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The Water of Life

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The Quality of Water and the Quality of Life

Michigan is a state defined, literally, by water. Without the Great Lakes, Michigan's peninsulas would not exist. Nor would much of the state's manufacturing, shipping and tourism offerings. Water is necessary for life — every human needs water to live, as do the plants and animals that provide us with food and shelter. According to the Michigan Department of Environmental Quality, Michigan has more households — 1.12 million — served by private wells than any other state. Approximately 25,000 domestic wells are drilled per year. Water is a critical factor in human health. Joan Rose, MAES-affiliated water scientist who holds the Homer Nowlin Endowed Chair in Water Research, said that access to safe drinking water is one of the most serious public health crises facing the world.

In January, President George W. Bush and Gov. Jennifer Granholm both turned their attention to Michigan's waters. The president announced that he is asking Congress for $45 million to clean up contaminated lake sediments in the Great Lakes. The request for the 2005 budget is a significant increase from the $10 million budgeted for 2004 under the Great Lakes Legacy Act.

Gov. Granholm announced a comprehensive water initiative for the Great Lakes, addressing water withdrawal, invasive species, open water disposal, water discharge permits, a revised sanitary code, wetlands protection and federal funding for Great Lakes restoration projects.

"Our waters are more threatened today than perhaps they have ever been," Granholm said. "A thirsty country looks to our resources and sees a source of free, clean, fresh drinking water. Pollution and growth continue to threaten their health. Our critical job providers cry out for water to bottle their products, to cool their furnaces and to clean their new cars and trucks."

The Michigan Agricultural Experiment Station has long supported research on water quality, water use, pollution remediation and watershed management. Water research is the cornerstone of one of five MAES 2004 target research areas: environmental stewardship and natural resource policy and management. In this issue of Futures, we introduce you to several new MSU water scientists who are affiliated with the MAES and offer a synopsis of some of the research happening in this important area.

Because water is a vital component of so many industries — agriculture, manufacturing and tourism, just to name a few — and affects both human and animal health, the scientists studying water are experts in a variety of disciplines. Microbiology, chemistry, pathobiology, fisheries, soil science, biosystems engineering, veterinary medicine and molecular genetics are just a handful of the specialties of scientists studying water at MSU.

Their projects are also diverse — from studying the relationship between zebra mussels and toxic blue-green algae to removing pollutants from soil and water using plants and other natural materials to identifying new waterborne pathogens, MAES scientists are at the forefront of water research in the United States.

We hope you enjoy this issue of *Futures*. If you have comments or questions, please send correspondence to *Futures* editor, 310 Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039, or send an e-mail to depolo@msu.edu.

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For their gracious assistance with the cover photograph, I would like to thank the Barondess family, especially Abby; Walt Peebles, of Kresge Art Center; and the University Relations Multimedia Group.

::: Jamie DePolo

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The Water of Life

As the holder of the Homer Nowlin Chair in Water Research, MAES-affiliated scientist Joan Rose has a vision for water research in Michigan that focuses on the importance of water for the health of humans, animals and the environment.

Water is the basis of life itself. According to the Environmental Protection Agency (EPA), a person can live for more than a month without food but only one week without water. Every product, whether human- or nature-made, requires water for formation. It takes about 1 gallon of water to process 1/4 pound of hamburger, but a cow consumes hundreds of gallons of water before reaching the butcher.

In 2003, the EPA celebrated the 30th anniversary of the Clean Water Act (CWA). Growing public awareness and concern for controlling water pollution led to enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the CWA. The act established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave the EPA the authority to implement pollution control programs, such as wastewater standards for industry. It made it unlawful for anyone to discharge any pollutant from a point source into navigable waters unless a permit was obtained under its provisions. It also funded the construction of sewage treatment plants under the construction grants program and recognized the need for planning to address the critical problems posed by non-point source pollution.

"There is an important and critical relationship between water and health which has often been taken for granted."

WATERFACT

About 3,100 cubic miles of water, most in the form of water vapor, is in the atmosphere at any one time. If it all fell as precipitation at once, it would be enough to cover the Earth with about 1 inch of water.

In 1972, Joan Rose, MAES-affiliated fisheries and wildlife and crop and soil sciences scientist, who holds the Homer Nowlin Endowed Chair in Water Research, was just starting her bachelor's degree in microbiology at the University of Arizona (technically, she started in biology and then switched to microbiology). She did not know it at the time, but her interdisciplinary and wide-ranging education was preparing her to be one of the country's top water scientists.

Growing up in the high desert of California, Rose was always interested in science.

"I had a chemistry set and aquarium — all that stuff," she said. "But I was never really sure what I wanted to do."

As a college undergraduate at the University of Arizona, Rose had the good fortune to meet USDA scientist Martha Gilliam, who studied microbes of the gut in bees. Quitting her job at Taco Bell to work in Gilliam's lab, Rose saw that women could become research scientists.

Gilliam urged Rose to attend graduate school at Gilliam's alma mater, the University of Wyoming. As a graduate student, Rose began working with another woman scientist, Martha Christensen, a fungal/soil ecologist. The two worked with the USDA bee lab on an emerging fungal disease of bees.

"There was this new disease showing up in bees in the United States for the first time," Rose explained. "It had been in Europe for a while but somehow it was transported to the United States, and we began studying the appearance of this fungus in the bees and the spread of the disease throughout the United States. I took classes in entomology, botany and microbiology, and it gave me a strong background in interdisciplinary research. Microbiology and the environment was still the direction I wanted to go," she said. "I was in the College of Agriculture — it was a great place for integrating the sciences, as the focus was on land, energy, food and conservation. There water became one of my strong interests."

Rose decided to stay in water for her doctorate at the University of Arizona and took classes in law, hydrology and environmental science in addition to microbiology.

"After I got my Ph.D., there was another new disease outbreak in the United States, this time in people," she said. "The first waterborne outbreak of *Cryptosporidium* occurred in 1985, and I got a grant to study the spread of this parasite in water in the United States. Then there was a *Cryptosporidium* outbreak in London, and I was invited over there to study it."

Cryptosporidium is a single-celled parasite that lives in the intestines of animals and people and causes a disease called cryptosporidiosis, which is characterized by watery diarrhea and intestinal cramps. There is no drug that cures cryptosporidiosis, but most people with healthy immune systems recover after several days. For the very young, the elderly and anyone with a compromised immune system, however, the disease can be deadly. The disease is common in young farm animals, such as calves, and is spread by contact with infected feces.

In 1987, 13,000 people in Carrollton, Ga., became ill with cryptosporidiosis. This was the first report of the disease's spread through a municipal water system that met all state and federal drinking water standards. The largest waterborne outbreak of cryptosporidiosis ever documented in the United States occurred in 1993 in Milwaukee, Wis. Drinking water was contaminated with *Cryptosporidium*. An estimated 400,000 people became ill and the disease contributed to the deaths of 100 people, even though the water met all national standards. These outbreaks focused attention on the risk of waterborne cryptosporidiosis and on microbes in water.

Rose became an expert on *Cryptosporidium* in water supplies. As her body of research grew, she became an international expert in water pollution microbiology, waterborne diseases and public health/public policy issues. As a researcher at the University of South Florida's College of Marine Science until her appointment to the Nowlin chair last year, she was interested in coastal pollution and wastewater impacts — issues similar to those of concern in Michigan. She serves on numerous national and international committees, including the Science Advisory Board of the International Commission of the Great Lakes, the Research Advisory Council for the Water Reuse Foundation, the Alan T. Waterman Award Committee of the

The availability of clean water is important to Michigan because both groundwater and surface waters serve the state's urban, agricultural and rural populations. Michigan's water research agenda represents the struggles with water globally.

National Science Foundation, the USA National Committee for the International Water Association, the International Water Association's Specialty Group Health-Related Water Microbiology, the Research Advisory Board of the National Water Research Institute, the Board of Directors of the Association of Environmental Engineering and Science Professors, and the Council Policy Committee for the American Society of Microbiology.

"I think my early experience in jumping into things I wasn't familiar with gave me a good appreciation and background for work in water science," she said. "If it seemed interesting, I wanted to work on it. Michigan State is known for its microbial and environmental focus — the opportunity to work with people doing things in environmental studies that can be applied to human health is very important to me. There is an important and critical relationship between water and health which has often been taken for granted. Access to safe drinking water is one of the most serious public health crises facing the world. At MSU, the administrators and scientists truly believe in interdisciplinary studies, which is not the case everywhere. I'm thrilled to be able to study water issues here in Michigan."

"Dr. Rose's skills and expertise are paramount in meeting the research challenges of the future," said J. Ian Gray, director of the Michigan Agricultural Experiment Station. "I know her strategic research is having a positive impact on Michigan's citizens and water resources."

Rose's Water Research Agenda

Rose understands the importance of water to Michigan, and the breadth of her research program demonstrates that knowledge.

"Water quality has always been important to the citizens of Michigan," she explained. "What we do here in Michigan represents the struggles with water globally. Clean water is important to Michigan because both groundwater and surface waters serve the state's urban, agricultural and rural populations. Water quality degradation is, for the most part, human induced. Wastewater, biosolids, storm water, combined sewer overflows, industrial discharges, septic tanks, ballast waters and agricul-

Joan Rose, holder of the Homer Nowlin Chair in Water Research, understands the importance of water to Michigan, and the breadth of her research program demonstrates that knowledge. Health is the goal of her research, and she plans to use new technology to attain that goal.

tural practices may contribute pathogens, pharmaceuticals, pesticides and nutrients to the water environment. This could potentially affect public health, animal health, agricultural health and ecosystem health."

Through her collaborations at MSU, a vision of water research in Michigan has emerged, resembling an archery target — health is the big red bull's-eye in the middle. Just outside this goal is a ring representing new technology, including computer models, biosensors, biochips and better surveys. The outermost ring represents the water environment, including sources, transport and fate of pollutants.

"The integrated research has to incorporate all three of the rings," Rose explained. "Health is the goal, and we have to use new technology to study the water environment to get there."

She is collaborating with researchers across the MSU campus and at other universities in Michigan to study waterborne diseases and public health and has just finished a proposal for a Center for Water Quality and Health at MSU. Though the center has not yet been funded, Rose is optimistic.

"Whether the research is funded or not, there are key areas where more studies are warranted, given recent water issues that have been highlighted nationally and in the state," she said. "The vision for water research here in Michigan will be shaped by these issues, and the faculty members at MSU certainly have the expertise to address them."

Antibiotics in Water and Development of Resistance

The use of antibiotics to improve animal health and productivity has been increasing since the 1970s. According to a 2000 survey by the Animal Health Institute, 32.2 million pounds of antibiotics (64.5 percent of the total) were used in the United States for food products used for human consumption, 14.7 million pounds (29.5 percent) for therapeutic and non-therapeutic practices in livestock, and 3.1 million pounds (6 percent) for growth promotion. According to more recent data from the same group, the use of antibiotics as growth promoters rose to 13 percent of the total use in 2003. The non-therapeutic use of antibiotics for animals has been reported in approximately 70 percent of large swine feedlot operations and in 25 percent of small feedlot operations. More than 70 percent of large cattle feedlots use antibiotics in at least 58 percent of their herds. Approximately 88 percent of large dairy operations administered antibiotics to up to 40 percent of their cows during lactation periods.

"Correspondingly, both veterinary and human antibiotics are being detected in waters throughout the United States, and evidence of spread of antibiotic resistance [AR] is also emerging," Rose said.

Approximately 50 percent of streams were found to be contaminated with a range of antibiotics. Erythromycin-H20, a metabolite of erythromycin, was the most frequently reported by the U.S.

"Health is the goal, and we have to use new technology to study the water environment to get there."

Geological Service. A research team at MSU has found new classes of tetracycline resistance in soils containing manure from tetracycline-treated livestock. Further measurements with new methods such as real-time PCR (polymerase chain reaction) tests showed that tetracycline resistance genes were present only in manured soils — they were not detectable in the adjacent non-manured soils.

Rose explained that a group of antibiotics known as fluoroquinolones have been used as growth promoters in poultry, and some of these animals have been found to harbor fluoroquinolone-resistant strains of *Campylobacter*, another water- and food-borne pathogen that causes gastrointestinal illness in humans. Other common zoonotic pathogens (pathogens that can be transferred from animals to humans) such as *Salmonella*, *Enterococcus* and *Staphylococcus* may also acquire resistance. When these resistant pathogens are transmitted from their animal hosts to humans, drugs normally used to treat the disease may not work, leaving people with limited treatment options.

"Addressing the issue of antibiotic resistance will require a deeper understanding of the spread of antibiotics and genetic AR determinants through the environment and within communities of bacteria," Rose said. "We need rapid detection devices, high throughput identification and quantification tools, and mathematical models to quantitatively integrate the information related to the production and use of antibiotics, their environmental fate and the presence of AR, both within the host and in the environment."

