WATER CHEMISTRY IN RECYCLE SYSTEMS

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Introduction

Management of water chemistry is one of the most important considerations in recirculating aquacultural systems. Proper system management results in the minimization of stress, which in turn leads to healthier fish and hopefully more profitability. The different components in a recirculating system are designed to control one or more water quality functions, such as ammonia, temperature, dissolved oxygen, or solids. With some basic understanding of water chemistry and the ability to manipulate it, you should be able to manage many of the water quality problems associated with recycle system aquaculture. This overview of water chemistry will outline the basic requirements for recycle systems and review some of the more important water chemistry considerations.

Temperature

What is it?

Water temperature is a relative measure of hotness or coldness.

Why is it important?

Fish are ectothermic or "cold-blooded" and must rely on the culture water temperature to maintain their body heat and to govern metabolic rates. Different fish require different temperature regimes, for example trout prefer colder water and catfish prefer and grow better in warmer water. Changing water temperature suddenly in a culture system can be lethal; try to keep changes in temperature to less than a few degrees if possible.
Temperature affects many processes related to fish culture, including fish activity, behavior, feeding, growth, and reproduction. Temperature also affects the activity of the biological filter as the bacteria in the filter behave in a similar fashion as the fish with respect to temperature. Most chemical processes are affected by temperature, such as ammonia toxicity or dissolved oxygen levels.

How can we measure it?

Temperature can be measured with an ordinary thermometer and a wide variety are available ranging from simple glass thermometers to more elaborate (and expensive) electronic thermometers.

What is optimal?

Temperatures should be matched to the particular species being raised. Warmwater species such as catfish require temperatures in the range of 75-90°F, with about 85°F considered optimal. Coolwater species such as hybrid striped bass, yellow perch, or walleye desire temperatures in the range of 60-80°F. Trout are an example of a coldwater species and they prefer temperatures in the range of 48-65°F for optimal growth. Properly designed

recirculating systems offer the advantage of allowing for temperature control and maintenance.

Problem solving

When temperatures are outside of desired ranges in a recirculating system, check to make sure that the heating/cooling components are functioning properly. The solution may be as simple as a tripped circuit breaker or as expensive as a component failure. Remember, do not heat or cool the water too rapidly, slow changes reduce stress and fish kills. Always temper newly introduced fish in the quarantine area slowly.

Dissolved Oxygen

What is it?

When oxygen from the atmosphere (or other sources) comes into contact with water, an equilibrium is established and a small percentage dissolves in the water. When none of the oxygen is consumed in the water the equilibrium established is the saturation level of oxygen. This saturation level is a function of temperature and salinity. Cold water has a higher saturation level than warmer water and fresh water has higher saturation levels than salt water.

Why is it important?

Dissolved oxygen is probably the most critical factor to manage in a recycle system. Low dissolved oxygen levels can become deadly to your crop in a matter of minutes. In recirculating systems, there are many competitors for the available oxygen in the system. These include the fish, nitrifying bacteria (which break down ammonia and nitrite), and other bacteria that consume organic carbon in the system (commonly referred to as biochemical oxygen demand or BOD). Oxygen levels in a recirculating system will vary according to the density of fish in the system—the more fish, the greater the oxygen demand. Changes in metabolic rates of the fish can also affect the dissolved oxygen levels in a recirculating system. These metabolic rate changes are a function of water temperatures and fish activities. Feeding is one management activity that affects the metabolic activity of fish and can dramatically change the oxygen demand in a recycle system.

How can we measure it?

Dissolved oxygen can be measured with wet chemistry test kits or with electronic instruments. For small-scale systems, test kits could be used, but the chemical tests require about 10-15 minutes per test to complete. For most applications, electronic meters are recommended for monitoring dissolved oxygen. A good meter and probe will probably cost about $500, but the cost is well worth the convenience and durability of the equipment. Dissolved oxygen should be measured routinely in recirculating systems. Measure dissolved oxygen at least once daily at the same time of day and at the same time in relation to feeding activity. For example, measure dissolved oxygen each day at 8 AM, just prior to feeding. This will provide a good basis for comparison. Measure more frequently for changing conditions in your system, when the fish appear to be stressed, or during the initial start-up of a system. Periodically measure dissolved oxygen about 10-15 minutes after feeding to determine peak demand periods.

What is optimal?

Dissolved oxygen levels should be kept as close to saturation as possible. Tables are readily available that show saturation levels of oxygen as a function of temperature and salinity. In all cases, dissolved oxygen should be maintained at 5 mg/L or more for most fish species. Levels lower than 5 mg/L are tolerable for many species, but are also stressful to the animals.

