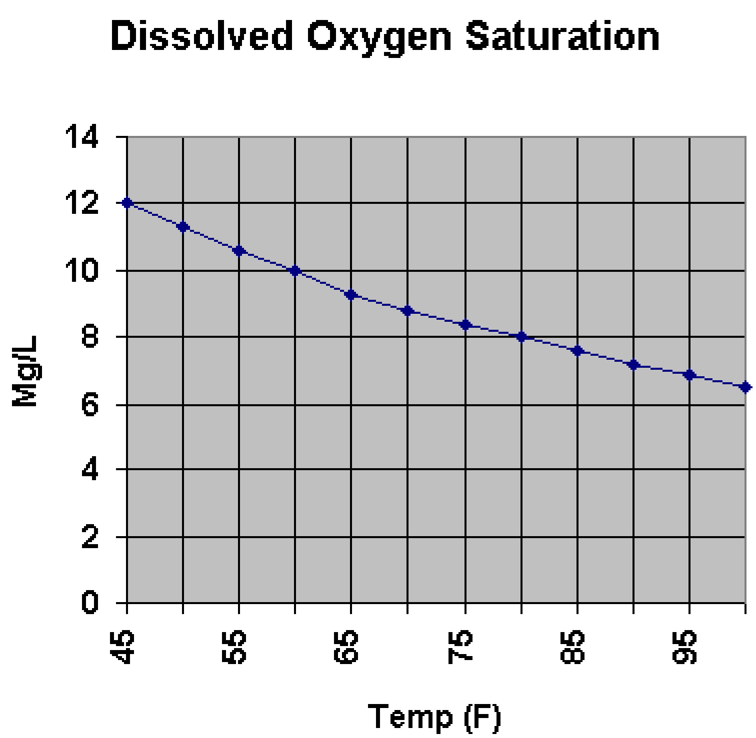
In all cases, try to feed only what the fish will normally consume in about 10 minutes.
Remove any uneaten food within an hour.

Fish do not like changes in their environment of any kind, including temperature. Any changes add stress to the fish and the larger and faster the changes, the greater the stress. This is considered by many to be the primary reason that fish do better in larger ponds. Another time that the Koi are subjected to stress from temperature changes is when they are being transferred to a pond from another location. My recommendation is that if the fish have been bagged for more than four hours, it is better to release them immediately than to subject the fish to the "bad" water in the bag for an additional half-hour. Thirty minutes of floating will prevent a sudden shock if the temperature difference is large, but it will not acclimatize the fish to the new temperature. Actual temperature acclimation of a fish takes several days, similar to us dealing with jet lag. It is not only the temperature the fish need to be accustomed to but also the pH, hardness, alkalinity, "the taste", etc. of it's new surroundings.

Other than providing some shade (summer and winter), little can be done or normally needs to be done to control an outdoor pond's temperature. A waterfall in dry climates can provide significant "swamp cooler" action and a large waterfall can provide considerable cooling (at a sacrifice of additional water evaporation losses). This same action can occur in the winter time as well and should be taken into account during the winter in cooler climates.

DISSOLVED OXYGEN

The earth's basic air envelope is made up of about 78% nitrogen, 21% oxygen, and 0.03% carbon dioxide. There are also traces of several other elemental and molecular gasses but they will be ignored since they have no known effects within the pond environment. Concentrations of these gases within water is a whole different story. The concentrations are much smaller and are measured in milligrams per liter (mg/l) or somewhat equivalently, in parts per million (ppm). A typical pond at a temperature of 70^{O} F. will have concentrations of about 13 mg/l nitrogen, 9 mg/l oxygen, and 35 mg/l carbon dioxide. As the air components dissolve into the water, a point is reached where no more can be added. This point is called saturation. The saturation points are different for each of the gases and are dependent upon several different factors but temperature is the most important. As the temperature increases, the water simply cannot hold as much of each type of gas. For oxygen, (See figure 2.) the approximate saturation level at 50^{O} F. is 11.5 mg/l; at 70^{O} F., 9 mg/l; and at 90^{O} F., 7.5 mg/l. Impurities added to the water (i.e. salt) or an increase in altitude (above sea level) further decrease these saturation levels. Four pounds of salt per hundred gallons of water (5 ppt) will decrease the oxygen saturation levels about 1 mg/l.



