SRAC Publication No, 461

Southern
Regional
Aquaculture
Center

November 1991

Water Quantity and Quality Requirements for Channel Catfish Hatcheries

Craig S. Tucker*

Simple and inexpensive production of seed stock is a key to successful aquaculture. Indeed, the rapid growth of commercial channel catfish culture is owed in no small part to the ease with which large numbers of channel catfish fry can be produced using relatively unsophisticated hatchery technology.

Although the production of channel catfish fry is technically a simple process, success in some hatcheries is poor year after year. Problems may include poor egg matchability, low fry survival, poor fry growth, or a high incidence of infectious diseases of eggs or fry. Sometimes these problems are related to poor management practices, but quite often they are the result of poor water quality within the hatchery.

With appropriate treatment, any water can be made suitable for use in a catfish hatchery. Cost of treatment is often not economically justifiable. It is usually good practice to use a source that provides, as nearly as possible, water of correct quality for optimum matchability of eggs and survival and growth of fry. Good water quality is maintained in the hatchery by providing adequate water flow and aeration to hatching and rearing troughs. Frequent removal of uneaten feed and other accumulated organic debris will also aid in maintaining proper rearing conditions within troughs or tanks.

Water sources

In many regions, water from several sources may be available for use in the hatchery. Sources may include ground waters from aquifers lying at different depths and various surface water supplies. Before the hatchery is built, the manager should become familiar with the quality and availability of these potential hatchery water supplies. The best water supply may then be selected by comparing desired water quality and flow requirements with the chemical characteristics, temperature, and availability of various water sources.

The success of other hatcheries using water from a common source is the best indicator of the suitability of a particular water. Obviously, if poor water quality at other hatcheries is causing low survival of eggs or fry, or if costly treatment is required to make the water suitable for use, then it may be wise to seek an alternative water source. If there are no other hatcheries in the area and the quality of the water supply is questionable, a pilot-scale hatchery can be constructed to ensure that the water is suitable for use.

Ground water

Ground water generally is considered to be the best source of water for catfish hatcheries. Ground waters are usually free of suspended matter, pollutants, and fish disease organisms. Temperature and chemical composition are relatively constant, and, in regions with abundant ground water, the supply is dependable. The chemical composition and well pumping rates for some ground water supplies may be obtained from well logs for existing nearby wells. Alternatively, a test well can be drilled to assess the source. The quality of most ground waters is relatively constant over time, so a single chemical analysis will suffice to characterize water quality. Nevertheless, it is good practice to have the supply reanalyzed every year or two.

Although ground waters are preferred for hatcheries, some waters may have to be treated to make them suitable for use. Depending upon the water, treatments may include:

* **Delta Research and Extension Center, Mississippi State University**

- aeration to increase dissolved oxygen concentrations;
- degassing to reduce total gas pressure and remove carbon dioxide and hydrogen sulfide;
- temperature regulation using water heaters or mixing of waters of different temperatures;
- sedimentation and filtration to remove iron; and
- addition of calcium to waters of low hardness.

Surface waters

Surface water supplies include streams and rivers, ponds, lakes, and reservoirs. Unpolluted surface water offers several advantages over ground water as a hatchery water supply. For example, dissolved oxygen concentrations tend to be near saturation; dissolved carbon dioxide and hydrogen sulfide concentrations are usually low; total gas supersaturation is seldom a problem; and iron concentrations are usually very low. Nevertheless, all surface water supplies suffer the disadvantages of variable quality and availability with time and exposure to sources of pollution and turbidity. For these reasons, carefully evaluate any surface water before use as a hatchery water supply.

Because quality and availability vary over time, historical record is necessary to predict whether the water will be suitable. Such records are not available for most waters, however, and changes in water temperature, chemical composition, and water availability caused by unusual weather events cannot be predicted by records. The best advice is to use common sense and avoid those waters that may become unsuitable for use during the time the hatchery is in operation.

Another major constraint to using surface water for hatcheries is the potential for contamination by fish disease organisms or water-borne predators. Most surface waters have a resident fish community. The fish in the water supply may serve as a reservoir for fish disease organisms that could enter the hatchery and cause major losses. Natural predators of catfish fry, such as wild fish, insects, and other invertebrates, can also enter a hatchery and cause losses of fry.

