



AES News, Fall 1999, Vol. 2, No. 4

Letter From Your President

Dear AES Members,

Time has passed quickly and this will be my last message to the membership of AES as President. I think we have had a reasonably productive year and the Society is still financially solvent, so I guess I've done my job! We have maintained a strong relationship with Elsevier Science, publishers of our journal (web site: <http://www.elsevier.nl:80/homepage/san/aqua/online/online.sht>). Brian Vinci, chairman of our web page committee has created and maintained a first-rate web page (<http://www.aesweb.org/>)! Thanks Brian! Thanks also go out to Dick Patterson who has taken over the editor's position for the AES engineering column in Aquaculture Magazine.

In November, I had the pleasure of hosting our first *AES Issues Forum* at NC State University. The goal was to hold a small meeting that would allow for in depth discussion of various issues related to aquacultural engineering. We had 65 participants from across the United States and around the globe. Members from the Netherlands, Australia, Iceland, Israel, Taiwan, Canada, and Ireland attended! I think everyone who attended would agree that we met our goals for the *Issues Forum*. Plenty of ideas, lively discussion, food and even a little beer and wine! Dr. Dave Brune and Dr. Jaw-Kai Wang deserve special recognition for their efforts in organizing this event! We hope to continue having *Issues Forums* and would like to explore the opportunities of having these events in other parts of the world in the future. If you are part of an aquaculture group that would be interested in co-sponsoring such an event, please contact me (Tlosordo@unity.ncsu.edu) and I will put you in touch with the proper AES Committee!

In the very near future (perhaps within days of you reading this) AES is sponsoring two workshops and a contributed research papers session at the *Aquaculture America 2000* conference in New Orleans. Dr. Ron Malone, incoming President of the AES, has worked hard as the program chairman for this conference. Thanks Ron for a job well done! If you are attending *Aquaculture America 2000*, please be sure to attend our Annual Members Business Meeting scheduled immediately following the last AES Workshop in the La Galeries 2 Room from 4:00 - 5:30 PM on Friday February 4.

Similarly, the AES workshops and contributed engineering papers session of *AQUA 2000*, the joint meeting of the World Aquaculture Society and the European Aquaculture Society, are set to take place in Nice, France! Many thanks to past-president of the AES, Dr. Raul Piedrahita, for his efforts in organizing these sessions!

In closing I would like to thank all those who have worked hard for the society this year! The Board of Directors has been active in decision making. Our Secretary / Treasurer, Dr. Steven Summerfelt, will soon be stepping down from this position after working four years for the benefit of

our members. Also, a special thanks goes out to Jo Ann Simmons at the Freshwater Institute (our home office), for her assistance in making the society run this year! I leave office with the society in very good hands. Dr. Ron Malone will become president in New Orleans with Dr. Barnaby Watten becoming 1st Vice-President, and Dr. Steven Summerfelt becoming 2nd Vice-President! I look forward to seeing you all in the near future at an AES event!

With Best Regards,

Tom

Thomas M. Losordo, President
Aquacultural Engineering Society

Membership Dues

It's time to renew! The AES will be collecting 2000 membership dues this fall and winter. Join AES for 2000 and receive eight issues (two 1999 volumes) of the journal *Aquacultural Engineering*, the *AES News*, and the AES Member Directory.

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Ozone Application in Aquaculture

By Sahdev Singh and Frederick W. Wheaton, Biological Resources Engineering Department,
University of Maryland, College Park, Maryland
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Large scale production of some commercial fish species such as striped bass and its hybrids, tilapia, salmon, and trout in recirculating aquacultural systems is economically viable provided the culture system is designed, operated, and managed optimally. As the name suggests, recirculating aquacultural systems continuously treat and recycle the culture water. Recirculating aquacultural systems offer many potential advantages over pond or other forms of traditional aquaculture including water conservation, higher intensity of production, year-round fish growth, better environmental control, proximity to the market, and consistent quality of final product, to name a few.

From an engineering point of view, the recirculating aquaculture technology is still in the developmental stage as several water treatment techniques are being investigated world wide for potential applications in recirculating aquacultural systems. Since, the technology is still developing, there are no standard system designs and operating procedures. However, most recirculating aquacultural systems have some provisions for waste removal. The main concern associated with recirculating aquacultural systems is effective and economical solid and dissolved waste removal from the culture water and aeration without harming the cultured fish.

