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Flow rate estimation for RAS

1 July 2015
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Control the build-up of ammonia-nitrogen, nitrite-nitrogen

Even if a facility has a properly sized or even oversized biofilter, as in this large moving-bed biofilter with ultraviolet treatment, yet the flow between the biofilter and culture tank is too slow, the biofilter capacity will never be fully utilized, and ammonia nitrogen can build up in the culture system. Photo courtesy of Mote Marine Lab.

The production of aquacultured species in land-based systems using tanks and recirculating aquaculture system (RAS) technology is expanding globally. This trend is driven by the need for intensified production while using less water, combined with the requirement to reduce the volume and strength of system effluent.

One important element of the unit processes involved in RAS technology is estimating the flow rate requirements for the water recirculated from the culture tanks to the biofilter. Using mass balance analysis, an estimate of the flow requirements can be made in order to control the build-up of ammonia-nitrogen and nitrite-nitrogen in the system.

Operating parameters

The water quality in a recirculating system is generally a function of the tank size, the biomass in the tank, the rate of feed input, and the waste removal and treatment efficiency of the system. The first operating parameters that need to be determined are the tank volume and maximum allowable stocking density.

Stocking density is determined by the species being cultured and its life stage. As an example, assume fish are in the growout stage of life and will reach market size at an average 680-g weight in a 50-cubic-meter culture tank. For the species in question, the maximum culture density is assumed to be 80 kg fish per cubic meter of tank volume. Hence, the maximum cultured biomass in this tank would be 80 kg/cubic meter x 50 m3 = 4,000 kg or 4 metric tons.

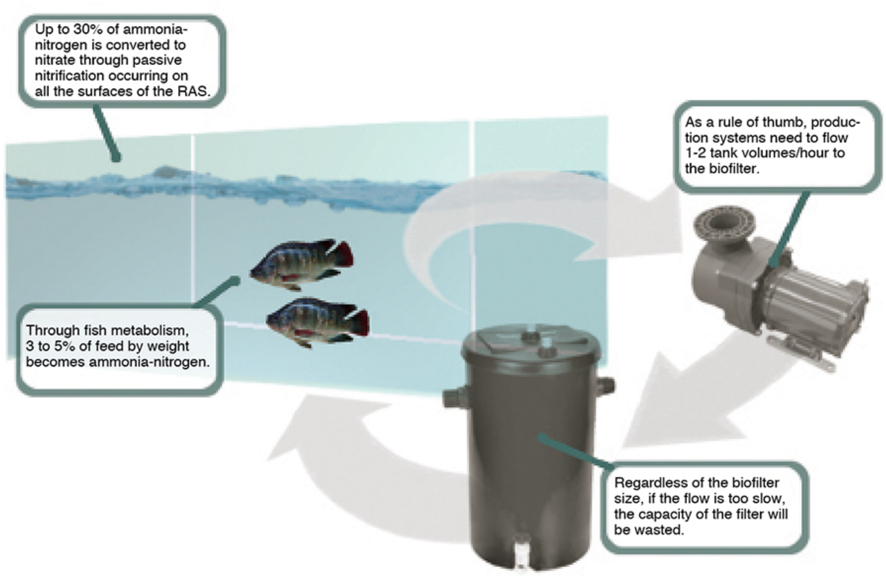
Assume the daily feed rate at this maximum density is 1.5 percent of the fish body weight. In this example, the maximum daily feed rate will come near the end of the production cycle and peak at 4,000 kg fish x 1.5 percent of biomass/day = 60 kg feed. Assume for this example that the protein content of the feed is 40 percent.

Ammonia-nitrogen production, conversion

Ammonia-nitrogen is excreted from the gills of fish as they assimilate feed and is also produced when bacteria decompose organic waste solids within the tanks and other components of the RAS. The amount of ammonia produced in an RAS is directly related to the rate of feed additions to the system, the protein content of the feed and an estimate of the nitrogen being wasted, which is related to the culture species and system design.

