**Aquacultural Engineering Society News**

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# Letter From Your President

Dear AES Members,

I believe that we, as a society, will look back on this year as the year in which we matured from a national to an international society. I have the pleasure of witnessing the blossoming of a seed sown by two of my predecessors as president of the AES, Drs. Lorsordo and Piedrahita. This transition is evidenced by a dramatic increase in participation by our international colleagues at virtually every event we have hosted in the United States, and by a dramatic increase in international travel by our North American membership in support of programs across both the Atlantic and Pacific Oceans. I personally have found this to be an enriching experience as my rather parochial engineering position is first challenged, then invigorated by new perspectives.

We are being told that the demand for aquacultural products will grow dramatically in the next decade. A ten-fold increase in production for the United States and select European countries can easily be envisioned if a myriad of socio-economic challenges are overcome. Engineering skills will be very important; yet, I observe that aquacultural engineering remains a relatively rare expertise. The membership of this Aquacultural Engineering Society, for example, is currently under 200. Although we can now boast a more rounded international membership, I believe the challenges are growing faster than our society. There is no easy solution since our growth is based upon training and experience that does not come easily. I can only conclude that we must continue to expand our net of inclusion and open all the channels of communication if we are to meet the engineering challenges that a rapidly expanding industry poses.

Speaking of challenges, our North American Environmental Regulatory Agency, the U.S. EPA, continues to systematically work towards the establishment of national effluent guidelines for aquacultural facilities. The guidelines would establish minimum treatment or effluent quality standards. In cases where existing state regulations are more stringent, the guidelines would have no effect. We, as a society, are participating in this process through the Effluents Task Force organized through the USDA with support of our National Sea Grant Program. You can plug into this process personally by visiting the Joint Subcommittee on Aquaculture homepage (http://ag.ansc.purdue.edu/aquanic/jsa/effluents/whatsnew.html) dedicated to this topic.

The EPA's staff is currently focusing on the development of baseline data describing the industry. I attended a meeting in Washington, D.C. during the last week of September 2000, where technical representatives of sub-committees critiqued the EPA's first attempt to describe the industry. It was a real eye-opener for all involved – clearly revealing the complexity of the task that confronts the EPA personnel. A number of our members participated and continued nudging the process towards technical accuracy. It is a long process and I believe it will be sometime in the spring of 2001 before the nature of these standards become evident.

The next time we will all have an opportunity to get together for more specific informational updates will be the *Aquaculture 2001* conference, which is being held in Orlando, Florida from January 21 through January 25, 2001. Our program chair for this meeting, Dr. Steve Summerfelt, has worked hard to put together a solid AES program that features a well-coordinated international session. We will also host a training session and a fair number of contributed papers. We will hold both board and general AES membership meetings. I look forward to seeing you there. Orlando is always a fun place to visit!

With Best Regards,

Ron

Ronald F. Malone, President
Aquacultural Engineering Society

## *Inside:*

# Design of Gas Transfer Systems For Aquaculture: Part 1. Site and Water Supply Considerations

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*There is more to gas transfer than oxygen transfer!*

## INTRODUCTION

In the intensive culture of aquatic plants and animals, important water quality parameters include dissolved gases such as oxygen, carbon dioxide, hydrogen sulfide, ammonia, and nitrogen. Operation of a gas transfer system designed to modify the concentration of a single gas, such as oxygen, may significantly change the concentration of other gases in solution. Consideration of gases such as nitrogen and argon may significantly affect the design of pure oxygen systems or may require gas stripping prior to the use of these systems. Hydrogen, methane, and radon may be found in significant concentrations in some groundwaters. The build-up of carbon dioxide in rearing units and its removal also becomes an important problem in pure oxygen systems. Thus design of a gas transfer system must consider potential impacts of all these dissolved gases and in some cases, water quality parameters such as reduced iron and manganese, hardness, and pH.

For any facility of significant size, a formal water quality sampling program is needed in the site selection process or at least before significant site-specific project costs have been incurred. It is difficult to economically design a gas transfer system if information on dissolved gas composition is not available. Many operating problems are the direct result of designs based on inadequate water quality information. It may be possible to treat any type of water to an acceptable quality, but the capital and operating costs required can be substantial.

Part 1 of this article will discuss the objectives of gas transfer, gases of interest, and recommendations for water quality sampling and analysis. This information is presented to help define potential water quality problems that may occur in a specific type of water source and to direct the site selection process. However, this section is not a substitute for a well-planned water quality sampling and analysis program. Part 2 will discuss rating of systems under standardized and field conditions, and Part 3 will discuss gas transfer design and aerator selection.

## GASES OF INTEREST IN AQUACULTURE

The dissolved gases in surface and groundwaters will depend strongly on the specific site and processes that have operated on the water. Some water sources have daily and seasonal variations, so a single gas determination may result in incorrect assumptions about dissolved gas concentrations at a given site. While oxygen is the primary gas of interest in aquaculture, nitrogen + argon, carbon dioxide, methane, hydrogen sulfide, ammonia, and radon must often be considered. Physical and biological characteristics of these gases are presented in Table 1. The four major gases in the atmosphere are nitrogen, oxygen, argon, and carbon dioxide. Detailed information on the biological importance and occurrence of these gases is presented in the following sections.

### *Oxygen Gas*

Oxygen is needed for oxidative phosphorylation, the underlying biochemical mechanism of energy transformation in fish. The minimum dissolved oxygen concentration to sustain life in water depends on species and life stage, but typically ranges from about 3-6 mg/L.

### *Groundwater and Springs*

Studies have shown that 2 to 8 mg/L of dissolved oxygen is present in water from a variety of deep (100 to 1000 m) aquifers in the United States. The common assumption, that dissolved oxygen in deep aquifers is close to zero, is not universally correct.

### *Streams and Rivers*

In fast flowing streams, the dissolved oxygen concentration is typically close to air-solubility values based on local temperature and pressure, and therefore will change seasonally with water temperature. Dissolved oxygen levels up to approximately 120% can be produced by waterfalls and natural bubble entrainment and air entrainment below dams can produce even higher levels of oxygen and nitrogen supersaturation. In slow moving streams, photosynthesis by algae attached to the bottom, floating aquatic plants, or rooted aquatic plants can produce dissolved oxygen swings from 0 to 300% on a daily basis.

Table 1. Physical characteristics of important gases.

| Gas | Symbol | Mole Fraction in Air (unitless) | Solubility in Air at 15°C (mg/L) | Solubility in Pure Gas at 15°C (mg/L) |
|---|---|---|---|---|
| Oxygen | $O_2$ | 0.20946 | 10.08 | 48.14 |
| Nitrogen | $N_2$ | 0.78084 | 16.36 | 20.95 |
| Argon | Ar | 0.00934 | 0.62 | 65.94 |
| Carbon Dioxide | $CO_2$ | 0.000350 | 0.69 | 1992.53 |
| Methane | $CH_4$ | $1.7 \times 10^{-6}$ | --- | 27.69 |
| Hydrogen Sulfide | $H_2S$ | 0 | --- | 4495 |
| Ammonia | $NH_3$ | 0 | --- | $>1 \times 10^6$ |
| Radon | Rn | 0 | --- | --- |

### *Lakes and Reservoirs*

Variation in dissolved oxygen concentration in lakes is complex, depending primarily on productivity, stability of the water column, pollutant inputs, and morphology. The dissolved oxygen concentration is typically not uniform in the vertical and horizontal directions and may have significant seasonal variations.

