WATER QUALITY PARAMETERS

Analysts determine water quality by testing for specific chemicals. Most often, the type of water being tested determines what *parameters*, or *analytes*, the analyst looks for. For example, chlorine is an important parameter in finished drinking water, but is not usually a factor in natural water. This section lists common water quality parameters important in drinking water, wastewater, and natural water. Many parameter listings include descriptions of the effects of analyte levels on living organisms.

ALKALINITY

Alkalinity is not a pollutant. It is a total measure of the substances in water that have "acid-neutralizing" ability. Don't confuse alkalinity with pH. pH measures the strength of an acid or base; alkalinity indicates a solution's power to react with acid and "buffer" its pH — that is, the power to keep its pH from changing.

To illustrate, we will compare two samples of pure water and buffered water. Absolutely pure water has a pH of exactly 7.0. It contains no acids, no bases, and no (zero) alkalinity. The buffered water, with a pH of 6.0, can have high alkalinity. If you add a small amount of weak acid to both water samples, the pH of the pure water will change instantly (become more acid). But the buffered water's pH won't change easily because the Alka-Seltzer-like buffers absorb the acid and keep it from "expressing itself."

Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity.

Limestone is rich in carbonates, so waters flowing through limestone regions generally high alkalinity — hence its good buffering capacity. Conversely, granite does not have minerals that contribute to alkalinity. Therefore, areas rich in granite have low alkalinity and poor buffering capacity.

Table 1. Some recommended alkalinity values

Industry and Process	**Recommended Maximum Total Alkalinity (in mg/L $CaCO_3$)**
Carbonated beverages	85
Food products (canning)	300
Fruit juice	100
Washing diapers	60
Pulp and paper making(ground-wood process)	150
Rayon manufacture	50
Tanning hides	135
Textile mill products	50-200
Petroleum refining	500

References 1,2

AMMONIA

Pure ammonia is a strong-smelling, colorless gas. It is manufactured from nitrogen and hydrogen or is produced from coal gas. In nature, ammonia is formed by the action of bacteria on proteins and urea. The Nitrogen Cycle shows the relationship.

Ammonia makes a powerful cleaning agent when mixed with water. For this reason, it is one of the most common industrial and household chemicals.

The formula for ammonia, NH_3, means it consists of one atom of nitrogen and three atoms of hydrogen. Ammonia is rich in nitrogen so it makes an excellent fertilizer. In fact, ammonium salts are a major source of nitrogen for fertilizers. Like nitrates, ammonia may speed the process of eutrophication in waterways.

Ammonia is toxic to fish and aquatic organisms, even in very low concentrations. When levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Ammonia levels greater than approximately 0.1 mg/L usually indicate polluted waters.

The danger ammonia poses for fish depends on the water's temperature and pH, along with the dissolved oxygen and carbon dioxide levels. Remember, the higher the pH and the warmer the temperature, the more toxic the ammonia. Also, ammonia is much more toxic to fish and aquatic life when water contains very little dissolved oxygen and carbon dioxide.

CARBON DIOXIDE

Carbon dioxide is an odorless, colorless gas produced during the respiration cycle of animals, plants and bacteria. All animals and many bacteria use oxygen and release carbon dioxide. Green plants, in turn, absorb the carbon dioxide and, by the process of photosynthesis, produce oxygen and carbon-rich foods. The general formulas for plant photosynthesis and respiration are summarized below.

Photosynthesis (in the presence of light and chlorophyll):

Carbon dioxide	+	Water	à	Oxygen	+	Carbon-rich foods
CO_2		H_2O		O_2		$C_6H_{12}O_6$

Respiration:

+ Oxygen à **Carbon dioxide + Water**

Carbon-rich foods	+	Oxygen	à	Carbon Dioxide	+	Water
$C_6H_{12}O_6$		O_2		CO_2		H_2O

Green plants carry on photosynthesis only in the presence of light. At night, they respire and burn the food they made during the day. Consequently, more oxygen is used and more carbon dioxide enters waterways at night than during the daytime. When carbon dioxide levels are high and oxygen levels are low, fish have trouble respiring (taking up oxygen), and their problems become worse as water temperatures rise. As you can see from the table, even small amounts of carbon dioxide can affect fish.