Viral Pathogens and Waterborne Disease

Rose said the assurance of safe drinking water in the United States continues to be a challenge as a result of emerging contaminants, more sensitive and specific detection methods, better investigations and more public awareness. Preventing microbial pathogens from contaminating beaches and drinking water, including viruses and parasites that can cause serious illnesses, will be the primary focus. In the past, coliform bacteria were considered indicator bacteria and were used (and are still used by most) to determine whether water was safe. If those bacteria were not there, the water was presumed safe. But this thinking is changing.

"It's now clear that the coliform indicator bacteria do not always provide the necessary measure of the microbiological safety of water, especially with respect to viral pathogens such as hepatitis A, and parasitic pathogens such as *Cryptosporidium* and *Giardia*," Rose explained. "Both drinking water and recreational waterborne outbreaks, as well as the recognition of other potential waterborne

Center for Water Quality and Health

pathogens, have been on the increase in recent years."

The Safe Drinking Water Act amendments of 1996 required the EPA to identify new chemicals and microorganisms for potential regulation every five years. The contaminant candidate list (CCL) is based on information about known and suspected health risks and the occurrence of the contaminant in water. Currently there are 13 microorganisms on the CCL, including several enteric viruses of concern. One of the government's goals is to use genetic databases to identify microbial risks in water, called virulence-factor activity relationships (VFARs).

"The conceptual approach was to use microbial genomic databases to identify new microorganisms, examine the potential human risks of microorganisms found in water, determine the occurrence (persistence, prevalence and magnitude) of the microbial contaminants in water and the potential for waterborne disease," Rose said. "The application of VFARs to water was defined as a measure of the potential to cause disease and incorporates the concept of environmental persist-

"MSU has the resources and brain power to help address the future of water in Michigan and become a leader in the Great Lakes."

WATERFACT

Water covers 71 percent of the Earth. Of this, 97 percent is salt water and 3 percent is fresh water. Of the fresh water, 2.5 percent is frozen in glaciers and ice caps, leaving only .5 percent potable drinking water.

ence in addition to pathogenicity. But this work is in its infancy and has yet to receive major national funding."

Rose said that viral pathogens in water continue to be a public health challenge. Hundreds of viruses can be excreted in high concentrations and then detected in sewage. They are stable in the environment and readily move into groundwater. Recently, viral agents were believed to be the cause of intestinal disease outbreaks associated with septic tanks in rural Wisconsin areas.

"The coliform indicator bacteria did not prove to be a sufficient measure of risk," Rose said. "And we don't know enough about the transport and exposure of these viruses as waterborne agents of disease.

"We need full characterization of the viral infections in a community, particularly of emerging viruses of concern," she continued. "This research will need to be integrated with new methods that can screen for hundreds of targets, which will allow us to identify the source in water and link it to clinical cases."

Elemental Toxins

Though antibiotics and viral pathogens are the primary focus of Rose's research, there are other water contaminant issues that she and other MSU scientists are interested in studying.

"The more 'traditional' elemental toxins — lead, arsenic, copper — continue to be of concern both locally and globally," she said. "The EPA estimates that 20 percent of human exposure to lead is attributable to drinking water. However, some of these toxins are either reemerging or newly emerging concerns. The upcoming Goldschmidt Conference, the premier conference on geochemistry, lists uranium and fluoride as anticipated 'next wave' pollutants."

In many cases, water quality issues associated with uranium and fluoride are the result of high natural concentrations or natural concentrations that have been increased by people disturbing the environment. According to David Long, professor of aqueous and environmental geochemistry in MSU's Department of Geological Sciences, 86 percent of wells used for drinking water in the Ethiopian part of the Rift Valley fail the World Health Organization (WHO) guidelines for water quality because of these elements. Ninety percent of drinking water within a large area of Argentina is contaminated with high levels of fluoride. In portions of the Balkans, Long and his colleagues wonder whether uranium concentrations could be related to the occurrence of Balkan endemic nephropathy (BEN), a kidney disease that leads to renal failure. It is found in small agricultural villages, and its distribution pattern has not changed since it was identified.

"Issues associated with contaminants like fluoride and uranium in drinking water involve more than monitoring," Rose said. "We need to develop indicators and indices that empower decision makers to create strategies to more effectively manage major endemic diseases. For example, the research in the Balkans found that well water used for drinking in most of the villages had nitrate levels that exceeded WHO guidelines. Wells are typically in the yards of homes surrounded by vegetable gardens. The gardens are heavily fertilized, which is a source for nitrate, and pesticides are used extensively. Thus, similar to nitrate, the pesticides also may be getting into the water supply, endangering health. Nitrate in this case is a surrogate indicator — cost-effective and easily measured — of potential health problems.

"These studies demonstrate two other challenges in water quality and health," Rose continued. "How do mixtures of chemicals influence health? And what is the cause of disease outbreak? With the high levels of nitrate in the village wells in the Balkans, how are the toxicological properties of other chemicals in the water influenced? Could, for example, low levels of some agent become more toxic by certain synergistic reactions? Mixtures with fluoride are suspected of being a health problem in developing countries. The outbreak of BEN is particularly intriguing because the disease occurs in village clusters across portions of the Balkans, the locations of which have not changed. People are getting sick, it is not known why, although a major hypothesis is that drinking water is the exposure route, but the agent — chemical, microbiological or a mixture of the two — is unknown. These are the

According to MAES-affiliated researcher Joan Rose, water quality degradation is mostly human-induced. Wastewater, biosolids, storm water, combined sewer overflows, industrial discharges, septic tanks, ballast waters and agricultural runoff may contribute pathogens, pharmaceuticals, pesticides and nutrients to water, which could potentially affect public health, animal health, agricultural health and ecosystem health.

questions we want to answer."

These types of questions are not so different from those facing the up to 40 percent of Michigan's residents who get their water from small community wells in rural areas.

"Monitoring and understanding the contamination with nitrates or viruses and the risk to health, particularly to children's health, have not been adequately addressed in the state," Rose said.

Rose has begun studying the occurrence of toxins produced by blue-green algae blooms, which preliminary research suggests may follow zebra mussel invasions. (Please see the story on page 20.)

"The researchers in this area have so much expertise, it is great to be able to work with them," she said.

A Michigan Priority

Rose's research focus ties in nicely with Gov. Jennifer Granholm's January announcement of her initiative to protect Michigan's water. The initiative addresses major concerns facing the Great Lakes today: water withdrawal, invasive species, open water disposal, the National Pollution Discharge Elimination System, the revised sanitary code, wetlands protection and securing federal funding for Great Lakes restoration projects. The governor also issued an executive order prohibiting the dumping of dredge material contaminated with toxic substances, such as dioxin or PCBs, into the waters of the Great Lakes. (For information on MAES research on remediation of toxic substances, see story on page 25.)

"The Great Lakes fuel our economy, color our character and literally define the shape of our state," Granholm said. "They are our most vital resources, which makes their preservation and protection all too important to approach haphazardly. Our waters may be more threatened today than they have ever been. A thirsty country looks to our resources and sees a source of free, clean, fresh drinking water. Pollution and growth continue to threaten their health."

"MSU has the resources and brain power to help address the future of water in the state of Michigan and become a leader in the Great Lakes," Rose said. "If you look at President Bush's proposed budget, which may include as much as $45 million for Great Lakes cleanup, Michigan, whose coastline is outlined by the Great Lakes, should be at the forefront of the water science and technology needed to make important decisions for protecting the waters of the state and the region.

"I see this unfolding in three areas," Rose continued. "One: balancing the water budget to be assured that the water sectors — including the agricultural, industrial, tourism, community and ecosystem sectors — are integrated and have access to the quality and quantity of water they need for continued economic growth. Two: provide healthy beaches for healthy children. Coastlines are at risk, and the beach closures and pollution show this. Children are the most vulnerable, and a strategy for cleaning the beaches means that we will be able to protect children's health as well as the coastline. Three: enhance community infrastructure and environments. We know that 'cool cities' are clean cities. There is a great need to address wastewater, combined sewer overflow storm water and other non-point source pollution. New environmental rules will require development of plans for science and risk-based public/environmental harm assessment. Prioritization schemes based on risk reduction, economics and ability to demonstrate problem abatement will be an important need."

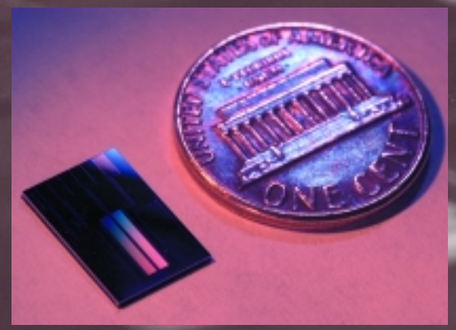
::: Jamie DePolo

sensing and identifying DANGER

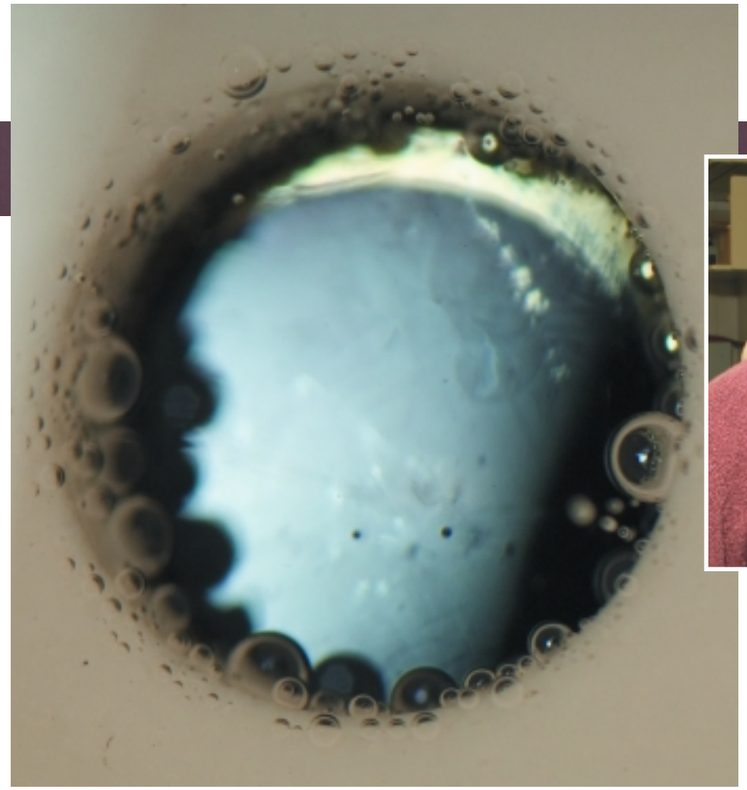
MAES scientists are creating sensors to detect harmful pathogens in water and food, as well as studying new, emerging pathogens that can jump from animals to people.

When President Bush released his 2005 budget proposal earlier this year, most domestic programs faced stagnant or declining resources. One notable standout was the Food and Drug Administration (FDA) budget. The president proposed a $1.8 billion budget for the FDA — an increase of 8.8 percent over the current fiscal year.

The increase would be to support the FDA's role in a new, multidepartment counterterrorism program to protect the food and water supply and to pay for more labs to analyze food samples for biological, chemical and radiological agents; for more inspections of imported foods; and for increased coordination with the Department of Homeland Security.



Developed in MAES scientist Evangelyn Alocilja's lab, this biosensor is smaller than a penny and can detect the presence of specific pathogens, such as *E. coli* O157:H7, in food and water. The biosensor uses biological receptors to detect the pathogens.



MAES biosystems engineering researcher Evangelyn Alocilja *(inset)* is working on a number of biosensors. Each is specific to one pathogen and is rapid, accurate and sensitive at low contamination levels. In the larger photo, a nano-tubular silicon biosensor for detecting food-borne pathogens is being prepared.

The proposed increase in FDA funding for counterterrorism is matched by a similarly large proposed increase for the U.S. Department of Agriculture's work on food safety. The president issued an executive order directing the Department of Health and Human Services (which oversees the FDA), the Department of Agriculture, the Department of Homeland Security and the Environmental Protection Agency to develop new ways to protect the nation's food supply. Many bioterrorism experts have warned that the U.S. food supply is vulnerable to attack, and HHS Secretary Tommy Thompson has been a strong advocate for increasing research on how to combat the potential threats.

"The Sept. 11 attacks underscored the need for biosecurity for the nation's food supply chain," said Evangelyn Alocilja, MAES biosystems engineering scientist. "From farm to table, there are numerous vulnerabilities where food and water can be contaminated with pathogenic bacteria."