Solid waste removal by physical separation and nitrification of ammonia and nitrites into nitrates by a biofilter, as practiced in most recirculating aquacultural systems at present, are slow processes requiring significant filter retention times. As a result, at any given time, up to 50% of the system water may be in the treatment units, leaving only the remaining half for rearing fish. Faster waste removal from the system water can permit more water to be allocated to the culture tank, thereby improving the carrying capacity and hence economics of the production operation. Air or oxygen is introduced into the culture water using one or more of many available techniques of gas transfer.

Ozone has been used widely for several decades in some Western European

countries and for the last couple of decades in the United States of America as a tertiary treatment of municipal and industrial wastewaters and drinking water. Closed aquacultural systems or recirculating aquacultural systems have adapted many of the same water treatment technologies as used in these traditional water works installations. However, aquaculture water treatment goals and priorities differ significantly from those used in the drinking water applications. In drinking water applications, ozone treatment is used as a final polishing step to remove odor and tastes and for disinfection. Moreover, although the cost of ozone application is important, it is still placed much lower in the list of priorities than the human safety issued associated with the final product, i.e. the drinking water.

This article is intended as a primer for the people interested in applying ozone treatment techniques to intensive fish production using recirculating aquaculture systems. The article introduces some basic principles of ozone treatment and issues involved in its application in recirculating aquaculture systems. To achieve this objective a question-answer type of format will be used.

WHAT IS OZONE?

Under normal atmospheric conditions, ozone is a clear, faintly blue colored gas. It produces a pungent odor at low concentrations (<5ppm) in atmospheric air and becomes acrid and unpleasant at high concentrations (>5ppm). When an oxygen molecule (O_2), a diatomic or two-atom substance, is forced to bond weakly with a third atom of oxygen, the resulting substance, a triatomic or three-atom molecule, is called ozone (O_3). Ozone is highly unstable because the loosely bonded third atom easily breaks away from the molecule. This property makes ozone a very strong oxidizer and therefore an ideal water treatment method.

WHAT DOES OZONE DO?

In the treatment of municipal and industrial wastewater and drinking water,

ozone has been used for one or more of the following purposes (compiled by Hochheimer and Wheaton, 1995):

- bacterial disinfection;
- viral inactivation;
- the precipitation of metals, such as iron and manganese;
- releasing organically-bound heavy metals;
- precipitation of dissolved organic compounds;
- taste and odor control;
- color removal;
- algae control;
- removal of sulfides and nitrites;
- degradation of organic substance, such as pesticides and detergents; and
- enhancement in nitrification.

In recirculating aquaculture, ozone application can potentially play the role of a major water treatment process, because it addresses most of the aquacultural water treatment goals including dissolved organic and inorganic waste removal, enhanced nitrification on the biofilter, suspended solids control, and disinfection. These benefits are attributed to ozone's strong oxidizing properties and rapid decomposition to produce oxygen (a beneficial residual substance for fish). Ozone reacts very rapidly with most impurities found in water and therefore, requires short contact times. Ozone's rapid reaction rate makes it possible to use ozone application units that have a short retention time, allowing faster removal of waste from the culture water.

WHAT ARE THE PROBLEMS WITH OZONE APPLICATION IN AQUACULTURE?

Not everything about ozone is so wonderful. Ozone toxicity to aquatic organisms, particularly in early stages of their life-cycle, and cost of ozone application are two major obstacles that prohibit easy integration of this technology into recirculating aquacultural systems. Therefore, it is very important that a correct amount of ozone be applied at a correct location within the system and at a correct time in a given situation so that the water

quality objectives can be met and at the same time the culture fish are not exposed to any residual ozone. At present, there exists no well-researched scientific criterion for ozone application in recirculating systems. However, some pilot studies on recirculating systems provide rough guideline for ozone dose determination.

The residual ozone in the culture water can be harmful to the fish. Moreover, available ozone sensitivity studies suggest varying maximum acceptable residual ozone concentrations (0.002 to 0.3 mg/L) in aquaculture water. This variation can, in part, be attributed to the differences in ozone resistance of different aquatic organisms and in part to lack of species-specific research on ozone sensitivity. These uncertainties can be overcome only by comprehensive research on ozone application in recirculating aquaculture systems.

