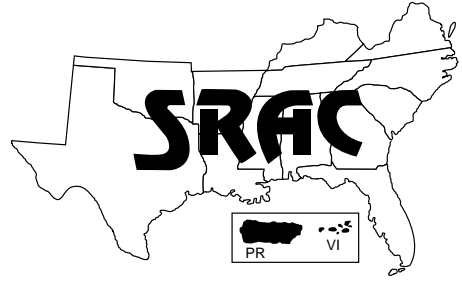


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Carbon Dioxide in Fish Ponds

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The primary sources of carbon dioxide in fish ponds are derived from respiration by fish and the microscopic plants and animals that comprise the fish pond biota. Decomposition of organic matter is also a major source of carbon dioxide in fish ponds. While producers are rightly concerned with maintaining adequate concentrations of dissolved oxygen, knowledge of the “flip-side” of the oxygen equation is also important.

Fish ponds can be thought of as “breathing” over a 24-hour period. During the day, when the sun is shining brightly, oxygen is supplied to the pond by photosynthesis of algae and other aquatic plants (the “inhale”). During the night, photosynthesis ceases, and the algae, sediment and fish consume oxygen (the “exhale”), producing the characteristic fluctuating pattern of dissolved oxygen concentration well known to fish farmers. The daily pattern of carbon dioxide concentration is gen-



erally opposite that of dissolved oxygen (Figure 1). During the day, algae take up or “fix” carbon dioxide that is free in the water and carbon dioxide concentration is therefore lowest (often 0 mg/L) during late afternoon, when dissolved oxygen is highest. During the night, the respiration of pond organisms produces carbon dioxide, which accumulates to a maximum (usually around 10 to 15 mg/L) at dawn.

The problem with the potential toxicity of carbon dioxide can be related to the daily fluctuating pattern of dissolved oxygen and carbon dioxide concentrations. Carbon dioxide concentrations are

highest when dissolved oxygen concentrations are lowest. Thus, dawn is a critical time for evaluating pond water quality from the standpoint of both dissolved oxygen and, to a lesser extent, carbon dioxide. In addition, there is some evidence to suggest that the toxicity of carbon dioxide is enhanced by low dissolved oxygen concentrations. Fish are able to rid themselves of carbon dioxide through

the gills in response to a difference in carbon dioxide concentration between fish blood and the surrounding water. If environmental carbon dioxide concentrations are high, the fish will have difficulty reducing internal carbon dioxide concentrations, resulting in accumulation in fish blood. This accumulation inhibits the ability of hemoglobin, the oxygen-carrying molecule in fish blood, to bind oxygen, and may cause the fish to feel stress similar to suffocation.

The density of the algae bloom has an important effect on the magnitude of daily fluctuations of oxygen and carbon dioxide.

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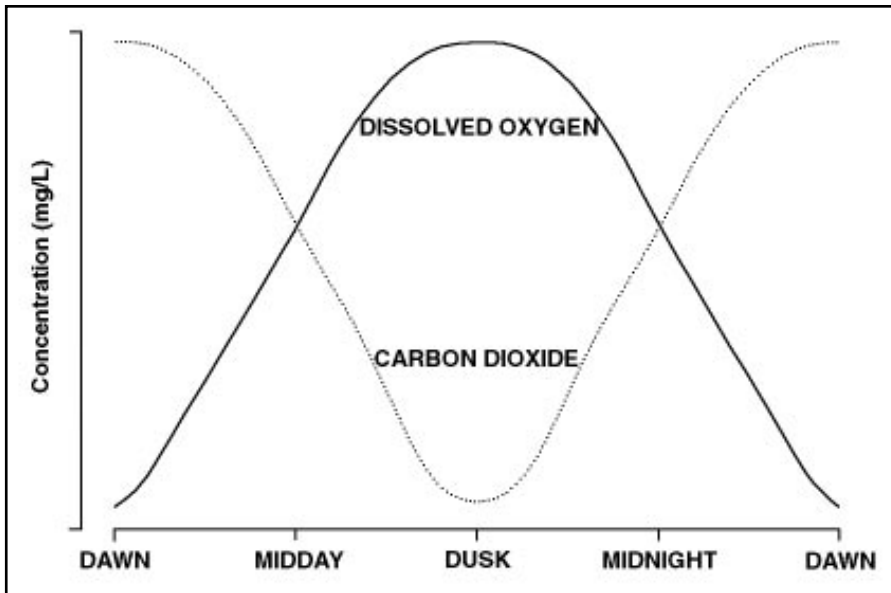


Figure 1. The daily cycle of oxygen and carbon dioxide in a fish pond.

