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Design and Construction of Degassing Units for Catfish Hatcheries

John A. Hargreaves and Craig S. Tucker*

In some catfish or baitfish hatcheries, water in egg-hatching or fry-rearing tanks may have a condition called "gas supersaturation" that is harmful to fish. Gas supersaturation means that the water contains more gas at a certain air (barometric) pressure and water temperature than would normally occur if the water was allowed to come to equilibrium with the atmosphere. Fish living in such waters may develop a stressful or lethal condition called gas bubble trauma. Gas supersaturation can occur frequently in hatcheries, and small fish confined in shallow tanks are especially susceptible to gas bubble trauma. Because the diffusion of excess gas out of water can be slow, water often must be treated before it is used in a hatchery. Gas supersaturation problems may be difficult to diagnose, but are easily remedied with simple, inexpensive equipment such as the packed-column aerator described here.

Definitions

Nitrogen, oxygen, carbon dioxide, and other atmospheric gases are dissolved to some extent in water. Total dissolved gas pressure is the sum of the partial pressures of all gases dissolved in water. The total amount of gas dissolved in water is commonly expressed as the difference between the sum of the pressure of all gases in water and the sum of the pressure of those same gases in the air (described by the term "ΔP," which is read as "delta P"). It also can be expressed as the percent saturation of the gases in water. Total dissolved gas pressure, barometric pressure, and P can be expressed in any of the units commonly used to express air pressure, such as millimeters of mercury (mm Hg) or inches of mercury (in Hg).

When the partial pressure of a gas in water is equal to the partial pressure of that gas in air ($\Delta P_i=0$), then that particular gas in the water is at equilibrium with the concentration of the gas in the atmosphere and there is no net movement of that gas either into or out of the water. If the partial pressure of a gas in water is less than the partial pressure of that gas in air (ΔP_i is less than 0), then water is undersaturated with that particular gas and it will diffuse into the water. If the partial pressure of a gas in water is greater than the partial pressure of that gas in air (ΔP_i is greater than 0), then water is supersaturated with that particular gas and it will diffuse out of the water to the atmosphere. It is possible for the total gas pressure in water to exceed barometric pressure (ΔP is greater than 0) while a particular gas is undersaturated.

Total dissolved gas pressure (TGP) is sometimes reported as a percentage of local barometric pressure. At saturation, TGP percent = 100 percent; when waters are undersaturated, TGP percent is less than 100 percent; and if the water is supersaturated, TGP percent is greater than 100 percent.

Table 1. Ways of expressing gas supersaturation.

Condition	ΔP (mm Hg)	TGP (%)	Direction of gas diffusion
Undersaturated	<0	<100	from air into water
Saturated (equilibrium)	0	100	no net diffusion
Supersaturated	>0	>100	from water into air

*Mississippi State University

Effect of supersaturation on fish

The effect of adding supersaturated water to a hatchery trough or fish tank is similar to opening a soft drink bottle. The pressure that held gases dissolved in water is now released and the gases will form bubbles and diffuse into the atmosphere. If fish are exposed to this water, the gas will diffuse across the gills into the fish. Bubbles can form in the gills, fins, skin and blood. Bubbles in the blood can block circulation and cause serious or fatal injury, particularly to fry or young fish. Some of the symptoms of gas supersaturation include "pop-eye" or hemorrhaging around the eyes, distended stomachs, coagulated yolk in yolk-sac fry, and more importantly, secondary bacterial or fungal infections related to stress. Catfish fry affected by gas supersaturation often become trapped upside down at the surface because bubbles form in the yolk sac.

Identifying gas supersaturation problems

Most problems with supersaturation are first identified when there are unexplained chronic or acute losses of fry in the hatchery. Sometimes the fry will exhibit some characteristic symptom, such as floating upside down or bubbles in the eyes, skin or fins. However, these clinical signs can appear and then disappear rapidly. Often there will be no obvious symptom at all. Gas supersaturation can be suspected if tiny bubbles form on the insides of the hatchery tanks. Running your hand over the inside of a tank will release a swarm of these small bubbles and make them easier to see.