Since ozone is a strong oxidizing agent, any materials used in an ozone treatment system must be highly resistant (if not inert) to ozone. Also, if an aquacultural facility uses ozone for water treatment, it is important that proper materials are selected for components that will hold or carry ozonated water. Operating costs of an ozone delivery system increase as the delivery system degrades with time. Greater amounts of ozone must be produced in systems with substandard material, since some of the ozone is lost in the oxidation of materials in the delivery system itself. Also, as the delivery system fails, it must be replaced,

adding to the overall cost of the operation. Ozone is toxic to humans and any system leakage is a serious safety hazard. Therefore, it is important to construct the ozone system from materials that will not corrode with time. Suitability of different materials for use in ozone systems is discussed later in this article.

HOW DO WE PRODUCE OZONE?

Because ozone is highly unstable and therefore difficult to store, it is always produced and used immediately on-site. In most commercial ozone generators available for use in recirculating aquacultural systems, ozone is produced either by a process called corona discharge or by using ultra-violet (UV) light. The corona discharge technique involves establishing a high electric potential between two parallel surfaces and passing dry air or oxygen as feed gas between the two surfaces (Rosenthal and Otte, 1980). The electrical energy across the parallel surfaces breaks some of the oxygen molecules into oxygen atoms (called oxygen radicals) which bond with the other oxygen molecules of the feed gas to produce ozone. With dry air as the feed gas, corona discharge technique can produce up to 60 g O₃/kWh of electricity and about twice this amount with pure oxygen as feed gas (Bablon et al., 1991). In the UV method of ozone generation, dry air or pure oxygen is exposed to UV light at a certain wavelength (140 to 190 nm) to break oxygen molecules and produce ozone. Bablon et al. (1991) report that UV

generators are capable of producing 1.8g O₃/kWh with dry air as feed gas while about 20g O₃/kWh when pure oxygen is used as a feed gas.

HOW DO WE APPLY OZONE?

Design of the ozone-to-water contactor is very important for successful application of this technology in recirculating aquaculture. The aquaculture industry has significant experience in transferring air or oxygen in water, but there are some additional design considerations when it comes to ozone transfer. The most important of these considerations are that (1) the contactor should be leak-free for safety reasons, (2) the ozone transfer should be efficient to avoid any wastage, and (3) the materials used in contactor construction should be ozone resistant.

There are several different designs of ozone-to-water contactors including conventional fine bubble diffusion, turbine contactors, injectors, and static mixers, packed columns, spray contact chambers, and deep u-tube reactors. Some of these methods are also used for oxygen transfer or aeration in recirculating aquaculture systems. Each of these ozone transfer methods has its advantages and disadvantages.

Damez (1982) discussed suitability of various materials for use with ozone. Table 1 presents the list of these commonly used materials in aquacultural facilities and their relative resistance to ozone. Some of the plastics such as Polyvinyl chloride (PVC) and polycarbonate can be used for temporary ozone contact, but they are not

Table 1. Suitability of material for use with ozone systems.

Material	Resistance	Material	Resistance	Material	Resistance
Metals		Plastics		Elastomers	
Chromium Nickel Silver	minor effect	ABS	minor effect	Buna N (Nitrile)	not recommended
Brass	minor effect	Acetel (Delrin)	moderate effect	EPODM	no effect
Alluminum	no effect	CPVC	no effect	Hypalon	no effect
Pig Iron	no effect	Hytre	moderate effect	Kel-F	no effect
Galvanized Steel	minor effect	LDPE	moderate effect	Natural Rubber	not recommended
304 Stainless Steel	minor effect	Nylon	not recommended	Neoprene	moderated effect
316 Stainless Steel	no effect	Polycarbonate	no effect	Silicone	no effect
Copper	no effect	Polypropylene	minor effect	Viton	no effect
		PTFE (Teflon)	no effect		
		PVC	minor effect		
		PBDF (Kynar)	no effect		
Others					
Concrete	no effect				
Glass	no effect				
Ceramics	no effect				

recommended for long-term applications. Also, the wall thickness of these plastics should be large enough to withstand ozone corrosion. Reinforced concrete should also be used with precautions as ozone may corrode galvanized steel reinforcing bars in the structure. For best results, 304 or 316 stainless steel for flanged or threaded applications and 304L or 316L for welded (tungsten inert gas, TIG) piping joints are best for all wet and dry gas piping components and flexible couplings (Robson, 1982). Valves should be made of stainless steel (both body and face) with Viton(, Teflon(, or Hypalon(membranes and gaskets (Robson, 1982). Concrete joints made from Sikaflex-1A(is also recommended for use with ozone systems (Robson, 1982).

