# pH

pH is the concentration of hydrogen ions ($H^+$) in a sample. pH is measured to determine the acidity of the water.

## Why do we measure pH?

pH is an important indicator of chemical, physical, and biological changes in a waterbody and plays a critical role in chemical processes in natural waters. pH values are on a scale from 0 to 14, with 7.0 considered neutral. Figure 1 shows typical pH values of common liquids. Solutions with a pH below 7.0 are considered acidic, and those with a pH above 7.0 are considered basic. The pH scale is logarithmic, meaning that every one-unit change in pH represents a ten-fold change in acidity. In other words, pH 6.0 is ten times more acidic than pH 7.0; pH 5.0 is one hundred times mores acidic than pH 7.0.

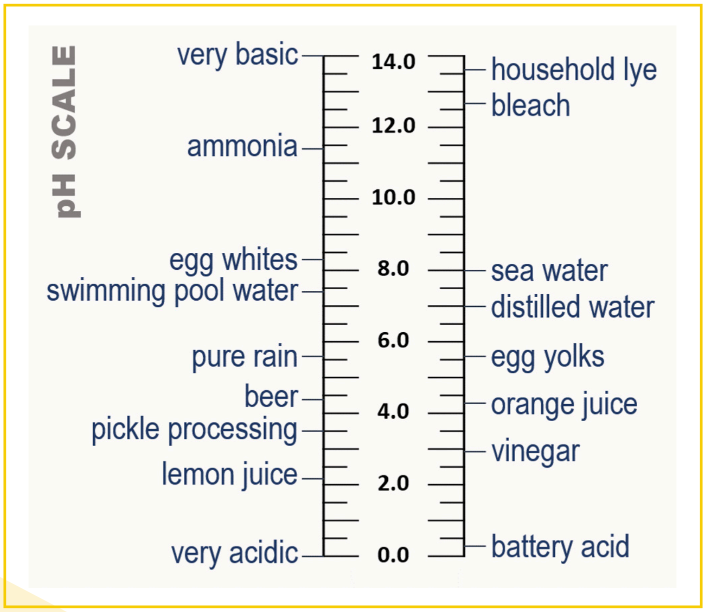


*Figure 1. Typical pH values of common liquids. Adapted from Water on the Web (2008)*

pH is a key factor in water chemistry and toxicity. A change in pH can alter the concentrations and forms of toxic chemicals in water. Metals such as aluminum, lead, mercury, copper, and arsenic are generally more soluble at a lower pH. Therefore, higher concentrations can be absorbed into the tissues of organisms, rendering these metals more toxic to aquatic life. In more basic waters (pH > 8.5), the conversion of the nontoxic form of ammonia to the toxic form is increased.

pH also plays a key role in aquatic health by affecting biochemical processes and the metabolism of aquatic organisms. Generally, if water is too acidic or too basic, damage can occur to an organism's gills, exoskeleton, fins, and other critical components. Of particular concern are pH-sensitive macroinvertebrates (small organisms without a backbone), fish eggs (most fish eggs cannot hatch at a pH less than 5), and juvenile fish.

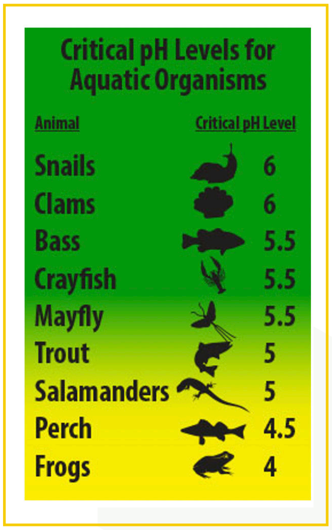


*Figure 2. Critical pH values below which key aquatic organisms may be lost. Source: USEPA (2020)*

Organisms vary in the pH ranges they can tolerate. Figure 2 illustrates the pH values at which key organisms may experience die-off or avoidance. Furthermore, even though an organism itself may tolerate a more extreme pH, its food source may not.