It's lucky for fish that "free" carbon dioxide (by "free" we mean it is not combined with anything) levels rarely exceed 20 mg/L (milligrams per liter), because most fish are able to tolerate this carbon dioxide level without bad effects.

When several days of heavy cloud cover occur, plants' ability to photosynthesize is reduced. When that happens in a pond containing lots of plant life, fish can be hurt in two ways: by low dissolved oxygen and by high carbon dioxide levels.

Carbon dioxide quickly combines in water to form carbonic acid, a weak acid. The presence of carbonic acid in waterways may be good or bad depending on the water's pH and alkalinity. If the water is alkaline (high pH), the carbonic acid will act to neutralize it. But if the water is already quite acid (low pH), the carbonic acid will only make things worse by making it even more acid.

Table 2. Effects of CO_2 on fish	
CO_2 (in mg/L)	**Effect**
1.0-6.0	Fish avoid these waters.
12	Few fresh-water fish can survive for long periods of time in water with a carbon dioxide level greater than this.
30	Kills the most sensitive fish immediately.
45	Maximum limit for trout
Above 50	Trout eggs won't hatch.
References 2,3	

CHLORINE

Chlorine is a greenish-yellow gas that dissolves easily in water. It has a pungent, noxious odor that some people can smell at concentrations above 0.3 parts per million. Because chlorine is an excellent disinfectant, it is commonly added to most drinking water supplies in the US. In parts of the world where chlorine is not added to drinking water, thousands of people die each day from waterborne diseases like typhoid and cholera.

Chlorine is also used as a disinfectant in wastewater treatment plants and swimming pools. It is widely used as a bleaching agent in textile factories and paper mills, and it's an important ingredient in many laundry bleaches.

Free chlorine (chlorine gas dissolved in water) is toxic to fish and aquatic organisms, even in very small amounts. (See table.) However, its dangers are relatively short-lived compared to the dangers of most other highly poisonous substances. That is because chlorine reacts quickly with other substances in water (and forms combined chlorine) or dissipates as a gas into the atmosphere. The free chlorine test measures only the amount of free or dissolved chlorine in water. The total chlorine test measures both free and combined forms of chlorine.

If water contains a lot of decaying materials, free chlorine can combine with them to form compounds called trihalomethanes or THMs. Some THMs in high concentrations are carcinogenic to people. Unlike free chlorine, THMs are persistent and can pose a health threat to living things for a long time.

People who are adding chlorine to water for disinfection must be careful for two reasons: 1) Chlorine gas even at low concentrations can irritate eyes, nasal passages and lungs; it can even kill in a few breaths; and 2) The formation of THM compounds must be minimized because of the long-term health effects.

Less than one-half (0.5) mg/L of free chlorine is needed to kill bacteria without causing water to smell or taste unpleasant. Most people can't detect the presence of chlorine in water at double (1.0 mg/L) that amount. Although 1.0 mg/L chlorine is not harmful to people, it does cause problems for fish if they are exposed to it over a long period of time.

Effects of chlorine on industrial processes

Chlorine may cause canned or frozen food to taste "funny". It also may effect the smoothness or brightness of plated metals. Chlorine levels as low as 0.3 mg/L can spoil the quality of high-grade paper during the manufacturing process.

Effects of chlorine in water used for irrigation

The concentration of chlorine in city water or treated wastewater rarely reaches 1.0 mg/L (ppm). So chlorine usually is not a problem to farmers and gardeners using either city water or wastewater to irrigate their crops.

Effects of chlorine on fish and aquatic life

The table shows how chlorine affects fish and aquatic organisms. It is important to realize chlorine becomes more toxic as the pH level of the water drops. And it becomes even more toxic when it is combined with other toxic substances such as cyanides, phenols and ammonia.

Phenols are organic chemicals produced when coal and wood are distilled and when oil is refined. Phenols are found in a number of products—from organic wastes to sheep dip. Although phenols are very toxic, dilute solutions of a phenol (carbolic acid) are used as a disinfectant.