Problem solving

A properly designed oxygenation system will have sufficient capacity to meet the demands of the fish and other consumers in a recycle system. Make sure that tanks are well mixed so that oxygen levels are close to uniform throughout the system. In the event of low oxygen events, back-up oxygenation supplies are required and should be a part of every recycle system. Do not feed fish during an oxygen crisis and keep them off feed for about 12-24 hours after the crisis. Bring them back up to optimal feeding rates over a few days to allow the system to respond. Treat the fish for stress as required in your operating plan.

Ammonia

What is it?

Ammonia is a metabolic by-product of the fish in your system. The fish consume food and excrete ammonia directly form their gills and in their feces. As fecal matter breaks down in the system, more ammonia is released. Ammonia is present in water in two forms. Ionized ammonia (NH_4) is one of the forms and it is relatively nontoxic to fish. Un-ionized ammonia (NH_3) is the other form and it is highly toxic or at least stressful to fish at relatively low levels.

The relative proportions of NH_4 to NH_3 are governed by other chemical factors in the water. Temperature, pH, and salinity all affect the relative proportion of NH_4 to NH_3. The proportion of NH_4 to NH_3 shifts towards NH_3 with higher salinity, pH and temperatures.

Why is it important?

Ammonia is highly toxic to fish. A properly designed system will have sufficient biological filtration capacity to maintain ammonia at levels that are minimally stressful to the fish. Elevated ammonia levels will normally be present in a system during the acclimation and start-up of a biological filter and when feeding levels are suddenly increased. Remember, the biological filter is a living system and it needs time to adapt to changes.

How can we measure it?

Ammonia can be easily measured with water test kits. These kits are available from several manufacturers and provide sufficient accuracy for management of recirculating systems. There are probes available for measuring ammonia, but they are expensive and require constant calibration.

What is optimal?

Ideally, ammonia in the form of NH_3 should be kept below 0.02 mg/L, but levels below 0.1 mg/L should be adequate for short-term exposures. Remember that ammonia is in two forms. Convert your ammonia measurement (usually either total ammonia or NH_4) to NH_3 by referring to the directions with the test kit. Tables are available for converting total ammonia

readings to NH_3 based on temperature and pH.

Problem solving

Elevated ammonia levels can be problematic to manage, but must be decreased as quickly as possible. Stop feeding the fish. Check for proper flows of water to and through the biofilter. Flush the system with new water if possible, but remember, that the new water must be at the proper temperature or the fish will be additionally stressed.

In general, the biological filter should be quite hardy and adaptable to slow changes in feeding levels. Increase feeding levels slowly over time, especially when the fish are larger and adjustments will result in relatively larger amounts of feed. Check the system pH and make sure that the pH is above 6.5. If not, add alkalinity to the system (see section below on alkalinity). Finally, make sure that there is sufficient oxygen in the filter by checking the effluent from the filter for oxygen. The effluent should have dissolved oxygen levels of at least 2 mg/L.

Nitrite

What is it?

Nitrite (NO_2) is an oxidized form of nitrogen that is a byproduct of the nitrification process in the biological filter. Nitrite is further oxidized in the biological filter to form nitrate (NO_3), which is relatively nontoxic to the fish.

Why is it important?

Nitrite is highly toxic to fish. Elevated nitrite levels will interfere with the fish blood's ability to transport oxygen. During the start-up of a biological filter nitrite levels will be sufficiently high to be toxic to the fish in a system. Nitrite levels can also be elevated when the biological filter is not operating properly or when feeding levels are increased dramatically.

How can we measure it?

Nitrite can be easily measured with water testing kits. These kits are available from a variety of manufacturers and provide reliable measurements for managing a recirculating system.

What is optimal?

Try to maintain nitrite levels below 0.1 mg/L.

Problem solving

Ensure that the biological filter is working properly. Check for oxygen levels in the biological filter effluent and make sure that there is at least 2 mg/L of dissolved oxygen. The addition of salt is not recommended for freshwater recirculating systems as a treatment for high nitrite levels because the salt will adversely affect the biological filter. Stop feeding the fish and determine the reason for the problem. Dilute the system water with new water if sufficient volumes are available at the proper temperature.

pH

What is it?

By definition, pH is a relative measure of the concentration of hydrogen ions in solution—pH is the negative logarithm of the concentration of hydrogen ions. From a practical consideration, pH gives us a relative comparison of the degree of acidity that a solution is. A neutral solution has a pH of 7.0, an acidic solution has a pH of less than 7.0, and a basic solution has a pH greater than 7.0.

Why is it important?