## What affects pH?

pH in a lake or river often fluctuates daily, with a higher pH (more basic) during the daytime due to consumption of $CO_2$ by aquatic plants and algae during photosynthesis. At night, aquatic plants and algae respire, giving off $CO_2$ and lowering pH (more acidic). Therefore, pH tends to be highest in late afternoon and lowest before sunrise. The pH of a well buffered pond may fluctuate between 7.0 and 8.4 (Figure 3). Buffering capacity refers to the ability for water to neutralize acids and bases and maintain a fairly stable pH level.

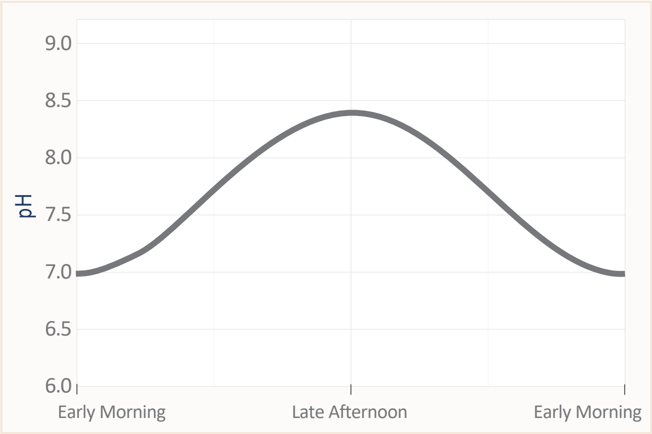


*Figure 3. Daily fluctuations in pH in a hypothetical well buffered pond. Adapted from Wurts and Durborow (1992)*

There are also seasonal changes in pH. Values are lower during seasons with high rainfall and snowmelt. When excess water runs directly into lakes or rivers without passing through soil, the slight acidity naturally present in precipitation does not get buffered. Additionally, pH in streams or at the surface of lakes is higher during the growing season (spring and summer) when there is more photosynthetic activity by aquatic plants.

pH can also vary with depth in the water column. Near the surface of lakes, pH is higher because light is available for algae to photosynthesize. In thermally stratified lakes, pH in the deeper water is often lower due to the lack of photosynthesis as well as respiration by organisms decomposing organic matter.

Both natural and human-induced factors can affect pH. For example, pH near the surface of lakes can increase with nutrient inputs and the growth of algae during algal blooms which consume $CO_2$. In addition, pH at the bottom of lakes may decrease due to decomposition of excess algae, plants, and other organic material.

pH can also decrease due to:

- Acid rain, which is typically caused by nitrogen oxides and sulfur dioxide from emissions of cars and coal-fired power plants. Regulations imposed in the last few decades to control acid rain have resulted in lake recovery in some heavily affected areas.
- Acid mine drainage from coal or sulfide mines, which can reach streams.

Local geology helps control pH, with certain types of bedrock such as limestone buffering the water against acid inputs.

## What are EPA's recommended ambient water quality criteria for pH?

In EPA's *Quality Criteria for Water* (1986), the recommended water criteria for pH ranges from 6.5 to 9.0 depending on what is protective of aquatic life and the particular system (fresh vs saltwater).

## How do we measure pH?

pH can be measured in the field using a water quality probe, indicator tests or strips, or from grab samples. Most commonly pH is measured in the field along with other water quality parameter measurements including temperature, dissolved oxygen, and specific conductance using a single or multi-parameter probe. pH should also be measured along with alkalinity, which is a measure of the capacity of water to neutralize acids. Alkalinity is also known as buffering capacity. Other parameters that may inform pH results include nutrients and metals because pH can indicate nutrient enrichment or impacts from metals.

pH can be measured at discrete times or continuously. Optimally, monitoring should take place at the same time every day if discrete measurements are being taken. Monitoring sensors (continuous monitoring) allow assessment of changes in pH throughout the day that cannot be captured with a single sample.

pH can vary both horizontally and vertically in a waterbody. Water samples should, therefore, be taken at regular increments across a waterbody and at various depths (or depth integrated, which is a sample that represents the entire water column).

## What are the challenges of using pH as a water quality parameter?

pH can be highly variable due to its sensitivity to natural and human-induced factors. This sensitivity can make it challenging to pinpoint the sources of long-term trends or water quality exceedances; evaluation of trends in other water quality parameters may help in identifying possible causes.