

Interpretation of Water Analysis Reports for Fish Culture

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Some aquaculture producers and pond owners choose to submit water samples to a water quality laboratory for analysis. Water testing services are often available through university laboratories, with sample submission through Extension Service offices. State Departments of Agriculture may also offer testing services, and private laboratories are available as well. Typically, water samples are mailed to or dropped off at a water quality laboratory; the laboratory tests the water and sends the results back. Costs for water analysis vary widely among states and laboratories and with the number of different parameters included in the testing. A “fish pond” test package can cost \$120 or more. In some states, Extension aquaculture specialists and county Extension faculty provide free testing services for common water quality parameters, such as total alkalinity, dissolved oxygen, pH, and ammonia.

This publication provides general guidelines for interpreting water analysis results from freshwater samples. It is essential to realize that these guidelines are necessarily simplifications and could be misleading in certain cases because of interactions among parameters and widely varying water quality tolerances among the many aquaculture species. The reader is encouraged to seek advice from Extension personnel regarding individual water test results.

When is testing useful?

Aquaculture water supply characteristics vary widely among and within locations in the southern region. Levee ponds typically are filled with groundwater from wells; dugout ponds are filled from groundwater; rain and runoff are the major sources for watershed ponds. Hatcheries and fish-holding facilities may be supplied with groundwater, surface water, or both. Waters from wells or springs that tap underground aquifers are often devoid of dissolved oxygen. These waters may also contain high levels of dissolved gasses, such as carbon dioxide and hydrogen sulfide (e.g., rotten egg smell), or metals, such as iron and manganese. On farms with multiple wells, it is important to have each well tested independently because even if wells are in close proximity their waters may have quite different properties. Surface waters are those exposed to the air and sunlight, such as streams, ponds, reservoirs, and lakes. The composition of surface water is influenced by watershed soils, land use, and management practices. It is important to know whether the water sample is from surface water or ground water to interpret the results correctly.

Routine laboratory testing provides useful baseline information on a water source. For example, the calcium concentration in water sources for catfish hatcheries is important because low calcium levels will reduce egg hatching rate and fry survival (see SRAC Publication No. 461). But many water quality problems cannot be detected by routine laboratory testing, including low dis-

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solved oxygen, a common pond problem and the leading cause of fish kills. Dissolved oxygen should be measured on-site, as it may change dramatically during a sample's shipment to the laboratory. Similarly, well water problems such as high carbon dioxide or hydrogen sulfide may not be detected in samples shipped by mail. Water quality parameters such as pH and ammonia can be influenced and altered by organisms (e.g., bacteria) naturally present in pond water samples and are best measured on-site as well. For accurate results, water quality analyses must be performed within a certain time period after sampling. Holding times vary among parameters, typically ranging from 8 hours to 28 days.

In the event of a fish kill, determining the cause requires a rapid response and a range of specialized tests; therefore, routine water analyses may not be helpful (see SRAC Publication No. 472). For help, contact your county Extension agent or the nearest fish disease diagnostic laboratory. If a pesticide is suspected, contact your State Plant Board, Department of Agriculture (Pesticide Division), or Department of Environmental Quality (or equivalent state agency) for advice and information regarding chain-of-custody, sample preservation, and specialized testing requirements. University water quality laboratories typically do not test public samples for pesticides or poisons. Private laboratories will provide such services, but at significant cost. It should be noted that pesticide poisonings are very rarely the cause of fish kills. Most fish kills are caused by low dissolved oxygen.

Examples of reports

Tables 1 and 2 are examples of water analysis reports from laboratories. As they illustrate, there is no standard list of water quality parameters that are measured, and units of measure will vary among laboratories. While some laboratories will conduct individual tests upon request, typically a set of tests is run on a sample. To maximize the usefulness of test results, select a service that provides an "aquaculture" or "fish pond" package if available. If additional tests are needed besides those provided in the package, be sure to request those additional tests.