Oxygen and carbon dioxide concentrations in ponds with a light algae bloom will not fluctuate very much between early morning and late afternoon, analogous to “shallow breathing.” In ponds with a thick, dense algae bloom, fluctuations are more extreme, analogous to “deep breathing.” Carbon dioxide problems are therefore more likely as the thickness of the bloom increases.

Carbon dioxide problems most likely in summer

Over an annual cycle, carbon dioxide concentrations are maximum during winter and minimum during summer. However, carbon dioxide is rarely a problem in winter because dissolved oxygen concentrations are usually well above saturation levels. Occasionally during the winter fish may appear to swim listlessly near the surface as if they were “under the influence,” possibly due to elevated carbon dioxide levels. Such a condition may arise after a period of extremely calm and cloudy weather, but quickly passes once sunny or windy weather returns.

Summer is the time of year when carbon dioxide is most likely to be a problem in fish ponds. Warm

water temperatures increase the metabolism of all pond organisms and therefore respiration rates are high. It is also a time of year when feeding rates are high. The decomposition of wastes generated by large quantities of organic matter added to fish ponds in the summer requires large quantities of dissolved oxygen and produces large quantities of carbon dioxide. During the summer, carbon dioxide concentrations are lower than during winter, but dissolved oxygen concentrations are often critically low. Fortunately, summer is also the time of year when ponds are aerated frequently. In addition to supplying critical dissolved oxygen, vigorous aeration will drive off some proportion of the carbon dioxide produced in the pond.

Measure pH to estimate carbon dioxide

Carbon dioxide can be measured directly with standard test kits. Alternatively, measurement of pH can be used to estimate carbon dioxide concentration because carbon dioxide acts as an acid in water. As carbon dioxide is added during the night, pH will decline. (Conversely, when carbon dioxide is removed during the day, pH will increase.) There are

important interrelationships between carbon dioxide, pH and total alkalinity. Knowing pH and total alkalinity will allow the estimation of carbon dioxide. Estimation of carbon dioxide by pH measurements is plagued by difficulty in obtaining an accurate pH measurement. Litmus paper, drop counting test kits, and various probes with meters have been used with varying success. The selection of measurement devices for pH is largely a situation in which “you get what you pay for.” For example, pH pens are inaccurate, particularly if not calibrated correctly, and do not compensate for changes in temperature. Some scientific supply houses now sell narrow-range litmus paper which allows for low-cost, rapid estimation of pH.

Graphical estimation technique is easy

A simple graphical technique for estimating carbon dioxide concentration is presented in Figure 2.

The first step is to determine the total alkalinity of the pond water using a standard test kit. Next, determine the pH from a water sample collected without splashing or bubbles. Draw a straight line up from the pH value to the curved line representing the total alkalinity value closest to that of the pond (Step 1). Now extend another straight line to the left-hand axis, indicating the free carbon dioxide concentration (Step 2). The straight line extending across from 20 mg/L represents a “critical” concentration, above which carbon dioxide may be a problem. Therefore, using the chart, a set of “critical” pH values can be determined for ponds with different total alkalinity (Table 1). In general, water can hold more carbon dioxide as temperature declines, although differences in temperature are less important than differences in total alkalinity and thus, for practical purposes, application of some kind of temperature correction is not necessary for estimation of carbon dioxide.