"Developing detection tools capable of rapidly and economically detecting a broad spectrum of harmful microorganisms is critical," said James Tiedje, MAES crop and soil sciences and microbiology and molecular genetics scientist and university distinguished professor.

Alocilja's and Tiedje's research teams are both working on creating sensors that can rapidly detect harmful pathogens in food and water before they cause widespread disease.

THE BIOSENSOR

Alocilja's work focuses on biosensors, sensors that use biological receptors — such as antibodies, enzymes and nucleic acids — to detect the presence of specific pathogens. By immobilizing the bioreceptors on thin wafers of metal or membrane and attaching the sensor to a computer, scientists can observe in real time when the antibodies, for example, bind to the target pathogen and send an electrical signal to the computer.

"We need a detection mechanism that is rapid, accurate and sensitive at very low levels," Alocilja explained. "Right now, detection and identification of pathogens such as *E. coli* O157:H7 and *Salmonella* rely heavily on conventional culturing techniques. You take a sample that is considered contaminated. Then you grow the culture in a lab and see if the pathogen is there. It can take from two to seven days to get results, which in many cases is too long. If a water supply is suspected to be contaminated, you don't want to wait seven days to know for sure."

Alocilja's biosensor looks like a computer chip and is a single-use sensor. Once it has detected a pathogen, it is thrown away and replaced with a new one.

"This is necessary because we can't remove the antibodies that are already bound to the sensor," she explained. "One of my students is working on developing a sensor that is continuous."

The continuous sensor uses enzymes that are inherent in the bacteria as the biological receptor. A chemical is added to the bacteria to break the cell structure and release the enzyme. This enzyme breaks another chemical structure and releases light in the process. This emitted light can be read by a computer, which would indicate the presence of the pathogen.

Currently, Alocilja's biosensors are specific to one pathogen, but she envisions a multi-analysis biosensor that could detect several pathogens at once, an idea that Tiedje is exploring.

"Industry might want a single biosensor to test for pathogens specific to that application," she explained, "while consumers might want a biosensor that can test for multiple pathogens."

Alocilja is eager to test her biosensor for *E. coli* O157:H7 in a real-world situation.

"We have created a biosensor for *E. coli* O157:H7 and it has performed perfectly in artificially contaminated situations," she said. "Meaning, in the lab, we've contaminated produce, water and ground beef with the organism and the biosensor has detected it. But we already knew it was there. We want to take it out in the field and test it in a feedlot to absolutely prove it works."

E. coli O157:H7 can be found in the intestines of many healthy cows and is excreted in manure. Meat can become contaminated during processing. This is why consumers are advised to cook meat to a temperature of at least 160 degrees. *E. coli* O157:H7 has also been found in unpasteurized milk and on produce, such as alfalfa sprouts. The bacterium often causes bloody diarrhea and abdominal cramps in people. While most people recover in five to 10 days, the young, the elderly and the immunosuppressed are affected more severely. The pathogen has caused kidney failure and death in these populations.

The National Institutes of Health (NIH) and the Environmental Protection Agency (EPA) have created a master list of the most troublesome pathogens on which the government would like researchers to focus. In addition to *E. coli* O157:H7 and *Salmonella*, the list includes *Listeria*, *Campylobacter*, *Cryptosporidium* and *Giardia*.

Alocilja wants to take her biosensor to a feedlot and test the manure to see if it can detect the bacteria. Once she has this final proof, she expects manufacturers to become more interested. In addition to the *E. coli* O157:H7 biosensor, she has also created biosensors to detect *Salmonella* and bovine viral diarrhea virus. Initial work is also being done to develop a biosensor for field-based detection of the foot-and-mouth disease virus.

"Biosensors are novel for food, water and agricultural biosecurity issues," she explained. "In the '80s and '90s, much of the work done on biosensors was for medical applications. The first one developed was a glucose test. But the research has progressed rapidly. We're moving toward sophisticated, user-friendly tests. There is a lot of potential for biosensors, especially for use in the field as a rapid screening tool. There are so many applications for biosensors — food safety, homeland security, clinical diagnosis, risk assessment, epidemiology, packaging, to name a few. Each day I come to work excited about what I'm doing."

THE DNA CHIP

The detection research of Tiedje's team differs from Alocilja's in two significant ways. First, his chip is made with pieces of DNA from the pathogen. If the contaminant is in the sample, the contaminant DNA binds to the DNA in the chip and glows.

"DNA testing is more sensitive than antibody testing," Tiedje explained. "It can detect different strains of bacteria. It also allows us to detect antibiotic resistance in the pathogens."

Tiedje sees a role for both types of sensors.

"Antibody detection could be the first level of detection," he said. "Then we would use the DNA chip to refine the detection. We will definitely need a 'detection train' as we become more sophisticated in our detection efforts."

Secondly, Tiedje and colleagues Syed Hashsham, civil and environmental engineering scientist; Tom Whittam, MAES food science and human nutrition and microbiology and molecular genetics scientist; and Joan Rose, MAES-affiliated fisheries and wildlife and crop and soil scientist; are working on developing a chip that can detect multiple pathogens at the same time.

"The total number of microorganisms that could compromise the safety of air, water, food, animals and agricultural products runs into the hundreds, so developing parallel detection tools is very important," Tiedje said.

"Another advantage of parallel detection is that we can look at what else is out there and examine the relationship between pathogens," Hashsham added. "We may be able to determine a better indicator for fecal contamination."

WATERFACT

If all of the world's water was poured on the United States, it would cover the land to a depth of 90 miles.

WATERFACT

The total water supply of the world is 326 million cubic miles. A cubic mile of water equals more than 1 trillion gallons.

For example, all water treatment plants routinely test for bacteria such as *E. coli* and coliform bacteria. However, these are poor indicators of many pathogens as well as risk. The water industry is very interested in better testing to assure the safety of water. By studying the relationships among the pathogens present in contaminated water, Tiedje and Hashsham may be able to find new "indicator" microorganisms that signal the presence of other pathogens and water at risk.

The design of Tiedje and Hashsham's DNA chip also sets it apart from other work being done in this area across the nation. At about 1 cm square, the chip fits easily into a human palm. The DNA sequences for the various pathogens are placed on the chip. One chip that Tiedje and Hashsham are currently testing has the ability to screen for up to 8,000 different targets. Working with Erdogan Gulari, a chemical engineering scientist at the University of Michigan, the researchers developed a design for the chip that is updatable — they can change or add DNA sequences to the surface of the chip without redesigning the whole chip.

"Dr. Gulari is internationally known for chip design," Hashsham said. "He designed the breast cancer detection chip and also developed one to detect SARS."

This updatable design translates into cost savings for the scientists. Scientists using a traditional design pay $50,000 for the creation of the initial chip and then several hundred dollars apiece for copies of it. The updatable chip costs about the same, whether it is the first or the 50th version.

"Chip-based detection is very hot right now," Tiedje said. "Most of the research is being done for human health. The idea is to be able to detect the gene for certain diseases, such as breast cancer. There are big profits in human health, so many companies are interested in that first. That drives interest in other applications, such as our work and for animal disease diagnosis."

"Since Sept. 11, many funding agencies, including the National Science Foundation, the National Institutes of Health, the USDA and the EPA, have established focused programs to support research on faster, more sensitive and better ways to detect pathogens," Hashsham said. "That's how important this work is considered."

Tiedje and Hashsham estimate that they will have a chip that can detect 20 waterborne pathogens to offer to manufacturers in approximately two years.

"Validation of each organism's detection is the bottleneck," Tiedje explained. "We have to ensure that the chip is detecting the organisms at appropriate levels and that they are detected when other organisms are present."

Ultimately, Tiedje and Hashsham want to make their chip foolproof so it can be used quickly and easily by many different people.

"For example, a water treatment plant manager could pull a sample and use our chip to test it," Hashsham said. "He or she could do it at the plant without sending the sample to a lab. That's our goal."

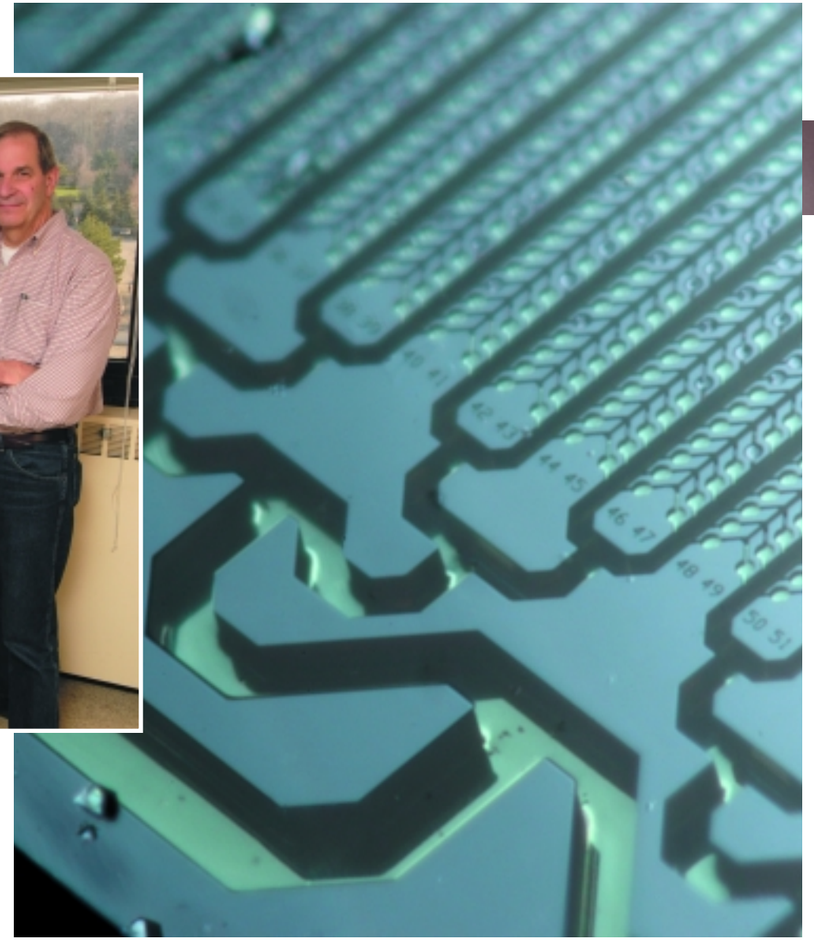
EMERGING ZOONOTIC DISEASES AND WATER

• In December 2003, the U.S. Department of Agriculture announced that a cow in Washington state was infected with bovine spongiform encephalopathy (BSE), better known as mad cow disease. Some scientific evidence has linked the consumption of meat products from BSE-infected cattle with Creutzfeldt-Jakob disease (CJD) in humans. After an investigation into the cow's herd history, more than 600 cows were euthanized to protect the food supply.

• In February 2004, as news of people dying from an avian flu outbreak in Vietnam and Thailand was being reported by the media, an outbreak of avian flu in chicken flocks in Delaware resulted in more than 72,000 chickens being destroyed. Industry experts emphasized that the strain of flu found in Delaware does not spread to humans, but the news of human deaths in Asia made many people nervous.

"Zoonotic infections clearly play a central role in emerging infectious disease in humans," said Carole Bolin, MAES pathobiology and diagnostic investigation scientist. Her research focuses on zoonotic pathogens, bacteria and viruses that infect both humans and animals, and how they are transmitted between the two.

As the world consumes more meat — over the past 25 years, per capita meat consumption in developing countries grew at three times the rate in developing countries — animal agriculture production has increased to meet the demand. It is estimated that global livestock production will have to double by 2020 to meet demand. More livestock production means more livestock manure to be disposed of, which means more potential for disease to spread via water.



James Tiedje, MAES crop and soil sciences and microbiology and molecular genetics scientist and university distinguished professor *(right)*, and Syed Hashsham, civil and environmental engineering scientist, have developed a sensor *(far right)* that uses DNA, which is more sensitive than antibodies, to detect pathogens. The DNA chip is capable of detecting multiple pathogens at the same time.

Working with Joan Rose, MAES-affiliated fisheries and wildlife and crop and soil scientist and holder of the Homer Nowlin Endowed Chair in Water Research, Bolin is studying several emerging zoonotic diseases and the role that water plays in their transmission. The pathogens that cause these diseases are on the NIH and EPA master list.

"Zoonotic pathogens account for 75 percent of emerging infectious diseases," she explained. "Many of them are transmitted by indirect contact — food, water, environmental contamination — and don't require direct contact between humans and animal hosts for transmission. Water plays a large role, whether it is in drinking water or recreational water activities. Feces and urine from both animals and humans are likely the largest source of environmental loading of pathogens associated with waterborne disease transmission."