Units

The specific units of measurement used vary among laboratories. Results are often given in milligrams per liter (mg/L) or parts per million (ppm), which are equivalent units. Results for trace elements, present at very low con-

Table 1. Water analysis report: fish (example).

pH	7.24
Electrical Conductivity	205 μ Siemens/cm
Alkalinity, Total	100.00 mg/L as CaCO ₃
Hardness, Total	103.80 mg/L as CaCO ₃
CO ₃ (Carbonate)	0.09 mg/L as CaCO ₃
HCO ₃ (Bicarbonate)	99.90 mg/L as CaCO ₃
Fe (Iron)	0.05 mg/L
Mn (Manganese)	0.01 mg/L
F (Fluoride)	0.15 mg/L
Cl (Chloride)	3.13 mg/L
SO ₄ (Sulfate)	3.21 mg/L
NO ₃ (Nitrate)	0.04 mg/L
NO ₃ -N (Nitrate-Nitrogen)	0.01 mg/L
NH ₃ -N (Ammonia-Nitrogen)	0.11 mg/L
NO ₂ -N (Nitrite-Nitrogen)	0.00 mg/L
PO ₄ (Phosphate)	0.06 mg/L

Table 2. Example of a water analysis report.

Parameter analyzed	Results	units
Calcium (Ca)	76	ppm
Magnesium (Mg)	18	ppm
Sodium (Na)	979	ppm
Potassium (K)	71	ppm
Boron (B)	4.02	ppm
Carbonate (CO ₃)	0	ppm
Bicarbonate (HCO ₃)	367	ppm
Sulfate (SO ₄ calculated from total S)	601	ppm
Chloride (Cl-)	1471	ppm
Nitrate-N (NO ₃ -N)	11.15	ppm
Phosphorus (P)	0.06	ppm
pH	7.33	
Conductivity	4680	μ mhos/cm
Hardness	15	grains CaCO ₃ /gallon
Hardness	264	ppm CaCO ₃
Alkalinity	301	ppm CaCO ₃
Total Dissolved Salts (TDS)	3598	ppm
SAR	26.2	
Charge Balance (cation/anion*100)	81	

centrations, are often given as micrograms per liter ($\mu\text{g/L}$) or parts per billion (ppb). A $\mu\text{g/L}$ is 1/1000 of a mg/L ; for example, 25 $\mu\text{g/L}$ is the same as 0.025 mg/L . Instead of the micro symbol (μ), a lower case “u” may be used. In some cases, the concentration of a parameter is below the limits of the test method. Results may then be presented as being less than (<) the minimum level that the analytical method could detect, e.g., < 0.01 $\mu\text{g/L}$. Typical units for conductivity in water samples are either $\mu\text{Siemens/cm}$ ($\mu\text{S/cm}$) or the older $\mu\text{mhos/cm}$; these are equivalent units in that 1 $\mu\text{S/cm}$ = 1 $\mu\text{mhos/cm}$. pH is expressed as a number only, without units.

Phosphorus (P) and nitrogen (N) are primary plant nutrients that occur in water in multiple forms and are expressed in various ways. Note that ammonia, nitrite, and nitrate (forms of nitrogen) will be in units of mg/L or mg N/L . Similarly, phosphorus concentrations will be in units of mg/L or mg P/L . N and P may also be expressed as $\mu\text{g/L}$ or $\mu\text{g N/L}$ and $\mu\text{g P/L}$, respectively. When interpreting test results, it is important to pay attention to the particular unit of measure that is used. As an example, nitrate (mg/L) and nitrate-nitrogen (mg N/L) are two ways of expressing the same parameter. However, nitrate-nitrogen expresses the concentration of nitrate based only on the weight of the nitrogen (N) in the nitrate, while nitrate (NO_3) is the sum of the weight of one nitrogen atom and three oxygen atoms. Nitrogen has an atomic weight of 14, while nitrate has a molecular weight of 62. To convert nitrate-nitrogen concentrations to nitrate, multiply the nitrate-nitrogen concentration by 4.43. For example, a nitrate-nitrogen concentration of 1.8 mg N/L would be equivalent to 8.0 mg/L nitrate.

By convention, total alkalinity and total hardness are expressed as “ mg/L as CaCO_3 .” This is because both of these parameters are composed of mixes of different ions or molecules, each with a different atomic or molecular weight, and the molecular weight of CaCO_3 is 100, facilitating conversions to a common unit. In some cases, hardness values are expressed in units of grains per gallon (gpg); 1 gpg of water hardness is equivalent to 17.1 mg/L as CaCO_3 .