In shallow lakes, photosynthesis during high light levels and low wind levels may result in dissolved oxygen concentrations in the range of 17-30 mg/L (170-300%), and these concentrations have resulted in major fish mortality. Warming of lakes during the spring and summer can produce gas supersaturation near the thermocline, and photosynthesis also increases the oxygen concentration above the thermocline.

Due to algal and bacterial respiration in the water and bacterial activity in sediments, the bottom water of many lakes and reservoirs may have extremely low levels of oxygen. These low levels are especially common in reservoirs in the Southeastern United States. Due to low dissolved oxygen concentrations and reduced iron and manganese, this water may be lethal to fish and other aquatic animals for many miles below a dam. Algal and bacterial respiration can also reduce dissolved oxygen concentrations to levels lethal to fish in shallow ice-covered lakes.

### *Intertidal and Marine Waters*

Dissolved oxygen in near-shore marine waters is close to the air-solubility concentration computed from the local temperature and salinity. Dissolved oxygen concentrations in the surf zone should be supersaturated due to air entrainment resulting from breaking waves, although documentation of this is lacking.

Dissolved oxygen in kelp-covered tidepools show extreme daily fluctuations due to photosynthesis. The direction and magnitude of these fluctuations depend largely on the phase of tidal and diurnal cycles at immersion time.

Shallow wells drilled or driven into beach sand are commonly used sources of seawater for laboratories and aquaculture facilities. The water obtained from these types of wells is filtered by the sand and has a relatively constant temperature. However, dissolved oxygen concentrations from these wells are low due to bacterial activity in the sand. Water from deep seawater wells may be devoid of oxygen and may contain a number of undesirable compounds, such as hydrogen sulfide and reduced iron and manganese.

### *Nitrogen + Argon Gas*

Nitrogen and argon are biologically inert gases but play major role in the development of gas bubble disease. Major processes producing gas supersaturation are (1) heating of water, (2) ice formation, (3) mixing of water of different temperatures, (4) air entrainment, and (5) photosynthesis. Gas supersaturation is measured in the field using a membrane-diffusion device. This type of instrument measures the △P, the difference between local barometric pressure and the total gas pressure. The △P is expressed in units of millimeter of mercury (mm Hg) and is the best measure of the risk to aquatic animals from gas supersaturation.

The △Ps of groundwaters and spring waters depend on physical conditions at the recharge area, chemical reactions of dissolved gases above and below the water table, and subsequent temperature changes of the water. The △P of groundwaters and springs range from negative values to approximately 300 - 500 mm Hg. Some springs show relatively constant △Ps over the year, but others show a seasonal maximum during the winter.

Natural air entrainment in fast flowing streams, rapids, or waterfalls and natural heating may be the primary mechanisms for production of gas supersaturation in streams. Maximum levels may range from 40 to 150 mm Hg and occur in the spring or early summer. The △P resulting from air entrainment is a direct function of stream flow and therefore may vary on a daily basis. Air entrainment at spillways can produce △Ps in the range of 200 to 350 mm Hg, and maximum levels occur during the spring runoff.

In shallow lakes with appreciable ice formation, solute freeze-out (gases are forced out of water as it freezes) can produce lethal gas supersaturation. Photosynthesis combined with solar heating in bays with restricted circulation can result in major mortality of fish.

### *Carbon Dioxide Gas*

The carbon dioxide gas concentration in groundwaters is highly variable and can typically range from below saturation to 30-40 mg/L, depending upon the depth and characteristics of soil, subsurface geology, and chemical reactions of dissolved carbon dioxide gas. Concentrations of carbon dioxide gas in soils are significantly higher than in air as a consequence of bacterial respiration and decay of organic matter; thus as groundwater percolates through soils, its carbon dioxide concentration increases. Carbon dioxide can be removed by the following reaction:

$$CaCO_3 + HOH + CO_2 \Rightarrow Ca^{2+} + 2HCO_3^-$$

Therefore, groundwater from areas with carbonate rocks may have carbon dioxide concentrations less than saturation. In the absence of $CaCO_3$ or other minerals, carbon dioxide concentrations in groundwater and springwater can be highly supersaturated.

The carbon dioxide status of a groundwater can be determined by comparing measurements of the pH of a non-aerated sample with that of an aerated sample:

| Change in pH upon Aeration | Carbon Dioxide Status |
|---|---|
| Increase | supersaturated |
| No change | equilibrium |
| Decrease | undersaturated |

Water in ponds containing phytoplankton or aquatic plants may show a daily fluctuation in carbon dioxide concentration.

The production of carbon dioxide in a rearing unit has three primary effects: (1) increase in dissolved carbon dioxide concentrations, (2) decrease in pH, and (3) reduction in the mole fraction of un-ionized ammonia due to the decrease in pH. In high-intensity pure oxygen systems, carbon dioxide is the most limiting parameter at $pH_e$s ($pH_e$ = pH of water in equilibrium with the atmosphere) ranging from 7.4 to 8.6. Maximum production of metabolic carbon dioxide occurs 3-4 hours after feeding. In some high-intensity hybrid stripped bass systems using pure oxygen, quicklime has been added to remove carbon dioxide during the peak production period. Pure oxygen systems remove a negligible amount of carbon dioxide gas and gas-to-liquid ratios in the range of 20-40 are needed to effectively remove carbon dioxide.

### *Methane Gas*

For vertebrates, methane gas can be considered biologically inert. Methane can be formed by bacteria in anaerobic sediments by degradation of organic compounds. Bubbles commonly observed rising from the bottom of ponds are largely methane. Anaerobic lake or ocean waters can be expected to contain measurable amounts of methane and carbon dioxide. Areas with bogs, highly organic sediments, or those near natural gas production areas may have high groundwater methane concentrations. Groundwater can contain methane levels high enough to be explosive and require degassing prior to use to avoid gas supersaturation problems.

### *Hydrogen Sulfide Gas*

Hydrogen sulfide is highly toxic to aquatic animals, and the current U. S. Environmental Protection Agency water quality criteria is 2 mg/L. Hydrogen sulfide is produced from the reduction of sulfate ions by bacteria in anaerobic waters and sediments. In the presence of oxygen, hydrogen sulfide is oxidized to either sulfate or elemental sulfur. The time required for the oxidation of hydrogen sulfide is measured in days.

### *Ammonia Gas*

Un-ionized ammonia ($NH_3$) is highly toxic to aquatic animals. Significant natural concentrations of ammonia are found in some groundwaters. Pollution from septic systems, feed lots, and municipal discharges may also increase ammonia concentrations in groundwater and surface waters. Because of its very high solubility, air stripping of ammonia is not feasible for most aquaculture applications.

### *Radon Gas*

Radon is a naturally occurring water soluble radioactive gas. It is anticipated that the U.S. Environmental Protection Agency will set a maximum contaminant level of 300 pCi/L (a measure of radioactivity) for radon. High levels of radon gas have been found in hatchery buildings resulting from degassing of spring waters prior to use. When radon is present, the off-gas from stripping systems should be discharged to the outside.

## OTHER WATER QUALITY PARAMETERS THAT MAY IMPACT GAS TRANSFER

Anoxic waters may contain reduced iron and manganese ($Fe^{+2}$ and $Mn^{+2}$). Upon aeration, these compounds will be oxidized and result in formation of particulate $Fe(OH)_3$ and $MnO_2$. These compounds can clog the gills of larval fish and crustaceans. In certain applications, it is necessary to settle or filter out these solids prior to use. The oxidation of these compounds can also represent a significant oxygen demand. These compounds may stain packing used in packed column aerators; however, this generally has little impact on performance.