Table 3. Effects of chlorine on fish and aquatic organisms

Total chlorine (in mg/L)	Effect
0.006	Kills trout fry in two days.
0.01	Recommended maximum for all fish and aquatic life.

0.01	Kills Chinook Salmon and Coho Salmon.
0.01-0.05	Oysters have difficulty pumping water through their bodies.
0.02	Maximum Brook and Brown Trout can withstand.
0.05	Maximum amount that can be tolerated by young Pacific Salmon in the ocean.
0.1	Kills most marine plankton.
0.25	Only the hardiest fish can survive.
0.37	Maximum fish can tolerate.
1.0	Kills oysters.
References 1	

NITRATES & NITRITIES

Nitrite and **Nitrate** are forms of the element **Nitrogen**, which makes up about 80 percent of the air we breathe. As an essential component of life, nitrogen is recycled continually by plants and animals, and is found in the cells of all living things. **Organic nitrogen** (nitrogen combined with carbon) is found in proteins and other compounds. **Inorganic nitrogen** may exist in the free state as a gas, as **ammonia** (when combined with hydrogen), or as **nitrite** or **nitrate** (when combined with oxygen). **Nitrites and nitrates** are produced naturally as part of the **nitrogen cycle**, when a bacteria 'production line' breaks down toxic ammonia wastes first into nitrite, and then into nitrate. **Sources of nitrites and nitrates**

Nitrites are relatively short-lived because they're quickly converted to nitrates by bacteria. Nitrites produce a serious illness (brown blood disease) in fish, even though they don't exist for very long in the environment. Nitrites also react directly with hemoglobin in human blood to produce methemoglobin, which destroys the ability of blood cells to transport oxygen. This condition is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0 mg/L should not be given to babies. Nitrite concentrations in drinking water seldom exceed 0.1 mg/L.

Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. When it rains, varying nitrate amounts wash from farmland into nearby waterways. Nitrates also get into waterways from lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, animal wastes (including fish and birds), and discharges from car exhausts.

Nitrates stimulate the growth of plankton and water weeds that provide food for fish. This may increase the fish population. However, if algae grow too wildly, oxygen levels will be reduced and fish will die.

Nitrates can be reduced to toxic nitrites in the human intestine, and many babies have been seriously poisoned by well water containing high levels of nitrate-nitrogen. The U.S. Public Health Service has established 10 mg/L of nitrate-nitrogen as the maximum contamination level allowed in public drinking water.

Effects of nitrates and nitrites on fish and aquatic life

Nitrate-nitrogen levels below 90 mg/L and nitrite levels below 0.5 mg/L seem to have no effect on warm-water fish*, but salmon and other cold-water fish are more sensitive. The recommended nitrite minimum for salmon is 0.06 mg/L.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is oxygen that is dissolved in water. It gets there by diffusion from the surrounding air; aeration of water that has tumbled over falls and rapids; and as a waste product of photosynthesis. An over simplified formula is given below:

Photosynthesis (in the presence of light and chlorophyll):

Carbon dioxide + Water à Oxygen + Carbon-rich foods

CO_2 H_2O O_2 $C_6H_{12}O_6$

Fish and aquatic animals cannot split oxygen from water (H2O) or other oxygen-containing compounds. Only green plants and some bacteria can do that through photosynthesis and similar processes. Virtually all the oxygen we breathe is manufactured by green plants. A total of three-fourths of the earth's oxygen supply is produced by phytoplankton in the oceans.

If water is too warm, there may not be enough oxygen in it. When there are too many bacteria or aquatic animal in the area, they may overpopulate, using DO in great amounts.

Oxygen levels also can be reduced through over-fertilization of water plants by run-off from farm fields containing phosphates and nitrates (the ingredients in fertilizers). Under these conditions, the numbers and size of water plants increase a great deal. Then, if the weather becomes cloudy for several days, respiring plants will use much of the available DO. When these plants die, they become food for bacteria, which in turn multiply and use large amounts of oxygen.