Results may also be expressed as milliequivalents per liter (meq/L), although most aquaculture-related publications use units of mg/L when discussing relevant concentrations. Converting meq/L to mg/L requires that one find the atomic or molecular weight of the substance and the amount of ionic charge, known as the valence state. As an example, let’s convert 1.5 meq calcium/L to mg/L . The atomic weight of calcium is 40, and the valence state is +2, or Ca^{2+} . To obtain mg/L , first divide the atomic or molec-

ular weight by the valence state to calculate the equivalent weight. In this example, 40 divided by 2 would be 20 milligrams/milliequivalent (mg/meq). Then multiply the 1.5 meq/L times the equivalent weight, 20 mg/meq , to obtain the result of 30 mg/L of calcium. Extension personnel can help with unit conversions upon request.

Submitting samples

Testing services usually provide written guidelines for sample collection and shipment, and it is important to follow the specific directions provided by the laboratory you will use. Proper labeling of the water sample is also essential. Typical collection instructions are that a clean plastic bottle with a screw cap is thoroughly rinsed with water from the source to be tested; this is called field rinsing. It is best to partially fill the bottle, cap it, and shake it a few times before discarding the water away from the location where you are collecting the sample. This should be repeated two or three times. After field rinsing, the bottle is then completely filled with water and tightly sealed. In ponds, be careful to avoid contamination from debris, mud, or algae in surface films. Samples should be collected by submerging the bottle completely under the water surface to a depth of about $\frac{1}{2}$ to 1 foot, in a location out several feet from the edge of the pond. Water samples should be kept cool, preferably on ice and out of the sun, and submitted to the laboratory as soon as possible. To preserve water samples until analysis, laboratories immediately chill arriving samples. If possible, reduce delays during shipping and avoid submitting samples at times when they will reach the laboratory on a holiday or weekend, as the unpreserved water sample may deteriorate.

Interpreting results

Typical parameters listed in water analysis reports are explained in the following sections. While some of these parameters are important in fish culture, others are measured incidentally in the process of water analysis and are ordinarily of little concern to fish farmers or pond owners, but may be of interest if the water is used for irrigation.

pH

Desirable range	Acceptable range
6.5 – 9.0	5.5 – 10.0

The pH of water is a measure of how acidic or basic it is on a scale of 0 to 14, with 7 being neutral. In fish ponds, the time of day a sample is taken often influences the pH

because of variations in the carbon dioxide (CO₂) concentration in the water. During the day, as algae and plants in the water remove carbon dioxide for photosynthesis, the pH will increase. At night, the pH will decrease as carbon dioxide accumulates from the respiration of fish, plants, and other organisms. Increasing the total alkalinity concentration in water helps buffer against pH changes. Most fish species do well within the pH range of 6.5 to 9.0. Chronic pH levels below 6.5 may reduce fish reproduction and are associated with fish die-offs that sometimes occur in the late winter. Newly hatched fish (fry) and freshwater prawns are sensitive to pH levels above 9.0 to 9.5. In certain waters (sandy soil, no metals such as aluminum), fish communities may thrive at pH levels below 4.5, but these are unusual conditions. High pH also increases the toxicity of ammonia present in the water (see section on “Ammonia”). For information on managing high pH in ponds, see SRAC Publication No. 4604.

The pH of water sent to the testing laboratory will change during shipment in waters that have large amounts of organic matter (e.g., algae and bacteria) or elevated carbon dioxide concentrations. Nevertheless, pH testing is useful to detect possible mineral acidity. A pH reading below 4.5 indicates that there is strong mineral acidity, which is typically harmful to fish and difficult (expensive) to neutralize. A pH between 4.5 and 6.5 can be increased by adding crushed agricultural limestone to increase the pH of pond bottom soil and the total alkalinity and hardness of the water (see SRAC Publication No. 4100).

Electrical conductivity

Desirable range	Acceptable range
60 – 2,000 µS/cm	30 – 5,000 µS/cm

Electrical conductivity (EC) is a measure of how well a solution conducts electricity. It is related to salt content; the higher the salt content, the higher the EC will be. Freshwater fish generally thrive over a wide range of electrical conductivity. Some minimum salt content is essential to help fish maintain their osmotic balance; the upper range of tolerance varies with fish species. Channel catfish, for example, can withstand salinities up to half-strength seawater (16 parts per thousand) or a conductivity of about 25,000 to 30,000 µS/cm. Electrical conductivity also can be used to give a rough estimate of the total amount of dissolved solids (TDS) in water. Typically, the total dissolved solids value in mg/L is about half of the electrical conductivity (µS/cm). Conductivity changes little during shipment to the laboratory.