Water containing high levels of calcium and carbon dioxide is common in some parts of the country. Upon degassing of the carbon dioxide, the pH will increase, and calcium carbonate may precipitate. In some cases, enough calcium carbonate is formed to significantly reduce water flow and performance of some types of aerators in a matter of weeks.

Table 2. Water quality problems in actual facilities.

| | Problem Gas | | | | |
|---|---|---|---|---|---|
| Parameter | Gas Supersaturation and Oxygen | Gas Supersaturation | Methane/Gas Supesaturation | Radon | Hydrogen Sulfide & Ammonia |
| Type of water | wellwater | surface water | wellwater | spring water | wellwater |
| Characteristics | groundwater | large river or reservoir | groundwater | groundwater | limestone basement area |
| Facility | production | production hatchery | production hatchery | production hatchery | laboratory |
| pH | | | | | |
| influent | -- | -- | -- | -- | 7.5 |
| equilibrim | -- | -- | -- | -- | 8.9 |
| processwater | -- | -- | -- | -- | 7.8-7.9 |
| Problem | high gas supersaturation and low dissolved oxygen | gas supersaturation from air entrainment at dams (both nitrogen and oxygen supersaturated) | lethal levels of gas supersaturation | operation of degassing columns resulted in high levels of radon gas in hatchery building | high hydrogen sulfide and ammonia concentrations |
| Impact | increased mortality | high mortality | total mortality if not degassed; explosion potential | human health concerns | increased mortality |
| Variability in dissolved gases | relatively constant; some seasonality | occurs during high flow periods | relatively constant | unknown | strongly depends on the local subsurface geology and rainfall, highly variable |
| Location | various states | Idaho, Washington, & Oregon | California | Montana | Central Florida |

-- = pH unknown

Table 3. Dissolved carbon dioxide problems in actual facilities.

| Parameter | Carbon Dioxide Problems | | | |
|---|---|---|---|---|
| Type of water | surface water | surface water | spring | wellwater |
| Characteristics | small stream | from large spring | spring | groundwater |
| Facility | hatchery, 3-pass pure oxygen system | production hatchery | production hatchery | laboratory |
| pH | | | | |
| influent | 8.0 | 8.1 | 8.9 | 6.6 |
| equilibrium | 8.0 | 8.8 | 7.8 | 8.3 |
| process water | 7.0 (3rd pass) | -- | -- | -- |
| Problem | high concentration of carbon dioxide following feeding (no carbon dioxide removal by pure oxygen aerators) | high carbon dioxide and hardness; precipitation of calcium carbonate upon aeration | water undersaturated with carbon dioxide; high initial pH before aeration | high carbon dioxide not removed by pure oxygen system; necessary to convert to atmospheric system |
| Impact | reduced growth in third raceway | operational problems due to sediment production; high pHs | unknown; hatchery not built | increased mortality |
| Variability in dissolved gases | daily | relatively constant | relatively constant | relatively constant |
| Location | Oregon | Central Texas | Washington | Oregon |

-- = pH unknown

## SITE SPECIFIC INFLUENT WATER QUALITY DATA REQUIREMENTS

Many operational problems of gas transfer systems are the direct result of inadequate water quality information used in system design. It is impossible to adequately design a gas transfer system if one does not know what gases are present. Tables 2 and 3 present a number of actual cases where gas transfer was needed. However, in many of these examples, the problems were identified only after the facilities were being operated. Water quality monitoring is commonly omitted in the site selection process because the site selection process is often driven by non-technical considerations, and test wells are very expensive. The required sampling interval and duration will depend strongly on the source and potential variability in the important water quality parameters. It is not wise to assume that just because someone is successfully raising fish nearby, that a new site will have acceptable water quality.

Based on experience in the Salmonid Enhancement Program in British Columbia, Shepherd recommended water quality monitoring of both surface and groundwater at least four times over a full one-year period. When temperature data is lacking, a recording thermometer should be installed. Wells should be pumped at a minimum 300 gallons per minute over 96 hours, sampled every 24 hours, and water should be analyzed for the following parameters:

Ammonia
Nitrate
Carbon Dioxide
Dissolved Oxygen
Hydrogen sulfide
Alkalinity
Hardness
pH
Suspended Solids
Temperature
Total Gas Pressure (△P)
Metals (Aluminum, Chromium, Copper, Iron, Lead, Nickel, Manganese, Mercury, Silver, Selenium, Zinc)

Surface waters should be sampled more often, especially if gas supersaturation problems are suspected.

Dissolved oxygen and total gas pressure (△P) must be analyzed on-site. Special bottles and sampling techniques are required for hydrogen sulfide and heavy metals. An observation of the pH change upon aeration can reveal a great deal about the carbon dioxide concentration. The aerated sample should be observed after several days for the formation of precipitates such as iron oxides, manganese oxides, or calcium carbonates that could cause problems.

## SUMMARY OF SITE AND WATER SUPPLY CONSIDERATIONS

Oxygen is the most commonly transferred gas in aquaculture. Other gases such as nitrogen + argon, carbon dioxide, hydrogen sulfide, methane, and radon may be important for some facilities. An oxygen transfer system may have a smaller impact on the concentration of soluble gases such carbon dioxide, hydrogen sulfide, or ammonia. It is difficult to design an effective gas transfer system without information on the concentration and variability of actual gases. Recommendations are presented for a pre-project sampling program.

This ends Part 1 of Design of Gas Transfer Systems for Aquaculture. Part 2 will discuss rating of systems under standardized and field conditions.

# Design of Gas Transfer Systems For Aquaculture: Part 2. Rating of Aerators Under Standard and Field Conditions

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## INTRODUCTION

This is the second of a three-part series on the design of gas transfer systems for aquaculture. Part 1 discussed site and water-supply considerations. Part 2 will discuss the rating of aerators under standard and field conditions. Standardized rating procedures have been developed in the wastewater treatment field. These rating procedures can be used to compare different types of aerators, but can not be used directly for design because the rating conditions are quite different from the operation conditions in aquaculture applications. However, the performance of gas transfer for aquaculture applications can be estimated from the standardized ratings. For some types of gravity aerators, alternative performance parameters may be more appropriate. Part 3 of this article will explore the design and selection of aerators.

## PRINCIPALS OF GAS TRANSFER

The transfer of gas across the air-water interface is controlled by the gas-film and liquid film resistances. The relative importance of the two terms depends of the solubility of the gas. The transfer characteristics of gases will be discussed in terms of soluble and slightly soluble gases.

### *Gas Transfer for Soluble Gases*

For soluble gases such as hydrogen sulfide or ammonia, the overall mass transfer coefficient depends on both the gas and liquid phase mass transfer coefficients:

$$\frac{1}{K} = \frac{1}{K_L} + \frac{1}{K_G H_Y}$$

where

$K$ = overall mass-transfer coefficient (l/t)
$K_L$ = overall liquid phase mass-transfer coefficient (l/t)
$K_G$ = overall gas pase mass-transfer coefficient
$H_Y$ = dimensionless Henry's constant for a gas

The units in Equation 1 are expressed in terms of l (length) and t (time).