Water quantity requirements

The success of a hatchery will suffer if insufficient water is available, even if that water is of optimum initial quality. Low water flow rates through hatching and rearing troughs allow waste products to accumulate which may quickly cause deterioration of water quality.

The typical trough (Figure 1) used for egg hatching and fry rearing holds roughly 100 gallons of water and is about 8 feet long, 2 feet wide and 10 inches deep. Troughs this size can hold 10 spawns at a time without crowding. Although the number of eggs per spawn varies with the size of the female brood fish, the ten spawns will contain (as a rough average) a total of 200,000 eggs. After the fry begin feeding, hold only about 100,000 fry in a trough of these dimensions. Thus, in a traditionally managed hatchery, two fry rearing troughs are available for each egg hatching trough.

Experience has indicated that minimum water turnover time (defined here as trough volume in gallons divided by water flow in gallons per minute) in hatching and rearing troughs should be about 40 minutes. Thus for a single 100 gallon trough, water flow should be a minimum of 2.5 gallons per minute. Larger troughs require proportionately higher flow rates. More water flow is also needed when egg or fry densities are higher.

Over a 10-to 12-week spawning season, each set of three 100-gallon troughs (one for eggs, two for fry) could be expected to produce roughly 1 to 1.5 million fry and would require a minimum flow of 7.5 gallons per minute (three troughs times 2.5 gallons/minute per trough). A hatchery capable of producing about 10 million fry per spawning season will typically contain 21 to 30 troughs and require a minimum water flow to the hatchery of 50 to 75 gallons per minute.

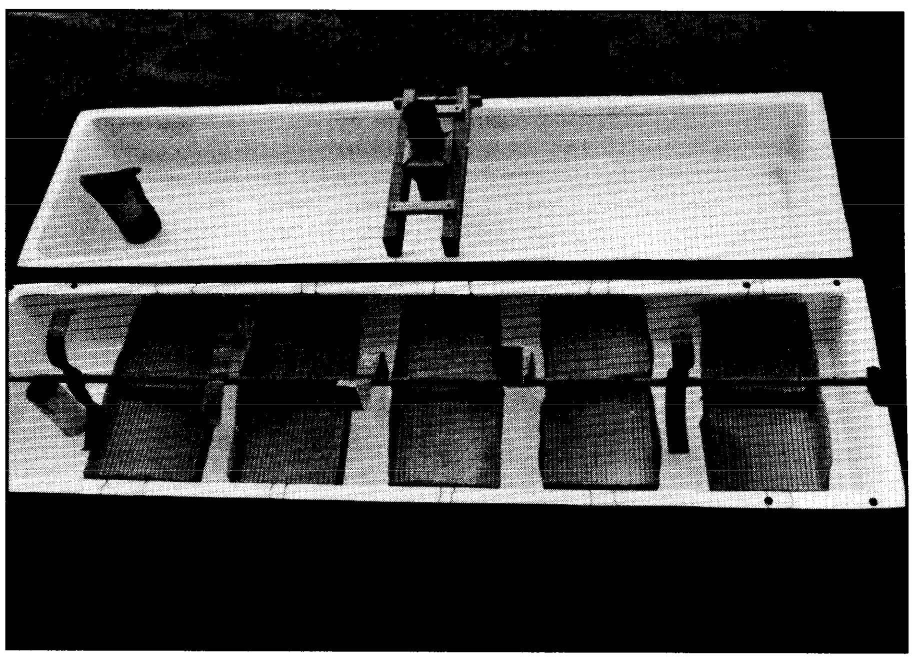

Figure 1. Traditional equipment used in a channel catfish hatchery: a fry rearing trough (top) with a 1/20-horsepower electric agitator and an egg hatching trough (bottom) with egg baskets and paddles.

The calculations above represent minimum flows. It is good practice to use at least twice those flow rates (turnover times of 20 minutes) to ensure against deterioration of water quality within hatcheries. Additional water flow is particularly important during the peak of the spawning season when the number of spawns arriving at the hatchery and the number of fry being reared temporarily exceeds the planned hatchery capacity. Thus, as a rough guide, a hatchery expected to produce 10 million fry per season should be supplied with roughly 100 to 150 gallons of water per minute.