LEPTOSPIROSIS

Bolin has studied leptospirosis, a disease caused by long, corkscrew-shaped *Leptospira* bacteria, for many years. The bacteria live in wild animals such as raccoons and deer but can also infect dogs, cows and mice.

Symptoms of leptospirosis include high fever, severe headache, chills, muscle aches and vomiting, and may include jaundice, red eyes, abdominal pain, diarrhea or a rash. If the disease is not treated, the patient could develop kidney damage, meningitis, liver failure and respiratory distress. In rare cases, death occurs.

"Of zoonotic diseases, leptospirosis is the most significant spread by water. Lots of wildlife carry it and any mammal can get it," Bolin explained. "Not many other things affect such a large number of animals. The bacterium adapts to live in certain animals and these animals don't look sick. Leptospirosis sets up shop in the kidneys and is shed in urine for months to years. There is a different variant of the bacterium for each species. So if a dog

Carole Bolin, MAES pathobiology and diagnostic investigation scientist, focuses on zoonotic pathogens and how a bacterium or virus jumps between animals and humans. Zoonotic infections play a central role in emerging infectious diseases in humans. Raccoon tracks *(left)* indicate the presence of the animals. Bolin was part of a team that studied the last big outbreak of leptospirosis in humans. The scientists were fairly certain the outbreak was caused by infected raccoons.

picks up a variety that it isn't the host for — say, a raccoon variety — it will get very sick. In this case, the dog is the non-reservoir host and the raccoon is the reservoir host. The reservoir animals are the real issue. Because they're unaffected by the bacteria, they can shed bacteria for a long, long time, causing infections in other animals and people."

After the leptospires are shed in urine, they can survive for several weeks outside a host, provided they stay wet and do not freeze. The bacteria have the potential to contaminate surface water, such as lakes, ponds and streams, if the urine flows into the water. Exposing the mucous membranes of the nose, eyes or mouth to the water through swimming or drinking allows the bacteria to corkscrew into the body. Often, outbreaks of leptospirosis in animals and humans are associated with unusually heavy rainfall or flooding.

"The last big outbreak of leptospirosis in humans was in 1998 in Springfield, Ill.," Bolin said. "A triathlon qualifier was held there, and a large percentage of the participants and community residents became ill. When they were tested, it was found that most had the raccoon or dog type of leptospirosis. The swimming portion of the triathlon was held in Lake Springfield, a man-made lake surrounded by heavy forests. It had been raining heavily for several days before the triathlon — the rain had just stopped right before the race. We speculated that the heavy rain caused infected raccoon urine to flow into Lake Springfield. *Leptospira* is a very infectious organism. It may take only one organism to infect a person. Swimming in open bodies of water is always a risk — there is always going to be wildlife urine in them."

Around the world there are 250 types of leptospirosis. In the United States, there are six to eight types. Vaccines are available for dogs and cattle for several of the U.S. types.

"If we can control the disease in these reservoir animals, we can reduce the risk of the disease infecting humans," Bolin said. "There are also economic reasons to control the disease in livestock and emotional reasons to control the disease in companion animals."

MYCOBACTERIUM AVIUM SUBSPECIES *PARATUBERCULOSIS*

Mycobacterium avium subspecies *paratuberculosis* (MAP) causes Johne's (pronounced "YO-nees") disease in cattle. A chronic intestinal disorder, Johne's causes diarrhea, weight loss, decreased milk production and death. The disease incubates in infected cows for two to seven years, and even though they show no symptoms, the animals begin shedding large numbers of the organisms — up to 1 billion organisms in 1 gram of feces. These infected feces are a potential environmental and water contaminant, especially when manure is applied to fields around farms. Cattle that are heavily infected will also shed the bacterium in milk.

"There is some evidence that MAP is infectious in people," Bolin said. "The link is not firm, but it has been connected to Crohn's disease. It's a controversial association, but there is increasing evidence that MAP is present in the intestinal tissue of a significant portion of Crohn's disease patients."

Crohn's disease causes severe inflammation of the gastrointestinal tract. It most often affects the small intestine but can strike any area of the tract. In addition to the pain caused by inflammation, the disease can cause diarrhea, stomach ulcers, malnutrition and other complications such as anemia. A cure is not available. Though the disease can go into remission, it always flares up again.

There are two other facets of MAP that researchers disagree on, and both have implications for human health. U.S. research has shown that pasteurization kills MAP in milk, but European research indicates that the bacterium is not killed 100 percent of the time. There are also questions about current water treatment's ability to kill MAP. According to Bolin, the organism has been isolated in water supplies after treatment.

"It is a very tough organism," Bolin said. "I think of it as a wax-covered BB. The coating protects it from a lot of things — chlorine won't kill it. It's also more resistant than other bacteria to heat, so it can survive at higher temperatures. And it's very small. It goes through filters designed to screen out other organisms. It may be able to survive our usual water treatment processes."

Mycobacteria are ever present in the environment, and because of their toughness, they survive for long periods of time.

"Because of the type of organism it is, if it were to get into the water supply, it could cause big problems," Bolin said. "The only thing that we know of right now that kills it is strong ultraviolet light."

Bolin and Rose are examining the issue from both the farm and the water side, looking for answers to questions such as:

- How much infected manure gets into the water supply and how much causes problems?
- How much goes to surface and groundwater?
- Does dilution affect the organism?
- What is the biology of the organisms and how much of it survives in the environment?
- What level of MAP causes infection?

"I'm studying the farm side," Bolin said, "and Joan is studying the water aspects. One infected cow may shed up to 10 trillion MAP organisms per day. Water is always running out of a dairy barn and it's a good bet that there is some manure in that effluvium. The organism will survive in that, so we want to determine the potential for it getting into the water supply. Many farms have ponds and streams — can the organism be transferred to other animals through these bodies of water?"

Rose is following the organism's path through the water cycle. Water from the barns usually sinks into the ground and is filtered by soil as it travels. She is studying the infected effluvium's movement through the soil to understand how and if it reaches groundwater.

"We have a series of on-farm procedures that producers can follow so other cattle are not infected," Bolin said. "But we don't know if spreading the manure on fields or composting it kills the bacteria.

"It's a good model organism to study because it is tough," she added. "If we can develop better water treatment systems to kill MAP, we know it will kill other organisms. This has the potential to be a real-world health issue."

"To conduct risk assessment on these types of pathogens, we need key pieces of information," Rose said. "The infectious dose-response of the pathogen, the concentration at which the pathogen can be found in water, and the impact of various water treatment strategies on reducing the infectiousness of the pathogen — we want to fill in these gaps in our knowledge."

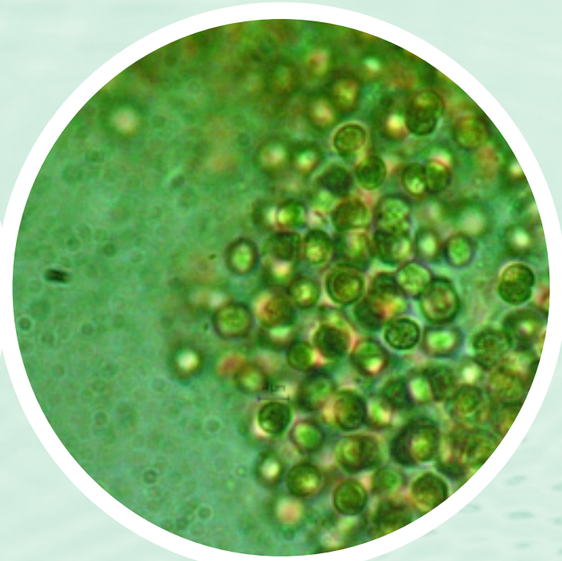
::: Jamie DePolo

WATERFACT

The 48 contiguous states receive a total volume of about 4 cubic miles of precipitation each day.

Zebra Mussels and Blue-green Algae:

A Toxic Link?



Certain strains of blue-green algae produce toxins that are harmful to humans and animals. Scientists are studying the link between zebra mussel infestations and blue-green algae blooms.

Zebra mussels (*Dreissena polymorpha*) are small mussels native to the Caspian Sea region of Asia. They are believed to have been transported to the Great Lakes via ballast water from a transoceanic vessel. The ballast water, taken on in a freshwater European port, was subsequently discharged into Lake St. Clair, near Detroit, where the first mussels were discovered in 1988. Since that time, they have spread to all of the Great Lakes and a growing number of U. S. and Canadian inland waterways. They have spread south down the Mississippi River and eastward to the Hudson River.

Most zebra mussels are thumbnail-sized, but they can reach up to 2 inches long in their two-year life span. The adult mussels form colonies of hundreds of thousands per square meter on hard underwater surfaces such as docks, boat hulls, commercial fishing nets, buoys, water intake pipes, native mollusks and other zebra mussels. The mussels' ability to populate a body of water quickly is due to a high reproductive rate and a limited number of natural enemies. Diving ducks and freshwater drum eat zebra mussels but have not significantly controlled them.

Zebra mussels have disrupted water withdrawal operations by clogging water intake pipes. This has caused serious problems in the Great Lakes region, where about 655 billion gallons of Great Lakes water are withdrawn each day for use by more than 25 million people, thousands of crop and livestock farms, hundreds of lakeshore industries, and dozens of nuclear and fossil fuel power plants. The U. S. Fish and Wildlife Service forecasts $5 billion in losses over the next decade to manufacturing, power and municipal water intake facilities that use Great Lakes water because of zebra mussel infestations.

Zebra mussels also affect the quality of the water. One zebra mussel can filter 1 liter of water per day. Dense colonies of mussels filtering tiny floating plants and animals (plankton) from the water are believed to cause increased water clarity in some areas. In the western basin of Lake Erie, water clarity has increased by 77 percent, or to 20 feet.

In addition to all the other problems that zebra mussels cause, MAES scientists are concerned about a possible link between zebra mussel infestation and subsequent blooms of toxic blue-green algae.

"If cyanobacterial [blue-green algae] blooms are a common side effect of zebra mussel invasion, then hard-fought gains in the restoration of water quality may be undone," said Orlando "Ace" Sarnelle, fisheries and wildlife scientist, who is studying the relationship between blue-green algae blooms and zebra mussels.

"The numbers of cyanobacterial blooms in Michigan have been increasing and appear to be correlated with the spread of zebra mussels," said Joan Rose, MAES-affiliated fisheries and wildlife scientist, and holder of the Homer Nowlin Chair in Water Research. She and Sarnelle are working together and with other researchers around the state to investigate this link.

BLUE-GREEN ALGAE ARE REALLY BACTERIA

Correctly known as cyanobacteria, blue-green algae are quite small, one-celled creatures with the potential to form colonies large enough for humans to see. They live in the water, where they manufacture their own food through photosynthesis. Cyanobacteria have been on the Earth for billions of years — they have the distinction of being the oldest known fossil at more than 3.5 billion years old. Several species of cyanobacteria — including *Anabaena*, *Aphanizomenon*, *Microcystis* and *Oscillatoria*

WATERFACT

Water usage falls into five usage categories:

Residential use= 38.3 percent

Industrial use= 27.3 percent

Commercial use= 19.1 percent

Public use= 5.5 percent

Miscellaneous= 9.8 percent

— produce toxins that are harmful to people and animals that drink water with cyanobacteria in it.

"Several cases of blue-green algae toxicosis in domestic animals have been recorded," Rose said. "A number of cattle died in a herd of 175 Hereford-Angus cattle in Burlington, Colo., after ingesting water containing an algal bloom. In February 1996, 52 patients at a dialysis center in Caruaru, Brazil, died from a syndrome now known as Caruaru Syndrome. High concentrations of microcystin toxins were detected in the water used for treatment."

In a healthy cyanobacterium cell, the toxin is typically contained in the cell. But when the cell is damaged or killed, such as when the water is treated with chlorine to ensure it is safe to drink, the toxin is released into the water. This makes increased numbers of blue-green algae blooms an issue for those who regulate the safety of drinking water supplies.

Blue-green algae also have the ability to form large, scummy blobs on the water's surface.