The pH of a water can directly affect the fish and other organisms living in that water and also has many indirect effects. Most aquatic species prefer a pH of about neutral to slightly basic. The pH also affects the toxicity of many other chemicals, including ammonia and nitrite. Ammonia is more toxic (i.e., in the form of NH_3) at higher pH levels and less toxic at lower pH levels. The toxicity of ammonia increases ten fold for every 1.0 increase in pH above 7.0. The biological filter in a recirculating system produces acid when it is working properly, so pH needs to be continually assessed and adjusted to ensure good water quality.

How can we measure it?

There are a variety of methods that can be used to measure pH, including simple test strips, wet chemistry test kits, and electronic probes. For most applications a wide-range test kit should provide adequate pH measuring capabilities.

What is optimal?

Optimal pH levels for most fish and the nitrifying bacteria are in the range of about 7.0 9.0. The pH in a recirculating system should, however, be kept in the range of about 6.8 to 7.2. Since ammonia is much more toxic at higher pH levels and the biological filter will operate satisfactorily at in this range, the margin of safety afforded the lower pH levels is the better management strategy for maintaining pH. Care must be taken to keep the pH from falling below 6.5, as the biological filter will not operate properly.

Problem solving

The most effective and safest way to maintain pH in a recirculating system is to use sodium bicarbonate (baking soda). There are many other compounds that can be used, but most contain undesirable chemicals that will lead to problems in recirculating systems. For example, limestone(calcium carbonate) is very similar to sodium bicarbonate, but the build-up of calcium in the system can lead to the precipitation of calcium throughout the system. Sodium bicarbonate also does not cause excessively high pH levels, as the maximum pH that can be achieved with sodium bicarbonate is about 8.2. It is not recommended that acids are added to a system in an attempt to lower pH, let the acid production of the biofilter gradually reduce the pH and then use sodium bicarbonate to maintain the desired levels.

Alkalinity

What is it?

Alkalinity is defined as the total of all of the bases (bicarbonate and carbonate are the predominate ones) in water. It is important to distinguish alkalinity from hardness, both of

which are usually expressed as mg/L of $CaCO_3$. Hardness is the concentration of calcium and magnesium in water. In many waters, the hardness and alkalinity are approximately equal. Both are important in fish culture, but in recirculating systems, the hardness can be much higher than alkalinity as the alkalinity is used up by the biofilter.

Why is it important?

Alkalinity serves two very important functions in a recirculating system. The equilibrium of carbon dioxide, bicarbonate, and carbonate in water serves as an effective means to keep the pH close to neutral. As acid is added to the system from the biological filter, the acid is neutralized by the bicarbonate in the water. This neutralization property is called buffering and it prevents large shifts in system pH. The bacteria in the biological filter also require bicarbonate to build cells as they consume ammonia.

How can we measure it?

Alkalinity can be easily measured with wet chemistry test kits.

What is optimal?

The alkalinity in a recirculating system should be maintained between 150 to 200 mg/L as $CaCO_3$.

Problem solving

The most effective and safest way to maintain adequate alkalinity in a recirculating system is to constantly add sodium bicarbonate. Once per day additions or as needed additions are satisfactory, but will produce minor fluctuations in pH. A concentrated solution can be mixed in water and constantly metered into a recirculating system with a peristaltic pump. The dose will depend on the feeding rate and can be easily calculated. Remember, pH levels below 6.5 will adversely affect the performance of the biological filter, but the performance can be quickly improved with the addition of alkalinity and increase in pH.

Suspended Solids

What is it?

Suspended solids are small solid particles that remain in the water column, even under quiescent conditions. Water with excessive suspended solids is termed turbid and should be distinguished from water that is transparent, but dark in color.

Why is it important?

Excessive suspended solids clog the gills of fish and make it difficult for them to breathe. Additionally, excessive solids in the water add to the oxygen demand in the system and provide surfaces for many bacteria to grow. Larger particles will settle relatively fast and are easily removed with properly designed solids removal components. Smaller particles tend to stay in the water column and are much more difficult to remove than larger particles.

How can we measure it?

Suspended solids are easily measured with a glass jar. Take a water sample from the culture tank, place it in the jar and let the jar sit still for about 3-5 minutes. If the majority of the solids in the sample are still in the water column and did not settle to the bottom, then

there probably high levels of suspended solids in the system. There are a variety of tests for measuring suspended solids and turbidity, ranging from simple test kits to electronic meters.

What is optimal?

When using a jar to determine the suspended solids in water, the water should be relatively clear after 3 minutes, with the majority of solids settled to the bottom of the jar.

Problem solving

Check the operation and maintenance of the solids filter if excessive suspended solids are present in a recirculating system. Add more filtration capacity if necessary.