Fish are remarkably well adapted for extracting oxygen from the very low concentrations found in water. The rate of oxygen consumption by Koi is closely related to the water temperature. Koi are "cold blooded", that is, their body temperature is essentially that of their environment. Their metabolic activities are basically enzyme-catalyzed chemical reactions that are temperature dependent. The metabolism and activity increase with temperature which increases their oxygen demand. There is both an optimum and maximum temperature at which the Koi live and function. At optimum temperature, oxygen consumption is high because of rapid growth and significant activity. Above this optimum temperature, the fish start to experience stress. This stress triggers their warning and defense systems which require a very high oxygen consumption. Unfortunately, as we saw above, the amount of oxygen available in the water also decreases with temperature. The combination of these two events normally limit the maximum temperature at which the Koi can survive.

Effects:
The minimum limiting oxygen concentrations for a fish is dependent upon its genetic makeup, water temperature, level of activity, long term acclimation, and stress tolerance. Water with an oxygen concentration of less than 3 mg/l will generally not support fish. When concentrations fall to about 3-4 mg/L, fish start gasping for air at the surface or huddle around the water fall (higher concentration points). Bio-converter bacteria may start to die, dumping toxins into the water and compounding the lack of oxygen to the fish. Levels between 3 and 5 mg/l can normally be tolerated for short periods. Young Koi are less tolerant of low oxygen than the older, larger ones although the larger ones consume considerably more oxygen. Above 5 mg/l, almost all aquatic organisms can survive indefinitely, provided other environmental parameters are within allowable limits. Whereas the fish are reasonably comfortable and healthy at 5-6 mg/L concentrations, many people consider the efficiency of the bio-converter to be at maximum only when the water entering the bio-converter media is near oxygen saturation. Ideally, our ponds should be at or near oxygen saturation at all times.

Measurement:
Pill, powder, and droplet (or combination) test kits are available. Most involve three steps and a final color metric chart. Recommended test kit range 0 - 15 mg/L. Note: Some test kits can show false readings if various chemical treatments are in the water. Electronic dissolved oxygen meters are also available. These are accurate and convenient, but quite expensive. A dissolved oxygen test kit is considered nice to have but not required for the average pondkeeper.

Source:
Whenever air is in contact with the water, whether through natural or artificial means, a transfer of oxygen from the air to the water takes place until the water becomes saturated. Plants under light convert carbon dioxide to oxygen in the water. Fish, plants at night, and aerobic bacterial action consume the oxygen.

Treatment:
It is not difficult to get all the air into the water that the fish need. Oxygen is continually transferred into the water at the surface of the pond and normally only a small water fall will bring the pond water to or near to saturation. Heavily populated ponds may need supplemental air and ponds with a large amount of algae may need supplemental air at night when the plants are not making oxygen but consuming it. It is very important that sufficient circulation is provided within the pond so that all areas have proper oxygenation.

Well water often has almost no oxygen content. When adding well water to a pond, use a fine spray nozzle over the surface of the pond or a great deal of agitation to add oxygen to the makeup water.

Almost all of the oxygen dissolved into the water from an air bubble occurs when the bubble is being formed. Only a negligible amount occurs during the bubbles transit to the surface of the water. This is why an aeration process that makes many small bubbles is better than one that makes fewer larger ones. The breaking up of larger bubbles into smaller ones also repeats this formation and transfer process.

A "sheet" type waterfall can provide more dissolved oxygen in a pond than the "cascade" type waterfall whose velocity is low when the water finally enters the pond. Although the cascade type waterfall provides better aeration of the water that is entering the pond, the sheet type provides better aeration of the water that is already in the pond. The sheet of water tends to shear the larger bubbles of air formed at surface entry into smaller ones below the surface. This action can occur at depths of up to three feet or more and result in oxygen transfer to a much larger amount of water than just that which is entering the pond. For most situations, the amount of water flow is determined by filtration requirements and either type will be more than sufficient to maintain the pond oxygen levels at or near saturation.

A common method of providing additional oxygen to the water is through the use of an eductor type air jet (sometimes called a venturi). An added advantage of this device is that it can simultaneously provide improved circulation of the pond water.

Air stones or similar bubble forming devices driven by an air pump can also be used to provide supplemental air. A single air stone can supply sufficient air for up to a 1000 gallon pond although pond water circulation problems may still exist. It is recommended that a backup air pump with tubing and air stones (size and quantity depending on pond size) be kept on hand in case of main water pump malfunctions. This could also be used to supply air to an isolation tank if needed. In an emergency, just splashing the water by hand or with a bucket can add enough oxygen to sustain the fish (particularly in a small pond) until the problem is corrected.