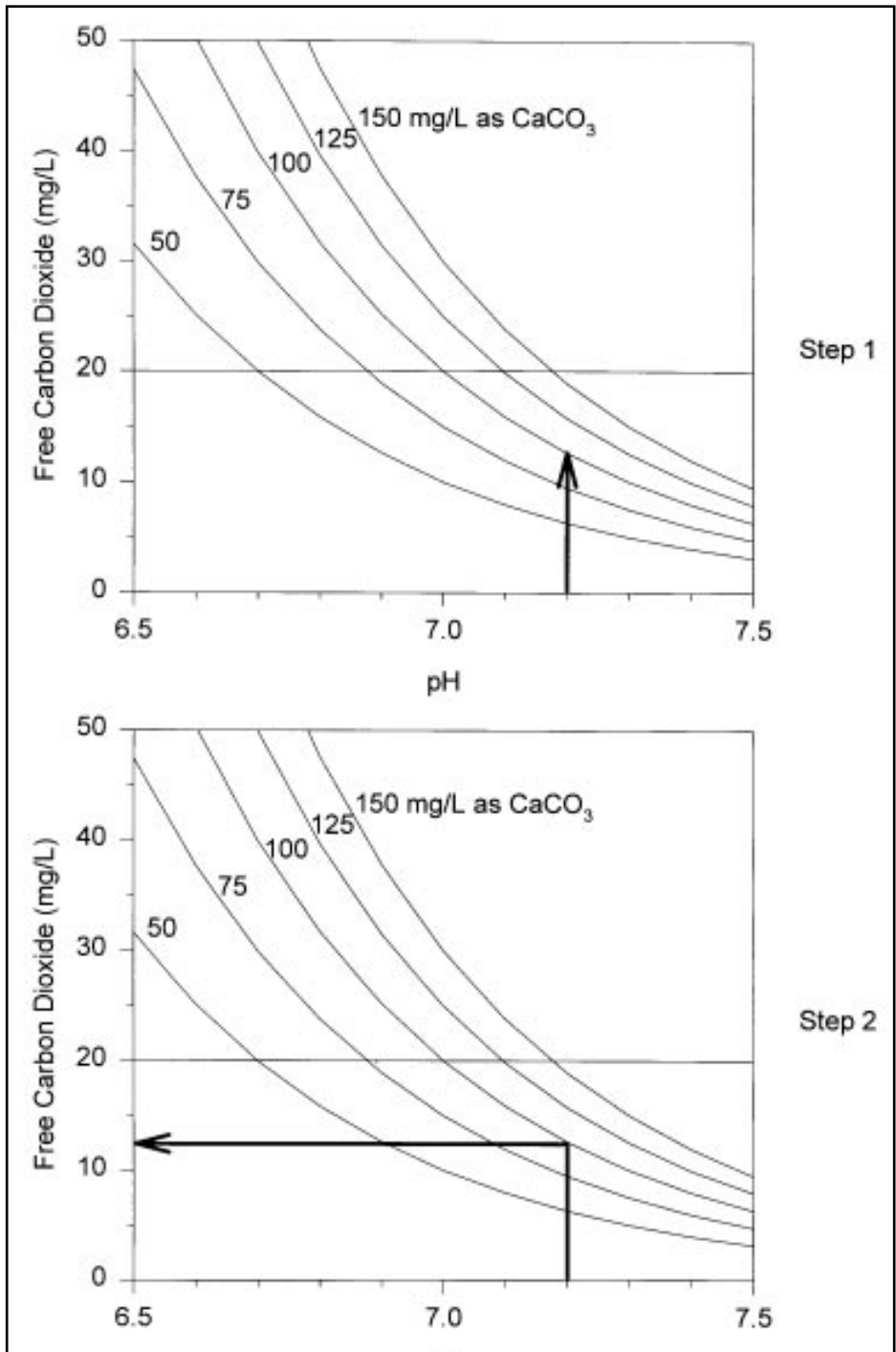


Figure 2. A graphical technique for estimation of carbon dioxide concentration.

Table 1. Critical pH values at a given level of alkalinity.	
Total alkalinity (mg/L as CaCO ₃)	Carbon dioxide may be a problem at a pH value less than:
50	6.7
75	6.9
100	7.0
125	7.1
150	7.2

ide. Figure 4 on page 6 is a blank graph that can be photocopied and used on the farm.

The graphic and the table indicate that carbon dioxide is more likely to be a problem as alkalinity increases. However, alkalinity provides “buffering capacity” to pH changes caused by carbon dioxide and pH is therefore unlikely to fall to such critical levels. The pH of most ponds at dawn is usually between 7.5-8. Carbon dioxide in ponds with low alkalinity (20 to 50 mg/L as CaCO₃) may cause the pH to fall to the lower limits of the range for optimum fish growth and production.

The potential for carbon dioxide problems can be evaluated by a simple, “quick-and-dirty” method. Collect a bucket of water and measure the pH. Put an airstone in the bucket and run air through the water for about 30 minutes. If the pH increases by more than one pH unit, then carbon dioxide may be a problem.

