POND AERATION

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Aeration, like feeds and feeding, is one of the most frequently discussed topics in aquaculture. This is true because, at any given temperature, the availability of oxygen plus nutritionally adequate food are defining factors in determining the extent to which oxygen-consuming organisms such as finfish and shellfish thrive and grow, both in nature and in aquaculture systems. Without sufficient oxygen, such organisms will not grow, regardless of good nutrition and otherwise near-optimum environmental conditions. Thus, dissolved oxygen above certain levels is essential not only for the maintenance of life, but also for good health and growth. The levels required to support life, good health and growth vary, depending on species, body size, water temperature and other factors. Under any given set of conditions, more oxygen is required to promote growth in a particular species than the minimum amounts needed to maintain health and, in turn, provide basic life support.

Aeration is also a topic of frequent discussion among aquaculturists and industry suppliers because it typically involves the use of equipment that must either be built or purchased, often at considerable cost. Both the trade and scientific literature on aeration are large, often contradictory, and quite confusing to read - even for trained aquaculture professionals. For the beginner, knowing that such confusion exists (and why) is key to the development of a sound understanding of aeration practices under practical culture conditions. One basic principle of pond aquaculture is that natural aeration and biological and chemical processes affecting the concentration of dissolved oxygen and other gases normally far exceed anything that can be achieved by mechanical aeration. The latter can be used to good effect to provide emergency or supplemental oxygen, but such beneficial uses can be readily overwhelmed by poor pond design or management practices.

Natural Dissolved Oxygen Dynamics in Aquaculture Ponds

<u>Dissolved Gases in Ponds</u>

Native oxygen (O_2) under normal atmospheric temperature and pressure conditions is a colorless chemically-reactive gas that is essential for (aerobic) respiratory processes in bacteria, plants and animals. Only certain bacteria and other primitive organisms can live and grow (anaerobically) in the absence of oxygen. Nitrogen gas (N_2) and oxygen make up about 78% and 21% of dry air, respectively. The remaining 1% consists chiefly of argon, along with small amounts of carbon dioxide (CO_2) and other gases. All of these gases are soluble in water to varying degrees, depending primarily on temperature and pressure. Water is considered to be saturated with a gas when the dissolved pressure of the latter in solution is in equilibrium with its pressure in the atmosphere immediately above the water surface. Supersaturation occurs when the dissolved pressure of a gas in solution exceeds its atmospheric pressure, or the pressure of the overlying water column.

The concentration of dissolved gases in water are normally measured in milligrams per liter (mg/L) or parts per million (ppm), which in most situations is essentially equal (e.g., 5 mg O_2/L = 5 ppm O_2). Both oxygen and carbon dioxide are biologically important gases. Aerobic respiration by bacteria, plants and animals consumes oxygen and generates carbon dioxide as a waste product. In turn, photosynthesis in plants utilizes carbon dioxide and generates oxygen. These life-supporting processes are operative in both terrestrial and aquatic systems, including aquaculture ponds. Dissolved gases in water diffuse far more slowly than gases in air. Likewise, water is much denser than air, and oxygen is invariably present at far lower concentrations in the former than the latter. Because of these physical realities, dissolved gas concentrations fluctuate far more widely, and the relative amount of energy committed to respiration is greater, in aquatic systems then in terrestrial ones.

Oxygen Dynamics in Ponds

An extensive literature exists on dissolved-oxygen dynamics in shallow warmwater aquaculture ponds, though certain important aspects of the information contained appear to be incomplete or contradictory, and in many instances founded more on extrapolations of basic limnological principles than on systematic investigations as to cause and effect. The main points of this literature, developed largely from data on ponds in southern or tropical climates, has been reviewed by Boyd (1990). To what extent the information outlined in this literature applies directly to the understanding of dissolved-oxygen dynamics in the USDA North Central Region (NCR), where climatic extremes are greater and aquaculture pond design and management practices differ, is unclear. For shallow warmwater ponds near the southern margin of the NCR, the same basic principles probably apply. However, significant differences should be expected with increasing latitude or elevation.

