ALLIANCE™
(https://gsa.rakadev.com)

Responsible Seafood ADVOCATE

Health & Welfare

Proper water circulation in aquaculture ponds critical

21 April 2016

By Fernando Kubitza, Ph.D.

Oxygen mixing an important consideration for effective management, successful production (Part 1)

Photosynthesis by microalgae (phytoplankton) is the main source of oxygen in aquaculture ponds. Microalgae often supply excess oxygen during the day, while during the night, the respiration of algae, pond bottom soil, fish and/or shrimp may deplete the oxygen reserves. For this reason, aquaculturists know the value of night time pond aeration to increase safety and production of fish and shrimp by maintaining adequate, needed levels of dissolved oxygen (DO).

Many shrimp farmers also provide some hours of aeration during daytime, to keep pond soils and bottom waters better oxygenated. The electricity cost associated with mechanical aeration is an important concern in pond aquaculture in many countries. Pond water circulation during the day time is an effective strategy to enrich pond water with oxygen from microalgae photosynthesis, and may substantially reduce the costs of nighttime supplemental aeration.

The basic principle behind water circulation is the consistent mixing of oxygen-rich surface waters with oxygen-depleted bottom waters, increasing the total reserve of oxygen in the ponds. Oxygen available at deeper strata accelerates the degradation of organic wastes on pond soil, preventing the build-up of potentially toxic, reduced compounds in bottom waters, particularly in deep and thermally-stratified

Effective water oxygenation and circulation are essential to maintain dissolved oxygen levels in ponds and other aquaculture production systems. Photo by Darryl Jory.

ponds. Efficient water circulation is applied during peak times of photosynthesis activity, when surface waters are supersaturated with oxygen. The fundamentals and benefits of water circulation in fish and shrimp ponds are discussed in this article.

Stratification of pond water

Levee or hillside ponds generally present water stratification. Pond water stratifies because surface green water (abundant in phytoplankton) absorbs sunlight and warms up during the day, while the light depleted bottom water remains cooler. Warm surface water is lighter (less dense) than the cool bottom water (denser). As the difference in temperature, and thus density, between surface and bottom waters accentuates, a strong physical stratification sets in place. One can actually feel this thermal/physical stratification when slowly entering into a pond: your belly feels warm, while your feet are cold. This physical stratification can only be disrupted by a strong force, such as mechanical aeration or strong winds. In the winter, as the surface water cools down and gradually approximates the temperature of bottom water, the physical/thermal stratification of a pond diminishes or disrupts.

Water stratification is also chemical. The presence of sunlight causes phytoplankton concentrate in the upper strata of a pond. Microalgae photosynthesis during day hours makes surface water richer in oxygen, higher in pH and lower in carbon dioxide compared to bottom waters. Microalgae also remove ammonia (NH_3 / NH_4^+) and other nutrients from water for photosynthesis and growth. Bottom water and pond soils, though, are mostly oxygen-depleted and harbor toxic compounds, such as ammonia, nitrite, methane, hydrogen sulfide and other reduced substances formed during the anaerobic decomposition of organic wastes (mainly dead algae, fish and shrimp feces, uneaten feed, leaves and decaying microbial biomass). Thus, phytoplankton photosynthesis in surface waters and organic matter decomposition on pond bottom soils magnify the chemical stratification of pond water (Fig. 1).