The ΔP of a hatchery water supply can be measured with a saturometer. Most hatchery managers do not have this rather specialized and expensive piece of equipment, and it is not an essential tool. Some government fisheries biologists or university researchers have access to a saturometer, so if you suspect a problem, you may be able to find someone who can visit the hatchery and make the measurement to confirm whether or not a problem exists. Note, however, that the severity of a gas supersaturation problem in a hatchery can change over time, sometimes suddenly, depending upon the water pumping rate and the condition of the plumbing in the hatchery. Fry should be observed vigilantly for potential gas bubble problems.

Sources of gas supersaturation

If you determine that the water in hatchery rearing tanks is supersaturated, it is important to identify the source of the supersaturated water. The most effective approach to solving the problem depends on the origin of the gas. The water source itself may be supersaturated, or the water may become supersaturated as it is pumped to the hatchery.

Supersaturation is usually not a problem in good quality surface waters, although other problems with using surface waters in hatcheries outweigh that small advantage (see SRAC Publication 461). Surface waters with dense growths of aquatic plants or algae can become supersaturated with dissolved oxygen on bright, sunny afternoons.

Most catfish hatcheries use deep groundwaters because the supply is consistently of high quality. Water from deep wells is warmed by the heat of the earth, making it unnecessary to heat the water to the optimum temperature for egg and fry incubation. However, groundwater often is supersaturated with dissolved gases. If that is the case, and there is no alternative water source for the hatchery, the water can be "degassed" and aerated in a packed-column aerator as described below.

Although not a common problem, especially when wells are properly constructed, waters can become supersaturated if air is sucked into the water supply when the well "surges." Surging occurs when sands dislodged during well drilling partially clog the screen or strainer at the bottom of the well casing. This impedes the flow of water into the casing, which results in water being pumped out of the well faster than it flows into the casing from the aquifer. When the water level inside the casing drops below the bottom of the intake pipe strainer, air is sucked into the line and gases are forced into solution as water passes through the pump. This problem is most common in new wells and usually corrects itself as the well is used. If surging persists, inform the person who drilled the well. Screens of older wells in areas with hard, alkaline groundwaters may become clogged by encrustations of lime or iron oxide. Cleaning with muriatic (dilute hydrochloric) acid will correct this problem and most well-drillers do this routinely.

Regardless of the water source and whether or not it starts out supersaturated, faulty plumbing of the water supply lines to the hatchery can cause it to become supersaturated (or more supersaturated). This occurs when air is sucked into the water through small, "pin-hole" leaks in the plumbing fittings and pipes on the suction side of pumps. As the entrained air passes through the pump, it is pressurized and some of the gases are driven into solution. More gas entrainment can occur on the pressure (outlet) side of a pump, particularly across a partially-open, true-union, PVC ball valve.

Problems caused by faulty plumbing can sometimes be remedied by finding the leak and repairing the line, although it is best to avoid or prevent the problem in the first place. When constructing the hatchery, pay particular attention to proper application of adhesives at plumbing joints and fittings. Clean fittings carefully with an approved solvent and generously apply adhesive to both pipe and fitting before joining with a quarter twist of pipe against fitting. Apply teflon tape or pipe compound liberally to the threads of reducer bushings or other threaded fittings, particularly at the pump inlet and outlet.

When catfish hatcheries are supplied with water from a well, diagnosing the source of the supersaturation is usually not difficult because most groundwaters in the Southeast do not contain dissolved oxygen. If the water flowing into the hatchery contains no dissolved oxygen but is nevertheless supersaturated with gas, the groundwater itself probably is supersaturated or has become supersaturated when heated in a closed boiler. If, however, the water flowing into the hatchery contains some dissolved oxygen (often just 1 or 2 mg/L), that means that the water has contacted air at some point and the problem is caused by an air leak in the plumbing or a surging well. Quite often, air bubbles entrained in the water by these two processes makes a hissing sound as the water travels along the piping. This sound is often most noticeable at elbows or "T" fittings.

Problems caused by an air leak in the plumbing can be differentiated from those caused by a surging well by turning the well off for an hour or two, and then turning it on while measuring the dissolved oxygen concentration of the water as it flows into the hatchery. If the problem is caused by an air leak in the supply line, dissolved oxygen will be detected in the water almost immediately after the well is turned on. If the problem is caused by a surging well, the water will not contain dissolved oxygen at first because anaerobic groundwater is being pumped into the hatchery. If, after some period of pumping, the water level inside the casing falls below the intake and air is sucked in, the dissolved oxygen level in the water will suddenly begin to rise, indicating a surging well. The time interval between turning the well on and the first surging depends on the well pumping capacity and the degree to which the screen is clogged; it can range from a few minutes to several hours.