In general, soluble gases are easy to dissolve into the water and difficult to strip out. High gas-to-liquid ratios (G/L) are required for stripping of these gases because of the low concentration of soluble gas in the gas phase.

### *Gas Transfer for Slightly Soluble Gases*

For slightly soluble gases such as oxygen or nitrogen, the overall mass transfer coefficient depends on the liquid phase mass transfer coefficients ($K_L$). The rate at which a slightly soluble gas such as oxygen is transferred into water is proportional to the area of the gas-liquid interface and the gradient between saturation and the existing concentration of gas in the water:

$$\frac{dm}{dt} = (K_L \bullet a)V(C^* - C)$$

where

$dm$ = rate of change in mass (m)
$dt$ = rate of change in time (t)
$K_L$ = overall liquid pase mass-transfer coefficient (m/t)
$a$ = area of interfacial contact between gas and liquid per unit volume ($1^2/1^3$)
$V$ = volume of a basin ($1^3$)
$C$ = dissolved gas concentration ($m/l^3$)
$C^*$ = saturation dissolved gas concentration at a given temperature, pressure, and mole faction ($m/l^3$)

The units in Equation 2 are expressed in terms of l (length), t (time), and m (mass). A positive gradient (C*-C) transfers gas into the liquid phase, and conversely, a negative gradient transfers gas from the liquid phase into the gas phase. The transfer rate can be increased by increasing the value of $K_L$, a, or $C^*$. For most gas transfer systems, it is impossible to determine $K_L$ and a independently, and the two parameters are lumped into an overall $K_La$ parameter.

### *Impact of Chemical Reactions on Gas Transfer*

Several important gases have significant chemical reactions in the liquid phase:

Carbon dioxide:

$$CO_{2(g)} = CO_{2(l)} + HOH \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{-2} + H^+$$

Hydrogen sulfide:

$$H_2S_{(g)} = H_2S_{(l)} \Leftrightarrow HS^- + H^+ \Leftrightarrow S^- + H^+$$

Ammonia:

$$NH_{3(g)} = NH_{3(l)} + H^+ \Leftrightarrow NH_4^+$$

In the above equations, the subscripts $_{(g)}$ and $_{(l)}$ are used to identify the concentrations in the gas and liquid phases, respectively. Liquid-phase reactions have two critical impacts on the rate of gas transfer. For example, the concentration of hydrogen sulfide can be written as:

$$H_2S = (\alpha_{H_2S})(C_T)$$

where

$\alpha_{H_2S}$ = mole fraction of hydrogen sulfide
$C_T$ = total soluble sulfide concentration measured by chemical analysis

The value of $\alpha_{H_2S}$ depends on pH and temperature. Therefore, the stripping of hydrogen sulfide will depend strongly on pH, and pH adjustment may be required. In gas stripping applications, only the gaseous component of a compound can be removed. If the kinetics of the liquid-phase reactions are slower than the detention time in the stripping unit, a significant amount of the non-gaseous form can not be removed by a single-pass gas transfer system. Multi-stage gas transfer systems with appropriate liquid-phase detention time between each stage may be required. The stripping of carbon dioxide and hydrogen sulfide must consider both the impact of liquid phase reactions on the concentration of gas and the speed of the liquid phase reactions.

## STANDARDIZED AERATOR TESTING UNDER CLEAN WATER CONDITIONS

Standardized testing and rating procedures for in-basin aerators have been developed for wastewater applications. While these methods are helpful, their use in aquaculture systems may not always be the most appropriate method to rate some types of aerators.

### *Unsteady-state Testing*

Unsteady-state testing procedures are conducted under standard conditions using an experimental test basin. Some test basins are as large as 3000 to 6000 $m^3$ and can be used to test aerators as large as 50 to 100 kW. Typically, a solution of sodium sulfite and cobalt chloride is used to deoxygenate the water by chemical oxidation. The aerator is then started, and the dissolved oxygen is measured periodically until the saturation concentration is approached. This testing procedure is termed the unsteady-state test, as the amount of oxygen transferred and the dissolved oxygen concentration are changing during the test.

Fundamental to the rating of in-basin aerators is the experimental determination of $K_La$ (Equation 2) and the computation of the standardized oxygen transfer rate (SOTR). The SOTR is the maximum rate of oxygen transfer in clear tap water at 20° C, 760 mm Hg, and of zero dissolved oxygen, and is expressed in lb/hr. The standardized aeration efficiency is expressed as follows:

$$SAE = \frac{SOTR}{P}$$

where

SAE = Standardized aeration efficiency (lb $0_2$/hp•hr)
SOTR = Standarized oxygen transfer rate (lb/hr)
P = Power input (hp)

The power input should be the measured wire power, that is, the actual power used by the (a) motor, drive, and blower or (b) motor, coupling, and gearbox. While measured wire power is the most useful power input, it is not uniformly used in all aeration literature.

The SOTR and SAE values reported by aerator manufacturers can be used to compare different types or brands of aerators. However, these values can not be used directly for design. The standardized procedure for the determination of $K_La$ reduces the uncertainty in aerator rating and allows more meaningful comparisons between units. For aquaculture applications it is necessary to compute the oxygen transfer rate under field conditions ($OTR_f$) and field aerator efficiency (FAE). The relationship between the four parameters is shown below:

| Parameter/Unites | Standardized Rating | Rating Under Field Conditions |
|---|---|---|
| Temperature (°C) | 20 | ambient conditions |
| Pressure (mm Hg) | 760 (1 atmosphere) | ambient conditions |
| Ambient dissolved oxygen concentration (mg/L) | 0 | ambient conditions (>3-5) |
| Water Quality | clean | dirty |
| Mass transfer (lb/hr) | SOTR | $OTR_f$ |
| Mass transfer/power input (lb/hp•hr) | SAE | FAE |

The computation of the OTRf and FAE will be covered in a following section.

### *Steady-state Testing*

For a number of gravity aerators such as packed columns, both the input and effluent oxygen concentrations can be directly measured. For these types of aerators, the field oxygen transfer rate and field oxygen transfer efficiency can be directly computed from the following two equations:

$$OTR_f = 5.00 \times 10^{-4} Qw (DO_{out} - DO_{in})$$

where

$OTR_f$ = Oxygen transfer rate under field conditions (lb/hr)
$Q_w$ = Water flow (gpm)
$DO_{out}$ = Effluent DO Concentration (mg/L
$DO_{in}$ = Influent DO concentration (mg/L)

Field Aeration Efficiency (FAE) is equal to:

$$FAE = \frac{OTR_f}{P}$$

where

FAE = Field aeration efficiency (lb 02/hp•hr)
$OTR_f$ = Oxygen transfer rate under field conditions (lb/hr)
P = Power input (hp)

Aeration effectiveness has also been used as a rating parameter:

$$AF = \left[\frac{C_{out} - C_{in}}{C^* - C_{in}}\right]100$$

where

AF = Aeration effectiveness under field conditions (%)
$C_{out}$ = Effluent dissolved oxygen concentration (mg/L)
$C_{in}$ = Influent dissolved oxygen concentration (mg/L)
C* = Saturation dissolved oxygen concentration (mg/L)

A high value of aeration effectiveness is desirable.

## PERFORMANCE AND RATING OF AERATION SYSTEMS UNDER FIELD CONDITIONS

The standardized oxygen transfer rate (SOTR) and standardized aeration efficiency (SAE) are computed for 20° C, 760 mm Hg, tap water, and zero dissolved oxygen. Actual performance under field conditions depends primarily on the required dissolved oxygen concentration (C) and to a lesser extent on temperature, pressure, and water characteristics. The computation of these parameters assumes that the unit installed in the field is identical to the unit tested under standard conditions.