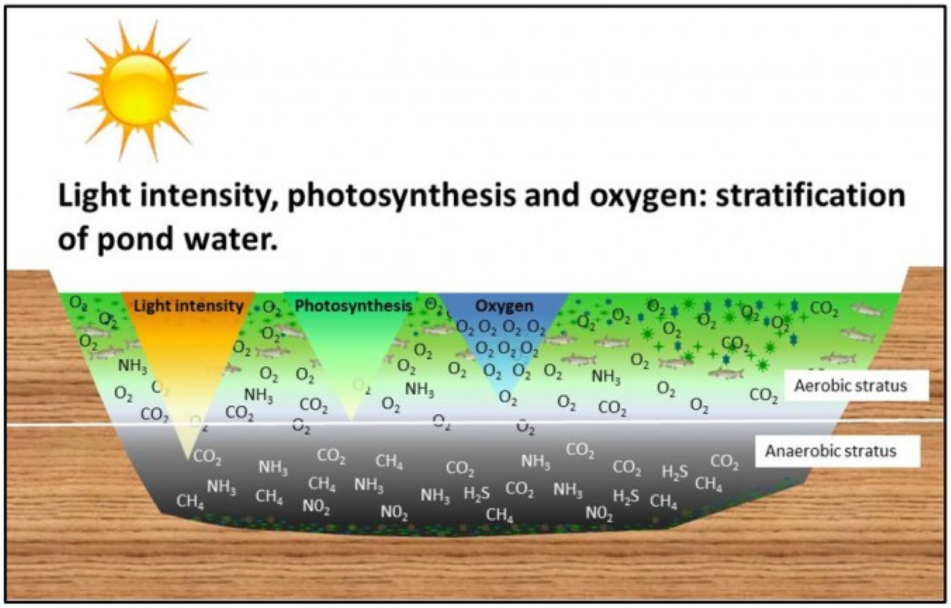

Fig. 1: Physical and chemical stratification of pond water. From surface to bottom there is a decline in light intensity, photosynthesis, oxygen levels and water temperature. Without oxygen, bottom water and pond soil become anaerobic and build up toxic reduced substances. Fish and shrimp avoid anaerobic areas in the ponds.

Plankton abundance and stratification

Phytoplankton abundance can be assessed through the color and transparency of water. Water transparency can be determined using a Secchi disk and can be used to predict the risk of an oxygen deficit occurring in a pond. The Secchi disk is, therefore, a simple but very valuable tool for aquaculturists, especially when DO meters are not available. In static-green water ponds, water transparency is often in the range of 20 to 60 cm. The lower the water transparency is, the less light will be available at the deepest strata of a pond. There is a direct relationship between water transparency and the depth at which the production of oxygen through photosynthesis (P) is equal to the oxygen consumption in respiration (R).

In limnology (the science that studies inland waters), P equals to R at a depth of 2.4 times the water transparency. Therefore, in a pond with 0.5 meters water transparency, P should equal R at a depth close to 1.2 meters. Below 1.2 meters, R exceeds P and oxygen levels sharply decline towards the bottom. For a pond with 0.2 meters water transparency, R started to exceed P at depths more than 0.5 meters. Therefore, the lower the water transparency, the greater will be the pond volume depleted of oxygen (and thus, anaerobic). For this, as well as for economic reasons, aquaculture ponds should not be constructed too deep. However, when building hillside ponds, it is almost unavoidable to have deep areas (over 5 to 6 meters) at the center of the dam, as dams often need to be very tall to allow for the impoundment of a large surface area.

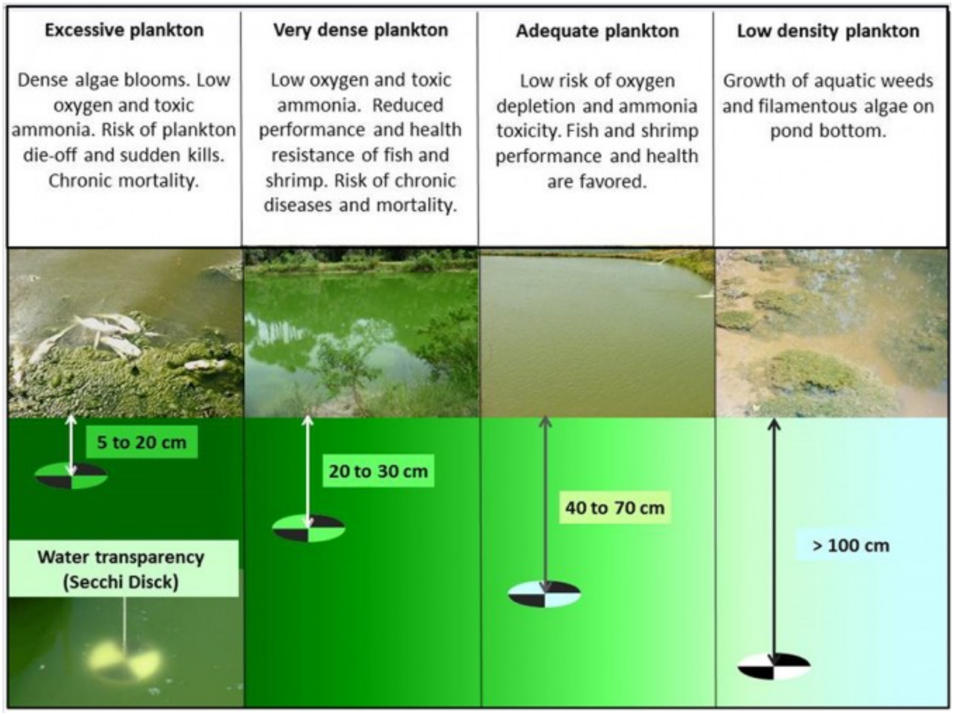

Fig. 2: Water transparency measured with a Secchi disk. The lower the water transparency (the denser the plankton population), the more severe and accentuated will be the water stratification and the risk of oxygen depletion and fish kills in a pond.