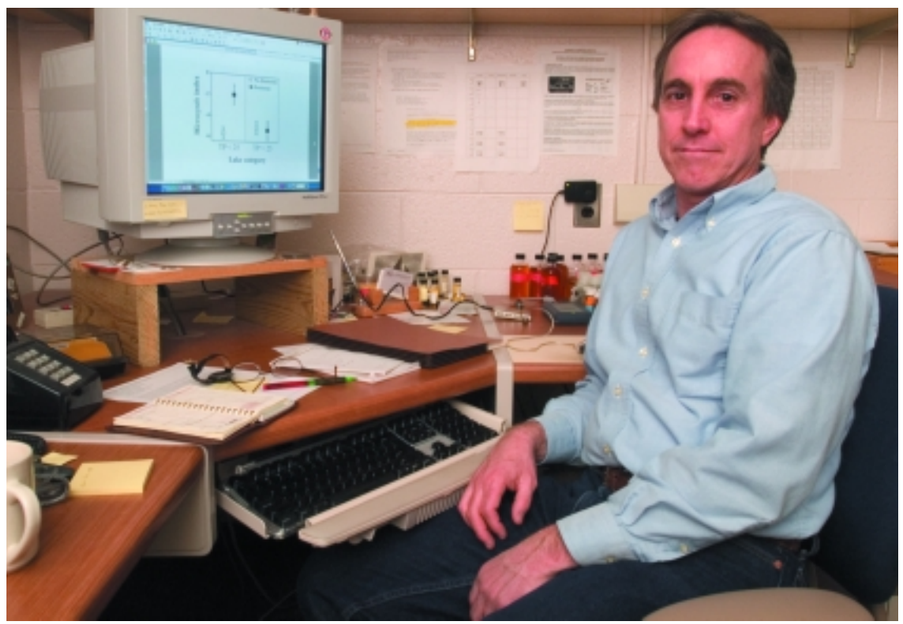
"Blue-green algae are famous for their scum-forming ability," Sarnelle said. "If the wind blows it to the edge of the lake and a big collection of scum forms, that is often a problem for animals that drink from the lake. If a dog took a drink from the spot where the scum was, it would soon keel over dead. It's very toxic."

According to Sarnelle, research has long demonstrated that summer blooms of harmful cyanobacteria typically occur in lakes with an excess of nutrients in them, particularly phosphorus. To reduce the cyanobacterial blooms, lake managers have spent much money and effort to reduce the amount of nutrients flowing into lakes. But new data suggest that phosphorus may not be the only trigger for cyanobacterial blooms.

"For example, Lake Erie, which at one time was highly impaired, has undergone a major reduction in point-source phosphorus loading," Sarnelle explained. "Recent data from the western basin indicate that phosphorus levels are currently low enough that cyanobacteria should not be the main type of algae bloom occurring over the summer. However, intense cyanobacterial blooms have been reported since the establishment of zebra mussels. Similarly, data from the Bay of Quinte in Lake Ontario show a dramatic increase in the biomass of the cyanobacterium *Microcystis aeruginosa* after zebra mussel establishment.

"Toxic algal blooms in the Saginaw Bay and Lake Erie are disturbing because they come after many years of expensive reductions in nutrient loading to improve water quality," Sarnelle concluded.

"The EPA is concerned about blue-green algae toxins," Rose added. "The toxin has been on the contaminant candidate list for five years. The EPA is examining the toxin's effects on human health at various levels and will then decide if regulations are needed."



Orlando "Ace" Sarnelle, fisheries and wildlife scientist, is working with Joan Rose, holder of the Homer Nowlin Chair in Water Research, to study the relationship between blue-green algae and zebra mussels. Blue-green algae, correctly known as cyanobacteria, produce toxins that are harmful to people and animals that drink water with cyanobacteria in it.

Rose pointed out that Canada already has regulations/guidelines on cyanobacterial toxins, as does the World Health Organization.

"With more blue-green algae blooms, people are being exposed to higher levels than Canadian regulations permit," Rose said. "People thought that blue-green algae would be a problem in the South, not in northern states. We need research to study how and when the algae produce the toxin. Is there a way to stop the algae from producing the toxin?"

UNTANGLING THE CAUSE AND EFFECT

Determining the relationship between zebra mussels and blue-green algae blooms is anything but straightforward. The number of variables is high and scientifically sound data are sometimes difficult to find.

"Data on blue-green algal blooms are hard to get — a lot of it is anecdotal," Sarnelle explained. "I hear things like, 'There wasn't any, now we see a lot.'"

So Sarnelle and his colleagues conducted a survey of inland lakes in Michigan and found the presence of zebra mussels cancelled the expected relationship between high phosphorus levels and increased blue-green algae blooms. They believe this influence is due to an interactive effect of the zebra mussels and the level of phosphorus in the lake on the blue-green algae.

"There was a dramatic positive influence of zebra mussels on the amount of blue-green algae in lakes with phosphorus levels between 10 and 25," Sarnelle explained. "Most of the shallow-water habitats in the Great Lakes have phosphorus levels in this range."

M. aeruginosa made up as much as 86 percent of the algae in lakes with these phosphorus levels that had zebra mussels. In lakes that had phosphorus levels higher than 25, the zebra mussels had no effect on the amount of blue-green algae.

"Our hypothesis was that in lakes with low to medium phosphorus levels, zebra mussels had a high effect, meaning there would be more blooms. In lakes with high phosphorus levels, the zebra mussels would have a low effect, meaning fewer cyanobacteria blooms," Sarnelle explained.

The scientists went to the Kellogg Biological Station on Gull Lake at Hickory Corners to test their theories experimentally. Gull Lake has low to medium phosphorus levels and has been infested with zebra mussels since 1994. The researchers anticipated finding a strong positive effect of zebra mussels on blue-green algae. What they found, however, was that there was less blue-green algae where there were more zebra mussels.

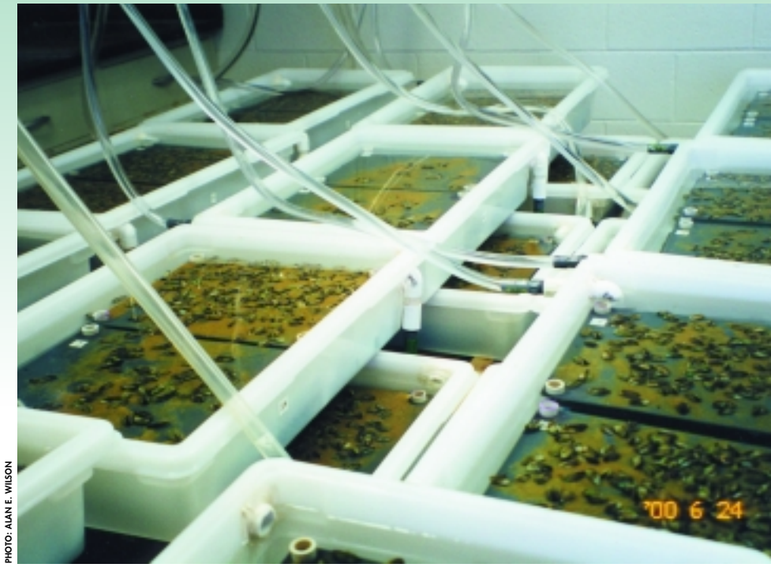


PHOTO: ALAN E. WILSON

At the Kellogg Biological Station at Gull Lake in Hickory Corners, Sarnelle and his research team tested their hypothesis on the relationship between zebra mussels and blue-green algae and the influence of phosphorus. The scientists got the mussels to attach to plastic boards in the lakeside laboratory. After a week or two in these basins, which were fed continuously with water from Gull Lake through those hoses, the boards were hung in experimental enclosures out in the lake.

"That made us shake our heads," Sarnelle said. "But when we reviewed all the data, we noticed that the phosphorus levels in Gull Lake were extremely low compared to other Michigan lakes we had surveyed. Gull Lake had a phosphorus level of 6, and most lakes in Michigan are between 10 and 25."

So they decided to find out what would happen if the phosphorus levels were brought up to between 10 and 25. Would their original theory be supported?

"A year later, we brought the levels up and we saw the anticipated positive effect on cyanobacteria," Sarnelle said.

The scientists now had experimental evidence to back up their survey results that phosphorus levels affect the zebra mussel-cyanobacteria relationship. This might explain why some lakes showed a strong correlation between the two and others did not.

But many questions remain. The scientists are looking at when a lake was invaded by zebra mussels and how long after that a blue-green algae bloom occurred.

"We don't have enough data on that yet," Sarnelle said. "We don't see any patterns so far. The size of the system may affect that relationship. In Gull Lake, it took only two years for blue-green algae to bloom, while in Lake Erie, it took six."

Sarnelle is planning his next experiment, look-

WATERFACT

The average person uses about 168 gallons of water per day. This roughly breaks down as:

Toilet flush= 29 percent

Washing machine= 21 percent

Shower=21 percent

Faucet=12 percent

Bath=9 percent

ing at the interactive effects of zebra mussels and phosphorus levels on *M. aeruginosa*, all in the same year, rather than a year apart as in his previous project.

"That will allow us to compare apples to apples," he said. "Our first project offered some interesting data, but because it was done in two different years, we can't be absolutely sure another variable didn't alter the results."

Another twist that may affect the zebra mussel-cyanobacteria relationship is the fact that zebra mussels eat *M. aeruginosa* at varying rates.

"Zebra mussels are herbivores, so they will eat blue-green algae," Sarnelle said. "But we don't know why they eat it in differing amounts. The zebra mussels in Lake Oneida in New York appear to like the blue-green algae and eat a lot of it. In Lake Erie, the zebra mussels don't eat the algae."

Sarnelle speculated that size may play a role. *M. aeruginosa* has small cells but forms large colonies. Because they are filter feeders, zebra mussels select their food by size. So in lakes with large blue-green algae colonies, the zebra mussels may simply not be able to eat them.

After zebra mussels eat the algae, they convert it to food, ammonia and phosphorus. The ammonia and phosphorus are excreted as waste into the water.

"But if the phosphorus levels in the water are very low, the zebra mussels don't excrete much phosphorus," Sarnelle explained. "They keep it because they need it to grow. *M. aeruginosa* really needs phosphorus. So this may also be a factor in the relationship. If the phosphorus levels are extremely low, it may decrease the growth rate of the blue-green algae, which may affect their potential to bloom."

PARTNERING AROUND THE STATE

The scientists are working with the Great Lakes Environmental Research Laboratory in Ann Arbor to study the zebra mussel-blue-green algae relationship in Lake Erie.

And Rose is just beginning to work with Tim Ervin, a researcher at the Water Studies Institute at Northwestern Michigan College, in Traverse City, and Meg Woller, stewardship director of the Leelanau Conservancy and coordinator of the Leelanau Watershed Council.

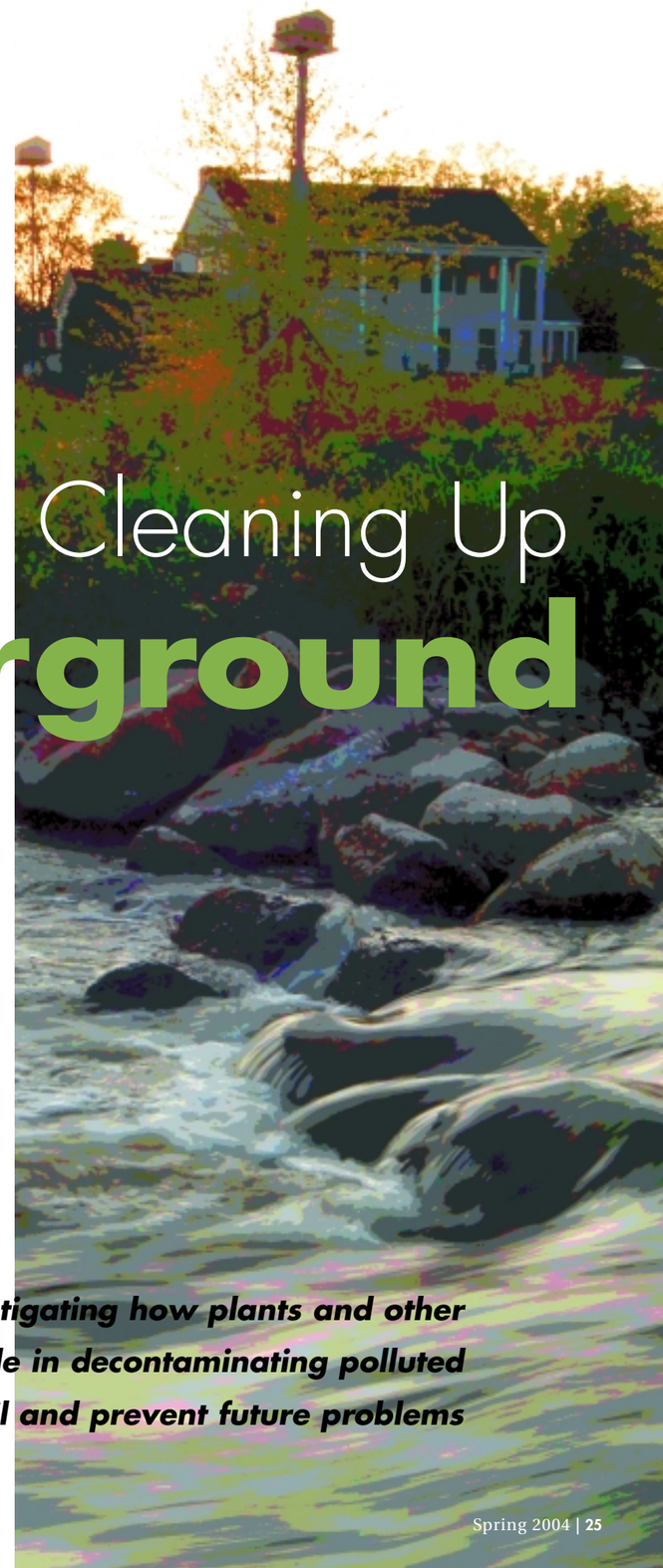
"Northwestern Michigan College's Water Studies Institute is collaborating with Joan and the Leelanau Watershed Council and Bowling Green University on a three-year study of the impact and public policy implications involving zebra mussel infestations in some high quality oligotrophic lakes, particularly in the Leelanau County area," Ervin said.