Major principles of dissolved-oxygen dynamics that in most cases probably apply to aquaculture ponds in both the NCR and the South are as follows: (1) Photosynthesis by aquatic plants during daylight hours is the main source of dissolved oxygen, particularly in warmwater ponds. (2) The degree to which oxygen is consumed in a pond is largely determined by the total biomass and respiration rates of aquatic plants and bacteria in the water column and bottom sediments. (3) The potential for oxygen depletion in a pond is greatly exacerbated by the build up or presence of excessive organic matter, which may come with runoff from surrounding lands, will normally accompany the accumulation of waste products and uneaten feed or fertilizer addition to intensively managed ponds, or may occur naturally in the bottom sediments of poorly sited or improperly constructed ponds. (4) The amount of oxygen required for the aquaculture species being produced constitutes only a small percentage of the total amount needed to support a healthy pond.

Most ponds during the growing season, both in the South and in the NCR, exhibit daily cycles of oxygen depletion at night due to respiration, and replenishment during the day due to photosynthesis. The extent to which these cycles exist, and dissolved oxygen levels fluctuate in ponds, is geared largely to the abundance, type and health of aquatic plants present that can release photosynthetically generated oxygen into the water. Another critical factor is light intensity, which affects the rate of photosynthesis. On bright sunny days, aquatic plants in ponds can produce high (supersaturated) levels of dissolved oxygen (e.g., over 20 ppm), which are more than adequate to offset oxygen consumption at night due to respiration. Several critical factors can alter or interrupt this cycle. Among them are: a reduction in photosynthetic activity caused by a succession of cloudy days; and the death of aquatic plant life due to natural senescence, excessive use of herbicides, oxygen depletion, or the exhaustion of an essential plant nutrient.

Dissolved Oxygen in Northern Ponds

Common differences between aquaculture ponds in the NCR and those in southern climates, and the potential impacts of these differences on dissolved-oxygen dynamics, are as follows: (1) Aquaculture ponds in the NCR typically have a smaller surface area (i.e., 1/4-10 acres) and greater maximum depth (6-12 feet) than those in the South (1/4-50 acres and 3-8 feet, respectively). Because of this, ponds in the NCR are more likely to stratify during the summer, resulting in potentially dangerous oxygen depletion in deeper waters. (2) Ice movement during winter and spring can cause major damage to pond banks and water inlet and outlet systems in the NCR (which is why pond surface areas are typically smaller), and heavy ice and snow cover on ponds can block photosynthesis and result in oxygen depletion (which is one reason why pond depths are traditionally deeper). (3) The average annual and average mid-summer water temperatures in ponds in the NCR are generally lower than in the South, and the growing season is shorter.

Collectively, these differences greatly influence such factors as the solubility and distribution of oxygen and other gases in pond water; the extent to which wind can play a significant role in aerating pond water, especially at cool temperatures (i.e., 40-70°F); the species composition of all the organisms in a pond; and the selection of an appropriate aquaculture species for production. Two coolwater fish species of interest to aquaculturists in the NCR are the yellow perch and the walleye, both of which spawn in the spring. The fingerlings of both species are usually reared from small larvae in fertilized ponds, starting in late April or early May when pond water temperatures may fluctuate from 40 to 70°F. Under such conditions, maintaining dissolved oxygen levels in ponds can be difficult or easy, depending on the weather, organic load in the ponds, etc. The solubility of oxygen and other gases in water is inversely related to temperature. However, this is no guarantee that dissolved oxygen levels will be high in ponds when water temperatures are low.