Alkalinity, total

Desirable range	Acceptable range
50 – 150 mg/L (measured as CaCO ₃)	More than 20 mg/L and less than 400 mg/L for ponds More than 20 mg/L for hatchery water

Total alkalinity is a measure of the concentration of bases (typically carbonate and bicarbonate) in the water that reduce large and rapid changes in pH. By convention, the units are expressed in mg/L as calcium carbonate (CaCO₃). Total alkalinity of less than 20 mg/L limits primary productivity in water. Ponds with low alkalinity benefit from the addition of lime. See SRAC Publication No. 4100 for information on liming ponds. Application rates of copper sulfate for algae control are based on the total alkalinity of the water, and copper sulfate should not be used at all in waters with fish if the total alkalinity is less than 50 mg/L. Total alkalinity greater than 150 mg/L can cause copper to precipitate from the water, greatly reducing the effectiveness of copper to control algae. The total alkalinity of a surface water sample sent to a testing laboratory usually will not change significantly over a 2- to 3-day shipping period.

CO₃ (carbonate) and HCO₃ (bicarbonate)

Carbonate and bicarbonate, together with dissolved carbon dioxide, are components of total alkalinity. The relative amount of each of these compounds depends upon the pH of the water sample. Thus, there are no specific recommendations for levels of these compounds. See the “Alkalinity” and “pH” sections for more details. SRAC Publication No. 464 provides information on the relationship among these parameters.

Hardness, total

Desirable range	Acceptable range
50 – 150 mg/L as CaCO ₃	More than 20 mg/L as CaCO ₃

Total hardness is generally a measure of the calcium and magnesium concentrations in water. As with total alkalinity, the units are expressed in mg/L as calcium carbonate. Other divalent ions (those with 2+ charges like magnesium) contribute to total hardness but are usually present in small amounts. However, in areas such as the Piedmont, ferrous iron (Fe²⁺) may contribute significantly to groundwater hardness levels. The amount of calcium hardness is important in pond fertilization because higher

rates of phosphorus fertilizer are required at higher calcium hardness concentrations (see SRAC Publication No. 471). At least 5 mg/L of calcium hardness is needed in catfish hatchery water, and more than 20 mg/L is desirable (see SRAC Publication No. 461). Like total alkalinity, total hardness will not change much during shipment.

Ca (calcium)

Desirable range	Acceptable range
More than 20 mg/L	More than 5 mg/L

Calcium is an essential element for fish, and moderate calcium levels in aquaculture water aid in fish osmoregulation during stressful periods. As noted above, calcium is important for egg and larvae development. Most well water has sufficient calcium for hatcheries; 80 percent of the domestic well water sampled by the U.S. Geological Survey had between 7 and 95 mg/L of calcium (DeSimone et al., 2009). However, certain aquifers may have very low levels. Calcium concentrations greater than 400 mg/L may be detrimental to crustaceans and fish.

Calcium and magnesium are the major constituents in total hardness. The typical unit of measure is “mg/L,” not “mg/L as CaCO₃.” Thus, calcium and magnesium concentrations cannot be summed to obtain total hardness.

Some species are very sensitive to unstable pH (such as freshwater prawns, which can die when pH rises above 9.5) so stabilizing pH is imperative. This can be achieved by making sure that calcium hardness is close in value to total alkalinity. Prawn farmers often add a source of calcium to their ponds (such as calcium chloride or gypsum, calcium sulfate) to elevate calcium hardness up to the total alkalinity concentration in the pond water.

Magnesium (Mg)

Magnesium is not normally a limiting factor in freshwater aquaculture. Magnesium is essential for fish growth, but a specific recommended concentration is not available. The U.S. Geological Survey reported median (middle) concentrations in domestic and public well water as 11.0 and 10.7 mg/L, respectively (DeSimone et al., 2009, Toccalino et al., 2010). For inland production of marine shrimp, pond water may require supplementation with both potassium and magnesium, as saline inland waters typically contain less of these elements than dilute sea water of equal salinity (see SRAC Publication No. 2601).