When a power loss or other malfunction causes water flow to stop and hence most aeration to also cease, several problems develop. The oxygen concentration drops and ammonia starts building up. The size and population density of the pond will determine how long before this becomes a problem but the bacteria in the bio-converter will start dying off at about the 4 hour point without circulation. After about 4 hours, it is important that before flow through the bio-converter is restored, it should be drained to remove any toxins released by the dying bacteria. The ammonia levels and nitrite levels should then be monitored closely for the next few days.

Note how this implies the importance of oxygenated water being circulated through the filter 24 hours a day. The pumps moving water between the pond and the filter system should never be shut off except for short periods during maintenance. If the pond design includes water features such as fountains or large water falls that are desired to be shut off at times, they should be provided with a pump separate from the filtration system pump.

Oxygenation During Transport

When plastic bagging fish for transport, use only enough water to just cover the dorsal fin. Ensure the bag is of sufficient size that the fish can have an inch or more space from the sides and ends of the bag (and sufficient strength to support the weight of the water and fish. 3-4 mil thick bags are normally used). Squeeze out the current air, add 5-10 times the amount of oxygen as water. This is normally sufficient oxygen for up to 24 hours. If oxygen is not available, just the air in the bag is sufficient for an hour or so.

Ammonia build up and temperature control then become the major problems. Placing the bags in a Styrofoam picnic cooler can help maintain temperature controls. Cover the top of the box that the bags are in. The darkness soothes the fish a bit and thus decreases the ammonia generation. If transporting in a car, put the cooler in the passenger compartment, not the trunk. This is of more importance during the summer than winter but applies to all times. Do not leave them in a locked car while stopping for lunch, use a fast food drive through.

Based on reported controlled experiments, it was found that floating transport bags in the pond for 30 minutes prior to release slightly decreased the mortality rate, particularly for small fish. This test was conducted with the fish bagged for one hour. For fish that had been bagged for four hours, it was found that the mortality rate increased slightly for all sizes of fish if the bag was floated for 30 minutes. My recommendation is that if the fish have been bagged for four or more hours, and the temperature difference between the transport water and pond water is less than 10 degrees, it is better to release them immediately than to subject the fish to the "bad" water in the bag for an additional half-hour. Thirty minutes of floating will prevent some shock if the temperature difference is large, but it will not acclimatize the fish to the new temperature. Actual temperature acclimation of a fish takes several days, similar to us dealing with jet lag. It is not only the temperature the fish needs to be accustomed to but also the pH, hardness, alkalinity, "the taste", etc. of it's new surroundings.

Remember the relationship between pH and ammonia toxicity? When the fish are in their sealed transport bags and expelling carbon dioxide, it causes the pH to drop. This makes the ammonia less toxic. I have made measurements of fish bagged for over 24 hours and found pH readings below 5.0 with ammonia concentrations over 12 ppm. Yet the fish were in very good condition. When floating a bag, do not open the bag until ready to release the fish and **DO NOT MIX ANY POND WATER WITH THE TRANSPORT WATER**. Just opening the bag can release some of the built up carbon dioxide thus raising the pH, and even worse, mixing pond water into the transport water can suddenly raise the pH to where the ammonia is highly toxic. Bottom line is never add pond water to transport water and never add transport water to pond water.

If a transport tank is being used for moving fish, an air stone or aeration column can be used. A venturi (air jet) is not recommended since the strong currents induced require the fish to "work" harder which increases both the oxygen consumption and, of more importance, the ammonia waste products in the small tank. An air stone can be fed directly from bottled oxygen or from a small air pump. An aeration column can be fed from a small submersible water pump ideally located at the opposite corner or end from the aeration column. Fish can be transported more safely in a sealed, oxygenated bag than in a transport tank.

> **CAUTION**: Make sure that the transport tank's air supply cannot be contaminated with the vehicle's exhaust. Carbon Monoxide is very soluble in water and can be even more deadly to the fish than to you.