"Tim and Meg have trend data on blue-green algae in lakes before zebra mussels came," Rose said, "which is very important. There isn't a lot of that data. We want to see how we can work together on this project. I'm very interested in how a state university like MSU can help citizens at the local level."

::: Jamie DePolo

PHOTO: CARRIE SCHEELE

After the research project at Gull Lake was completed, the plastic boards were thoroughly cleaned of zebra mussels. The experiment will be repeated and data will be taken in the same year, instead of over two years, for more accurate analysis.



Cleaning Up Underground

In 2002, the Environmental Protection Agency celebrated the 30th anniversary of the Clean Water Act (CWA), a law designed to restore and maintain the chemical, physical and biological integrity of the nation's waters. Before passage of the CWA, industrial and residential sewage discharge into water was unregulated, and there were no policies in place to oversee the types and amounts of chemicals that agricultural operations were adding to the water supply. In 30 years, the CWA has radically improved the quality of the country's water by reducing and regulating chemical inputs.

Some contaminants dumped into water 30, 40 or 50 years ago are still there, however. Even though its use was banned in the United States in 1972, DDT (dichlorodiphenyltrichloroethane), a pesticide used to control agricultural insect pests and insects that carry diseases such as malaria, is still used in some countries. Scientists are finding DDT in sediments that affect surface water. A $100 million Superfund cleanup of DDT-contaminated sediments is currently underway 50 miles north of MSU at the Velsico/Pine River site in St. Louis, Mich. Polychlorinated biphenyls (PCBs) are a family of 209 chemical compounds that are highly flame resistant, making them ideal for use in heat-

MAES scientists are investigating how plants and other natural materials can play a role in decontaminating polluted water and soil and prevent future problems

Stephen Boyd, MAES environmental chemistry scientist, is studying the chemical processes that influence the transport and mobility of chemicals such as benzene, toluene and chlorinated solvents in the soil. He wants to know why the chemicals end up where they do.

ing coils, carbonless carbon paper, lubricating oils for industrial drills, caulking compounds for skyscraper windows, and electrical motors in refrigerators, air conditioners, typewriters and power saws. At one time, a wide variety of products — from cereal boxes, degreasers, varnishes and lacquers to waterproofing materials and bread wrappers — used PCBs. Even though PCBs are no longer commercially produced in the United States, high levels of the chemicals remain in various parts of the country, including the Hudson River in New York and the Kalamazoo River in Michigan.

MAES scientists are investigating why these and other pollutants remain in the environment and how plants, microbes and natural materials such as clay can be used to clean up or sequester them.

The Environmental Fate of Contaminants

"We know that applied chemicals, especially persistent ones, are going to wind up in water," said Stephen Boyd, an MAES crop and soil science researcher who specializes in environmental chemistry. "We are looking at why some end up in groundwater and some in the sediment, which affects surface water."

Boyd explained that chemicals such as DDT and PCBs end up in sediments and contaminate fish. This problem becomes an even bigger problem when people eat the fish. Benzene, toluene and xylene are components of gasoline that leaked out of underground storage tanks and ended up in groundwater. Chlorinated solvents such as TCE (trichloroethylene), an ingredient in adhesives, paint removers, typewriter correction fluids and spot removers; and PCE (perchloroethylene), an ingredient in degreasers and dry-cleaning fluid, also end up in groundwater.

"We are interested in the chemical processes that influence the transport and mobility of these chemicals in the soil," Boyd said. "We want to know why the chemicals end up where they do."

Boyd and his team are studying the components of soil that interact with pollutant chemicals and immobilize them. If the pollutant is essentially trapped and held by the soil, it is unlikely to pollute groundwater. The scientists want to determine how soil components hold on to the pollutant, as well as how the soil holding a pollutant may affect its availability and toxicity to humans. For example, what happens when a child eats soil?

"Today, the chemicals used to control pests are designed to degrade relatively quickly in soils," Boyd noted.

The pesticides break down into non-toxic compounds and, when used according to label recommendations, are generally present in soil and water at acceptable levels set by the Environmental Protection Agency. Pollutants such as DDT and PCBs do not break down as quickly or easily. This is why they are still detected in soil and water.

"We know the fate of these chemicals is related to how strongly they bind to soil. This determines how the chemicals move through the soil, how quickly they reach groundwater and the concentration of the chemical in the water," Boyd said. "There is an interrelationship between the chemical compound's sorption by soil and its environmental persistence and toxic effects, which is referred to as bioavailability. Bioavailability is the soil-bound chemical's availability to plants, bacteria, humans or other species. It determines how much of a contaminant — for example lead, DDT or dioxins — stay in our bodies when contaminated soil is ingested. This is especially important in small children, who ingest about 200 mg of soil per day [about the size of an aspirin tablet]."

Understanding the ultimate fate of these chemicals can provide data for policy-makers who determine how to focus and prioritize cleanup efforts for contaminated areas.

"There is an emerging concept called 'environmentally acceptable endpoints' in cleanup criteria," Boyd explained. "For example, let's say that there is a certain concentration of a chemical found in soil. Cleanup standards based on risk assessment may dictate that if the total concentration is higher than level X, the soil must be remediated or removed. What that analysis fails to take into consideration is that a concentration higher than X could be acceptable if the bioavailability is low. Some people feel that cleanup standards may be too stringent for sites with low bioavailability — that too much money is being spent to clean up too few sites."

Capturing and Holding Contaminants

One approach for sequestering contaminants that Boyd has investigated for a number of years is to modify natural materials in soils to optimize immobilization. Organoclays are made by adding positively charged organic surfactants (cations) to the negatively charged surface of regular clay. These organic surfactants, which are commonly used in products such as mouthwash, detergents and fabric softeners, attract the toxic organic contaminants and hold them in the clay.

"The organic cations, unlike the usual inorganic cations in clay, do not attract water," Boyd explained. "They attract the organic contaminant in the water, and the water continues moving through the clay and emerges without the contaminant."

Boyd is interested in the bioremediation of a group of chemicals known as nitroaromatics or energetics. This group includes many explosives, such as TNT (trinitrotoluene). The chemicals are found primarily on military lands and explosives manufacturing sites. The binding of nitroaromatics by clay can be controlled by adding specific types of cations to the clay. By using a particular cation, Boyd can make the clay hold the nitroaromatic pollutants or release them.

"If the goal is to prevent movement of the nitroaromatics so that they do not contaminate groundwater, it can be done very easily and simply, according to our basic studies," Boyd said. "There are sites that have this type of groundwater contamination. It is possible to saturate the soils with a natural cation, such as potassium, that enables the clay to effectively immobilize nitroaromatics. The chemistry we have discovered is simple and utilizes harmless reagents. It can render the compounds unavailable while we work toward more permanent solutions that destroy pollutants. For example, we may wish to release the bound contaminants in a controlled manner, making them available for bioremediation."

Boyd's research, while helping to solve an older and persistent issue, is providing knowledge about the movement of pollutants through soils to help ensure that no new problems of this nature are created.

"We are dealing with old problems, such as lead, DDT, PCBs and explosives contamination, while trying to prevent new chemical usage prob-

Understanding the fate of chemicals in soil and water can provide data for policy-makers who determine how to focus and prioritize cleanup efforts for contaminated areas.

WATERFACT

Nine countries account for 60 percent of the world's fresh water reserves: Brazil, Canada, China, Colombia, India, Indonesia, Russia, the United States and Zaire.

MAES crop and soil sciences researcher Clayton Rugh specializes in phytoremediation, the use of plants to break down pollutants and extract them from the soil. Rugh is working with the Ford Motor Company to investigate the feasibility of using phytoremediation to clean up the coke oven facility at Ford's River Rouge Complex.

lems," he said. "Making that mistake once was enough. Looking at the underlying mechanisms helps us apply our basic knowledge widely to prevent mistakes from happening. This is why basic research is so important to solving these issues."

Planting a Pollution Solution

Like Stephen Boyd, MAES crop and soil scientist Clayton Rugh investigates methods to clean up or remediate chemical pollutants. But Rugh specializes in phytoremediation, the use of plants to break down the pollutants as well as extract them from the soil.

"Naturally occurring plants have been shown to be effective for treatment of a wide range of hazardous compounds, including heavy metals and organic compounds such as solvents, petroleum compounds and explosives," Rugh explained. "Plant-based remediation is considered a desirable approach for site rehabilitation because of lower costs, reduced incidental pollutant discharge, concurrent habitat restoration and appealing aesthetic qualities."

By combining the correct species of plant and agricultural practice, Rugh and his research team enables the plant and the microbial community in the soil around the plant's roots to degrade contaminants such as PCBs, nitroaromatics and polycyclic aromatic hydrocarbons (PAHs), a group of 10,000 compounds that includes naphthalene (mothballs) and fluoranthene. Most PAHs are in the environment from the incomplete burning of carbon-containing materials such as oil, wood, garbage and coal.

Part of Rugh's research took place in a phytoremediation facility in Allen Park. The facility is open to the public, and information about the project is posted alongside the plots.

"We view these plants just like any other crop, but their purpose is to degrade contaminants rather than provide food or fiber," Rugh said.

As head of the Phytoremediation Research Lab at MSU, Rugh and his research team are working with the Ford Motor Company and the William McDonough and Partners architectural design firm of Charlottesville, Va., to investigate the feasibility of phytoremediation as a cleanup solution for Ford's River Rouge Complex coke oven facility. Most of the pollutants at the historic site are PAHs formed when coal is processed into coke for use in smelting. Because the plant is still operating, the scientists have taken soil samples from the facility and placed them in plots for managed treatments to see which techniques are the most successful and sustainable. After the treatments are evaluated, a phytoremediation system will be designed.

"A large number of native Michigan plant species have been identified as natural degraders of PAHs," Rugh said. "These include joe-pye weed, little bluestem, leadplant, prairie cordgrass and New England aster. During the first testing season [in 2001], the treatment plot experiments showed that the plants had accelerated the PAH biodegradation rate in the contaminated soils."

Education and demonstration are also components of the research. The managed treatments took place in a phytoremediation demonstration facility in Allen Park. Public access and information about the project are posted in an introductory area and along an observational walkway alongside the plots.

Two bottles of nursery bed runoff water await analysis. Nurseries want to reduce the amount of water they use, as well as the chemical content in the runoff water.

MAES horticultural researcher Tom Fernandez *(right)* takes data at one of his test plots. Fernandez is investigating the ability of ornamental plants to serve as both a commercial crop and a water filter.

"The phytoremediation demonstration facility is intended to serve as a valuable resource for the development of ecologically based remedial strategies and additionally as a benchmark in systems design to achieve this purpose," Rugh said.

A Product and a Filter

MAES horticultural scientist Tom Fernandez is also studying phytoremediation, but his area of focus is plant nurseries. Specifically, Fernandez wants to remediate runoff water from nurseries that sell container plants. Because the growing medium is designed to drain well, some of the fertilizers and pesticides used to keep the plant healthy and growing vigorously drain out of the containers and make their way into the nurseries' runoff water.

Fernandez is investigating how nurseries can reduce the amount of water they use, as well as the chemical content in the runoff water.

"Some nurseries use grass buffer strips to slow and filter the water as it drains and reduce the amount of chemicals in the water," Fernandez explained. "This is a good solution, but it takes quite a bit of land out of production for the nursery. We're investigating the ability of ornamental plants to serve as both a commercial crop and a water filter."

This would mean that the remediation area is also a production area that adds value to the nursery.

Currently, Fernandez and his research team are

Up On the **Rooftop**

In addition to his work in phytoremediation at the Ford River Rouge complex, MAES crop and soil scientist Clayton Rugh has also helped Ford create the world's largest living roof system.

The team of Rugh; Bradley Rowe, MAES horticulture researcher; Don Russell, Ford sustainable design project manager; architect William McDonough and Systementwicklung, a German green roof company, designed the system. The 10.4-acre roof is planted with sedum, a low-growing, drought-resistant perennial that requires little maintenance. The sedum roof keeps the building cooler, makes storm water runoff cleaner and lasts at least twice as long as an unprotected roof.