HOW MUCH OZONE DO WE APPLY?

At present, there exists no well-established criterion for ozone does determination for recirculating aquacultural systems. This is partly because the nature of ozone reaction with different waste components is not known completely. Recirculating aquacultural systems, being sensitive to system configuration, species reared, feed and feeding strategy, and other system variables, exhibit varying waste characteristics. Most studies on ozone application in recirculating aquaculture systems suggest daily fish feeding rates as the only criterion to determine the amount of ozone required to achieve desired water quality. This method may be applicable to a recirculating aquaculture system on which the relationship between the amount of feed and required ozone dose has been developed experimentally. However, it may lead to over or under application, if a different recirculating aquaculture system or different operating conditions are used. Because ozone is consumed by the pollutants in the water, optimum ozone dosage should directly depend on the system waste characteristics rather than on the feeding rate. The optimum ozone quantity can be termed as the ozone demand of the recirculating aquaculture system as it represents a sum of ozone demands for organic waste (BOD/COD) removal, nitrification enhancement, disinfection, color or turbidity removal, suspended solids removal, and other desired effects.

Research is in progress at several institutions to accurately quantify the ozone demand of aquacultural waters. Until the results of these studies become available, two recent studies, one at Virginia Tech (Brazil et al., 1996) and the other at Freshwater Institute (Bullock et al., 1997; Summerfelt et al., 1997) recommend ozone application rates ranging from 13 to 39 g ozone per kg feed. These two studies reported significant improvement in water quality and fish growth as a result of ozone application.

WHERE CAN WE FIND MORE INFORMATION ABOUT OZONE?

Ozone application in recirculating aquaculture systems has been shown by a number of researchers to improve the water quality and the overall system performance in terms of increased fish growth and reduced effluent discharge (Colberg et al., 1977; Rosenthal and Otte, 1980; Williams et al., 1982; Sutterlin et al., 1984; Poston and Williams, 1988; Paller and Lewis,

1988; Tipping, 1988; ; Brazil et al., 1996; Bullock et al., 1997; Summerfelt and Hochheimer, 1997; Summerfelt et al., 1997). Rosenlund (1974), Arthur and Mount (1975), Ward (1977), and Hall et al. (1981) discuss ozone toxicity to most commercially cultured aquatic organisms. Hall et al. (1981) studied the ozone toxicity to striped bass and found pronounced effects. Based on their research, Hall et al. (1981) developed regression relationships of percent mortality of striped bass with concentration of ozone-produced oxidants (OPO) and exposure time. Ward (1977) indicates that the residual ozone levels even less than 0.1 mg/L have the potential to cause significant mortality to a wide range of fresh and salt-water organisms. For aquacultural systems, Brazil et al. (1996) and Summerfelt et al. (1997) suggest ozone dosage rate between 13 and 39 g O₃ per kg of feed. Practically, it is difficult to isolate the ozone demand of individual micropollutants (Bablon et al., 1991). The reference list at the end of this article provides some very useful sources for further information on ozone technology.

AQUACULTURE AMERICA 2000

"Unmasking the Marvels of Aquaculture"

February 2-5, 2000

New Orleans Marriott
New Orleans, Louisiana

THE NATIONAL CONFERENCE & EXPOSITION OF



Hosted by

THE LOUISIANA AQUACULTURE ASSOCIATION

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UPCOMING MEETINGS

Aquaculture America 2000

The AES sessions at *Aquaculture 2000* in New Orleans (February 2-5, 2000) will focus on recirculating technologies. See the World Aquaculture Society Homepage for registration information (<http://www.was.org/>). The first AES session, moderated by Fred Wheaton, is a training session that addresses recirculating fundamentals. A baseline sixty-minute water quality lecture by Kelly Rusch, will be followed by five 30 minute talks on the design and management of recirculating systems. Intended to be basic training for the novice, this session includes presentations of by the likes of Mike Timmons, Paul Hundley and Philip Lee and will make significant contributions to the knowledge envelop for most of our membership.