In general, estimate that 50 percent of the nitrogen added to the system via feed is not utilized by the fish and is a source of total ammonia-nitrogen (TAN). Given that 16 percent of protein is nitrogen and there are 1.2 g TAN/g nitrogen, the production of TAN in the example production system can be estimated as:

This formula estimates that roughly 4 percent of the feed becomes TAN within the RAS. In general, with feed protein content varying from 30 to 55 percent, this equation estimates TAN production rates as 3 to 5 percent of the weight of the feed, a reasonable estimate that is often cited.



In general, an RAS requires water to flow from the culture tank to the biofilter once or twice an hour depending on the desired tank TAN concentration and biofilter efficiency.

The next step is to estimate the amount of TAN lost from the system in effluent. First estimate the volume of daily effluent from the system in liters and the TAN concentration desired in the culture tank. In this example, assume the TAN in the effluent is the same as in the tank, which is not always the case. The amount of TAN lost in the effluent can be estimated as:

TAN produced (kg/day) = 60 kg Feed/day x 40% Protein x 50% Nitrogen wasted x 0.16 g Nitrogen/g Protein x 1.2 g TAN/g Nitrogen

TAN produced = 2.3 kg TAN/day

For this example, assume the desired TAN concentration is 1.5 mg/L, and the amount of effluent is 10 percent of the system volume per day or 5,000 L. This calculating is not really necessary in a typical RAS due to the minimal discharge volumes and low TAN concentration. Only 7.5 g of TAN would be discharged in the effluent in this example.

However, there is a secondary ongoing process in the RAS called passive nitrification. This is due to the nitrifying bacteria within the system growing on all of the surfaces of the system. These bacteria, like their “cousins” on the biofilter surfaces, can convert at much as 30 percent of the TAN to non-toxic nitrate-nitrogen. In this example, assume 20 percent passive nitrification. As such, the biofilter would need to nitrify 80 percent of the TAN produced within the system or 1.84 kg of TAN.

Estimating biofilter flow rate

Mass balance can be used to estimate the flow required to go from the culture tank or tanks to the biofilter to maintain the desired TAN concentration. The efficiency of a biofilter depends on the TAN concentration of the water entering the biofilter, biofilter type and flow rate through the biofilter.

For most biofilters used today, approximately 50 percent of the TAN is removed per pass through the biofilter. Using this estimate and the numbers above yields an estimate of the daily flow required to go to the biofilter as:

TAN discharged in effluent (g/day) = [Tank TAN concentration (mg/L) x Effluent volume (L/day)]/ 1,000 (mg/g)

In the example, the TAN available to the biofilter after accounting for passive nitrification is 1.84 kg/day. The desired tank TAN concentration is 1.5 mg/L, and the biofilter removal efficiency is estimated at 50 percent.

Using the numbers given for this example in the equation, the flow rate from the tank or tanks to the biofilter can be estimated at 2,453,333 L or 2,453 m3/day, which is 102,000 L or 102 m3 hourly. Note that in the 50-m3 tank, this equation estimates the total volume of the tank will need to flow through the biofilter more than twice every hour.

It is instructive to note that if the concentration in the tank is allowed to be higher, say up to 3 mg/L, the flow rate to the filter would be cut in half to roughly one hourly exchange. Hence, the lower the required TAN concentration, the higher the required biofilter flow.

Therefore, carefully specifying the required maximum TAN concentration in the tank can be instrumental in reducing the energy use in pumping water to the biofilter and back to the tank. Coldwater RAS for salmonids commonly operate with tank turnover rates of 30 minutes or less, while warmwater RAS often operate with 60-minute turnover rates. The difference can be attributed to the lower TAN concentration required to grow coldwater species.

(Editor's Note: This article was based in part on research conducted by the author and Alexander Hobbs at North Carolina State University and published in the Volume 23, 2000 journal of Aquacultural Engineering*. The spreadsheet in that publication presents all of what is described here in spreadsheet format.)*

(Editor's Note: This article was originally published in the July/August 2015 print edition of the Global Aquaculture Advocate*.)*

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