"The green roof is an ecologically beneficial technology," Rugh explained. "Overflow of storm water is a big problem for industrial areas. When that is combined with the runoff from streets, the combined sewer overflow gets compromised and the water goes untreated into the River Rouge. Ford wanted to manage and contain that water within the facility.

"The function of the roof is to collect and filter rainfall and reduce the amount of polluted storm water runoff flowing into the river," he continued. "The sedum roof takes in the water, retains it, slows its progress to the ground and filters it so there are fewer contaminants in the runoff. Also, the sedum never needs mowing and protects the roof against ultraviolet (UV) radiation."

The green roof, combined with other vegetation features (landscape berms, ponds and plant-filled ditches) and porous parking lots at the plant, delays the storm water runoff flowing in the River Rouge by as much as three days and saved Ford the expense of putting in a multi-million-dollar storm water treatment system.

"Ford is not in the business of horticulture, so when the architect suggested putting a green roof on the facility, we came to Michigan State University to see if it were possible," Russell said. "With MSU's research facilities and the expertise of Drs. Rugh and Rowe, we were able to see what the roof would look like with the varieties of sedum. Initially we thought the sedum could be grown in removable plastic trays. But thanks to MSU's research, we found out that plastic trays didn't work, but a vegetation blanket did. That also saved us money."

According to Russell, the sedum roof has been in place for about a year and is filling in nicely. Butterflies, birds and bees are returning to the area after a long absence.

Ford has shared its innovations at the Rouge plant with its facility managers around the world, its competitors, major corporations and businesses and the military.

"We've had quite a few inquiries, about the green roof, in particular," Russell said. "Ford is being looked at as a legitimate purveyor of green roofs. Really, all we want to do is sell cars. If green roofs help in that endeavor, then we're all for it."

WATERFACT

Michigan uses about 1.9 billion gallons of water per day.

studying the filtering abilities of aquatic and semi-aquatic plants that are popular garden plants, such as iris, willow, Michigan holly, elder and acorus. Chemicals in the runoff water are affected not only by the plants but also by light, temperature and the microorganisms living in the plants' root zones. The more time the runoff water spends in this remediation area, the more likely it is that the chemicals will be broken down.

"The chemicals bind to the growing medium the remediation plants are in," Fernandez said. "The plants use the chemicals and can sometimes convert them to non-toxic compounds. By using the runoff water to irrigate these plants, the nurseries are also using less water overall and producing more plants."

So far, results from Fernandez's research plots are promising. Water in the remediation areas has been found to contain 30 percent less pesticide than water coming directly from nursery beds. He has also found that some plants can filter out up to 40 percent of nitrates in runoff water.

::: Jamie DePolo and Robin Usborne Millsap

Animal Agriculture, Manure and Water Quality

MAES Research Provides Solutions to Keep Farming Profitable and Water Potable

According to numbers provided by the Michigan Agricultural Statistics Service, Michigan is home to 990,000 cattle, 8 million chickens, 860,000 hogs and pigs, and 75,000 sheep, as well as uninventoried numbers of goats, mink and alpaca. Each of those animals produces a specific amount of manure per day. The challenge for agricultural producers is to manage the manure without threatening surface and groundwater resources. Manure contains nitrogen, phosphorus, inorganic salts, organic solids and microorganisms. Nitrogen and phosphorus are necessary for successful crop production, but all of these compounds are potential contaminants of both surface and groundwater.

As the distance between rural and urban/suburban areas shrinks, MAES scientists are studying manure management practices that are environmentally sensitive and economically viable.

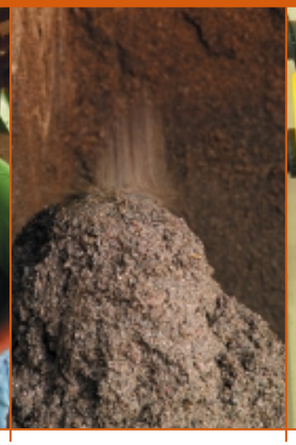
"Manure management is one of the most important challenges facing animal agriculture," said Bill Bickert, MAES agricultural engineering researcher, who directs manure and nutrient management programs at MSU. "It's a social as well as technical issue, and it has the attention of several segments of society besides farmers. Everyone has to work on this issue together. One group won't be able to solve it."

The Phosphorus Connection

Robert von Bernuth, MAES agricultural engineering scientist, believes one key to successful manure management is to consider the entire farm as a system and balance the phosphorus and

Bill Bickert, MAES agricultural engineering scientist, who directs manure and nutrient management programs at MSU *(left)*; Dana Kirk *(center)*; and James Wallace *(right)* compare manure samples for nutrient content. Kirk and Wallace are graduate research assistants in biosystems and agricultural engineering.

Wallace, Bickert and Kirk watch the sand-manure separator as it works to separate liquid manure and sand. Once heavy sand is removed, the manure can be stored and used as a nutrient source.



Clean sand forms a pile at the end of the sand-manure separator process. The clean sand can be reused as bedding for cattle.

In Bickert's lab, signs above the storage vats warn visitors about the quality of the water.

Robert von Bernuth, MAES agricultural engineering scientist, believes successful manure management considers the entire farm as a system.

PHOTO: BILL NORTHCOTT

Part of MAES agricultural engineering researcher Bill Northcott's work focuses on keeping manure out of water tile lines by using alternative management practices. The water sample on the right was pulled before field manure application. The sample on the left was taken 10 minutes after application.

MAES scientist Bill Northcott studies field samples. He is part of a team that includes researchers from Ohio State University and the USDA Natural Resources Conservation Service and Agricultural Research Service.

nitrogen that enter and exit the system.

"I've been an advocate for looking at the bigger picture from the point of view of phosphorus, which has no significant gaseous phase and ends up being trapped in the soil," he explained. "Nitrogen is principally a groundwater issue, and phosphorus is principally a surface water issue. The bottom line is we would be much better off from the nutrient cycle angle if we reduced phosphorus and conserved nitrogen."

About 95 percent of manure's phosphorus occurs in livestock feces; the remaining 5 percent is found in urine. Keeping the liquid and solid wastes separate makes it easier to account for phosphorus in a farming system and allows it to be used on the crops that will benefit most, rather than applying it wherever and whenever it is convenient. Keeping liquids and solids separate also results in a product that is easier to transport and use away from the farm, a bonus for farmers who work fields that are miles apart. The product also smells better. When urease, an enzyme found in urine, mixes with feces, ammonia is produced, which gives manure its distinctive aroma. Separating the two components keeps ammonia levels and related odors low.

Von Bernuth is investigating swine housing designs as part of a strategy for better balancing nitrogen and phosphorus on farms.

In his research, pigs are housed in a barn with a slatted floor, a fairly common component of traditional swine housing. Underneath the floor, however, is a sloped trough, a new addition that was adapted from a Japanese design. Urine and feces fall through the slats to the sloped floor, where they are moved along by a V-shaped scraper. Liquid runs through a filter to a pipe to an ozonation system that bubbles in ozone to remove odor before sending the liquid to a slurry storage tank. There it is held until it is applied to fields. Solids are removed and sent to a composting facility.

Current analysis shows the system is capturing between 87 and 92 percent of the phosphorus in the feces. This is phosphorus that easily can be directed to sites that need nutrients, rather than applied to those that are simply within easy driving distance of the hog barn.

"We need to get away from treating manure as a waste byproduct and getting rid of it as fast as we can," von Bernuth said. "We have traditionally applied manure to fields close to the barn and spread commercial fertilizer on outlying ground. We've got to find alternative ways to handle manure."

Von Bernuth advocates farming within a mass balance system. Producers monitor inputs such as feed and fertilizer and outputs such as animal sales and concentrations of phosphorus and manure. Keeping inputs and outputs balanced should also keep soil nutrients balanced and limit the possibilities for runoff and leaching.

To Till or Not to Till

No-till farming systems are known for helping to prevent wind and soil erosion, limiting compaction and improving soils. These systems can also help keep manures in the soil, making nutrients available to crops and preventing nutrient runoff. On tile-drained fields, however, pores in the soil that are not broken up by tillage can provide water rich in manure nutrients a direct pathway to nearby surface water.

The potential threat to water quality is an issue that has gained attention especially in southeastern Michigan, where housing development is booming and farms are increasingly surrounded by non-farm residents.

"We have to strike a balance with tillage if we want to keep nutrients from going through the soil," said Tim Harrigan, MSU Extension agricultural engineering scientist, who collaborates with MAES scientists on research projects and conducts his own. "Our goal is to develop guidelines for effective use of low-intensity tillage in preventing soil erosion, runoff and overland flow of sediment and contaminants from cropland."

Harrigan is studying the effectiveness of low-disturbance, low-intensity tillage in preventing runoff, sediment and nutrient loss from grassland and cropland where manure has been applied.

The research seeks to balance the benefits that tillage can bring to a tile-drained field crop system while limiting wind and water erosion.

"A modified no-till system will reduce soil erosion by improving infiltration and conserving crop residue, improve soil quality by building soil organic matter and provide for more efficient use of manure as a nutrient source," Harrigan said.

Under some conditions, liquid manure applied to drain-tiled fields can quickly move through the soil via wormholes and other large soil pores. Low-intensity tillage fractures the soil and disrupts these openings but leaves crop residue that helps limit erosion.

"Tillage breaks up the continuity of wormholes and macropores and can slow the movement of liquid manure through the soil," Harrigan added. "If we can stabilize the manure in the soil, natural biological processes can quickly convert livestock manure into crop nutrients and other beneficial compounds."

The research is comparing runoff on tilled ground three, 10 and 21 days following manure application. It will examine the amounts of phosphorus, nitrogen and sedimentary materials, as well as contaminants such as *Escherichia coli*.

"We suspect that if we can slow down water movement and keep it in the soil, we can save nutrients for crop growth and provide an opportunity for the soil to process the pathogens as innocuous compounds," Harrigan explained.

MAES agricultural engineering scientist Bill Northcott is also studying ways to keep manure out of water tile lines. As part of a team that includes researchers from Ohio State University and the USDA Natural Resources Conversation Service and Agricultural Research Service, Northcott is evaluating alternative management strategies to reduce the risk of liquid manure reaching tile drains.

"This is a quiet issue, but more farmers are starting to hear about it," Northcott said. "As the boundary between urban and rural places starts to blur, more people are paying attention to water quality issues. It's something we want to hit hard quickly and come up with answers to give farmers. We are looking at different agronomic management practices farmers can do to help decrease the chance for liquid manure to travel through the macropores of the soil," he said, "specifically, tillage effects prior to manure applications."

The scientists are looking at how water with

WATERFACT

Of the fresh water on the Earth, much more is stored in the ground than is available in lakes and rivers. More than 2 million cubic miles of fresh water is stored in the ground, most within a half-mile of the surface. Contrast that with the 60,000 cubic miles of water stored as fresh water in lakes, inland seas and rivers. The largest stockpile of fresh water is in the 7 million cubic miles of water found in glaciers and ice caps, mainly in the polar regions and Greenland.

manure in it moves through the soil on a tile-drained, no-till field planted with a typical Michigan field crop rotation (corn, soybeans and wheat). Manure was applied to the fields early in 2003 and again at the end of the year.

Three experimental treatments have been applied to the field. No tillage is used on the control treatment. The second includes chisel plowing (a practice most farmers can easily incorporate) prior to manure application to break up the continuity of the pores in the soil. The third treatment is tillage using a ground-driven surface cultivator that Northcott is evaluating for use on tile-drained farms.

"It really breaks up and pulverizes the soil surface, but it also has the ability to keep residue on the surface and does a good job of preventing erosion," Northcott noted.

Early research results show that adding tillage seems to allow less water leaching through soil pores than no-till. Another way to reduce nutrient losses is applying manure at a rate equal to the crop's nutrient use rate. The investigators know that overapplication on no-till fields definitely leads to problems, and they intend to determine the best combination of manure application rates, timing and application techniques for Michigan farmers.

Protecting Both the Environment and Farmers' Livelihood

The Clean Water Act, passed in 1972 and amended in 1977, allowed the Environmental Protection Agency (EPA) to implement pollution control programs such as wastewater standards for industry. Usually originating from pipes or drains, these point-source flows could be monitored, measured and controlled in a more straightforward manner than non-point sources, which include agriculture, homeowner fertilizer and pesticide applications, and runoff from parking lots and streets.

As both animal agriculture and Michigan's population began to grow, large-scale animal agriculture operations were reclassified as point sources and now fall under state and federal pollution regulations, something this sector of agriculture never had to take into consideration. It is now struggling to meet industrial pollution prevention standards without a chance to prepare.