How much DO an aquatic organism needs depends upon its species, its physical state, water temperature, pollutants present, and more. Consequently, it's impossible to accurately predict minimum DO levels for specific fish and aquatic animals. For example, at 5 ^{o}C (41 ^{o}F), trout use about 50-60 milligrams (mg) of oxygen per hour; at 25 ^{o}C (77 ^{o}F), they may need five or six times that amount. Fish are cold-blooded animals, so they use more oxygen at higher temperatures when their metabolic rate increases.

Numerous scientific studies suggest that 4-5 parts per million (ppm) of DO is the minimum amount that will support a large, diverse fish population. The DO level in good fishing waters generally averages about 9.0 parts per million (ppm).

When DO levels drop below about 3.0 parts per million, even the rough fish die. The table in this section shows some representative comparisons.

Table 4. Effect of dissolved oxygen level on fish		
Fish Species	Lowest DO level at which fish survive for:	
	24 hours (summer)	**48 hours (winter)**
Northern Pike	6.0 mg/L	3.1
Black Bass	5.5	4.7
Common Sunfish	4.2	1.4
Yellow Perch	4.2	4.7
Black Bullhead	3.3	1.1
References 2		

How Dissolved Oxygen Affects Water Supplies

A high DO level in a community water supply is good because it makes drinking water taste better. However, high DO levels speed up corrosion in water pipes. For this reason, industries use water with the least possible amount of dissolved oxygen. Water used in very low pressure boilers have no more than 2.0 ppm of DO, but most boiler plant operators try to keep oxygen levels to 0.007 ppm or less!

pH

The balance of positive hydrogen ions (H^+) and negative hydroxide ions (OH^-) in water determines how acidic or basic the water is. Notice the ' + ' and ' - ' in the chemical symbols above. They indicate that these chemical forms are 'ions' — they have a positive or negative electrical charge. This means the molecule in question is either missing an electron or has an extra electron. Since electrons have a negative charge, an extra one in the OH molecule makes it OH^-, and a missing one in the H molecule gives it a "missing-minus" charge — in other words, positive — and makes it H^+. When analysts measure pH, they are determining the balance between these ions.

The pH scale ranges from 0 (high concentration of positive hydrogen ions, strongly acidic) to 14 (high concentration of negative hydroxide ions, strongly basic). In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7.

In a lake or pond, the water's pH is affected by its age and the chemicals discharged by communities and industries. Most lakes are basic (alkaline) when they are first formed and become more acidic with time due to the build-up of organic materials. As organic substances decay, carbon dioxide (CO_2) forms and combines with water to produce a weak acid, called "carbonic" acid — the same stuff that's in carbonated soft drinks. Large amounts of carbonic acid lower water's pH.

Most fish can tolerate pH values of about 5.0 to 9.0, but serious anglers look for waters between pH 6.5 and 8.2. The vast majority of American rivers, lakes and streams fall within this range, though acid rain has compromised many bodies of water in our environment.

Synergistic Effects of pH

Synergy is the process whereby two or more substances combine and produce effects greater than their sum. For example, 2 + 2 = 4 (mathematically). But synergistically, 2 + 2 = much more than 4! Synergy is a mathematical impossibility, but it is a chemical reality. Here's how it works:

> When acid waters (waters with low pH values) come into contact with certain chemicals and metals, they often make them more toxic than normal. As an example, fish that usually withstand pH values as low as 4.8 will die at pH 5.5 if the water contains 0.9 mg/L of iron. Mix an acid water environment with small amounts of aluminum, lead or mercury, and you have a similar problem—one far exceeding the usual dangers of these substances.

The pH of sea (salt) water is not as vulnerable as fresh water's pH to acid wastes. This is because the different salts in sea water tend to buffer the water with Alka-Seltzer-like ingredients. Normal pH values in sea water are about 8.1 at the surface and decrease to about 7.7 in deep water. Many shellfish and algae are more sensitive than fish to large changes in pH, so they need the sea's relatively stable pH environment to survive.
Shallow waters in subtropical regions that hold considerable organic matter often vary from pH 9.5 in the daytime to pH 7.3 at night. Organisms living in these waters are able to tolerate these extremes or swim into more neutral waters when the range exceeds their tolerance.