Waters also can become supersaturated when heated in a closed boiler where excess gases can not escape completely. This occurs because the solubility of gases decreases with increasing temperature, so if gases cannot escape when water is heated, the water will be supersaturated at the final temperature. This occurs often in hatcheries that use cool groundwaters or surface waters early in the spring spawning season. Heating water from 20º C (68º F) to 26º C (80º F) in a closed boiler can cause an increase in ΔP sufficient to cause chronic gas bubble trauma in channel catfish sac-fry.

Packed column design

Some problems with gas supersaturation can be avoided by properly plumbing the water supply line to the hatchery and by using good well drilling and maintenance practices. Water flowing into hatchery tanks can be partially degassed by vigorously aerating the holding tank with a number of diffusers or with an agitator, although these techniques are not very efficient and not completely effective. Water can also be degassed somewhat by breaking the flow into a fine spray with a common garden-hose spray nozzle and spraying water into the hatching or rearing tank. However, one of the simplest and most effective ways to manage gas supersaturation problems is to use packed-column aerators.

Packed columns serve two roles, depending upon the quality of incoming water. If the water is supersaturated with dissolved gases, then a properly designed and constructed packed column will relieve the supersaturated condition. If the dissolved oxygen concentration of the water is low, and usually dissolved oxygen is absent in groundwater, then a properly designed and constructed packed column will also saturate the water with dissolved oxygen.

A packed column consists of a vertical vessel filled with packing medium. The medium should have a large (about 90 percent) void or empty space per unit volume and should pack in a way that allows the water flow to break up randomly into a thin film that trickles down through the column, following a very circuitous pathway. Various packing media are sold under the names ballast rings, Bio-barrels®, Actifil® pall rings, Tri-pack® spheres, and Nor-Pac®. A perforated support plate holds the medium in at the bottom of the column. Near the top of the column, a water distribution plate with many holes is placed over the packing medium.

The height of the packing is an important design variable of a packed column. Packing height is based on a number of design criteria and will depend upon the characteristics of the incoming water. Two cases are presented below to illustrate how to configure the packed column.

In the first case, assume that the water contains no dissolved oxygen but is not supersaturated. The packed column will be used only as an aerator and Figure 1 can be used to estimate the height of the packed column required to provide the desired dissolved oxygen concentration at the outlet. To use

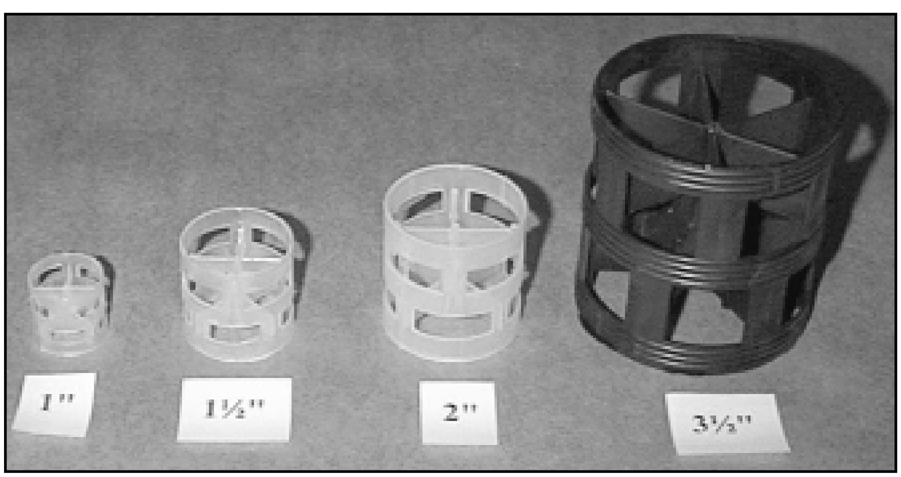

Figure 1. Pall rings of various sizes can be used as media in packed columns.