### *Computation of Field Oxygen Transfer Rate ($OTR_f$)*

The field oxygen transfer rate ($OTR_f$) is the rate of oxygen transfer under field conditions and can be derived from the standardized oxygen transfer rate:

$$OTR_f = SOTR \; \frac{\left(1.024^{(t-20)}\right)\left(C^* - C\right)}{9.092}$$

where

$OTR_f$ = Field oxygen transfer rate (lb/hr)

C = Minimum dissolved oxygen concentration (mg/L)

9.092 = Dissolved oxygen concentration at standard conditions (mg/L)

Computation of the field oxygen transfer rate ($OTR_f$) requires (1) SOTR, (2) water temperature and atmospheric pressure ($C^*$ is a function of pressure and temperature), and (4) minimum DO value (C).

Equation 12 can be written in the following form:

$$\frac{OTR_f}{SOTR} = \frac{\left(1.024^{(t-20)}\right)\left(C^* - C\right)}{9.092}$$

or

$$OTR_f = A(SOTR)$$

where

$$A = \frac{\left(1.024^{(t-20)}\right)\left(C^* - C\right)}{9.092}$$

### *Computation of Field Aeration Efficiency (FAE)*

Similarly, the field aeration efficiency (FAE) is the oxygen transfer/unit power input under field conditions and can be derived from the standardized aeration efficiency:

$$FAE = SAE\,(A)$$

where A was previously defined in Equation 11.

## WHAT FACTORS IMPACT THE FIELD AERATOR EFFICIENCY

### *Similarity to Test Units*

The computation of these parameters assumes that the field unit is identical to the unit tested under standard conditions. This includes not only the size, type, and physical characteristics of the aerators, but the number and orientation of the units and depth of the system. In general, changing one or more of these parameters will greatly decrease the accuracy of the estimated field parameters. Many submerged aerators are tested in 4-5 m water depths, typical of the aeration basins used in wastewater applications. Therefore, published SOTR and SAE will significantly over-estimate field values for the 1-2 m water depths common in aquaculture.

### *Dissolved Oxygen Concentration*

The required dissolved oxygen concentration has the largest impact on the $OTR_f$ value for aquaculture conditions. The effects of dissolved oxygen and temperature are presented in Table 1 in terms of the factor A ($OTR_f$/SOTR). Increasing the required dissolved oxygen concentration decreases the value of $OTR_f$ and the amount of oxygen transferred. For example, to maintain a DO concentration of 6 mg/L at 20° C, the value of $OTR_f$ is equal to only 34% of the value of SOTR. To maintain 8 mg/L at 20° C, $OTR_f$ is reduced to only 12% of SOTR. The closer one gets to the local saturation concentration, the smaller the A value gets and negative values of A occur when the desired DO value is higher than saturation. At saturation, the value of $OTR_f$ is equal to zero (no oxygen transfer).

### *Elevation*

Increasing the elevation decreases $OTR_f$ as a result of the decrease in pressure and $C^*$ concentration. Values of A are presented in Table 2 for an elevation of 5,000 feet (Denver, Colorado). Notice that for the same C and temperature values, the value of A is less than that at sea level (Table 1). Elevation has a significant impact on the design of aeration systems in high mountains.

Table 1. Values of factor "A" as a function of temperature and required minimum dissolved oxygen (C), assuming barometric pressure = 760 mm Hg (sea level).

| C | Temperature (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (mg/L) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 40 |
| 3.0 | 0.80 | 0.75 | 0.72 | 0.69 | 0.67 | 0.65 | 0.64 | 0.60 |
| 3.2 | 0.78 | 0.74 | 0.70 | 0.67 | 0.65 | 0.63 | 0.61 | 0.57 |
| 3.4 | 0.77 | 0.72 | 0.68 | 0.65 | 0.63 | 0.60 | 0.58 | 0.53 |
| 3.6 | 0.75 | 0.71 | 0.67 | 0.63 | 0.60 | 0.58 | 0.55 | 0.50 |
| 3.8 | 0.74 | 0.69 | 0.65 | 0.61 | 0.58 | 0.55 | 0.52 | 0.46 |
| 4.0 | 0.73 | 0.68 | 0.63 | 0.59 | 0.56 | 0.53 | 0.50 | 0.43 |
| 4.2 | 0.71 | 0.66 | 0.61 | 0.57 | 0.54 | 0.50 | 0.47 | 0.39 |
| 4.4 | 0.70 | 0.65 | 0.60 | 0.56 | 0.52 | 0.48 | 0.44 | 0.36 |
| 4.6 | 0.69 | 0.63 | 0.58 | 0.54 | 0.49 | 0.45 | 0.41 | 0.32 |
| 4.8 | 0.67 | 0.61 | 0.56 | 0.52 | 0.47 | 0.43 | 0.38 | 0.28 |
| 5.0 | 0.66 | 0.60 | 0.55 | 0.50 | 0.45 | 0.40 | 0.36 | 0.25 |
| 5.2 | 0.64 | 0.58 | 0.53 | 0.48 | 0.43 | 0.38 | 0.33 | 0.21 |
| 5.4 | 0.63 | 0.57 | 0.51 | 0.46 | 0.41 | 0.35 | 0.30 | 0.18 |
| 5.6 | 0.62 | 0.55 | 0.49 | 0.44 | 0.38 | 0.33 | 0.27 | 0.14 |
| 5.8 | 0.60 | 0.54 | 0.48 | 0.42 | 0.36 | 0.31 | 0.25 | 0.11 |
| 6.0 | 0.59 | 0.52 | 0.46 | 0.40 | 0.34 | 0.28 | 0.22 | 0.07 |
| 6.2 | 0.58 | 0.51 | 0.44 | 0.38 | 0.32 | 0.26 | 0.19 | 0.04 |
| 6.4 | 0.56 | 0.49 | 0.42 | 0.36 | 0.30 | 0.23 | 0.16 | 0.00 |
| 6.6 | 0.55 | 0.48 | 0.41 | 0.34 | 0.27 | 0.21 | 0.13 | -0.03 |
| 6.8 | 0.54 | 0.46 | 0.39 | 0.32 | 0.25 | 0.18 | 0.11 | -0.07 |
| 7.0 | 0.52 | 0.44 | 0.37 | 0.30 | 0.23 | 0.16 | 0.08 | -0.10 |
| 7.2 | 0.51 | 0.43 | 0.35 | 0.28 | 0.21 | 0.13 | 0.05 | -0.14 |
| 7.4 | 0.49 | 0.41 | 0.34 | 0.26 | 0.19 | 0.11 | 0.02 | -0.17 |
| 7.6 | 0.48 | 0.40 | 0.32 | 0.24 | 0.16 | 0.08 | -0.01 | -0.21 |
| 7.8 | 0.47 | 0.38 | 0.30 | 0.22 | 0.14 | 0.06 | -0.03 | -0.25 |
| 8.0 | 0.45 | 0.37 | 0.29 | 0.20 | 0.12 | 0.03 | -0.06 | -0.28 |
| 8.2 | 0.44 | 0.35 | 0.27 | 0.18 | 0.10 | 0.01 | -0.09 | -0.32 |
| 8.4 | 0.43 | 0.34 | 0.25 | 0.16 | 0.08 | -0.02 | -0.12 | -0.35 |
| 8.6 | 0.41 | 0.32 | 0.23 | 0.14 | 0.05 | -0.04 | -0.15 | -0.39 |
| 8.8 | 0.40 | 0.31 | 0.22 | 0.13 | 0.03 | -0.07 | -0.17 | -0.42 |