SALINITY

Common salt, sodium chloride, NaCl, has been termed "The KOI Wonder Drug". A misnomer perhaps, but salt is a proven staple in the health care and maintenance of Koi worldwide. Koi maintain an internal concentration of salt in their body fluids higher than that of their liquid environment. Osmosis causes water to transfer from the lower salinity of the pond water into the tissues of the fish. This additional water build up must be eliminated by the kidneys. Although salt in higher concentrations may slow some disease causing bacterial growth in the pond, the predominantly accepted theories ascribe the primary benefits of salt to lowering the osmotic pressure. This reduces the effort the fish must expend in eliminating the excess water. The saved energy is then available for use by the fish's own immune system to take care of other potential problems. The presence of salt also helps counteract any nitrite toxicity. In some cold climate areas, it is added in the Winter to lower the freezing point of the water.

Salt can cause pond plant damage as the concentration increases. Floating plants, (water hyacinth, water lettuce, etc.) are affected at lower concentrations than most bog plants. Related, salt may provide some minor control of algae in the higher concentrations.

The amount of salt dissolved in water is termed the salinity and is measured either as a per cent, in parts-per-thousand (ppt), or in parts-per-million (ppm) (where 10 ppt = 1% = 10000 ppm). The more common parts-per-thousand measurement is the weight of the salt in pounds per thousand pounds of water (about 125 gallons). Pond-keepers often talk about the pounds of salt per hundred gallons of water. Since 100 gallons of pure water weighs about 800 pounds, one pound of salt per hundred gallons equates to a salinity of 1.25 ppt (0.125% or 1250 ppm). (1 ppt = 0.8 pounds per hundred gallons)

[Note: Koi internal fluid salinity is on the order of 9 ppt (about the same as ours). Sea water is around 35 ppt to 70 ppt depending upon geographical location. The Great Salt Lake has a nominal concentration of about 250 ppt.]

There is some disagreement about salt in Koi ponds. Our San Diego tap water often has a salinity of up to 0.5 ppt. This amount cannot be tasted but we drink it and we put it into our ponds as make up water. If our Koi were put into an absolutely pure (distilled) water environment, the osmotic pressure would be so high that some would be unable to eliminate the excess water and would die almost as if by drowning. On the other hand, if the salinity approaches that of the internal tissues of the fish, the osmosis process will decrease or even reverse. This can cause the fish to die, essentially of dehydration. Any discussions should therefore center not on should salt be in the pond but how much.

Salinity acceptable range: 0 - 5 ppt

The addition of one to two pounds of salt per hundred gallons of water (1.25-2.5 ppt) is recommended for most ponds, especially in the Spring and Fall. This is a fairly conservative dosage but unless one has an accurate measurement method, higher concentrations should be avoided. If nitrite is present, two pounds of salt per hundred gallons is appropriate to reduce the nitrite toxicity. After the initial application, the dosage applies ONLY to the amount of water being taken out and replaced, NOT to the amount of water in the entire pond, and NOT to water being added to replace that lost by evaporation. Except for very short-term medicinal baths at concentrations often around 25 ppt (1 pound per 5 gallons), and administered under tightly controlled conditions, it is not recommended that Koi be subjected to a salinity exceeding 5 ppt (4 pounds per hundred gallons), especially for extended periods.

Salinity levels are normally maintained by the addition of salt to increase it and by water change outs to decrease it. Introduce the salt, if possible, at the discharge side of the bio-converter (not at the bio-converter inlet nor directly into the pond). If the addition must be made directly into the pond, dissolve the salt in a bucket of pond water and distribute it evenly around the edges of the pond. Inquisitive Koi will check to see if any new addition to the pond might be something to eat. Although they will probably not swallow the pieces of salt, direct contact of crystalline salt with the fish for more than a few seconds can cause injuries similar to burns. When making the initial or any large application, it is probably better to divide it into two to four daily partial additions rather than putting it in all at once. Inexpensive and quite pure solar-dried or kiln-dried salt used in home water softeners is available at most supermarkets and home improvement centers. Do not use pelletized water softener salt that has binding agents or any type of iodized salt.

The floating hydrometers that are used to measure the salinity of salt water aquariums will not supply the accuracy necessary for use in a Koi pond. Electronic conductivity meters will give an indication of the amount of salt but can give false readings due to other substances in the water. A chemical test kit is available from LaMotte that is designed to measure 0-20 ppt. By increasing the sample size by four and dividing the reading by four, the kit can be used to measure our desired range of 0-5 ppt. Aquarium Pharmaceuticals also has an inexpensive salinity test kit available that is quite accurate over the designed range of 0-2.4 ppt. The water sample can be mixed with an equal amount of distilled water and then multiply the reading by two to extend the range to 0-4.8ppt.