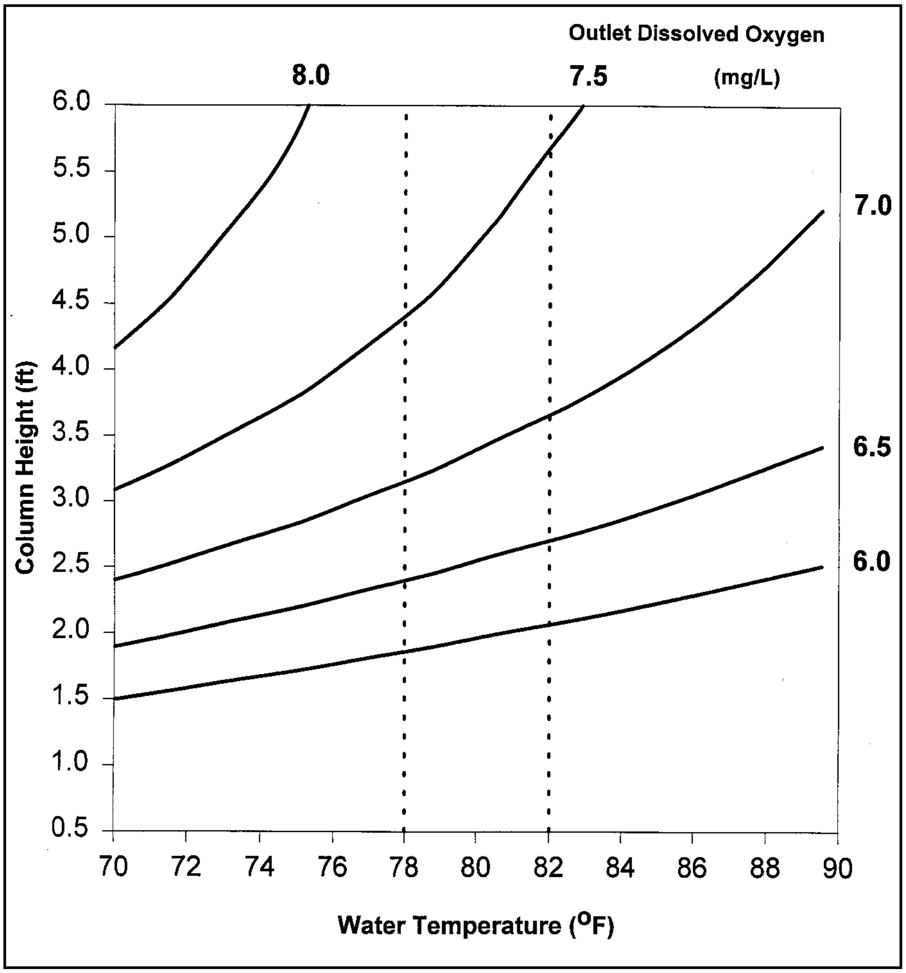

Figure 2. Packed column height required to result in various outlet water dissolved oxygen concentrations at a range of water temperatures. Area within dashed lines indicates the optimum temperatures for channel catfish egg incubation.

the figure for design purposes, begin by selecting the water temperature. Extend a vertical line up to the desired dissolved oxygen concentration. Then, extend another line horizontally to the left, at a right angle to the first line, to select the packing height. For example, if the temperature of a catfish hatchery water supply is between the optimum of 78 and 82° F and the desired dissolved oxygen concentration of the water flowing out of the packed column is 90 percent of saturation (between 7.0 and 7.3 mg/L), then a packing height of 3.5 to 4 feet is necessary. As water temperature increases, the packing height required to achieve a given dissolved oxygen concentration increases, although the packing height required to achieve 90 percent saturation is not affected by temperature and stays at about 3 feet 8 inches.

In the second case, assume that the water is supersaturated with dissolved gases. Use Figure 2 to estimate the required packing height for the desired gas pressure differential (ΔP) between the outlet water and the atmosphere. Most hatchery waters should have a ΔP between 10 and 20 mm Hg and should not exceed 40 mm Hg. From the figure, it can be seen that as the ΔP of the incoming water increases, the packing height required to produce a given ΔP of the outlet water increases. The lower the desired ΔP of the outlet water, the greater the packing height required. The vertical dashed line on the figure provides a point of reference by indicating the average ΔP of well water from 27 catfish hatcheries in the Mississippi Delta. But remember, the ΔP of well waters can change through time and may suddenly become a severe problem. To use the figure for design purposes, begin by selecting the ΔP of the incoming water. Extend a vertical line up to the desired outlet ΔP. Then, extend another line horizontally to the left at right angles to the first line to select the packing height. As an example, if the ΔP of incoming well water is about average for catfish hatcheries in the Mississippi Delta, and the desired outlet ΔP is about 10

Table 2. Guidelines for selecting packed column diameter, size of medium, and air flow rate based on water flow rates.