Water quality requirements

Some of the more important water quality requirements for hatchery water supplies are discussed in the following sections. Aside from these specific requirements the water should also be:

- free of pesticides, solvents, petroleum products, and other pollutants;
- free of fish disease organisms;
- of relatively constant quality and availability.

Temperature

The optimum temperature range for development of eggs and rearing of fry is between 78 and 82°F (26 to 28°C). If the temperature is too low, hatching and development are prolonged, and fungi, which thrive in cool waters, often invade the egg mass. At higher water temperatures, embryos develop too fast and there may be a high incidence of malformed or nonviable fry. Also, bacterial diseases of eggs or fry and channel catfish virus disease of fry are more common if the water temperature is greater than 82°F (28°C).

Considerable energy is required to heat or cool water, and it is usually too costly to attempt major changes in water temperature. Therefore, the temperature of the water supply should be near 80°F before it enters the hatchery.

Ground water from deep wells (500 to 1,000 feet deep) is warmed by the internal heat of the earth and may be suitable for use in channel catfish hatcheries without temperature modification. Water from shallow wells (less than 300 feet) and some surface waters are too cool to use directly. Cool ground waters can be impounded in a small reservoir pond where solar heating will raise the temperature to some extent.

Nevertheless, water temperatures in the reservoir pond and in most other surface waters will vary with local weather conditions and still may be too cool for use early in the spawning season. An in-line water heater can be used to ensure a minimum temperature in the inlet water. The opposite condition may be encountered late in the spawning season when surface waters become too warm for use in hatcheries. It is very expensive to cool large volumes of water using refrigeration or chiller units, The best method of reducing water temperature is to mix the water that is too warm with cool water (such as water from a shallow well) to achieve the correct temperature.

Dissolved oxygen

Adequate dissolved oxygen is critical in hatcheries because eggs and fry have high metabolic rates and thus a high requirement for oxygen. Dissolved oxygen concentrations should not fall below 4-5 ppm at any time within the hatchery. Proper management of dissolved oxygen involves two distinct considerations: (1) ensuring that the water is oxygenated before use and (2) providing adequate aeration in hatching and rearing units to maintain optimal levels of dissolved oxygen throughout the hatchery.

Waters deficient in dissolved oxygen should be aerated before use. Pre-aeration not only ensures adequate initial levels of dissolved oxygen, but also may benefit some waters by partially degassing waters supersaturated with total dissolved gases and by removing some carbon dioxide and hydrogen sulfide. The two most common systems for pre-aerating water supplies for catfish hatcheries are packed column aerators (Figure 2) and aeration of water in an aeration tank.

Properly designed packed columns are highly effective aerators and relatively inexpensive to operate. They offer an added advantage of being good degassing devices for waters supersaturated with total dissolved gases. Packed columns are filled with a high surface area plastic packing. Influent water is evenly distributed at the top of the column and flows down over the packing in a thin film where gas exchange with the atmosphere occurs. Various plastic materials have been used as packing media and materials specifically designed for use in packed columns are commonly available from aquaculture supply companies.

Specific design criteria for packed columns are based upon water flow, water temperature, dissolved gas concentrations in the influent water, and desired dissolved gas concentrations in the effluent. These considerations are discussed in detail in appropriate references listed at the end of this report. As a rough guide, a packed column 4 to 6 feet high and about 30 inches in diameter will be sufficient to pre-aerate water for a catfish hatchery supplied with 100 gallons per minute of anoxic, 80°F groundwater.