Oxygen depletion and toxic compounds in bottom waters

Physical and chemical stratification are less pronounced in shallow ponds, as winds generally promote reasonable water circulation and mixing. This mixing supplies oxygen to the lower strata. However, in deep ponds, water stratification is quite pronounced. As the deepest strata receive limited light, and regular winds only promote water circulation to a limited depth, oxygen levels are usually zero, or even negative, at pond depths greater than 2.5 meters. Negative oxygen levels mean that there is an additional demand for oxygen to oxidize reduced substances (such as nitrite, ammonia, methane and hydrogen sulfide) built-up at deep waters or pond soils during the anaerobic decomposition of organic matter. This additional oxygen demand is known as “negative redox potential” of pond soil or water. Pond soil and bottom water are often in a negative redox potential. Thus, the bottom of a deep pond (such as a hillside pond) or a large reservoir is generally inhospitable and can even be a threat to fish and shrimp due to the lack of oxygen, high CO_2 and the presence of various toxic compounds. The build-up of organic matter also provides shelter and nutrients for pathogenic — and often opportunistic — organisms to proliferate. The deeper a pond is, the bigger the volume of anoxic and toxic water it will have in its deepest strata.

The risk of a sudden turnover

A pond with anaerobic and toxic bottom waters is like a bomb set to explode anytime. A rapid and complete mixing of bottom and surface waters (a pond turnover) may occur, causing oxygen depletion and a rise in carbon dioxide and toxic compounds in the pond. Strong winds, large volumes of runoff and sudden falls in air temperature are some conditions that may cause an abrupt pond turnover. Animals can be severely distressed and mass mortality often occurs after a pond turnover. In deep ponds, dissolved oxygen is often zero at depths beyond 2.5 to 3.0 meters. The deeper a pond is, the greater the volume of “rotten-anaerobic-poor quality” water in its deep strata. In ponds with depths exceeding 5 meters, the volume of noxious bottom water far exceeds the volume of good quality surface water (Fig. 3). For this reason, when a deep pond turns over, fish or shrimp in the deepest area are more likely to die or be severely distressed than those caught in the shallows.

Large watershed ponds are often used to farm fish in cages. Invariably, the cages are positioned at the deepest area, close to the dam, to keep fish as far as possible from their own fecal wastes. Farmers also take advantage of the road on the dam to easily access the cages. However, placing cages at the deepest area of a pond increases the risk of losing the entire fish stock if the pond turns over. Fish confined in the cages have no chance to move toward less affected areas in the pond and will often die (Fig. 3). To lessen the risk of pond turnovers and fish kills, small- to regular size cages (1.5 to 2.0 meters deep) should be positioned over shallower areas, allowing 0.5 to 1.0 meters distance from the cage bottom mesh to the pond bottom soil. In addition, routine mixing of oxygen-rich surface water with oxygen-depleted bottom water helps to incorporate oxygen into the deeper strata of ponds, weakening the damage caused by a possible turnover.

Fig. 3: Illustration of a hillside pond with fish cages. The sudden mixing of bottom and surface waters (pond turnover) imposes serious risk of fish mortality in cages positioned at the deepest area of a watershed pond, as the volume of anaerobic-noxious bottom water far exceeds the volume of oxygenated-good quality surface water. The risk of fish kill is reduced in cages placed over shallower areas. Note the episode of massive mortality of tilapia in cages at a 4-hectare hillside pond due to a sudden pond turnover after a thunderstorm. By the time the damage was assessed, dissolved oxygen at the pond surface close to the dam was nearly zero.

Author

FERNANDO KUBITZA, PH.D.

Acqua Imagem Services in Aquaculture
Rua Evangelina Soares de Camargo, 115
Jardim Estádio – Jundiai/SP – CEP 13203-560 Brazil

fernando@acquaimagem.com.br (mailto:fernando@acquaimagem.com.br)