Recommended flow rate (gpm)	Maximum flow rate (gpm)	Column diameter (inches)	Media size (inches)	Air flow rate (cfm)	"Squirrelcage" blower size (amps)
15	20	8	1	6	0.2-0.3
35	50	10	1	14	0.2-0.3
70	100	12	1.5	28	0.4
125	150	16	1.5	50	0.5
150	250	18	2	60	0.6
250	450	24	2	100	0.7
450	700	30	3.5	180	2.1

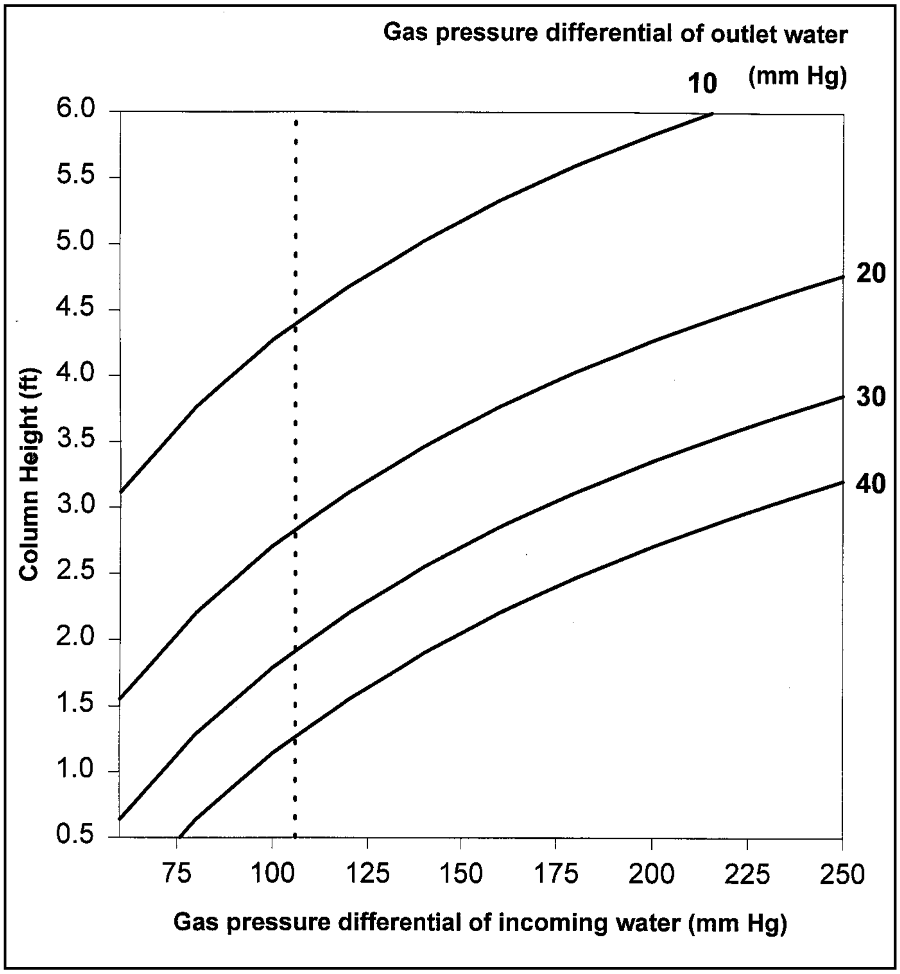

Figure 3. Packed column height required to result in various outlet water gas pressure differentials as a function of incoming water gas pressure differential. Dashed line indicates average gas pressure differential in groundwaters used in catfish hatcheries in the Mississippi Delta.

mm Hg, then the required packing height is 4 to 4.5 feet. Such a column height will also achieve at least 90 percent saturation of water with dissolved oxygen.

In both design cases, an additional 1.5 to 2 feet should be added to the column height to accommodate inlet and outlet plumbing adjacent to water distribution and media support plates.