Table 5. Effects of pH on fish and aquatic life

pH value		Effects observed under research
Min	Max	
3.8	10.0	Fish eggs could be hatched, but deformed young were often produced.
4.0	10.1	Limits for the most resistant fish species.
4.1	9.5	Range tolerated by trout.
4.3	--	Carp died in five days.
4.5	9.0	Trout eggs and larvae develop normally.
4.6	9.5	Limits for perch.
5.0	--	Limits for stickleback fish.
5.0	9.0	Tolerable range for most fish.
--	8.7	Upper limit for good fishing waters.
5.4	11.4	Fish avoided waters beyond these limits.
6.0	7.2	Optimum (best) range for fish eggs.
1.0	--	Mosquito larvae were destroyed at this pH value.

3.3	4.7	Mosquito larva lived within this range.
7.5	8.4	Best range for the growth of algae.
References 2		

Industrial processes that use water can be affected by the pH level, and in many instances the pH is adjusted by adding chemicals or buffers. The table below shows optimal pH levels for a few different industrial processes.

Table 6. Optimal pH for industrial water supplies		
Process	**Minimum**	**pH Range**
Food canning and freezing	7.5	--
Washing clothes	--	6.0-6.8
Rayon manufacturing	--	7.8-8.3
Steel making	--	6.8-7.0
Tanning leather	--	6.0-8.0
References 2		

PHOSPHATES

The element phosphorus is necessary for plant and animal growth. Nearly all fertilizers contain phosphates (chemical compounds containing the element, phosphorous). When it rains, varying amounts of phosphates wash from farm soils into nearby waterways. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterway's quality of life. If too much phosphate is present, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen. Many fish and aquatic organisms may die.
The Phosphorus Cycle is said to be "imperfect" because not all phosphates are recycled. Some simply drain off into lakes and oceans and become lost in sediments. Phosphate loss is not serious because new phosphates continually enter the environment from other sources.

The Phosphorus Cycle
Phosphates come from fertilizers, pesticides, industry, and cleaning compounds. Natural sources include phosphate-containing rocks and solid or liquid wastes.
Phosphates enter waterways from human and animal wastes (the human body releases about a pound of phosphorus per year), phosphate-rich rocks, wastes from laundries, cleaning and industrial processes, and farm fertilizers. Phosphates also are used widely in power plant boilers to prevent corrosion and the formation of scale.

Effects on Humans
Phosphates won't hurt people or animals unless they are present in very high concentrations. Even then, they will probably do little more than interfere with digestion. It is doubtful that humans or animals will encounter enough phosphate in natural waters to cause any health problems.

Forms of Phosphate
Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorus in a different chemical formula. Ortho forms are produced by natural processes and are found in wastewater. Poly forms are used for treating boiler waters and in detergents; they can change to the ortho form in water. Organic phosphates are important in nature and also may result from the breakdown of organic pesticides which contain phosphates.
Hach Company makes kits to test for the presence of phosphate. You'll probably use the cube kit that measures the most common form—orthophosphate—or the color disk that determines orthophosphate and metaphosphate. A total phosphate kit measures all three types of phosphates. Some values for total phosphate-phosphorus are given below.

Table 7. Phosphate-phosphorus levels and effects

Total phosphate/ phosphorus*	**Effects**
0.01-0.03 mg/L	Amount of phosphate-phosphorus in most uncontaminated lakes
0.025 mg/L	Accelerates the eutrophication process in lakes
0.1 mg/L	Recommended maximum for rivers and streams

* If an orthophosphate test cube or ortho/metaphosphate color disk gives you values above the total phosphate/ phosphorous values given above, there is cause for concern.
References

TEMPERATURE

Variables that affect a waterway's temperature include:

1. The color of the water. Most heat warming surface waters comes from the sun, so waterways with dark-colored water, or those with dark muddy bottoms, absorb heat best.
2. The depth of the water. Deep waters usually are colder than shallow waters simply because they require more time to warm up.
3. The amount of shade received from shoreline vegetation. Trees overhanging a lake shore or river bank shade the water from sunlight. Some narrow creeks and streams are almost completely covered with overhanging vegetation during certain times of the year. The shade prevents water temperatures from rising too fast on bright sunny days.
4. The latitude of the waterway. Lakes and rivers in cold climates are naturally colder than those in warm climates.
5. The time of year. The temperature of waterways varies with the seasons.
6. The temperature of the water supplying the waterways. Some lakes and rivers are fed by cold mountain streams or underground springs. Others are supplied by rain and/or surface run-off. The temperature of the water flowing into a lake, river or stream helps determine its temperature.
7. The volume of the water. the more water there is, the longer it takes to heat up or cool down.
8. The temperature of effluents dumped into the water. When people dump heated effluents into waterways, the effluents raise the temperature of the water.