Our premier session will be moderated by our AES President, Tom Losordo, and will focus on the topic of Marine Recirculating Systems. Jim McVey of the National Sea Grant Office and Ed Rhodes of National Marine Fisheries Service are preparing a talk addressing their perspectives on the future of marine aquaculture. This introduction is supported by six additional speakers who will be addressing technical issues that have arisen from applications on clams, shrimp, squid, sharks and finfish throughout the country. In an attempt to encourage interdisciplinary thinking, a special effort has been made to include a number of experienced recirculating marine system users to provide the engineers with a "users group" perspective.

The two organized sessions are supported by a set of fourteen excellent contributed papers that deal with a variety of aquaculture topics including nitrogen management, aquaponics, tilapia production, and fish health management. Moderated by Philip Lee, this session is expected to form a foundation for extended discussions in the fine restaurants and other "establishments" that can be found in the downtown New Orleans area. Our Louisiana members are determined that a good time be had by all.

AES Contributed Sessions at Aquaculture America '2000

Moderator: Dr. Philip Lee, Biomedical Research Institute, Texas

Ratio of Plants to Fish in Aquaponic Systems. James E. Rakocy, University of the Virginia Islands

Nitrogen Partitioning in a Zero Water Exchange Shrimp Culture System for *Litopenaeus vannamei*. Lytha Conquest, Douglas E. Conklin, David Ziemann, and Albert Tacon, Oceanic Institute

Nitrification and Characterization of Biochemical Oxygen Demands in a High Density, Zero Water Exchange Outdoor Shrimp Tank System (*Litopenaeus vannamei*) Using a Bacterial Supplement Treatment With Varied Protein Diets. C. K. Hart, T. M. Samocha, A. L. Lawrence, D. A. McKee, and J. B. Mott, Texas A&M University-Corpus Christi

A Nitrogen Budget for a Closed Recirculating Mariculture System. Eric S. Thoman, D. Allen Davis, Ellery D. Ingall, and Connie R. Arnold, University of Texas at Austin

Diurnal Nitrogen and Organic Carbon Fluctuation in Recirculating Aquaculture Systems. Valdis Krumins and James Ebeling, Biological Resources Engineering

Evaluation of Alternative Media for Enhanced Nitrification Rates in Propeller-Washed Microbead Filters. T. J. Peiffer, L. E. Beecher, and R. F. Malone, Louisiana State University

Kinetic Reaction Rate Analysis of Nitrifying Bead Filters in Aquaculture- Part One: Laboratory Scale Bioreactor. James M. Ebeling, Fred W. Wheaton, Biological Resources Engineering Department

Kinetic Reaction Rate Analysis of Nitrifying Bead Filters in Aquaculture- Part Two: Commercial Bubble-Washed Bead Filter. James M. Ebeling, Fred W. Wheaton, Biological Resources Engineering Department

Impact and Recovery of Nitrifying Biofilters From Operating Disturbances. Catherine Lyssenko, Fred Wheaton, Department of Biological Resources Engineering

A Survey of U. S. Tilapia Producers Who Utilize Recirculating Technology. Kerry W. Tudor, Ono Juarno, Patrick D. O'Rourke, and Patrick Foley, Department of Agriculture

Field Evaluation of Four Species/Strains of Tilapia in Louisiana Greenhouse-Based Recirculating Systems. C. Greg Lutz, Louisiana State University Agricultural Center

Daily Ozone Cycling. Valdis Krumins, James Ebeling, and Fred Wheaton, Biological Resources Engineering

Fish Health Management of Recirculating System. David Crosby, Virginia State University



UPCOMING MEETINGS

Aquaculture Europe & World Aquaculture '2000

The year 2000 provides an opportunity to organize a landmark event to celebrate the beginning of a new millennium, and to examine the current status of global aquaculture and the way ahead. For this reason, the European Aquaculture Society has combined its *Aquaculture Europe 2000* meeting with the annual meeting of the World Aquaculture Society, *World Aquaculture 2000*. This meeting has been named *AQUA 2000* and will take place May 2 - 6 (2000) in Nice, France, at the Acropolis Convention Center on the coast of the Mediterranean. For more information visit the *AQUA 2000* website at: <http://www.was.org/confer/nice/aqua200.html>