The required diameter of a packed column will depend on water flow rate (Table 2). Flow rates to packed columns range from 40 to 100 gpm / ft^2 of column cross-sectional area. Table 2 offers some guidelines on the selection of appropriate column diameters. Most catfish hatcheries require a water flow of 100 to 150 gpm, and so will require columns 12 to 18 inches in diameter. Flow rate should not exceed the design maximum, as this will flood the column and prevent degassing. Also avoid using columns with diameters smaller than 6 inches because of potential problems with short-circuiting water flow down column walls.

One of the most important, and often neglected, design parameters of packed columns is air flow rate. Good air flow is essential for effective performance. Air flow provides oxygen and strips away undesirable dissolved gases such as carbon dioxide, hydrogen sulfide and methane. If the top and bottom of the column are open to the air, then air flow through the column should be sufficient to degas the water. In such a case, add 2 additional feet to the packing depth as determined by Figures 2 and 3. However, if the bottom of a packed column is placed in a sump or is sealed, then forced-air ventilation is necessary.

The principal behind a packed column is to break water up into thin layers, across which gas can transfer efficiently. This process is enhanced by passing a relatively large volume of air through the column in the opposite direction (counter current) to the water flow. At least 2 to 3 unit volumes of air should be added to the column for each unit volume of water (Table 2). “Squirrel-cage” blowers or regenerative blowers can be used for this purpose, but “squirrel-cage” blowers are a better choice because they are designed to deliver air against a very low pressure gradient, typical of packed columns, whereas regenerative blowers are designed to move air against a fairly low head pressure of water (typically 24 to 48 inches). Counter current air flow requires that the lower end of the packed column be sealed or submerged in a water collection sump or else the air will flow out of the column in the same direction as the water. It also requires an air ventilation riser pipe through the water distribution plate near the top of the column.

Packed column construction

Once column height, column diameter, medium size and blower size have been selected, the packed column can be constructed. Columns are generally cylindrical in shape; therefore, PVC pipe, concrete culverts, and lined grain silo rings are suitable materials for construction. Materials less than 1/8 inch thick can be used for packed columns. Packed columns can be integrated with water supply head tanks or built as “stand-alone” units.

The advantage of integrating the packed column with an exterior head tank is that water flow to the hatchery can be regulated by the head pressure of water in the tank. However, water must then be pumped to some relatively small additional head to account for the packed column height.

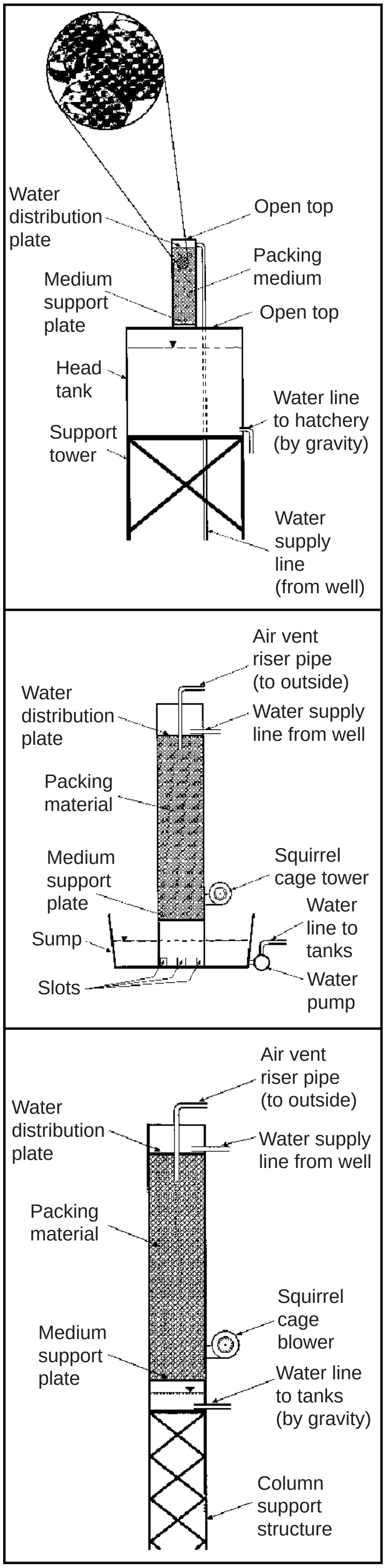

Figure 4. Components and suggested configurations of packed columns for channel catfish hatcheries.