Carbon dioxide is an unusual problem in fish ponds

In general terms, carbon dioxide is rarely a cause for concern in fish ponds with sufficient alkalinity. There are a few specific circumstances or scenarios in which carbon dioxide may be a problem, such as the period following the crash of an algae bloom or the application of an algicide, such as copper sulfate. Large quantities of organic material derived from dead plankton are quickly decomposed, reducing oxygen and increasing carbon dioxide. Again, emergency aeration practices serve the dual role of supplying oxygen and reducing carbon dioxide.

Under certain circumstances, carbon dioxide can be a problem in ponds deeper than 4 or 5 feet, such as in so-called combined watershed/levee ponds. Deep ponds may “stratify” or develop layers of relatively lighter,

warmer, oxygen-rich water overlaying layers of relatively more dense, cooler, stagnant (and carbon dioxide rich!) water. In ponds that have not been aerated or mixed for several weeks during warm and relatively calm weather, strong sustained winds or vigorous aeration can cause ponds to “roll over” and mix deep water with surface water, thereby increasing carbon dioxide concentration throughout the water column. During the summer, when carbon dioxide is most likely to be a problem, ponds are typically aerated through the night. Although deep ponds may stratify and destratify daily, water currents established by aeration and wind blowing over the water surface usually keep the water column well-mixed and, as a result, carbon dioxide problems rarely occur.

Carbon dioxide may accumulate when fish are held at high density, such as in live-cars, hauling tanks or crowded in front of aerators during low oxygen episodes. Even though carbon dioxide levels may rise dramatically, the problem can usually be alleviated by aeration, which adds oxygen while driving off some carbon dioxide.

Chemical treatment is a temporary solution

Carbon dioxide can be removed by chemical treatment of pond water with liming agents such as quicklime, hydrated lime or sodium carbonate (Table 2). These liming agents chemically react directly with carbon dioxide, resulting in reduced carbon dioxide and increased alkalinity and pH. Agricultural lime will not chemically remove carbon dioxide from pond waters.

In order to calculate the amount of a particular liming agent to apply to a pond, the following generalized formula can be used. Alternatively, consult Figure 3 for a quick, graphical estimation of quicklime treatment requirements for a given pond size.

$$\begin{aligned} & \text{factor from table} \\ & \times \text{ carbon dioxide concentration (mg/L)} \\ & \times \text{ pond area (acres)} \\ & \times \text{ average depth (ft)} \\ & = \text{pounds of liming agent to add} \end{aligned}$$

For example, the amount of hydrated lime required to treat a 10-acre pond with an average

depth of 4 feet and a carbon dioxide concentration of 20 mg/L is $3.45 \times 20 \times 10 \times 4 = 2,760$ pounds or approximately 1.4 tons. Treatment of the same pond with sodium carbonate would require 5,184 pounds or 2.6 tons. Clearly, large quantities of liming materials are required to chemically treat a carbon dioxide problem.

At best, treatment with liming agents represents a temporary solution. Once carbon dioxide is consumed by reaction with liming agents, additional carbon dioxide may accumulate because treatment of ponds with liming agents does not address the root cause of a presumed carbon dioxide problem. In ponds receiving feed at very high rates (>100 lbs/acre per day) or in which rapid decomposition occurs following an algae crash, treatment with a liming agent does not affect the rate of carbon dioxide production and thus represents a temporary, “band-aid” solution.

Perhaps a more serious consequence of chemical treatment of carbon dioxide problems is related to pH, which may exceed 10 in poorly buffered (low alkalinity) waters following treatment with certain liming agents (such as quicklime and hydrated lime). High pH causes a shift towards a greater proportion of the more toxic form of ammonia. Consequently, a well intended application of certain liming agents to “treat” what is thought to be a carbon dioxide problem can result in a very stressful environment for fish.