Table 2. Values of factor “A” as a function of temperature and required minimum dissolved oxygen (C), assuming barometric pressure = 636 mm Hg (Denver, Colorado).

| C | Temperature (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (mg/L) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 40 |
| 3.0 | 0.63 | 0.59 | 0.56 | 0.53 | 0.5 | 0.48 | 0.46 | 0.4 |
| 3.2 | 0.62 | 0.58 | 0.54 | 0.51 | 0.48 | 0.45 | 0.43 | 0.37 |
| 3.4 | 0.6 | 0.56 | 0.52 | 0.49 | 0.46 | 0.43 | 0.4 | 0.33 |
| 3.6 | 0.59 | 0.54 | 0.51 | 0.47 | 0.44 | 0.41 | 0.37 | 0.3 |
| 3.8 | 0.58 | 0.53 | 0.49 | 0.45 | 0.42 | 0.38 | 0.34 | 0.26 |
| 4.0 | 0.56 | 0.51 | 0.47 | 0.43 | 0.39 | 0.36 | 0.32 | 0.23 |
| 4.2 | 0.55 | 0.5 | 0.45 | 0.41 | 0.37 | 0.33 | 0.29 | 0.19 |
| 4.4 | 0.54 | 0.48 | 0.44 | 0.39 | 0.35 | 0.31 | 0.26 | 0.16 |
| 4.6 | 0.52 | 0.47 | 0.42 | 0.37 | 0.33 | 0.28 | 0.23 | 0.12 |
| 4.8 | 0.51 | 0.45 | 0.4 | 0.35 | 0.31 | 0.26 | 0.21 | 0.09 |
| 5.0 | 0.49 | 0.44 | 0.38 | 0.33 | 0.28 | 0.23 | 0.18 | 0.05 |
| 5.2 | 0.48 | 0.42 | 0.37 | 0.31 | 0.26 | 0.21 | 0.15 | 0.01 |
| 5.4 | 0.47 | 0.41 | 0.35 | 0.29 | 0.24 | 0.18 | 0.12 | -0.02 |
| 5.6 | 0.45 | 0.39 | 0.33 | 0.27 | 0.22 | 0.16 | 0.09 | -0.06 |
| 5.8 | 0.44 | 0.38 | 0.31 | 0.26 | 0.2 | 0.13 | 0.07 | -0.09 |
| 6.0 | 0.43 | 0.36 | 0.3 | 0.24 | 0.17 | 0.11 | 0.04 | -0.13 |
| 6.2 | 0.41 | 0.34 | 0.28 | 0.22 | 0.15 | 0.08 | 0.01 | -0.16 |
| 6.4 | 0.4 | 0.33 | 0.26 | 0.2 | 0.13 | 0.06 | -0.02 | -0.2 |
| 6.6 | 0.38 | 0.31 | 0.24 | 0.18 | 0.11 | 0.03 | -0.05 | -0.23 |
| 6.8 | 0.37 | 0.3 | 0.23 | 0.16 | 0.09 | 0.01 | -0.07 | -0.27 |
| 7.0 | 0.36 | 0.28 | 0.21 | 0.14 | 0.06 | -0.02 | -0.1 | -0.3 |
| 7.2 | 0.34 | 0.27 | 0.19 | 0.12 | 0.04 | -0.04 | -0.13 | -0.34 |
| 7.4 | 0.33 | 0.25 | 0.18 | 0.1 | 0.02 | -0.07 | -0.16 | -0.37 |
| 7.6 | 0.32 | 0.24 | 0.16 | 0.08 | 0.00 | -0.09 | -0.19 | -0.41 |
| 7.8 | 0.3 | 0.22 | 0.14 | 0.06 | -0.02 | -0.12 | -0.21 | -0.44 |
| 8.0 | 0.29 | 0.21 | 0.12 | 0.04 | -0.05 | -0.14 | -0.24 | -0.48 |
| 8.2 | 0.28 | 0.19 | 0.11 | 0.02 | -0.07 | -0.16 | -0.27 | -0.52 |
| 8.4 | 0.26 | 0.17 | 0.09 | 0 | -0.09 | -0.19 | -0.3 | -0.55 |
| 8.6 | 0.25 | 0.16 | 0.07 | -0.02 | -0.11 | -0.21 | -0.32 | -0.59 |
| 8.8 | 0.23 | 0.14 | 0.05 | -0.04 | -0.13 | -0.24 | -0.35 | -0.62 |

### *Characteristics of Culture Water*

### *Alpha (a)*

The effects of water characteristics on oxygen transfer are corrected for by the alpha factor (a), which can be calculated as follows:

$$\alpha = \frac{K_L a - \text{field conditions}}{K_L a - \text{standard conditions}}$$

where

$K_L a$ = Volumetric mass transfer coefficient (1/t)

The value of a depends primarily on the concentration of surfactants in the water. In production catfish ponds, a ranged from 0.66 to 1.07 and averaged 0.94. In recycle systems, a values as low as 0.36 have been measured following feeding. The depression of a appears to depend on the leaching of soluble compounds from feed or from compounds produced by algae.

### *Beta (b)*

The effects of water characteristics on oxygen solubility are corrected for by the beta factor (b), computed as:

$$\beta = \frac{C^* - \text{field conditions}}{C^* - \text{standard conditions}}$$

The beta factor is influenced primarily by dissolved solids and to a lesser extent by dissolved organics and suspended solids. Unfortunately, b values for aquaculture conditions are unavailable. Beta values can not be measured using a dissolved oxygen probe.

The value of Factor A can be adjusted to account for the effects of  and :

$$A = \frac{\left(\alpha 1.024^{(t-20)}\right)\left(\beta C^* - C\right)}{9.092}$$

The value of alpha and beta can have a major impact on the performance of aerators, but their effects are largely ignored.

## SUMMARY OF RATING OF AERATORS

Aerators are rated under standard conditions: clean tap water at 20° C, 760 mm Hg, and a dissolved oxygen concentration of zero mg/L. Standard oxygen transfer rate (SOTR) is the amount of oxygen transferred in lb/hour. The standard aerator efficiency (SAE) is the amount of oxygen transferred per unit of power input (lb/hp hr). These parameters can be used to compare the efficiency of different aerators, but can not be used directly for design. The oxygen transfer rate under field conditions ($OTR_f$) and field aerator efficiency (FAE) depend on the standard parameters and actual field conditions. The ratio of $OTR_f$/SOTR is a measure of the relative performance of an aerator under field conditions. Commonly, the performance of an aerator in the field may be only 20-40% of its reported standard values. The performance of an aerator depends primarily on the minimum DO needed, elevation (pressure), temperature, and water characteristics.

This ends Part 2 of Design of Gas Transfer Systems for Aquaculture. Part 3 will discuss design and selection of aerators.

## Membership Dues

The AES will begin collecting 2001 membership dues this winter. AES members receive eight issues of the journal *Aquacultural Engineering*, four issues of the *AES News*, and the AES Member Directory.