As an alternative to packed columns, influent water maybe pumped into a metal or fiberglass tank and oxygenated with surface aerators or underwater diffusers. In such a system considerable initial aeration can be accomplished by running the influent water onto a splashboard or through an expanded metal grate to break the flow into small drops. The aeration tank should be large enough to provide adequate water residence time for aeration, but the appropriate tank volume will

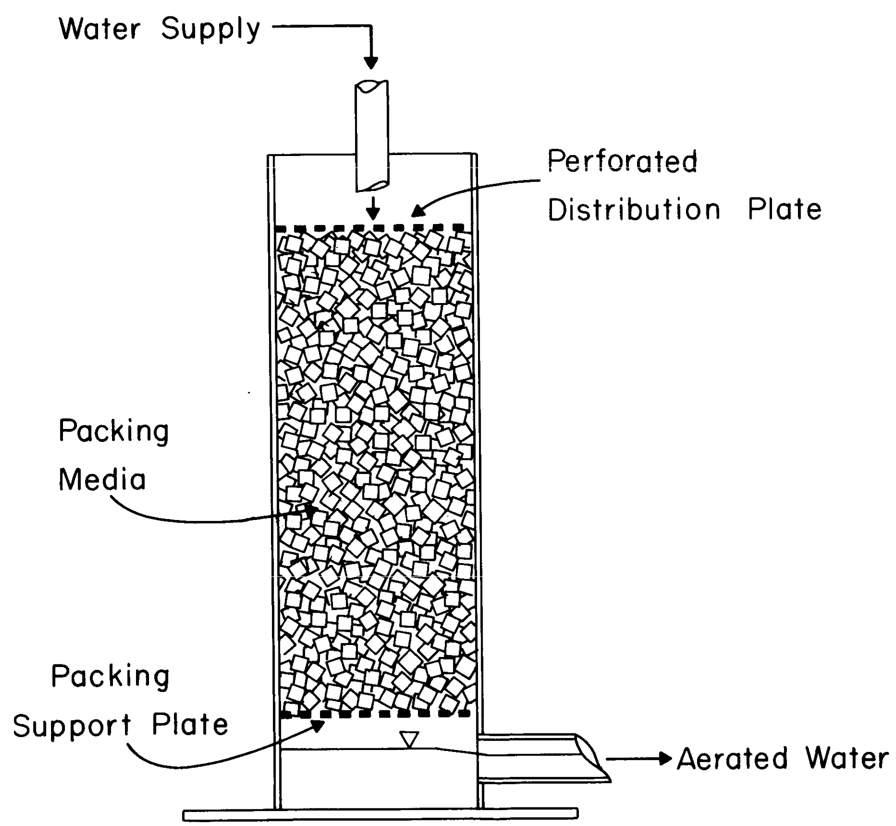

Figure 2. Cross section of a simple packed-column aerator.

depend upon the type and size of aerator used. Some experimentation may be required to find the best combination of tank volume and aeration device; the goal is generally to achieve an effluent dissolved oxygen concentration exceeding about 5 ppm.

As a starting point, pre-aeration tanks used in many existing catfish hatcheries provide a turnover time of 10 to 15 minutes (a capacity of 1,000 to 1,500 gallons for a water flow of 100 gallons per minute). Water is aerated with one or two 1/3-horsepower surface agitators (Figure 3).

Some type of aeration device must be provided to each trough within the hatchery to replenish dissolved oxygen lost as eggs or fry respire. Again, some trial and error may be necessary to find the right size and type of aerator. Common practice is to provide one 1/20 horsepower surface agitator per 100-gallon fry rearing trough. The agitators should be covered with small-mesh screening to prevent injury to fry.

Water circulation, in addition to adequate dissolved oxygen, is important in egg hatching troughs because oxygenated water must flow around and through the egg mass to ensure that all eggs receive sufficient dissolved oxygen. A common sign of inadequate water circulation in hatching troughs is the presence of dead eggs in the center of the egg mass. Those areas may serve as foci for fungal or bacterial infection. Slowly rotating paddles in egg hatching troughs serve both to aerate and circulate the water through the egg mass. Vigorous aeration with diffusers (air stones) may also be used to aerate and circulate water in hatching troughs. Air flows and the size and placement of diffusers must be determined through experience.

Carbon dioxide

High levels of dissolved carbon dioxide interfere with respiration by eggs and fry. Ideally, water supplies for catfish hatcheries should not contain measurable levels of dissolved carbon dioxide, but concentrations up to at least 10 ppm seem to be well tolerated, provided that dissolved oxygen concentrations are adequate. Some groundwaters may contain in excess of 20 ppm dissolved carbon dioxide and should be vigorously aerated to drive off some of the gas.

