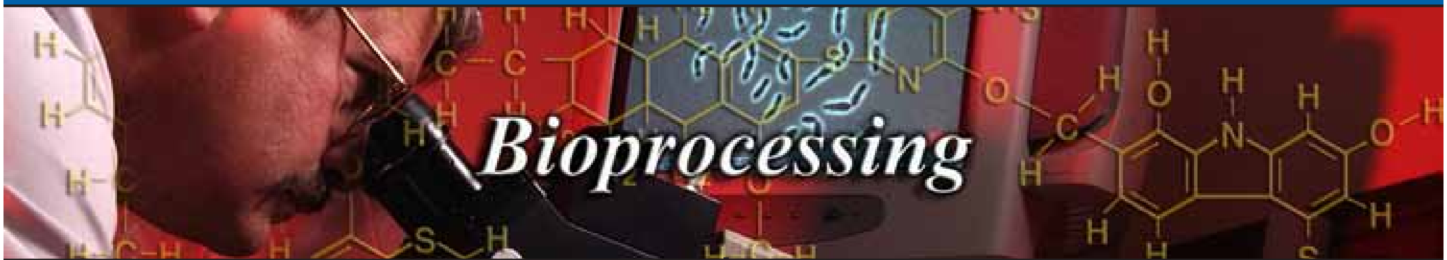


Successes

Environmentally Safe Control of Zebra Mussel Fouling

Advanced Research

To support coal and power systems development, NETL's Advanced Research Program conducts a range of pre-competitive research focused on breakthroughs in materials and processes, coal utilization science, sensors and controls, computational energy science, and bioprocessing—opening new avenues to gains in power plant efficiency, reliability, and environmental quality. NETL also sponsors cooperative educational initiatives in University Coal Research, Historically Black Colleges and Universities, and Other Minority Institutions.

Accomplishments

- ✓ **Process improvement**
- ✓ **Cost reduction**
- ✓ **Greater efficiency**
- ✓ **Ecological gains**

Description

The colonization of zebra mussels *(Dreissena polymorpha)* and their close relatives quagga mussels *(Dreissena rostriformis bugensis)* on power plant cooling water intake structures can lead to significant plant outages and unwanted expense. Though small in size (maximum length is typically about 1 inch), these fouling mussels have become the most troublesome freshwater organisms in North America. Although *D. r. bugensis* has the special common name of "quagga mussel", both species are often referred to collectively as "zebra mussels" because of the stripes on the shells of both. These species have been steadily invading North America's rivers and lakes since they were first introduced from Europe in the mid-1980s, blocking intakes and pipes that provide process water to factories and power plant cooling towers, as well as drinking water delivery systems. Economic damage to electric utilities has exceeded $1 billion since then, with total economic impacts of over $3 billion. Ecological damage — eliminating native mussel species and disrupting the food chain — also has been significant.

There is a clear need for economical and environmentally safe methods to control these mussels where these two invasive and prolific species have become a problem. A wide variety of methods has been used to attempt to combat their infestation, including preoxidation of intake water, mechanical controls, and filtration. A lack of effective options has led many facilities to rely on broad-spectrum, chemical biocides for control. However, biocide treatments, such as continuous chlorination for periods of three weeks, are widely regarded as environmentally unacceptable because they can harm native species and can form potentially carcinogenic substances. There is growing concern within the power generation industry that such broad-spectrum biocides will be banned by individual states and/or the federal government because of increasingly stringent environmental regulations.

Credits: New York State Museum, D. Wray (inset)

The small zebra mussels densely colonize inside cooling water intake pipes of power plants thus leading to significant power outages and expense.

Credit: Duke University

Mussels clogging power plant condenser tubes.