# UPCOMING MEETINGS

## *World Aquaculture 2001*

*World Aquaculture 2001* is the next triennial meeting of the National Shellfisheries Association, the Fish Culture Section of the American Fisheries Society and the World Aquaculture Society. The Conference and Tradeshow will be held January 21-25, 2001, at Disney's Coronado Springs Resort in Orlando, Florida, USA. These triennial meetings are extremely popular and attendance can exceed 4,000. For more information on the overall program and tradeshow at *World Aquaculture 2001*, please contact John Cooksey, WAS Director of Conferences (phone: +1 760-432-4270: fax: +1 760-432-4275; e-mail: worldaqua@aol.com), or visit the World Aquaculture Society's website at: http://www.was.org

The AES is organizing a one day workshop on 'Intensive Fin-Fish Systems and Technologies,' a half day special session on 'International Recirculating Systems,' and a 1-day session of contributed aquacultural engineering papers during *World Aquaculture 2001*. The workshop on "Intensive Fin-Fish Systems and Technologies" is intended for fish farmers, biologists, and engineers with some prior fin-fish culture experience. The special session on "International Recirculating Systems" will overview a wide range of recirculating technologies used internationally to culture different species of fish. The contributed paper session contains a wide range of aquacultural engineering presentations. Steven Summerfelt (s.summerfelt@freshwaterinstitute.org) is coordinating the AES involvement.

### **Tuesday, January 23, 2001** *AES Workshop: "INTENSIVE FIN-FISH SYSTEMS AND TECHNOLOGIES"*

| TIME | SPEAKER | PRESENTATION TITLE |
|---|---|---|
| *Culture Environment* | | |
| 8:30-9:00 | Watten, Barnaby (USA) | Carrying Capacity and Production Efficiency |
| 9:00-9:30 | Timmons, Michael (USA) | Culture Tank Designs |
| 9:30-10:00 | Wilton, Sean (Canada) | Fish Pumping and Grading Technologies |
| 10:00-10:30 | BREAK | |
| *Treatment Processes* | | |
| 10:30-11:00 | Vinci, Brian (USA) | Solids Removal |
| 11:00-11:30 | Ebeling, James (USA) | Biofiltration |
| 11:30-12:00 | Liltved, Helge (Norway) | Ozonation and UV disinfection |
| 12:00-12:30 | Piedrahita, Raul (USA) | Gas Control |
| 12:30-14:00 | LUNCH BREAK | |
| *Intensive Fin-Fish Systems* | | |
| 14:00-14:45 | Muir, James (Scotland) | Coastal & Open Ocean Pen/Bag Systems |
| 14:45-15:30 | Brune, David (USA) | Ponds |
| 15:30-16:00 | BREAK | |
| 16:00-16:45 | Losordo, Thomas (USA) | Tank Systems in North America |
| 16:45-17:00 | Informal discussion | |

### **Thursday, January 25, 2001** *AES Special Session: "INTERNATIONAL RECIRCULATING SYSTEMS"*

| TIME | SPEAKER | PRESENTATION TITLE |
|---|---|---|
| 8:30-9:15 | Eding, Ep and Andries Kamstra | Design and performance of recirc systems for European eel (Anguilla anguilla) and African catfish (Clarias gariepinus). |
| 9:15-10:00 | Warrer-Hansen, Ivar | Recirculating systems for salmon smolt and turbot |
| 10:00-10:30 | BREAK | |
| 10:30-11:15 | van Rijn, Jaap, Tamir Erez and Israel Snir | Design and performance of closed tilapia recirculating systems |
| 11:15-12:00 | Samocha, T. M., A. D. Davis, A. L. Lawrence, C. R. Collins, P. Van Wyk | Intensive and super-intensive production of the pacific white shrimp Litopenaeus vannamei in greenhouse-enclosed raceway systems |

## **Wednesday, January 24, 2001** *CONTRIBUTED AQUACULTURAL ENGINEERING PRESENTATIONS*

| TIME | SPEAKER | PRESENTATION TITLE |
|---|---|---|
| 8:30 | Malone, R. F., Q. Wu, and J. M. Ebeling | In defense of the bioclarification strategy: mitigating the impact of solids accumulation on nitrification rates |
| 8:45 | Ebeling, J. and F. W. Wheaton | Nitrification kinetics and performance curves for a bubble-washed bead filter |
| 9:00 | Sandu, S., G. D. Boardman, B. J. Watten, and B. L. Brazil | Factors influencing the nitrification efficiency of fluidized bed filters with a plastic medium |
| 9:15 | Summerfelt, S. T., J. Davidson, and T. Waldrop | Cyclo biofilter start-up and preliminary evaluation in a coldwater reuse system |
| 9:30 | Hovanec, T., J. Sears-Hartley, L. L. Wilson, J. L. Coshland, C. M. Phalen, S. Wirtz, J. Niemans, P. C. Burrell | Investigations into the lack of efficacy of starter bacterial cultures for nitrification in seawater and freshwater systems |
| 9:45 | Wong, K. B. and R. H. Piedrahita | Enchanced solids removal for aquaculture raceways |
| 10:00 | BREAK | |
| 10:30 | Monita, D. | Low cost on site oxygen generation |
| 10:45 | Heikes, D. | Development of in-pond grading technology for commercial aquaculture |
| 11:00 | Summerfelt, S. T. | A bottom-center drain designed to flush dead fish |
| 11:15 | Beecher, L. E., T. Guo, C. R. Weirich, and R. F. Malone | Evaluation in the effectiveness of a greenhouse structure in maintaining water temperature for an extended growing season in south Louisiana. |
| 11:30 | Hall, S. G., R. P. Lang, and T. R. Tiersch | Design of a geothermal temperature control system for aquaculture broodstock ponds |
| 11:45 | Peterson, E. L. and G. Indran | Process control of pond sediment redox |
| 12:00 | Tsukuda, S. and S. T. Summerfelt | Dynamic process control for intensive production systems |
| 12:15 | Benson, B., T. Guo, and K. A. Rusch | Modeling light dynamics within a hydraulically integrated serial turbidostat algal reactor (HISTAR) |
| 12:30 | LUNCH BREAK | |
| 14:00 | Christensen, M., C. Stahl, C. Williams, and K. Rusch | Commercial implementation of the hydraulically integrated serial turbidostat algal reactor (HISTAR) |
| 14:15 | Rakocy, J. E., D. S. Bailey, R. C. Shultz, and J. M. Martin | Improvements to a commercial-scale aquaponic system and preliminary evaluation of the production of red tilapia, Oreochromis niloticus and 13 types of vegetables |
| 14:30 | Gandy, R. L. and T. M. Samocha | The effect of blood worms and Artemia feeding on induced maturation and spawning of Farfantepenaeus aztecus in a closed recirculating system |
| 14:45 | Dixon, H. and F. Whitney | Commercial recirculating system for F. duorarum live bait shrimp production in Florida |
| 15:00 | BREAK | |
| 15:30 | Nichols, J. and L. E. Beecher | Design and evaluation of recirculating systems used in the commercial baitfish industry |
| 15:45 | Evetts, B. | Corrosion - a back to basics primer |
| 16:00 | Helfich, L. A., C. Liston, and D. Weigmann | Evaluation of a helical pump to transport chinook salmon and striped bass |