Total gas pressure

Total gas pressure is a measure of the “concentration” of all gases dissolved in water. It is expressed in pressure units such as millimeters of mercury (mm Hg). When total gas pressure in water exceeds local barometric pressure, water is supersaturated and gas will tend to leave the water by diffusion or by forming bubbles. Gas bubble trauma (also called gas bubble disease) may occur in fish living in gas-supersaturated water when gases in the blood or tissues come out of solution and form bubbles. The bubbles can block blood flow or damage tissues.

Instruments called “saturometers” are used to measure total gas pressures. Values are usually expressed as delta-P, which is the total gas pressure in water compared to local barometric pres-

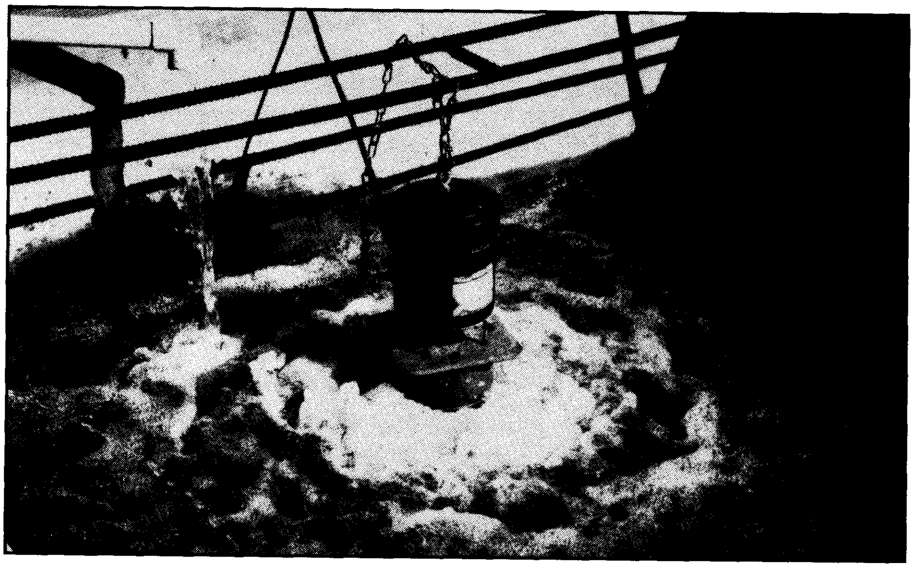

Figure 3. A 1/3-horsepower surface agitator used to oxygenate water in a pre-aeration tank.

sure. Positive delta P values mean the water is supersaturated. Saturometers are not commonly available to catfish hatchery managers, but supersaturated conditions can sometimes be diagnosed by the formation of bubbles on the surface of tanks or the milky appearance of water as gases come out of solution.

Channel catfish eggs are fairly resistant to high delta P-values because the naturally high pressure within the eggs helps prevent bubble formation. Eggs appear to withstand delta P-values at least as high as 100 mm Hg with no adverse effects. At high delta P-values, bubbles may form on and in the egg mass causing it to float high in the egg hatching basket. The top of the egg mass may be above water and will tend to dry out. Dislodging the bubbles by shaking and rotating the mass will temporarily alleviate the problem, although decreasing the delta P of the water is the best solution. Quite often, however, the first indication of supersaturated conditions is death of fry.

Clinical signs of gas bubble trauma in catfish fry include loss of equilibrium, abnormal swimming and gas bubbles in the yolk sac, behind the eyes, or on the skin. The bubbles prevent normal swimming and feeding and fry may become trapped at the surface. In severe cases, newly hatched fry rapidly die as blood flow is restricted or the yolk sac ruptures. Gas bubble trauma may occur in fry when delta P-values exceed about 70 to 80 mm Hg. To be safe, delta P-values should not exceed about 40 mm Hg in channel catfish hatcheries.

Gas supersaturation can be caused by a variety of natural and man-made conditions. Many groundwaters and some surface waters are naturally supersaturated. Surface water gas supersaturation is common below dams where air is entrained in the spillway overflow or when water is heated in electrical generating facilities. Gas supersaturation can also be caused within the hatchery water supply system.