The AES has organized a Workshop on "Recirculating System Scale Up and Energy Use" tentatively scheduled for the afternoon of May 5. On the morning of May 6 (tentatively), the AES has organized two invited aquacultural engineering sessions on the topics: "Reduced Discharges from Aquaculture Operations" and "Engineering Shrimp Production in Low- or No-Effluent Pond Systems." These two invited sessions will be followed in the afternoon by a contributed paper session containing around ten aquacultural engineering presentations. Dr. Raul Piedrahita (RHPiedrahita@UCDavis.edu) is coordinating the AES involvement.

The 3rd International Conference on Recirculating Aquaculture

The *3rd International Conference on Recirculating Aquaculture* will be held July 20-23, 2000, at the Hotel Roanoke & Conference Center in Roanoke, Virginia.

This conference and trade show provides the world's premier forum for sharing ideas, opportunities, and technologies in commercial scale recirculating aquaculture. Entrepreneurs, researchers, facility operators, aquaculture managers, fishery biologists, veterinarians, engineers, food technologists, food safety specialists, government regulators, business managers, financial institution representatives, and extension and advisory personnel will all benefit from participating. A series of symposia will feature presentations and discussions on such topics as: design of recirculating systems, operations and management, business plans, economic analysis, marketing, fish health and disease, legal issues, food safety and HACCP standards, quality control, systems engineering and resource recovery. And an expanded trade show is a highlight of the conference.

For more information, contact Dr. George Libey at Virginia Tech (tel: 540-231-6805; e-mail: aqua2000@vt.edu) or log on to <http://www.conted.vt.edu/recirc/aqua.htm>

Call for Papers & Instructions for Abstract Submission

The Aquacultural Engineering Society (AES) and Virginia Polytechnic Institute and State University (VPI) are calling for technical papers for the *Third International Conference on Recirculating Aquaculture*. Authors must submit a short abstract (see [Abstract Guidelines](#) below) by February 1, 2000, to either Michael B. Timmons (AES) or George S. Libey (VPI). Authors of accepted abstracts will be notified by February 15 and will receive detailed instructions for submission of full papers. Final manuscripts must be submitted to George S. Libey and received by April 1, 2000 in "camera ready" format. These papers will be published in a proceedings that will be available at the conference.

All papers in the general area of aquacultural engineering are invited. However, specific topics of interest include:

Waste management

- Harvesting and handling
- Feeding management strategies
- Water chemistry control and Biofiltration
- Automation

Sessions will be organized based upon paper submission.

Submit the abstracts by mail or e-mail to:

Dr. Michael B. Timmons

302 Riley Robb Hall

Department of Agricultural and Biological Engineering

Cornell University, Ithaca, NY 14853

Email: MBT3@cornell.edu

Abstract Guidelines.

1. Abstracts should be concise and limited to one typewritten page.
2. Use single spacing, 12 pt font, and allow 2.5 cm for left and right margins.
3. Titles should also be concise but clearly relate the subject of the article.
4. Include the name(s) of the author(s) and their affiliation(s) and address(es).
5. Submit your abstract to Dr. Timmons at the address listed above by February 1, 2000.
6. Submit the abstract either by email as an attachment, or on a 3.5" disk. If sending a disk, please label it with your name and include a hardcopy of the abstract. Please ensure that your file is virus-free.

If your abstract is accepted, you must submit a revised abstract with your complete paper (by April 1) for publication in the conference proceedings.

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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e-mail: info@praqua.com
web site: www.praqua.com

Aquaculture Systems & Equipment

108 Industrial Ave., New Orleans,
LA 70121
ph: (504) 837-5580
fax: (504) 837-5585
web site: www.aquasales.com

Marine Biotech, Inc.

54 West Dane Street, Unit A, Beverly,
Massachusetts 01915, U.S.A.
ph: (978) 927-8720
fax: (978) 921-0231
e-mail: sales@marinebiotech.com
web site: www.marinebiotech.com

**For more information on the AES, visit the AES web page at:
<http://www.aesweb.org>**

To join the AES, please fill out the following information and send with payment to: Steve Summerfelt, 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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