# UPCOMING MEETINGS

## Cornell University and Freshwater Institute 7th Annual Aquaculture Water Reuse Systems Short Course

### July 17 - 20, 2001

### "Hands-On" or "Distant Learning"

**Program**

This one-week course is intended to give a thorough coverage of the design, operation, and management of water reuse systems for finfish. Offered as a "hands-on" course at Freshwater Institute or in a Distant Learning environment. Limited coverage will be given to engineering economics. Members of the Cornell Aquaculture Program and Freshwater Institute will teach the course. A combination of "hands-on" laboratories and classroom presentations will be offered. Ath the conclusion of the workshop, individuals should be able to design their own water reuse systems and have a fundamental knowledge of the principles influeincing design decisions. The following topics will be addressed:

- System carrying capacity (oxygen, solids, ammonia, carbon dioxide, anc constraints)
- Space and volume requirements
- Flow requirements and fluid mechanics
- Nitrification principles and bio filter design
- Water chemistry
- Monitoring and control systems
- Tour of local aquaculture facilities

**Location**

Freshwater Institute, RR1, Box 256 Turner Road, Shepherdstown, WV 25443

**Facilities**

Freshwater Institute is the site of the "hands-on" intensive water reuse production facilities housed inside a 10,000 square foot heated space. Currently arctic char and rainbow trout are being cultured; breeding and hatching facilities are in operation. A variety of tank sizes and nitrification systems are in operation, as well.

**Housing**

Bavarian Inn

- Double occupancy, $45.00/night, shared with the same gender, subject to availability.
- Single occupancy, $85.00/night

**Dates**

July 17 - July 20, 2001. (4 days); 8:30 am - 5:pm

**How to Get Information**

See our website: http://www.aben.cornell.edu/shortcourse/ or contact Brenda Snowberger and a complete registration packet will be sent to you by US mail as soon as the request is received.

**Cost**

"Hands-On" - $700.00. The fee covers: course materials, daily breakfasts, lunches and a banquet dinner.

"Distant Learning" - $175.00 (discounted from the regular fee of $350.00 for first time offer). Fee covers: CD Rom and book prior to course. Requires Internet access to participate in dialy instructor chat room and video observation of labs (student option).

**Registration**

Requires pre-registration and deposit by June 8,2001. Limited enrollment.

***Deposit:***

"Hands-On" - $250.00

"Distant Learning" - $50.00

Check payable to Cornell University and mail to Brenda Snowberger at the address below or pay by credit card, see registration form.

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**Course Instructors**

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Cornell University, Agricultural & Biological Engineering, 302 Riley-Robb Hall, Ithaca, NY 14853, Phone: (607) 255-2801, Fax: (607) 255-4080.

- Dr. Michael Timmons, E-mail: mbt3@cornell.edu

Freshwater Institute (FI), PO Box 1889, Shepherstown, WV 25443, Phone: (304) 876-2815, Fax: (304) 870-2208

- Dr. Steven Summerfelt, E-mail: s.summerfelt@freshwaterinstitute.org
- Brian Vinci, E-mail: b.vinci@freshwaterinstitute.org
- Dr. James Ebeling, E-mail: j.ebeling@freshwaterinstitute.org

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**Course Coordinator**

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Brenda Snowberger, Cornell University, Agricultural & Biological Engineering, 312 Riley-Robb Hall, Ithaca, NY 14852, Phone: (607) 255-2495, Fax: (607) 255-4080, E-mail: bls19@cornell.edu

# UPCOMING MEETINGS

## *AES Issues Forum Planned for November 2001*

An AES issues Forum is being planned for November 5-8, 2001. AES officers Barnaby Watten and Steven Summerfelt will be the hosts and organizers for this AES members only meeting. As in the past, the Issues Forum is intended for members of the AES to gather and reflect upon the advances that have been made in the art and sciences of aquacultureal engineering and to discuss important issues members will face in the future. Session topics under consideration include net pen systems. Aquaculture effluents, fish handling and processing, ozone and UV light treatment, pond production methods (algae, suspended bacteria..), and nitrification. The AES Forum 2001 will be held, pending final approval, at the US Fish and Wildlife Service National Conservation Training Center, located near historic Shepherdstown, WV. This recently constructed center (campus) is the crown jewel of the Interior Department's Training Facilities and has been used by President Clinton to hold foreign affair meetings. Forum participants will be invited to a reception at the Freshwater Institute and a tour is planned of the New USDA-ARS National Center for Cool and Coldwater Aquaculture Research. Plan to register early for the Forum as space is limiting the number of participants to 65.

# RECENT EVENTS

## DAVID E. BRUNE (PAST AES PRESIDENT) APPOINTED TO ENDOWED CHAIR OF NATURAL RESOURCES ENGINEERING

Dr. David E. Brune, Professor of Agricultural and Biological Engineering, has been appointed to the Charles Carter Newman Endowed Chair of Natural Resources Engineering at Clemson University in South Carolina.

The Newman chair was established by an endowment in excess of $500,000 from J. Wilson Newman and his wife Clara, in honor of his father. The position stipulates that; "An individual of outstanding accomplishment in the application of engineering principles to solving problems in the management of natural resources, be designated to lead multi-disciplinary research and education programs targeted at protecting natural resources on a local, regional and national basis." Additional responsibilities of the Chair include developing and teaching courses on the utilization of natural resources compatible with preservation of environmental quality, writing textbooks and scientific articles dealing with the protection and use of land air and water resources, organizing scientific symposia in natural resources engineering and management, and identifying statewide concerns.

Dr. Brune's research in aquacultural engineering is recognized nationally and internationally. In 1987 he initiated a research program to radically modify traditional pond fish culture using a new design, which he titled "The Partitioned Aquaculture System." This research program has grown to become an interdisciplinary effort involving a dozen faculty, staff and graduate students in three academic units. Within the last four years, this team has demonstrated that the PAS process is capable of achieving catfish yields three to four higher than conventional pond fish culture while requiring 1/8 as much water. Clemson University recently applied for a U.S. patent on the PAS process. To date, commercial growers in eight states, several foreign countries, and other U.S. agricultural experiment stations are planning, installing or operating PAS facilities.

In addition to his work in aquaculture, Dr. Brune has also worked to develop an electronic technique that is capable of remotely sensing and quantifying groundwater and surface water pollution. This technique, referred to as "electromagnetic terrain conductivity" is being used by Dr. Brune and co-workers to rapidly and economically locate areas of water pollution within agricultural watersheds to target for recovery or remediation.

Dr. Brune earned his bachelor's and master's degrees in Agricultural Engineering and his doctorate in Sanitary Engineering, from the University of Missouri at Columbia. He was honored by the American Society of Agricultural Engineering with the Outstanding Young Researcher Award of 1990. Dr. Brune is a founding member and past president of the Aquacultural Engineering Society and is a member of the Sigma Xi scientific research society, and Alpha Epsilon, the agricultural engineering honor society, among other professional societies.

# AES Sponsors

The AES is looking for sponsors within the aquaculture industry to support the increased cost of producing the *AES News*. The sponsors listed below have donated generously to support the AES. For this donation, the AES will be inserting a one-page product literature sheet in one of the newsletter mailings, and list the vendor as an AES supporter in four consecutive newsletters. Please contact one of the *AES News* Co-Editors if you would like to be a sponsor.

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To join the AES, please fill out the following information and send with payment to: Brian Vinci, c/o Freshwater Institute, P. O. Box 1889, Shepherdstown, WV, 25443, USA (fax: 304-870-2208). Make cheques payable to the Aquacultural Engineering Society. You do not have to provide education information to become a member.

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