The most common cause of supersaturation in supply systems is entrainment of air from a leak in the pipes on the suction side of a water pump. Some of the gases in the entrained air are driven into solution as the water is pressurized after moving through the pump. In those situations, it is often possible to hear air bubbles moving through elbows and valves in the delivery system. Heating water can also cause considerable increases in delta P unless the water is degassed after heating. The increase in delta P attributable to heating can be substantial: if water is heated from 70°F to 80°F, delta-P increases by more than 60 mm Hg.

Pre-aeration of the influent water is commonly used to reduce supersaturation to tolerable levels. Packed column aerators are particularly effective at degassing supersaturated waters, but other types of systems providing vigorous aeration may be used. Be aware, however, that underwater diffused aeration (air bubbled through airstones) is relatively inefficient at degassing waters and, in some systems, may actually cause supersaturation. If supersaturation is caused by air leaks in the water supply line, the first course of action is to locate and repair the problem.

Salinity

Salinity is the dissolved salt content of water and is often expressed as the parts of salt by weight per thousand parts of water by weight (ppt). Channel catfish can breed and reproduce over a wide range of salinities. Eggs can hatch and fry will develop in waters with salinities up to at least 8 parts per thousand, but the optimum salinity for channel catfish hatchery supplies appears to be between 0.5 and 3 ppt (500 to 3,000 ppm).

Hardness

Hardness refers to the amounts of calcium and magnesium in the water and is expressed as ppm of equivalent $CaCO_3$. Adequate concentrations of environmental calcium are required for “hardening” of eggs and for normal bone and tissue development of fry. Symptoms of environmental calcium deficiency include swelling and poor matchability of eggs and slow development, lack of vigor, poor stress resistance, and low survival of sac fry.

A minimum of 5 ppm calcium hardness is required for adequate egg matchability and for development and vigor of sac fry. Higher calcium concentrations are desirable because calcium also protects fry from ammonia and metal toxicosis. All things considered, hatchery water supplies should contain at least 20 ppm calcium hardness. Calcium levels can be increased by adding a solution of calcium chloride to the water supply. The calcium solution can be added by chemical metering pumps or by using an inexpensive “drip system” where a concentrated solution of calcium chloride is slowly dripped into the pre-aeration system.

Alkalinity

Alkalinity is a measure of the capability of water to neutralize acids. In most natural waters, the predominant bases are bicarbonate and carbonate. Alkalinity is expressed as ppm equivalent $CaCO_3$. Catfish eggs and fry thrive in waters with a wide range of alkalinity, although waters of very low alkalinity (<10 ppm as $CaCO_3$) should be avoided as hatchery supplies if possible. These waters are poorly buffered and pH can fluctuate drastically with small additions of acid or base. More importantly, dissolved metals such as copper and zinc are very toxic to fry in waters of low alkalinity. Copper and zinc can leach from pipes used to plumb the hatchery water distribution system.

pH

pH expresses the intensity of the acidic or basic character of the water. The pH scale is usually represented as ranging from O to 14. Conditions become more acidic as pH values decrease and more basic as they increase. At 77°F, pH 7.0 is the neutral point. The pH of most fresh waters is a function of total alkalinity and dissolved carbon dioxide concentration. Generally, if levels of those two variables are within the desired range, pH will be between 7.0 and 8.5, which is the desired pH range for incubating eggs and rearing fry.

An important exception to this general rule exists when surface waters containing dense submersed plant communities are used as a water supply. During sunny afternoons, rapid carbon dioxide removal by photosynthesizing plants may cause pH values to temporarily rise above pH 9. In extreme instances, values well above pH 10 have been recorded. Exposure to pH-values above 9 are undesirable and even short-term exposure to waters of pH 10 or above may kill fry and reduce egg matchability. Vigorous aeration of such waters will add some carbon dioxide to the water and somewhat reduce the pH, but this reaction is not rapid enough to be effective in extreme circumstances. The best solution is to avoid the use of surface waters that contain dense stands of submersed plants.