A salinity test kit is not considered to be a requirement for the average pond but one should be used if attempting to maintain salinity levels above 4 ppt.

CHLORINE

Measurement:
Chlorine (Cl), measured in ppm, is a gas which has been added to tap water to control harmful bacteria. City provided tap water is normally found to have 0.5 - 3.0 ppm but higher surges are sometimes observed. Some city water supplies can still be found that either do not require chlorination or may have the chlorine removed before the water is distributed. This would not be of concern to those who take their tap water directly from a private well. Droplet and pill test kits are available. Recommended test kit range 0 - 4 ppm. A chlorine test kit is not considered necessary for the average pond.

Acceptable concentration 0

Effects:
Chlorine is a quick killer in fairly low concentrations (less than 0.5 ppm). Even in very small concentrations, it burns the edges of the gills with long term after effects. It also can be deadly to the bio-converter bacteria.

Treatment:
In an open container, water will release about 1/4 of the chlorine concentration per day to the air . Water that has set in an open container for a week or just for a couple days if aerated, is normally safe to use or better yet, pretreat tap water with one of the commercial chemical products. Follow the manufacturer's directions (Or make your own).

Homemade Chlorine Neutralizer

Make a solution consisting of 4 ounces (1/4 lb) Sodium Thiosulfate crystals (photo or technical grade) dissolved in 1 gallon of distilled or deionized water. Use 5 ml (1 teaspoon) of the solution for each 10 gallons of makeup water to neutralize up to 3.75 ppm chlorine. One cup can be used for each 500 gallons. (The entire one gallon of solution will treat about 7500 gallons of tap water.) The shelf life of the solution is about six months when stored in a cool location. The crystals will keep for several years if kept dry.

When pretreating replacement water, the dosage is for the quantity of water being replaced, not the total pond capacity! Although it would be better to treat all tap water being added, small amounts of replacement water without dechlorination treatment are often added without noticeable effects to the fish. It is recommended that any time more than one percent of the pond water is being added, it be treated. Do not use chlorinated tap water to clean your bio converter (filter) media unless you are actually trying to sterilize it. Water from the pond is a much better choice for this task.

CHLORAMINE

Chloramine is a compound of chlorine and ammonia that is also added to tap water to control bacteria. It can also be formed by adding water containing free chlorine to a pond containing ammonia. If any ammonia is present in a pond, be sure and treat it before adding any tap water containing chlorine. To determine if chloramine is in your tap water, fill a 5 gallon bucket with tap water, add the proper amount of chlorine neutralizer, and then test the water for ammonia using your ammonia test kit. Chloramine is present if a positive indication of ammonia is found. Chloramine is difficult to measure quantitatively in low concentrations, and particularly when a combination of chlorine and chloramine is present.

Acceptable concentration 0

Chloramine does not decrease concentration nearly as fast as chlorine when exposed to air. It produces the same general effects as chlorine but is usually found in the lower concentrations that result in long term damage to the fish. The same treatment actions as for chlorine apply except that the ammonia remains after neutralization. A "healthy" bio-converter will take care of the ammonia or a chemical treatment may be used. Some commercial products incorporate treatment to both neutralize the chlorine and bind the ammonia components at the same time. Check the manufacturer's directions.

WATER CHANGE OUTS

Partial water change outs can reduce the amount of anything dissolved in the water but not totally remove it. Although it is sometimes necessary, draining and refilling a pond should only be used as a last resort! Do not use large water change outs to clear green water conditions. A large water change out will normally make the situation worse, not better. Often, several partial water change outs, performed over a period of days or even weeks, can reduce the concentration of an undesired item to acceptable levels without serious after effects. A water change out reduces the amount of a substance in the water by the same amount as the percentage of water replaced. Remember the concentrations of any "good" stuff in the pond is being reduced at the same time as the "bad" stuff. Also the water being used for replacement may have undesirable components as well.

A water change out is considered to be when a measured amount of water is removed from the pond and then replaced. Just adding water and letting the pond overflow will not accomplish the desired results unless significantly more water is transferred. Water added to replace that lost by evaporation is not part of a change out.

Example: It is desired to decrease the Salt in a pond by one half. Any of the following will have the same approximate result:

a. Seven successive 10% change outs.
b. One 25% change out followed by four 10%.
c. Two successive 25% change outs followed by one 10%.
d. One 50% change out.