Sponsored by the U.S. Department of Energy's Office of Fossil Energy (DOE-FE), and funded through the National Energy Technology Laboratory's (NETL) divisions of Power Systems Advanced Research and Innovations for Existing Plants, researchers with the New York State Museum have been conducting an innovative study to evaluate a particular strain of a naturally occurring bacterium — *Pseudomonas fluorescens* — that has been shown to be selectively lethal to these mussels but benign to non-target organisms such as fish and other bivalves, including native freshwater mussels. Laboratory testing has been conducted successfully at the New York State Museum's Field Research Laboratory in Cambridge, New York, with additional experimentation on the service water treatment system for Rochester Gas and Electric Corporation's Russell Station, a coal-fired plant that withdraws 4-5 million gallons daily from Lake Ontario.

Project Duration

Start Date
09/22/03

End Date
02/29/08

Cost

Total Project Value
$1,455,444

DOE/Non-DOE Share
$1,160,688 / $294,756

Industrial Partners

Marrone Organic Innovations, Inc.
Davis, CA
http://www.marroneorganicinnovations.com

Particle and Coating Technologies, Inc.
St. Louis, MO
http://www.pctincusa.com/

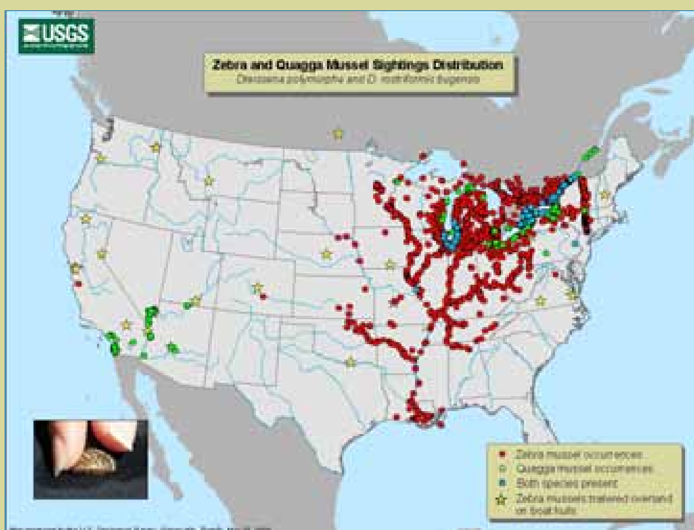
Rochester Gas & Electric
Rochester, NY
http://www.rge.com/

Project Goals

The objective of this research is to develop an environmentally safe biological control technology for zebra and quagga mussels within power plant cooling/service water systems. Experimental treatments of power plant house service water have achieved up to 98 percent mussel kill to date. Research efforts are now under way to increase the toxicity of the bacterial cells so that such high mortality can be consistently achieved. Once that is accomplished, favorable evaluation of safety data by the U.S. Environmental Protection Agency (EPA) and partnership with an established biopesticide company will make commercialization a reality.

Zebra and Quagga Mussel Distribution Throughout the United States

These mussels were found for the first time in North America in 1988 in Lake St. Clair, the water body connecting Lake Huron with Lake Erie (two of the Great Lakes). From there, these invasive mussels, which can thrive in a wide range of water quality and temperatures, have colonized many waterways across the United States from Vermont to California. Both species are native to freshwater regions surrounding the Black and Caspian Seas in southeastern Europe. Expansion of commercial boat traffic through canals aided the spread of these species into most of Europe over the past two centuries. They most likely were transported to North American waters as planktonic (i.e., floating) larvae or as attached juveniles or adults on debris in the freshwater ballast of transatlantic ships. Ballast contamination has been identified as the source of 36 of the 50 non-native species that have entered U.S. waters through the St. Lawrence Seaway — the entryway to the Great Lakes and other U.S. waterways.

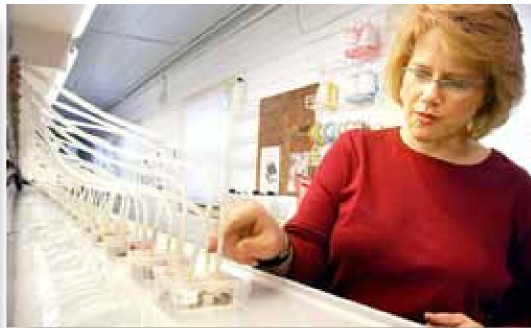


Technical Approach/Accomplishments

This technology involves use of bacterial toxins that only affect zebra and quagga mussels, and are derived from *Pseudomonas fluorescens* strain CL145A (Pf-CL145A). The challenge was to learn how to economically produce and formulate Pf-CL145A cells in such a way that they would prove to have good product shelf-life, be environmentally safe, and be highly effective in killing these mussels in power plant service water pipes.