Fe (iron) and Mn (manganese)

Desirable range	Acceptable range
Iron: For hatchery water— Ferrous iron: none Ferric iron: none For pond water—any level of ferric iron, no ferrous iron	Iron: For hatchery water— No ferrous iron Ferric iron—Less than 0.1 mg/L for fry, less than 1.0 mg/L for most fish For pond water—any level of ferric iron, presence of ferrous iron acceptable if limited to zone around water inlet (see text)
Manganese: 0 – 0.01 mg/L	Manganese: up to 1 mg/L

These two elements behave similarly and will be discussed together. Well and spring water may contain elevated levels of iron (ferrous iron) and manganese, but still appear clear to the eye. When the well water is exposed to oxygen, the iron is changed into rust (ferric iron), giving the water a rusty brown color. Water high in iron and/or manganese should be treated before it is used in a fish hatchery. Typically, well water is aerated to oxidize the iron and manganese, and then the water is passed through a sand filter to remove the floc (small clumps). Or, well water can be pumped into a settling pond for oxidation and floc settlement before water is used in a hatchery. Ordinarily, waters high in these elements can be used “as is” for outdoor culture ponds because the iron floc settles to the pond bottom and does not interfere with fish in the water column. If a pond must be stocked immediately after filling, water can be aerated to speed up the oxidation process and render the water safe for fish. While the relative amounts of the various forms of iron or manganese might change during shipment, the total values will be unaffected. The analysis at a water quality laboratory typically does not distinguish between ferric and ferrous iron, so if the total dissolved iron exceeds the acceptable range, contact a fisheries or aquaculture specialist for assistance in developing a plan to manage this parameter.

Cl (chloride)

Desirable range	Acceptable range
More than 100 mg/L (for commercial catfish ponds)	10 times the nitrite concentration (for commercial catfish ponds)

Chloride (Cl) and sodium (Na⁺) together form common salt (sodium chloride). Chloride should not be

confused with the gas, chlorine (Cl₂). *Chlorine* is a highly reactive compound and is used as a disinfectant. *Chloride* is the same element in the form of a salt. While chlorine is very lethal to fish, chloride is a component of most waters and is essential in helping fish maintain their osmotic balance. In commercial catfish production, chloride (in the form of salt) is often added to water to obtain a minimum concentration of 100 mg/L. This is done because catfish and certain other species are susceptible to “brown blood” disease, caused by excess nitrite in the water. Maintaining a chloride to nitrite ratio of 10:1 prevents nitrite from entering the fish, thus reducing the occurrence of nitrite poisoning. Chloride concentrations can easily be increased by adding “mixing” salt to the water. Salt is also often used for the treatment of common fish diseases and parasites. Chloride levels higher than 70 mg/L are a concern if the water is also used to irrigate sensitive land-based crops. Sensitivity to chloride varies widely among plants; contact your Extension office for detailed information.

SO₄ (sulfate)

Sulfate is a common compound in water. It results from the dissolution of minerals from soil and rocks. Typical levels are between 0 and 1,000 mg/L. Some well water and most coastal pond water will have higher sulfate concentrations. Fish tolerate a wide range of sulfate concentrations, and levels of sulfate greater than 500 mg/L are a concern only if the water is used for other purposes such as watering cattle or irrigating crops.

NO₃ (nitrate) and NO₃-N (nitrate-nitrogen)

Nitrate levels in drinking water for humans and livestock are a major concern. The U.S. Environmental Protection Agency (EPA) has set a maximum level of 10 mg/L in drinking water for human consumption. Typical levels in surface waters range from 0.005 to 0.5 mg/L nitrate-nitrogen (NO₃-N). The levels can increase depending upon watershed soils, land use, and fertilizer management. Nationally, the median nitrate-nitrogen concentration in domestic wells tested between 1994 and 2004 was 0.55 mg/L (DeSimone et al., 2009). However, nitrate is relatively non-toxic to fish and is not a health hazard except at exceedingly high levels (more than 90 mg/L NO₃-N).