The bottom line

Application of chemicals to treat a carbon dioxide “problem” is likely to be of limited, temporary benefit. Aeration and mixing are the most effective available mechanical methods for the management of carbon dioxide and dissolved oxygen. Vigorous aeration accelerates the diffusion of carbon dioxide out of water and

Liming Agent	Chemical formula	Factor	Comments
Quicklime	CaO	3.45	-caustic (protect skin and eyes) -potential for high pH -relatively low solubility
Hydrated lime	Ca(OH) ₂	4.57	-caustic (protect skin and eyes) -potential for high pH -relatively low solubility -relatively inexpensive
Sodium carbonate	Na ₂ CO ₃	6.48	-safe -low potential for high pH -relatively high solubility -quick reaction with carbon dioxide

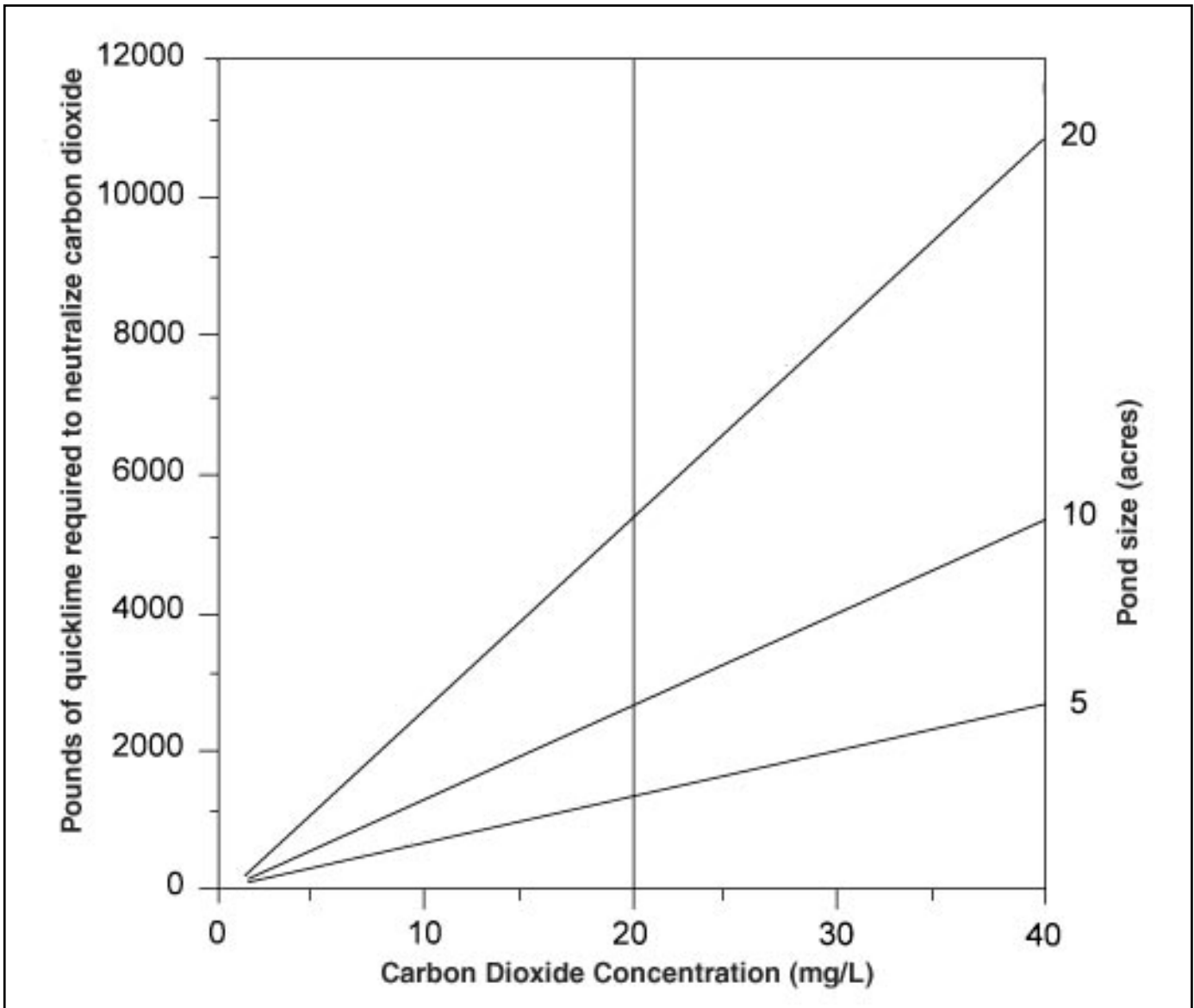


Figure 3. A graphical technique for estimation of quicklime required to neutralize carbon dioxide.

mixing will prevent or minimize the establishment of a carbon dioxide-rich layer of water near the pond bottom. Maintaining a moderate plankton density (Secchi disk visibility between 6-12") will maximize the biological uptake of carbon dioxide.