Results obtained so far indicate that, in mussel populations held in small pipes, mortalities of 70 to 100 percent can be routinely achieved. When a zebra mussel ingests artificially high densities

The Pseudomonas fluorescens strain of bacterium used in the testing is toxic to zebra mussels, but benign to non-target organisms



Research scientist Denise Mayer adjusts the air reaching zebra mussels as part of a laboratory test of the technology

of this bacterium, the biotoxin within these bacterial cells destroys the mussel's digestive system. Dead bacterial cells are equally as effective against zebra mussels as live cells, providing clear evidence that the mussels die from a biotoxin, and not from infection.

The microscopic sized crustacean, *Daphnia magna*, has been evaluated in non-target tests. *D. magna* is an aquatic filter feeder that ingests small suspended particles including bacteria, making it an appropriate organism for that purpose. Experiments indicated that Pf-CL145A is not lethal to this species, further advancing the potential for commercialization of Pf-CL145A, since *D. magna* is one of the primary species that the EPA uses to assess biopesticide safety.

Daphnia magna, a filter feeding microcrustacean used for non-target testing

Experiments also succeeded in achieving some 88 percent reduction in the cost of preparing the fermentation medium that is needed to produce high yields of toxic Pf-CL145A cells. This new fermentation medium, in conjunction with a revised fermentation protocol, will serve as the basis for future commercial production of large quantities of Pf-CL145A at relatively low cost. Thus, this bacterial approach to zebra mussel control has now become more economically competitive with the cost of biocides currently used by power plants.

In late 2005, a $100,000 request was submitted to the National Science Foundation (NSF) to work collaboratively with a St. Louis company, Particle and Coating Technologies (PCT), to develop a method to dry the bacteria to minimize the loss of toxicity when the bacteria is stored as a commercial product. This NSF program was specifically designed to advance the commercialization of biotechnological products by funding joint industry-governmental research collaborations. NSF awarded this grant, and joint research with PCT was successful.

In early 2008, the National Science Foundation awarded another small business, Marrone Organic Innovations (MOI) $500,000 to proceed to fully commercialize this promising green mussel control technology. The current joint research effort between MOI and the New York State Museum will be directed toward increasing bacterial cell toxicity via additional fermentation work, identifying the mussel-killing toxin, further improving formulation, and doing additional safety toxicology studies that will be mandated by the EPA for product registration. Commercial product sales could come as early as 2010.

Benefits

This DOE-NETL project has successfully addressed a serious economic and environmental challenge with an innovative biological control solution. Successful development and commercial application of this environmentally safe bacterial toxin as a zebra mussel control method will allow power plants and other facilities to reduce or eliminate the use of chlorination, reducing the risk of chlorine's potentially harmful effects on aquatic ecosystems.

"Successful development and commercial application of this environmentally safe bacterial toxin will allow power plants to reduce or eliminate the use of chlorination, reducing the risk of harmful effects on aquatic ecosystems."

States and Localities Impacted

Davis, CA

St. Louis, MO

Rochester, NY

Cambridge, NY

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South, Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street, Suite 1400
Tulsa, OK 74103-3519
918-699-2000

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681

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Contacts

Robert R. Romanosky
Technology Manager
Advanced Research
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4721
robert.romanosky@netl.doe.gov

Thomas J. Feeley, III
Technology Manager
Innovations for Existing Plants
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-6134
thomas.feeley@netl.doe.gov

Heino Beckert
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4132
heino.beckert@netl.doe.gov

Daniel P. Molloy
Principal Investigator
New York State Museum
Field Research Laboratory
51 Fish Hatchery Road
Cambridge, NY 12816
518-677-8245
dmolloy@mail.nysed.gov

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