NH₃ and NH₄⁺ (ammonia)

Ammonia is a dissolved gas present naturally in surface waters, wastewaters, and some well waters. It is

the major nitrogenous waste product of fish and also results from the decomposition of organic matter. It is quite soluble in water, especially at low pH, and ordinarily is removed by plants or bacteria (as a nutrient or energy source). Ammonia in water is present in two forms—unionized ammonia (NH₃) and ionized ammonia (NH₄⁺). The sum of the two forms, expressed in units of nitrogen, is called total ammonia nitrogen, or TAN. The relative proportion of each form depends on pH and temperature. As pH and/or temperature increases, the proportion of unionized ammonia increases. Unionized ammonia is very toxic to fish, while the ionized form is much less toxic. Table 3 shows maximum acceptable TAN concentrations (mg N/L) for a range of pH levels and temperatures. The toxicity of ammonia to fish also varies with the fish species and whether the fish has time to adjust to elevated levels. Salmonids (e.g., trout) are generally more sensitive to ammonia than warmwater fish. Catfish acclimate to high ammonia levels given time, and in commercial ponds, 2 to 5 mg/L of total ammonia nitrogen is common in the spring and fall. (For more information on ammonia in fish ponds, see SRAC Publication Nos. 463 and 4603.) Field test kits are available to measure ammonia concentrations on-site. Ammonia values in surface water samples shipped to a laboratory should be used for guidance only, as levels may increase during shipment because of the bacterial decomposition of organic matter, especially during the warmer months. Ammonia levels might also decrease if bacteria convert the ammonia to nitrite and nitrate through nitrification. Shipping water samples on ice will reduce bacterial decomposition and thus stabilize the ammonia concentration.

Table 3. Maximum total ammonia nitrogen concentrations (mg N/L) for warmwater fish, including early life stages (adapted from U.S. EPA, 1999).

pH	Exposure time			
	Acute (1 hour)	Chronic (days)		
		Water temperature (°F)		
		64	75	86
7.0	36.0	5.5	3.2	2.2
7.5	20.0	4.0	2.4	1.6
8.0	8.4	2.2	1.3	0.9
8.5	3.2	1.0	0.6	0.4
9.0	1.3	0.4	0.3	0.2

NO₂ (nitrite) and NO₂-N (nitrite-nitrogen)

Desirable range			Acceptable range		
< 0.1 mg/L NO ₂ -N			Minimum chloride:nitrite ratio of 10:1		
Minimum chloride:nitrite ratio of 20:1					
Concentration (mg/L)			Concentration (mg/L)		
Nitrite (NO ₂)	Nitrite-N	Chloride	Nitrite (NO ₂)	Nitrite-N	Chloride
3	1	20	3	1	10
16	5	100	16	5	50
33	10	200	33	10	100

Nitrite is another form of nitrogenous waste product found in water. Typical concentrations of nitrite-N in pond water range from 0.005 to 0.5 mg/L. Through the process of nitrification, bacteria can transform ammonia into nitrite and nitrite into nitrate. In commercial catfish ponds during the spring or fall, nitrite levels can increase greatly. Salt is added if necessary to prevent “brown blood” disease, caused by elevated nitrite concentrations (see “Chloride” section). The toxicity of nitrite to fish varies greatly with the species of fish. Some species such as trout are quite susceptible, while others such as largemouth bass and bluegill sunfish are very resistant. The desirable concentration for crawfish is less than 0.6 mg/L, and the upper lethal level is 5.95 mg/L (see SRAC Publication No. 240). For more information on nitrite in fish ponds, see SRAC Publication No. 462. As with ammonia, nitrite levels in surface water samples may change during shipment to the laboratory. Icing samples will help stabilize the nitrite levels. High levels measured in water samples should be addressed in consultation with a fisheries or aquaculture specialist.

PO₄ (phosphate)

Almost all of the inorganic phosphorus (P) in water is in the form of phosphate (PO₄). Units of measure for phosphorus may be as phosphate (mg/L) or based only on the phosphorus ion (mg P/L). Thus, 1.000 mg/L of phosphate is equivalent to 0.326 mg P/L. Much of the phosphorus in surface water is bound to living or dead particulate matter. It can be stored in the bottom sediments of ponds. Phosphorus is an essential plant nutrient and, because it is often in limited supply, adding phosphorus to water will stimulate plant and algae growth. This growth of algae can be undesirable, as in the case of pristine clear-water streams and lakes, or desirable, as in ponds for fish culture. The typical range for surface waters is 0.005 to 0.5 mg/L. Groundwater in certain aquifers may contain significant concentrations of phosphorus because of local geology. Ponds in watersheds fertilized with poultry litter or live-

stock manure may be fertile (or excessively fertile) because of the influx of phosphorus from animal wastes. Similarly, in urban settings, phosphorus from lawn fertilizers or leaking septic systems can cause algal growth in waters.