Depending on the urgency to carry out the action, the largest number of change outs over the longest time would be the best approach.

Unfortunately, this does not apply in the same way to pH. The change in pH for a given water change is dependent upon the Alkalinity and pH in the pond as well as the Alkalinity and pH of the replacement water. Adding water with a higher pH than the pond water will raise the pond water pH but it is difficult to predict how much. Remember that if the water being added to the pond has a pH higher than that of the pond, make sure any ammonia in the pond has been treated before adding the new water.

It is considered appropriate to change out from 5 to 10 percent of a pond's water per week. A small pond (500 gallons or less) should receive the 10% weekly change out. The 5% change out is appropriate for larger ponds (5000 gallons or more). Any water replaced after a back flush of a filter system or other maintenance actions can be included as being part of this weekly change out amount.

It is very common for pond keepers to skip making these routine water changeouts. After all the pond is full of water. Why should we just dump some of it and refill it? Many components in the water build up over time and this is the only way to reduce them. Experienced pond keepers know that their fish are healthier and stronger when these water changeouts are conducted.

When making the water replacement with tap water that contains chlorine and/or chloramine, it would be better to pretreat the water with the chlorine neutralizer before adding it to the pond (particularly small ponds). If this cannot easily be done, use a fine spray of water over the pond and divide the total computed neutralizer dosage into two to four parts and add while the makeup water is being added. **Don't Forget To Turn Off The Water!** Set a timer or do something to remind you that makeup water is running into the pond. Inexpensive flow timer shutoff devices that hook directly on the hose are available and are a good safety item to use.

GREEN WATER

Although it is sometimes called an algae bloom, normally the names it is called are unprintable. For some, it seems to happen every Spring (also sometimes in the Fall). For others, it is almost a way of life. A limited number of pond keepers have never or rarely experienced this "wonder" of nature. It is said that the Koi thrive in it, but you cannot see them to tell if they are thriving or not. You have heard many reasons why your water turns green and tried assorted mechanical wizardry and various chemical concoctions to clear it, (which may or may not have been harmful to your Koi), but it is still green. There is a lot of "snake oil" out on the market to clear green water.

Green water is caused by an excessively large number of tiny organisms in the water. Called phytoplankton, these minute plants are part of the algae family that has thousands of distinct species found in water (and ice) throughout the world. These organisms are very small, with the most common ones found in our ponds being around 15 microns (0.0006 inches) in diameter. All pond water contains large numbers of different kinds of these plants and other microorganisms. Water that appears to be crystal clear just doesn't have as many.

Some of the statements that follow are somewhat controversial, but they are based on several years of research and experimentation dealing with the subject. From this research, I have concluded that within our biologic converters, a third group of bacteria exist. When these heterotroph bacteria consume dead algae in an aerobic environment, they release an enzyme, possibly used to help them digest the dead algae. The flow of water through the media carries surplus amounts of this enzyme back into the pond where it Akills@ off the other algae.

This enzyme appears to be effective against many species of string algae as well as the bloom algae. It does not seem to have as much effect on the string algae which is only partially submerged or within a high flow area, i.e. in a splashing brook or around a waterfall. This may have to do with contact time requirements. The short blackish-green mat algae found on the walls of a "healthy" pond is composed primarily of dead string algae which is also believed to be a result of control by the antibiotic. Further, this mat area may also be providing a portion of the enzyme as it is being broken down by the heterotroph bacteria.

This seems to explain what we see in our ponds much better than many of the traditional myths which I believe arise from invalid extrapolations and application of true scientific findings based on studies of large lakes and oceans. Most of these findings just simply do not apply to the essentially closed environment of an established, circulating Koi pond. We will discuss only two of the myths here. For more and a detailed description of the experiments leading to these conclusions, see my article in the Mar-Apr 1998 issue of KOI USA.

MYTH: Pond algae blooms are primarily related to various nutrient concentrations in the water such as nitrate and/or phosphate.

FACT: There is no evidence to substantiate any relationship between nutrient levels and the inception or termination of the common algae blooms in most Koi ponds. Quite to the contrary, the measurable nutrient levels are normally so high, most questions should be why the algae bloom is not continuous. Commercial laboratory analysis consistently show very high concentrations of all required nutrients. These concentrations are much higher than could be expected to prevent such an event. Further, most of these levels actually show a slight increase after a heavy bloom subsides.