Fish and most aquatic organisms are cold-blooded. Consequently, their metabolism increases as the water warms and decreases as it cools. Each species of aquatic organism has its own optimum (best) water temperature. If the water temperature shifts too far from the optimum, the organism suffers. Cold-blooded animals can't survive temperatures below 0 ^{o}C (32 ^{o}F), and only rough fish like carp can tolerate temperatures much warmer than about 36 ^{o}C (97 ^{o}F).

Fish can regulate their environment somewhat by swimming into water where temperatures are close to their requirements. Fish usually are attracted to warm water during the fall, winter and spring and to cool water in the summer. Did you ever notice how fish swim down to the cooler parts of the lake to escape the heat of the noonday sun? Fish can sense very slight temperature differences. When temperatures exceed what they prefer by 1-3 ^{o}C, they move elsewhere!

Fish migration often is linked to water temperature. In early spring, rising water temperatures may cue fish to migrate to a new location or to begin their spawning runs. The autumn drop in temperature spurs baby marine fish and shrimp to move from their nursery grounds in the estuaries out into the ocean, or into rivers, as the case may be. As you can see, all sorts of physiological changes take place in aquatic organisms when water temperatures change.

Table 8. Water temperature and fish behavior

Temperatures are given as ºC (°F)

Fish Species	Optimum Temp	Above this temperature*:			
		Fish will not spawn	Fish embryos die	Fish growth stops	Fish die
Atlantic Salmon	--	5 (41)	11 (52)	20 (68)	23 (75)
Black Crappie	--	17 (63)	20 (68)	27 (81)	--
Bluegill	--	25 (77)	34 (93)	32 (90)	35 (95)
Brook Trout	--	9 (48)	13 (55)	19 (66)	24 (75)
Carp	32 (90)	21 (70)	33 (91)	--	36 (97)
Channel Catfish	--	27 (81)	29 (84)	32 (90)	35 (95)
Coho Salmon	20 (68)	10 (50)	13 (55)	18 (64)	24 (75)
Emerald Shiner	--	24 (75)	28 (82)	30 (86)	--
Lake Herring (Cisco)	--	2 (36)	8 (46)	17 (63)	25 (77)
Large Mouth Bass	23.5 (74)	21 (70)	27 (81)	32 (90)	34 (93)
Northern Pike	--	11 (52)	19 (66)	28 (82)	30 (86)
Rainbow Trout	13 (55)	8 (46)	15 (59)	19 (66)	24 (75)
Sauger	--	12 (54)	18 (64)	25 (77)	--
Small Mouth Bass	--	17 (63)	23 (73)	29 (84)	--
Sockeye Salmon	15 (59)	10 (50)	13 (55)	18 (64)	22 (72)
White Sucker	--	10 (50)	20 (68)	28 (82)	--

Yellow Perch	--	12 (54)	20 (68)	29 (84)	32 (89)

-- indicates information not available.
* The two left columns below this heading are a summary of reported values for maximum weekly average temperature for spawning and short-term maximum for embryo survival during the spawning season. The two right columns are examples of calculated values for maximum weekly average temperatures for growth and short-term maximum for survival of fish during the summer.
References 1,2

Fish are not the only organisms requiring specific temperatures. Diatoms seem to grow best at a temperature of 15-25 ^{o}C, green algae at 25-35 ^{o}C, and blue-green algae at 30-40 ^{o}C.
Warm water also makes some substances, such as cyanides, phenol, xylene and zinc, more toxic for aquatic animals. If high water temperatures are combined with low dissolved oxygen levels, the toxicity is increased.

