Pond pH and Ammonia Toxicity

Published as, Daily pH Cycle and Ammonia Toxicity, World Aquaculture, 34(2): 20-21

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Ammonia is a nitrogen waste released by aquatic animals into the production pond environment. It is a primary byproduct of protein metabolism. Ammonia is excreted directly from the fish gill into the water. Ammonia concentrations are usually at their highest late in the production season when biomass of the cultured species and the amount of protein fed are greatest. Ammonia is toxic to aquatic life and toxicity is affected by pond pH. Ammonia-nitrogen (NH_3-N) has a more toxic form at high pH and a less toxic form at low pH, un-ionized ammonia (NH_3) and ionized ammonia (NH_4^+), respectively. In addition, ammonia toxicity increases as temperature rises.

The measure of whether water is acidic, basic (alkaline) or neutral is known as pH. A scale of 1 to 14 is traditionally used, which represents the negative logarithm of the hydrogen ion concentration. A pH of 7.0 is neutral; above 7.0 is basic and below 7.0 is acidic; close to 7.0 is weak and far from 7.0 is strong. It is a common perception that the pH of water is neutral and constant at a value of 7.0. In an environment free of carbon dioxide, aquatic life, and compounds other than H_2O; pond pH would remain 7.0 or neutral. However, this combination of conditions is unlikely to occur on our planet. The pH of water is naturally acidic because the atmosphere contains carbon dioxide (CO_2). Carbon dioxide readily dissolves into water, raindrops and other sources of water exposed to air, forming a weak acid (H_2CO_3, carbonic acid). Therefore, events in the aquatic environment that affect CO_2 concentrations also affect pH. There are minerals in soil that can dissolve in water to create acidity and alkalinity as well.

Photosynthesis and Respiration

Pond CO_2 concentrations and pH, are affected by respiration and photosynthesis. Carbon dioxide is released during respiration and consumed for photosynthesis. As a result, pond pH varies throughout the day (Fig. 1).

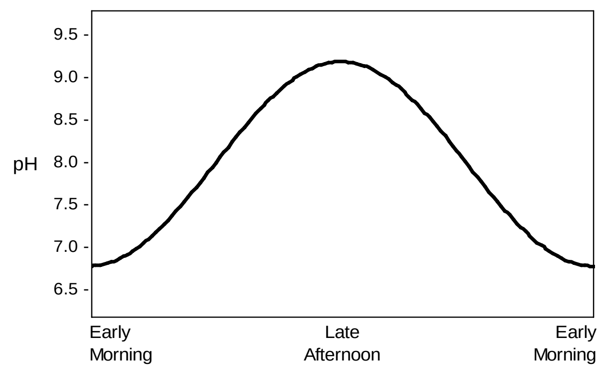

Fig. 1. Daily pH cycle in a hypothetical production pond.

The plant members of the pond plankton community, phytoplankton, absorb CO_2 for photosynthetic production of sugar. As daylight progressively intensifies, the rate of photosynthesis increases and so does the uptake of CO_2. The removal of CO_2 reduces the concentration of carbonic acid, and pond pH rises. Late in the production season, high waste nutrient concentrations can promote dense phytoplankton blooms which, in turn, can remove all of the CO_2 from pond water during photosynthesis. This can cause the water to become alkaline with pH levels greater than

9.0. Pond pH is highest late in the afternoon -- a few hours before sunset.

After sunset, photosynthesis and CO_2 uptake stop. However, respiration continues day and night. During respiration, plants and animals consume oxygen to free the energy stored in food. The end product of respiration is CO_2, which is released directly into the water. As photosynthesis is halted by the absence of light, CO_2 begins to accumulate and the carbonic acid concentration increases. The rising concentration of carbonic acid causes the pH to fall. Toward the end of the production season, the biomass and respiration of cultured animals and phytoplankton is high. Nighttime concentrations of CO_2, and therefore carbonic acid, can become excessive, lowering pH below 7.0. As such, pond pH would be lowest an hour or two before sunrise.

Effects of pH on Ammonia Toxicity

The daily interplay of photosynthesis and respiration creates a cyclical change in pond pH. Pond water becomes most acidic just before the period of darkness ends and most alkaline after several hours of daylight. The presence of un-ionized ammonia, the toxic form, increases as pH rises and decreases as pH falls which causes ammonia to become more ionized. The concentration of un-ionized ammonia in production ponds is lowest just before dawn and highest late in the afternoon.

This has significant implications for water quality monitoring, especially several weeks prior to harvest when fish biomass is greatest. For example (Table 1), a producer measures water quality at 0400 hr. The total NH_3-N concentration is 2.7 mg/L, pH is 7.0, and water temperature is 28 ^oC. The farmer then cross-references these values with a standard, pH-temperature table and calculates the concentration of "un-ionized" NH_3-N to be 0.019 mg/L. The producer decides to check water quality again at 1600 hr and finds that total NH_3-N is still 2.7 mg/L. But, pH and water temperature have risen to 9.0 and 30 ^oC. After checking the reference table, the farmer discovers that the un-ionized NH_3-N concentration is now 1.2 mg/L. An un-ionized NH_3-N level of 0.019 mg/L would be considered acceptable for channel catfish production. However, the un-ionized NH_3-N concentration of 1.2 mg/L recorded at 1600 hr could be lethal to channel catfish within several hours. Over a 12-hr period, the un-ionized ammonia concentration increased approximately 63-fold. The temperature change accounts for less than 10% of the increase in toxicity while the rise in pH from 7.0 to 9.0 is responsible for more than 90%.

Table 1. Amount of total ammonia-nitrogen (Tot/NH_3-N) present as un-ionized ammonia-nitrogen (UI/NH_3-N), for early morning and late afternoon pH and temperature measurements in a hypothetical production pond.

Time	Tot/NH_3-N (mg/L)	Temp °C	pH	UI/NH_3-N (mg/L)
0400 hr	2.7	28	7.0	0.019
1600 hr	2.7	30	9.0	1.2

Measuring pH and Ammonia

Photosynthesis and respiration have significant effects on pond pH. Because those processes affect pH, ammonia toxicity is influenced also. When monitoring water quality, it is important for producers to understand the daily shifts in pH and their impacts on un-ionized ammonia concentrations. First, for ammonia-nitrogen measurements to be useful, pH and NH_3-N must be measured at the same time. Second, a morning pH determination is not meaningful for assessing whether daily ammonia concentrations have reached unsafe levels in ponds. To have any practical value for pond management decisions, NH_3-N and pH should be tested late in the afternoon. A solid grasp of the pH cycle and its interrelationship with NH_3 is critical for the successful culture of any aquatic species.