MYTH: Providing shade over the pond will prevent an algae bloom.

FACT: It is true that algae needs light to grow and reproduce. But what is interesting is the small amount of light that is actually required. Controlled experiments using reduction in sun light of 90% still show significant algae growth. There are many examples of ponds that are heavily shaded but quite green and just as many others with direct sun exposure that have no algae bloom problems at all. There have been positive results reported of completely covering a pond suffering from green water with an opaque plastic cover for 5-10 days. I'm not too sure what the Koi think about this but it is obviously not an acceptable permanent solution. I do recommend providing shade over a pond, but more for temperature stability than for algae control.

So, what is the solution? It seems to be simply a properly sized biologic converter and a proper flow rate of oxygenated water through it. The bio-converter must be large enough to support the heterotroph bacteria colonies which need considerably more space than just the nitrification bacterial colonies. This has led to two rules of thumb. The first is that the amount of water in the pond and filter system should be circulated through the bio-converter at least once per hour. Second is that a flow rate of approximately 150 gallons per hour per square foot of media should be used. As an example of a 1500 gallon pond, we should be moving 1500 gallons of water through the bio-converter each hour and the bio-converter cross sectional area exposed to water flow should be 10 square feet. The thickness of the media is determined by the media selection.

Bubble bead or similar type pressurized filters do not generally have sufficient internal surface area to support the heterotroph colonies necessary for the enzyme production although they can provide the area necessary for the smaller nitrification colonies. They do an excellent job of capturing the dead algae and other solids. During the frequent backwashing processes, however, the dead algae and much of the heterotroph bacterial colonies are removed from the system giving insufficient time for the enzyme to be produced. This is why ponds using these type filters almost always require an ultraviolet system to handle the green water problem. A properly sized UV system will do a good job on eradicating the bloom algae. It will not affect the string algae, only the phytoplankton that actually pass through the unit. There are also some indications that the UV radiation may destroy or at least weaken any enzyme action.

POLLUTANTS

This catch all category of pollutants means anything added to the pond that is not wanted in the pond. Pollutants can consist of items which may or may not be harmful to the fish and they may or may not be visible. They may float on the surface, sink to the bottom or dissolve into the water. They may come from outside the pond or from within the pond itself, i.e. oil leaking from a submerged pump. Some pollutants are easy to identify and control and/or remove, i.e. leaves, pollen, dead rats, etc. Some just add to the filter load if not removed but cause little other problems if not in excessive amounts, i.e. bird droppings. Most of the harmful pollutants that dissolve into the water are hard to identify or quantify. Surface water runoff that can enter the pond is often a major source of pollutants. This is why all ponds should be designed with a raised edge or at least some type of channel around it so that the surface water will not enter the pond. Any roof runoff from adjacent buildings should also be controlled. Other than preventing these pollutants from being introduced into the pond, they can only be controlled through water change out procedures.

Here in sunny southern California, where we get very little rain over long periods of time, heavy buildups of "stuff" on the covers, shade cloth, plants, or trees hanging over our ponds often occur. When it does rain, all of a sudden there is a large amount of this material that is washed off and added to the pond water with possible detrimental effects. (We are all familiar with oil coming up from the roadways during a rain following a dry spell and how the cars go slip-sliding down the interstate.) If the material overhanging the pond is rinsed off with a hose every couple of weeks, then the individual additions are much smaller and are more easily controlled through the routine water change outs. This rinse down of overhanging material should be part of each pond keeper's routine pond maintenance (at least montly).

TOXIC PLANTS

One pollutant area that is often overlooked by pond keepers has to do with the plants in the pond or those that are part of the landscaping around (and over) the pond. The seeds of most plants can swell and plug up the digestive tract of the Koi. A partial list of the plants or parts of plants that have been reported as having some toxicity to Koi (and pets and people) for various reasons include:

Amaryllis - bulbs	Baneberry - berries, roots	Bird of Paradise - seeds
Black Locust Bark - sprouts, foliage	Boxwood - leaves, stems	Buttercup - sap, leaves
Calla Lily - leaves	Cherry - bark, twigs, leaves, pits	Coral Plant - seeds
Daffodil - bulbs	Datura - berries	Death Camas - all parts
Eggplant - all but fruit	Elephants Ear - leaves, stem	English Ivy - berries
Foxglove - leaves, seeds	Hemlock - all parts	Holly - berries
Hyacinth - bulbs	Indian Turnip - all parts	Iris - bulbs
Jasamine - berries	Java Bean - uncooked bean	Lantana - immature berries
Laurel - all parts	Locoweed - all parts	Marijuana - all parts
Mayapple - all parts	Mistletoe - berries	Mock Orange - fruit
Morning Glory - all parts	Narcissus - bulbs	Oak - acorns, foliage
Pine - sap	Poinsettia - leaves, flowers	Potato - eyes, new roots
Privet - berries, leaves	Prunus varieties - seeds, some	Redwood - sap (from decks also)
Rhubarb - leaves	Ranunculus - all parts parts	Snapdragon - all parts
Snowdrop - all parts	Tiger Lily - all parts	Tomato - leaves
	Tulip - bulbs	
Have you identified all the plants in, over, and around your pond?		

FINAL THOUGHTS

Keep good records of your pond. A chronological log of chemical test results, treatments, maintenance actions, water change outs, and even addition or removal of fish can help determine the cause (and required treatment) of a future problem. I keep mine in a computer file but just a simple notebook is all that is needed.

Keep chemical test apparatus clean. Scrub out the test vials periodically. Just rinsing with pond water doesn't get out all the residue buildup. Whenever you buy a test kit, write the purchase date on it. If not otherwise stated on the test kit, replace any liquid based test kits every year. Replace the sealed packet dry powder and pill based kits every two years.

Be careful about anything that you put in your pond! Know your pond capacity and carefully calculate and measure dosages. Know what you are treating for; it is usually better not to treat at all than to dump in something because you think there might be a problem. Second only to ammonia poisoning, more Koi have died from improper treatment with medicines and chemicals than for any other reason.

Many times, the first indication of a problem can be detected by simply watching the behavior of the fish. Changes to their normal activities means it is time to get out the test kits. This is the best part of having the pond anyway so spend some quality time with your Koi and get to know them.

Approximate Conversion Factors

1 fluid ounce = 1.04 ounces (avoirdupois) = 29.5 ml
1 ounce (avoirdupois) = 28.35 grams
1 lb = 16.0 ounces (avoirdupois) = 454 grams
1 gallon = 4 quarts = 8 pints = 16 cups = 128 fluid ounces
1 gallon = 231 cu in= 8.33 lbs (pure water weight) = 3.79 liters
Note: 1 English (Imperial gallon) = 1.2 U.S. gallons
1 quart = 2 pints = 4 cups = 32 ounces = .945 liters
1 pint = 16 ounces = 2 cups
1 cup = 8 ounces = 16 tablespoons = 236 ml
1 tablespoon = 3 teaspoons
1 teaspoon = 5 ml = 110 drops (depends on dropper)
1 gallon/hr = 3.82 cu in/min
1 gallon/minute = 60 gallons/hour
1 gallon/second = 60 gallons/min = 3600 gallons/hour
1 ton = 2000 pounds = 240 gallons of water
1 pound per hundred gallons = 1200 ppm = 1.20 ppt = 0.120 %
1 foot = 12.0 inches = 0.305 meters
1 yard = 3.00 feet = 36.0 inches = .914 meters
1 mile = 5280 feet = 1.61 kilometers
1 acre = 4356 square feet
1 cu in = 0.00433 gal = .0164 liters = 16.4 ml
1 cu ft = 1728 cu in = 7.48 gal = 28.3 liters
1 liter (l) = 1000 milliliters (ml) = 0.001 cu meters = 0.264 gal = 61.0 cu in
1 liter/hr = 1.02 cu in/min
1 meter = 100 centimeters = 3.28 feet = 39.4 inches = 1.09 yards
1 centimeter = 10 millimeters
1 micron = 0.000001 meters = .0001 centimeter
1 kilometer = 1000 meters = 0.621 miles
1 ml water = 1 gram = 1 cubic centimeter
1 kilogram (kg) = 1000 grams (g) = 1000000 milligrams (mg) = 2.20 lb
1 percent (%) = 10 parts per thousand (ppt) = 10000 parts per million (ppm)
1 ppm = 1 mg/l = 1 pound per 120,000 gallons = 1 ounce per 7500 gallons
1 minute = 60 seconds
1 hour = 60 minutes = 3600 seconds

Temperature Fahrenheit <=> Centigrade

$^{O}F = 9/5\ ^{O}C + 32$

$^{O}C = (^{O}F - 32)\ 5/9$