Ammonia

Un-ionized ammonia is quite toxic to channel catfish sac fry and early swim-up fry. Ideally, water in rearing troughs should be free of ammonia for optimal health and growth of fry, and the maximum concentration of un-ionized ammonia that should be allowed is about 0.05 ppm NH_3-N. Above this concentration, fry develop more slowly and are more susceptible to infectious diseases.

Removing ammonia from water supplies is difficult, so waters containing appreciable ammonia should not be used to supply catfish hatcheries. Ammonia is a product of fish metabolism, and ammonia production can be significant when high densities of fry are held in rearing troughs. Ammonia levels in rearing troughs can be decreased by either decreasing fry density or increasing water flow to flush the troughs.

Iron

Most surface waters contain very low concentrations of iron. Some anoxic ground waters, however, contain considerable iron in a dissolved form. When the water is aerated the iron is oxidized to a rust-colored precipitate of iron oxide. Dissolved iron is considered to be of relatively low toxicity to most aquatic organisms. Solid precipitates of iron oxide are even less toxic but may coat the gills of fry and interfere with respiration. Dense precipitates of iron oxide also may cover eggs and hinder gas exchange and suffocate the eggs. Total iron concentrations should be less than about 0.5 ppm for hatchery water supplies.

The simplest system used to remove iron is to pump the water into a small reservoir pond (0.5 to 1 acre) where the dissolved iron is oxidized and some of the iron oxide precipitate settles out. Some of the remaining precipitate can be removed using sand filters. An alternate method is to oxidize the iron by vigorously aerating the water in a tank or chamber prior to sand filtration. Complete removal of iron is difficult regardless of the system used.

Hydrogen sulfide

Hydrogen sulfide gives water a “rotten-egg” odor and is very toxic to channel catfish fry. Sac-fry will be killed when exposed to as little as 0.005 ppm hydrogen sulfide. Avoid using waters containing appreciable hydrogen sulfide. If this is not possible, hydrogen sulfide should be removed from water before it enters the rearing trough. Vigorous aeration will remove some hydrogen sulfide by volatilization and by oxidation of the sulfide to sulfate, which is nontoxic.

Treatment processes

The most common water quality problems encountered in channel catfish hatcheries and the treatment processes required to correct those problems are summarized in Table 1. But remember, it is often easier to seek an alternative water source rather than add expensive treatment systems in an effort to make a particular water suitable for use.

Table 1. Common water quality problems in channel catfish hatchery water supplies.

Variable	Desired level	Problem	Solution
Temperature	78-82°F	too low	reservoir pond for solar heating or use water heaters
		too high	blend with cooler water
Dissolved oxygen	5 ppm to saturation	too low	vigorous aeration of incoming water and supplemental aeration in troughs
Carbon dioxide	less than 10 ppm	too high	vigorous aeration (degassing) of incoming water and supplemental aeration in vats or troughs
Total dissolved gases	delta P less than 40 mmHg	too high	vigorous aeration (degassing)
Calcium hardness	more than 20 ppm as $CaCO_3$	too low	addition of calcium chloride to water supply
Ammonia (un-ionized)	less than 0.05 ppm NH_3-N	too high	do not use as a water supply; avoid accumulation within hatchery by decreasing fry density or increasing water flow
Iron	less than 0.5 ppm total iron	too high	aeration (oxidation) followed by precipitation or sand filtration
Hydrogen sulfide	less than 0.005 ppm H_2S-S	too high	vigorous aeration (degassing) of incoming water

Additional readings

Bouck, G. R., R. E. King, and G. Bouck-Schmidt. 1984. Comparative removal of gas supersaturation by plunges, screens, and packed columns. Aquacultural Engineering 3:159-176.

Colt, J. and G. Bouck. 1984. Design of packed columns for degassing. Aquacultural Engineering 3:251 - 273.

Hackney, G. E. and J. E. Colt. 1982. The performance and design of packed column aeration systems for aquaculture. Aquacultural Engineering 1:275-295.

Tucker, C. S. and E. H. Robinson, 1990. Channel Catfish Farming Handbook. Van Nostrand Reinhold, New York.

Wheaton, F. W. 1977. Aquacultural Engineering. Wiley Interscience, New York.

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 89-38500-4516 from the United States Department of Agriculture.