TURBIDITY

The American Public Health Association (APHA) defines turbidity as "the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample." In simple terms, turbidity answers the question, "How cloudy is the water?" Light's ability to pass through water depends on how much suspended material is present. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals and coal dust. Any substance that makes water cloudy will cause turbidity. The most frequent causes of turbidity in lakes and rivers are plankton and soil erosion from logging, mining, and dredging operations.

Measuring Turbidity
The most accurate way to determine water's turbidity is with an electronic turbidimeter . The turbidimeter has a light source and a photoelectric cell that accurately measures the light scattered by suspended particles in a water sample. The results are reported in units called Nephelometric Turbidity Units or NTUs.
You also can measure turbidity by filtering a water sample and comparing the filter's color (how light or dark it is) to a standard turbidity color chart. You'll need the following equipment to do this: filter apparatus (Gelman or other manufacturer), some white membrane filters and a standard color chart to compare your findings. Your teacher will show you how to operate the filter equipment and will provide a color chart.
The procedure for using the Gelman filter apparatus to determine the turbidity of a water sample is as follows:

1. Place a white gridded filter on the filter apparatus. You may handle the filter with your fingers; it's not necessary to use a sterilized tweezers.
2. Use a plastic cup or bucket to take a water sample from the river, lake or stream. Be sure you scoop only the water, not the sediment on the bottom.
3. Pour 100 milliliters (mL) of your water sample into the top of the filter apparatus. The unit is graduated in milliliters. Just fill it to the 100-mL mark.
4. Filter the sample. You may need to use a hand-operated vacuum pump to pull your sample through the filter.
5. Remove the filter from the machine and let it dry.
6. Estimate the turbidity of your sample by comparing its color to the color chart furnished by your teacher.

7. Refer to the information below for a discussion of what these values mean.

Table 9. Turbidity level of water for industrial use	
Industrial Use	Maximum Turbidity Units
Beverages	1-2
Food products	10
Water used in boilers	1-20 (varies with type of boiler)
Making high grade paper	5-25
Making rayon	1
Making cotton	25
Baking	10
Water used for cooling	50
Ice making	0.5 (same as drinking water)
Tanning leather	20
References 2	

Drinking Water Standards
The APHA specifies drinking water turbidity shall not exceed 0.5 NTUs. However, some scientists think this standard is too generous. They want to see the value reduced to 0.1 NTUs.

Turbidity Effects on Fish and Aquatic Life
Turbidity effects fish and aquatic life by:
Interference with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light, photosynthesis—and the production of oxygen for fish and aquatic life—will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. It's important to realize conditions that reduce photosynthesis in plant result in lower oxygen concentrations and large carbon dioxide concentrations. Respiration is the opposite of photosynthesis. (See Carbon Dioxide.)
Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly.
Suspended particles may provide a place for harmful microorganisms to lodge. Some suspended particles may provide a breeding ground for bacteria.
Fish can't see very well in turbid water and so may have difficulty finding food. On the other hand, turbid water may make it easier for fish to hide from predators.
The table below shows the amount of plankton per acre which may be expected in ponds of different turbidities.

Table 10. Plankton density as a function of water turbidity			
Factor measured	**Clear ponds**	**Intermediate ponds**	**Muddy ponds**
Average turbidity units:	less than 25	25-100	over 100
Amount of fish in	162	94	29

pounds per acre:			
Comparative amount of plankton caught in nets	12.8	1.6	1

Note that the average amount of plankton in pristine (clear) water is almost 13 times that found in turbid (muddy) water. Turbidity in pristine water apparently comes from the healthy plankton population itself, an excellent food source for many fish.

ORGANISMS

Pollution Sensitive

- -water pennies
- -stonefly nymphs
- -caddisfly larvae
- -mayfly nymphs
- -hellgrammites (dobsonfly larvae)

Moderately Pollution Tolerant

- -crayfish
- -sowbugs
- -damselfly nymphs
- -dragonfly nymphs
- -cranefly larvae

Pollution Tolerant

- -midge larvae
- -tubifex worms
- -leeches

References:

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