Trace elements: other metals and metalloids

Laboratory testing may include analyses for metals such as boron, cadmium, chromium, copper, molybdenum, nickel, sodium, zinc, mercury, and arsenic; it may also include an analysis for silicon, which is a metalloid (between a metal and a non-metal). Silicon is typically found as silica, silicon dioxide. These trace elements usually come from rock weathering and are mostly found in water at concentrations of less than 1 mg/L. Only rarely are concentrations high enough to be of concern to aquatic life. In general, groundwater in humid regions such as the southern U.S. has lower concentrations of trace elements than groundwater in the more arid west. Toxic levels for metals vary with many site-specific factors (for example, copper and zinc are more toxic at low alkalinity levels). Dissolved metals are typically the toxic form. Metals are often found as salts or in compounds that render the metal relatively innocuous. In general, metals are more soluble, and thus more toxic, at the lower pH levels often found in low alkalinity waters. Given the complex interactions among parameters, it is not possible to list a single toxic concentration for each metal. Information on specific parameters is available in water quality criteria for protecting aquatic life, developed by the EPA and available at: <http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm>.

F (fluoride)

Fluoride is a trace element usually found in water at levels of 0.1 to 1.5 mg/L. It may be added to water to prevent tooth decay in humans (to a concentration of 0.7 mg/L). Levels at or above 3 mg/L are reported to cause losses of some fish species, depending upon complex water conditions.

SAR (sodium adsorption ratio)

Water testing services may automatically calculate the sodium adsorption ratio (SAR) in a water sample. This ratio predicts the extent to which soil-bound calcium and magnesium will be displaced by sodium. For ordinary fish culture purposes, sodium adsorption ratio values are not a consideration. However, if pond water is to be used for irrigation and the sodium adsorption ratio is above 3, consult your Extension Service before irrigating with this water.

Charge balance

A few testing services also calculate what is known as “charge balance,” or the ratio of positively and negatively charged ions (cations and anions, respectively) in a water sample. This is calculated more for internal laboratory purposes and is of no importance to fish culture. In theory, if all the compounds in a water sample could be determined exactly, the charge balance would equal 100, or equality between negative and positive charges. In practice, charge balance reflects the ratio in those elements and compounds that were measured. Non-analyzed substances, as well as sediment and organic matter, will cause it to deviate from 100.

Nutrient concentrations

Just as weeds are defined as plants out of place, elevated nutrient concentrations out of place may also be undesirable. Nutrients in the form of phosphorus and nitrogen are added to ponds to increase the growth of algae (phytoplankton) and make more natural foods available to fish. In this case, elevated levels of nutrients lead to desirable increases in fish numbers and sizes. However, water in such ponds is typically green or brownish green in color, which may be undesirable if ponds are managed for aesthetics. Nutrients may also lead to the growth of nuisance aquatic plants (macrophytes) and filamentous algae, and in rare cases can lead to the presence of some algal species that can produce compounds harmful to wildlife and humans (see SRAC Publication No. 4605).

Some pond owners desire clear water, which requires that nutrient inputs be strictly controlled. According to the EPA (U.S. EPA, 2000), a total phosphorus concentration of more than 0.01 mg/L and a total nitrogen concentration of more than 0.15 mg/L provide sufficient nutrients for algae blooms in the growing season. It may be difficult or impossible to keep concentrations below these levels, especially in areas with nutrient-rich geology and fertile soils or in watersheds with significant human disturbance or livestock production. National background levels in streams, for waters with no human disturbance, were estimated by the U.S. Geological Survey to be 0.034 mg/L total phosphorus and 0.58 mg/L total nitrogen (Dubrovsky et al., 2010). Thus, most streams naturally contain enough nutrients for algal growth, and ponds that fill from streams may develop algal blooms with no added fertilizer. For information on ways to reduce nutrient loading to ponds, contact your county Extension office. Ponds with dense growths of rooted aquatic plants often have clear, low-nutrient water, as the plants remove nutrients from the water column and from the soil.

Table 4. Summary of desirable and acceptable concentrations of selected water quality parameters for fish culture ponds. Units in are in mg/L (except pH).