Managing Dissolved Oxygen in Ponds in the North Central Region

Best Management Practices

As a business, the main goal of a commercial aquaculture operation is to generate profits. For the serious aquaculture entrepreneur, this goal should guide business planning, and supersede all pet theories and desires to substitute trendy equipment or hardware for sound planning. Simply stated, "Income minus costs equals profits." Mechanical aeration constitutes a cost. Therefore, its use should be evaluated carefully as it affects profits, as part of an overall management plan. Effective long-term planning in pond aquaculture starts with site selection and facility design, both of which can greatly influence natural aeration processes and the extent to which mechanical aeration ultimately proves to be necessary (or unnecessary). Ideally, good siting, pond design, and management practices should develop a strategy that produce the maximum amount of marketable product with the minimum amount of mechanical aeration.

Some practical considerations in aquaculture pond site selection and facility design, to minimize the need for mechanical aeration, are as follows: (1) The best pond sites are located in areas where water (preferably groundwater) is abundant and available at a low cost, to allow for rapid pond filling and flushing when water quality deteriorates. (2) Pond aquaculture facilities should not be sited in areas where the organic content of the soil is inordinately high (e.g., filled wetlands) and such soils cannot be readily removed for pond construction, or where surface runoff containing high levels of organic matter cannot be readily controlled. (3) Ponds should be designed to minimize surface runoff; constructed whenever possible (if their surface area is five acres or less) with their long axis oriented in the direction of prevailing winds; and built to allow for complete drainage and bottom drying (for the compaction, aeration, and when necessary, removal of accumulated organic matter and wastes). (4) Trees that are likely to drop leaves or other organic matter into ponds, or shade large areas of water from sunlight should be removed.

Some practical management strategies to help maintain dissolved oxygen levels in aquaculture ponds in the NCR include the following: (1) Maintain deep-rooted grass and clover filter strips around ponds to stabilize their banks and minimize the surface inflow of water containing particulate matter and nutrients. (2) With the possible exception of ponds managed extensively for fingerling production, do not add fertilizers to ponds in the NCR to maintain unicellular algae blooms. The likely consequence of this would be to stimulate excessive growth of rooted or floating aquatic plants or filamentous algae. (3) If ponds are being used for intensive aquaculture, feeding practices should be implemented to ensure minimum feed wastage - i.e., be sure the feed is being eaten. (4) To take the guesswork out of aquaculture pond management, procure the necessary water chemistry testing equipment or kits, develop an effective water chemistry monitoring program, and adhere to it. An effective monitoring program is essential for informed decision making, particularly with respect to determining whether and when mechanical aeration is needed.

Mechanical Aeration of Ponds

Claims made about different types of mechanical aeration equipment and systems, and the trade and scientific literature available on this subject, appear to be contradictory and confusing, because the people involved (e.g., industry suppliers, engineers, production economists, practicing aquaculturists) all have different interests and agendas. For example, suppliers of aeration equipment are interested in making sales, and quite understandably have technical data that present their product in the best possible light. Engineers, in turn, are primarily interested in the physical or mechanical efficiency of aeration equipment and systems, as well as capital, power, and other direct operating costs - often with relatively little attention given to potential maintenance costs or operational flexibility. Economists often start with engineering efficiency and direct cost assessments, adding estimates of interest, depreciation, inventory or property tax costs, etc. Practicing aquaculturists want cost effectiveness, durability and minimum maintenance, and operational flexibility.

Misunderstandings and conflicting ideas about operational flexibility and the exact purpose for which a particular type of equipment was initially designed are major sources of confusion when considering mechanical aeration in ponds. To clarify matters, it should be understood that there is no single "best" method of mechanical aeration for all ponds under all situations. Some types of equipment are best for emergency aeration, while others are better for intermittent or sustained supplemental aeration. Pond area and depth, oxygen demand, cultured species, and life history stage are all factors that should be considered when making decisions about buying, and how best to employ various types of aeration equipment. For more detailed information on the different types of aeration equipment and technologies available, and their uses and comparative merits, see the publications listed below, or contact your nearest aquaculture extension or outreach professional.

References

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