Ventilation of packed columns integrated with head tanks is probably not necessary, as the top and bottom of the column are open. The major disadvantage of integrating a packed column with a head tank is the relatively large heat loss that may occur across the packed column, particularly when operated early in the hatchery season. A large heat loss as water passes through the packed column might necessitate reheating the water in a boiler, which may defeat the purpose of using the packed column because heating the water may itself cause supersaturation.

Stand-alone units can be placed within the hatchery building, but this configuration may require that water be pumped a second time, usually from a collection sump placed at the base of the column. If a packed column is placed within a water collection sump, then the column must be mounted in such a way that the packing medium is not flooded. This can be accomplished by physically mounting the column above the water level or, if the base of the column rests on the sump bottom, by placing the medium retention plate at a height in the column above the water level of the sump. When a stand-alone packed column is placed within a hatchery the building must be ventilated or the air flow from the column vented to the outside so that carbon dioxide and other harmful gases will not accumulate.

To construct a packed column, first suspend the medium support plate in the column. If the column is a stand-alone unit, locate the support plate at least 3 to 6 inches above the water level of the collection sump. Vinyl-coated hardware cloth or perforated aluminum sheet metal are suitable materials for support plate construction. The support plate in larger diameter columns may be supported by extending re-enforcing rods ("re-bar") or other rolling stock through the column and sealing the holes with silicone caulk. Or, blocks or a ring for holding the support plate can be attached to the inner diameter of the column.

Next, cut a square hole, corresponding to the outlet from the squirrel-cage blower, near the lower end of the column. The blower should be mounted well above the water level of the sump to minimize the potential for electrical shock and flooding of the blower motor. The blower can be mounted on the column just before installation or right after the column is installed.

Construct the water distribution plate and place it about 6 to 9 inches from the top of the column. This allows space for water to splash before passing through the plate. The water distribution plate does not need to be as rigid as the medium support plate, although it should be about 3/16 inch thick. Suitable materials include perforated aluminum sheet metal, plexiglass, or fiberglass-reinforced plastic. The support plate should be drilled with holes, as suggested in Table 3, with a hole in the center large enough for a riser pipe (2- to 4-inch ID depending upon column diameter) that vents the air introduced by the blower at the bottom of the column. If flow rate is expected to vary predictably (for example, increasing during the hatchery season), then multiple and interchangeable water distribution plates can be fabricated.

Before placing the water distribution plate in the column, add the packing medium. Add small amounts at a time and shake the column or use a stick or piece of pipe to stir the medium so it will pack well. Once the medium is packed into the column, place the water distribution plate on the plate support structure. Sealing the support plate to the column wall with a bead of caulk helps direct water flow through the column rather than down the wall.

The inflow pipe can be placed over the top of the distribution plate, or water can be introduced from the side, through the wall of

Column diameter (inches)	Air vent riser pipe diameter (inches)	Hole diameter (inches)	Number of holes at recommended flow rate	Number of holes at maximum flow rate
8	2	1/4	35	50
10	2	1/4	50	60
12	2	3/8	40	60
16	3	3/8	70	80
18	3	3/8	80	140
24	4	1/2	80	140
30	4	5/8	90	140

Table 3. Guidelines for constructing a water distribution plate for a packed column of a given diameter.

the packed column. The top of the column can be open or fitted with a cover that can also hold the water supply plumbing in place.

A packed column requires very little regular maintenance. Many groundwaters contain fairly high concentrations of dissolved iron, which can oxidize and settle out on the medium as a rust-colored solid. It is highly unlikely that enough oxidized iron will settle out to clog the medium. Rust-colored solids passing through the packed column can be removed by directing the water flow through a settling tank, gravel bed, or sand filter. It is good practice to inspect the column between hatchery seasons and, if necessary, remove the medium and dislodge any accumulated solids with high-pressure water. The medium also can be removed and placed in a solution of muriatic acid for cleaning, but should be thoroughly rinsed with fresh water before it is used again.

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References

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.

Marking, L.L., V.K. Dawson and J.R. Crowther. 1983. Comparison of column aerators and a vacuum degasser for treating supersaturated culture water. *Progressive Fish-Culturist* 45:81-83.

Tucker, C.S. Water quantity and quality requirements for channel catfish hatcheries. Southern Regional Aquaculture Center Publication 461.

Weitkamp, D.E. and M. Katz. 1980. A review of dissolved gas supersaturation literature. *Transactions of the American Fisheries Society* 109:659-702.

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