Parameter	Desirable level (mg/L)	Acceptable level (mg/L)
Alkalinity, total (as CaCO ₃)	50-150	<20 and >400
Ammonia	Varies; see "Ammonia" section for details	
Calcium (Ca)	>20	>5
Chloride (Cl)	>100	10 times the Nitrite level
Hardness, total (as CaCO ₃)	50-150	>20
Iron (Fe)	Differs for hatcheries and ponds	
Manganese (Mn)	0-0.01	≤1
Nitrite-N (NO ₂ -N)	1/10 of Chloride level	1/20 of Chloride level
pH	6.5-9.0	5.5-10.0

Summary

Most waters are suitable for fish production, although tolerances to different water quality parameters vary among fish species. If the water is also used for other purposes, such as watering livestock or crop irrigation, be sure to check recommended levels of the compounds critical for these uses. In all cases, it is important to remember that these tests cannot detect all possible water quality problems because such testing would be prohibitively expensive. Water testing can guide management decisions, assist in determining potential problems, and help increase production. Since water supply characteristics can change over time and with different management strategies, it is important to re-test waters periodically.

Sources of information

Southern Regional Aquaculture Center

The Southern Regional Aquaculture Center publications mentioned are available at: <https://srac.tamu.edu/>

Other publications

Ayotte, J.D., J.M. Gronberg, and L.E. Apodaca. 2011. Trace elements and radon in groundwater across the United States, 1992–2003. U.S. Geological Survey Scientific Investigations Report 2011–5059, Reston, Virginia.

-
- Boyd, C.E. and C.S. Tucker. 1998. Pond aquaculture water quality management. Norwell, Massachusetts: Kluwer Academic Publishers.
- DeSimone, L.A., P.A. Hamilton, and R.J. Gilliom. 2009. The quality of our nation's waters—Quality of water from domestic wells in principal aquifers of the United States, 1991–2004. Overview of major findings. U.S. Geological Survey Circular 1332, Reston, Virginia.
- Dubrovsky, N.M., K.R. Burow, G.M. Clark, J.M. Gronberg, P.A. Hamilton, K.J. Hitt, D.K. Mueller, M.D. Munn, B.T. Nolan, L.J. Puckett, M.G. Rupert, T.M. Short, N.E. Spahr, L.A. Sprague, and W.G. Wilber. 2010. The quality of our nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004. U. S. Geological Survey Circular 1350, Reston, Virginia.
- Florida LAKEWATCH. 2000. A beginner's guide to water management—nutrients. Information Circular 102. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Florida. Available at: http://lakewatch.ifas.ufl.edu/circpdf/folder/102_NUTRIENTS_FINAL_2004Red.pdf
- Florida LAKEWATCH. 2003. A beginner's guide to water management—fish kills. Information Circular 107. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Florida. Available at: http://lakewatch.ifas.ufl.edu/circpdf/folder/fish_kill_LR.pdf
- Gibson, G., R. Carlson, J. Simson, E. Smeltzer, J. Gerritson, S. Chapra, S. Heiskary, J. Jones, and R. Kennedy. 2000. Nutrient criteria technical guidance manual: lakes and reservoirs. U. S. Environmental Protection Agency EPA-822-B00-001, Washington, D.C. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/lakes/upload/2009_04_22_criteria_nutrient_guidance_lakes_lakes.pdf
- Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water. U. S. Geological Survey Water Supply Paper 2254, Washington, D.C.
- Toccalino, P.L. and J.A. Hopple. 2010. The quality of our nation's waters—Quality of water from public-supply wells in the United States, 1993–2007. Overview of major findings. U. S. Geological Survey Circular 1346, Reston, Virginia.
- U.S. Environmental Protection Agency. 2012. Water quality standards handbook: second edition. EPA-823-B-12-002. Available at: <http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm>
- U.S. Environmental Protection Agency. 1999. 1999 update of ambient water quality criteria for ammonia. EPA-822-R-99-014. Available at: <http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/ammonia/upload/99update.pdf>
- Whitford, F., J. Becovitz, B. Robertson, B. MacGowan, G. Blase, B. Avenius, J. Donahoe, D. Zimmerman, and A. Blessing. 2009. What killed the fish? Purdue Extension PPP-79, Purdue University, West Lafayette, Indiana.

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