A clear determination of a carbon dioxide problem is required prior to any treatment. If a carbon dioxide problem is suspected, other water quality variables (particularly dissolved oxygen and ammonia) should be evaluated before attempting any treatment.

The toxicity of carbon dioxide increases as dissolved oxygen concentration declines. Often, the problem can be traced to something other than carbon dioxide.

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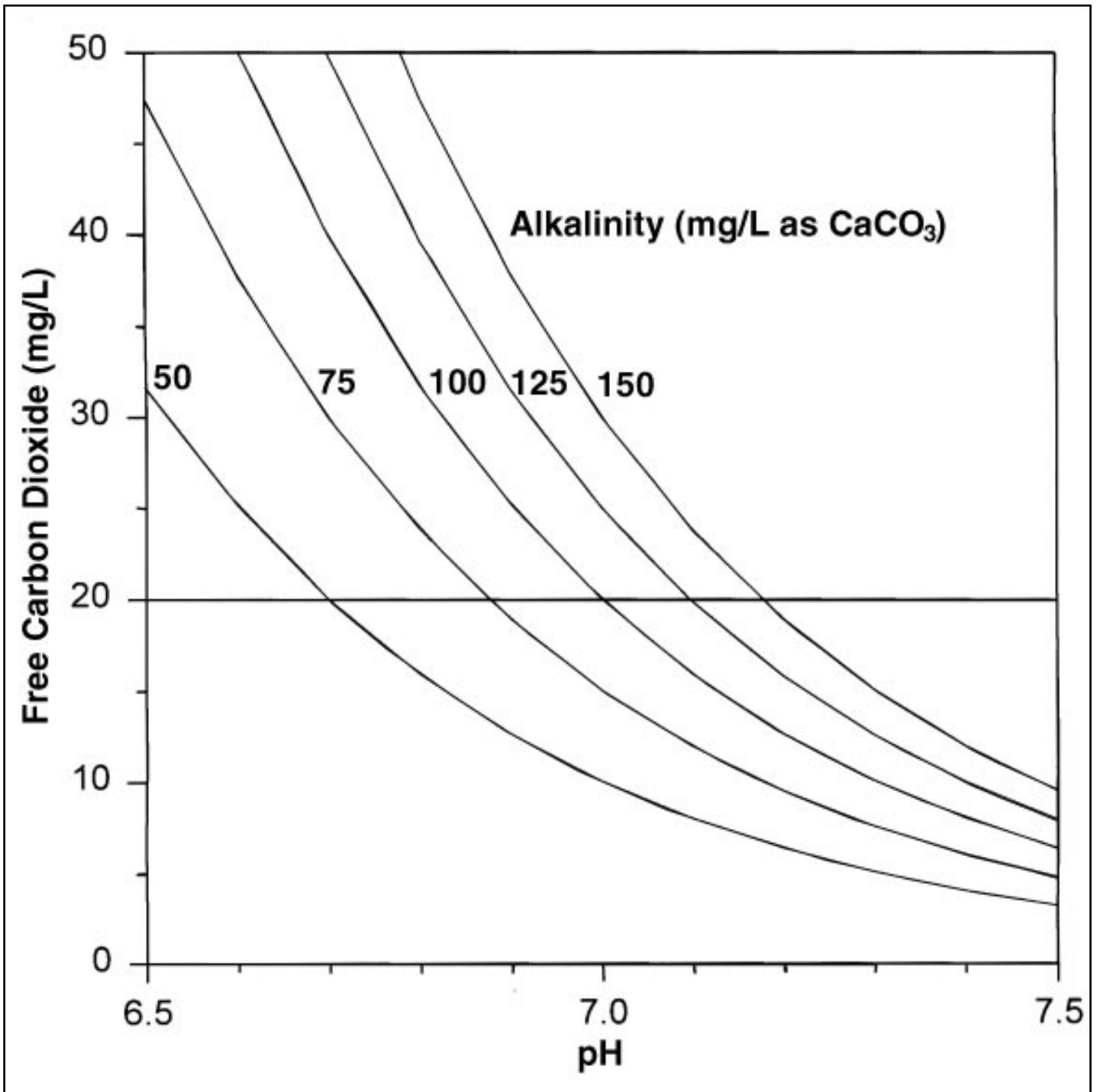


Figure 4. Blank graph for use by pond managers.