"Agriculture was focused on environmental stewardship and not expected by regulators to eliminate discharge," MAES agricultural engineering scientist Bickert explained. "Now, agriculture is expected to meet industrial requirements and do it immediately. The science has not caught up with the need."

Michigan's 1980 Right-to-Farm Act was one environmental stewardship effort. It offered farmers protection from nuisance lawsuits, provided they followed a set of generally accepted agricultural management practices, including practices for manure management and use.

In 1998, the Michigan Agriculture Environmental Awareness Program (MAEAP) was initiated as a voluntary approach to protecting both the environment and Michigan's agricultural industry viability. The MAEAP offers producers a voluntary, cost-effective and scientific approach to environmentally sound manure management. It is jointly sponsored by a number of organizations and agencies, including the Michigan Agricultural Experiment Station, MSU Extension, the Michigan departments of Agriculture and Environmental Quality, the Natural Resources Conservation Service and Michigan Farm Bureau.

Large animal agriculture producers may apply for an EPA-regulated national pollutant discharge elimination system permit, or (if they have not had a Michigan DEQ discharge in the past two years) they may choose to undertake the voluntary process to receive verification as environmentally sound through the MAEAP.

"MAEAP is a partnership of agencies and offers the opportunity to provide a forum for discussion about broad-based issues related to the environment and to provide concise information to farmers," Bickert said. "Some of these issues are discussed within departments or agencies, but not as a group. As time goes on, MAEAP will be recognized as a place where these things happen."

Manure – It's Not Just Waste Anymore

Bruce Bloom, who with his brother operates a 500-cow dairy farm in Branch County, has watched as opinions about farming, manure and water quality have evolved over the years.

"Twenty years ago, manure was something you got rid of as quickly as possible," he said. "People no longer look at it as something to be disposed of but a resource to be managed. We need to understand what we have as a whole. How does it all fit together in the environment? It's important to the state of Michigan for maintaining agriculture in Michigan as part of the tax base and preventing degradation of the environment."

::: Laura Probyn and Jamie DePolo

Protecting Michigan's Water Supply Takes Research, Education and Outreach

MAES scientists and funded groups work with MSU Extension specialists and governmental agencies to ensure clean groundwater and raise public awareness of its importance around the state and on the MSU campus.

The Michigan Agricultural Experiment Station is a research entity, funding the work of scientists on the MSU campus and at outlying field research stations across the state. The MAES also provides funding to other groups on campus, such as the Institute of Water Research (IWR) and Remote Sensing and GIS Research and Outreach Services (RS&GIS), which engage in research and outreach that further the MAES mission. Protecting water quality and the environment is one of the five MAES priority areas.

"When looking at water quality and quantity, we must look at the whole system of interaction between land and water resources," said Jon Bartholic, MAES community, agriculture, recreation and resource scientist and IWR director. "In developing water-related programs, the IWR works across colleges and departments at the university and with other research and resource conservation organizations to get the job done. It also extends information through workshops, educational materials and online programs."

The IWR and RS&GIS have worked to make Michigan a model for addressing water

To develop water-related programs, the Institute of Water Research works across colleges and departments at the university and with other research and resource conservation organizations. Staff members include *(left to right)* Da Ouyang, Lois Wolfson, Stephanie Smith, Jon Bartholic, Jeremiah Asher, Laura Bruhn, and Yi Shi.

quality issues by involving communities in developing water protection programs. David Lusch, senior research specialist at RS&GIS, and Ruth Kline-Robach, outreach specialist with the IWR, have been involved in groundwater protection since the late 1980s when the Groundwater Education in Michigan (GEM) program was developed. GEM was designed to educate citizens and community leaders about the importance of protecting groundwater resources and to initiate local education and protection programs. The IWR partnered with the W.K. Kellogg Foundation for 10 years to coordinate community-based projects.

'The projects created through the GEM program empowered people to clean up their act, and their actions filtered up to the state level," Lusch said. "This consciousness-raising helped legislators realize what a fragile and finite resource groundwater is."

Building on the success of the GEM program, the IWR helped craft the state's Wellhead Protection Program (WHPP) in 1986. The goal of the WHPP is to safeguard public groundwater supply systems from potential sources of contamination through wise land use planning and management. Each state was required to develop a WHPP as part of the Safe Drinking Water Act.

"The IWR worked with the Michigan Department of Environmental Quality [MDEQ] to develop the statewide program," Kline-Robach said. "The program is voluntary at the local level for communities that use groundwater as their drinking water source — that's about 43 percent of Michigan's population."

"Most people do not know they are drinking groundwater," Lusch said. "They just think of it as tap water without considering its source. People also have the misconception that there are several layers of government making sure the water supply is safe."

To date, more than 100 WHPP programs and 190 wellhead delineations have been approved by the MDEQ. To delineate a water source, scientists create mathematical models that map a 10-year time-of-travel zone. The 10-year travel time is how long it takes water to flow from the perimeter of the wellhead protection area to the water supply well.

"Sixty-seven communities currently have grants to address WHPP," Kline-Robach said. "Usually it takes just one dedicated individual to get the program going. Although developing and implementing a wellhead program can be resource-intensive, community response has been excellent. I enjoy helping these individuals manage their water supplies. This is a terrific program — in addition to being proactive and focused on pollution prevention, it has the potential to educate a large number of people about the importance of our groundwater resources."

"Humans tend to be episodic in their thinking rather than proactive, but we've got to be vigilant," Lusch said. "Michigan is probably the most vigorous state in implementing this program."

Though WHPP programs may look expensive at first glance — depending on the size of the well field, the type of aquifer and underlying geology in the area, costs can range from a few thousand dollars to as much as $100,000 — the cost of not doing a WHPP may be much higher. Kalamazoo County experienced firsthand the need to protect groundwater supplies after three municipal wells were found to be contaminated with organic chemicals.

"The MSU campus represents one of everything in Michigan."

The county gets its water from glacial drift aquifers that are very susceptible to contamination. The cost of the cleanup and treatment of the contaminated water was $7 million; one site alone cost more than $1.5 million. In Grand Ledge, a leaking underground fuel tank contaminated public supply wells; the cost to build a new filter system for the wells was $1.1 million. Pinckney, a village northwest of Ann Arbor, had to build a new public well system at a cost of $1 million when solvents from a local manufacturing facility contaminated dozens of residential wells. Solvents were also discovered in the groundwater in Atlanta, Mich. The water system had to be replaced at the cost of more $500,000. The state offers a 50 percent matching grant program to communities wanting to put together a WHPP.

Using MSU as a Model

The MSU campus is one community with an approved WHPP. The 17 wells on campus supply a total of 4 million gallons of water on an average day. All but one of the wells are located south of Mt. Hope Road. The campus relies entirely on groundwater for its water supply needs. The water is delivered directly to facilities south of Mt. Hope Road or to a central reservoir, where the water is treated before being pumped to buildings north of Mt. Hope. Before delivery to the main campus, the water is treated with fluoride, chlorine and phosphate. Approximately 50,000 people use MSU water each day; 19,500 of them live on campus.

"The MSU campus represents one of everything in Michigan," Lusch said. "We have hazardous chemicals, automotive chemicals and agricultural use, all in 10 square miles. We've put together a very comprehensive plan."

MSU began its wellhead protection process in 1993 by participating in a cooperative effort to delineate wellhead protection areas (WHPAs) in the tri-county area (Ingham, Clinton and Eaton counties). The delineations were performed by the U.S. Geological Survey (USGS) in 1996. The MSU WHPA delineations were approved by the state in 1999. They were revised in 2000 to reflect more accurate data that became available.

David Lusch, senior research specialist in GIS Research and Outreach Services, helped develop the state's Wellhead Protection Program (WHPP). Lusch says that most people don't know they're drinking groundwater.

Besides Lusch and Kline-Robach, other members of the MSU WHPP team are: Doug MacDonald, water works manager, MSU Physical Plant Power and Water Department; Ben Darling, assistant director, MSU Land Management Office; Bob Ceru, assistant director, MSU Office of Radiation, Chemical and Biological Safety (ORCBS); Tom Grover, environmental compliance officer, MSU ORCBS; Steve Hadersbeck, landscape architect, Campus Park and Planning; and Kevin Eisenbeis, director of MSU's Office of Environmental Safety.

As part of its WHPP, the team identified potential sources of contamination to MSU wells. After the initial review was done in 1999-2000, it was found that there were fewer problems to deal with than had been expected. Those that were found were taken care of quickly and efficiently. The team then developed seven management strategies tailored to MSU's unique landscape to protect the campus groundwater. The strategies include plugging abandoned wells, incorporating wellhead protection into campus planning activities, developing a geographical information system to manage wellhead protection data, and working with neighboring communities to provide input on planning and land uses in the portions of the MSU WHPAs that extend off-campus.

Ruth Kline-Robach, outreach specialist with the Institute of Water Research, also helped develop the WHPP. More than 100 WHPPs have been approved by the Michigan Department of Environmental Quality.

Education and outreach are also part of the MSU WHPP. For more information on the plan, visit the Web site at: www.orcbs.msu.edu/environmental/ programs/wellhead_protection/msu_whpp/ public_education.htm.

"Michigan would not be this far along in water quality assessment had it not been for the multiple activities it has engaged in, beginning with the GEM program," Lusch said. "Our next step is to develop better water use policy. The big challenge is continuing and enhancing water quality protection activities. The job is far from over, but we are ahead of the curve."

::: *Jamie DePolo and Robin Usborne Millsap*

Research *in the news*

2003 Spartan Innovator Award presented to University Farms Service Center

Tony Boughton, assistant farm manager for the University Farms Service Center, accepted the 2003 Spartan Innovator Award from Ben Darling, assistant director of the Land Management Office, at the 23rd Annual Farm Manager Seminar in February.

Boughton received the award on behalf of all University Farms staff members for ingenuity and innovation in designing and implementing a new manure tank power washing station. This new station provides a more automated system, making it easier to clean the exterior of the tanks without ladders or climbing.

This new award recognizes the outstanding efforts, positive contributions and achievements in the field by farm, station and property staff members to meet the changing and growing challenges of regulations, technology, research and funding.

In 2002, the first Spartan Innovator Award was presented to Mark Collins, farm manager of the Hancock Turfgrass Research Center (HTRC), on behalf of all HTRC staff members and students for their outstanding determination, perseverance, ingenuity, innovation and team efforts to ensure smooth development and installation of the new modular turf field for Spartan Stadium.

Future of Environmental Policy is in Interaction, MAES Scientist Says

They don't call it biocomplexity for nothing.

The future of environmental policy lies in embracing ambiguity — in the understanding that the days of dreaming of isolated fixes to problems are over. The future, an MAES ecology scientist told those at the American Association for the Advancement of Science (AAAS) annual meeting in Seattle, is all about understanding that there are no simple solutions, or at least none that isolated.

"It is necessary to focus on the interactions of different policies," said Jianguo "Jack" Liu. "Each policy may look really good, but if you put them together, they might have some unexpected negative impacts. We are learning to change the way we make policy and the ways in which we evaluate policy."

Liu told those attending the symposium "Frontiers in Biocomplexity Science: Reciprocal Interactions between Human and Natural Systems" that a major obstacle to effective environmental policy is myopia.

The environment, he said, is all about the big picture — not only about how humans have an impact on natural systems but on how changes to natural systems affect humans, and especially how policies affect one another. These types of complexity are not what traditional ecologists tackle.

Liu is not a traditional ecologist. He has spent nearly two decades juggling the complexities of human needs, wildlife necessities, political realities and technological potential. In a cover story in the British science journal Nature in January 2003, Liu and co-authors explored how increases in the number of households in 141 countries have a significant impact on wildlife and the environment, even where the population size declines.

Further work is showing the symbiotic relationships between humans and natural systems, and between one policy and another. Liu notes that though individual policies may elegantly work to solve an area's problems, they may over time conflict or create conditions that evolve into new challenges for both humans and nature.

At AAAS, Liu discussed the work that he and his collaborators had done at the Wolong Nature Reserve in the Sichuan Province of southwestern China, which is one of the largest homes to the endangered giant panda. In Wolong, the Chinese government has instituted three policies to preserve panda habitat: an eco-hydropower plant program to eliminate fuel wood consumption, a natural forest conservation program to prevent illegal forest harvesting and a grain-to-green program to return cropland to forest.

Liu said each program had been carefully considered, but already some policies are having unexpected effects now that people have started living them. For example, many new households were formed to take advantage of the natural forest conservation program because economic incentives from the government were provided on a per household basis. Furthermore, much of the money received from the natural forest conservation program was not used to buy electricity. As a result, most households continue to use fuel wood.

"We're finding that it's human nature to, if you have money, use it to buy what you like," Liu said. "Fuel wood is a common resource, and many people choose not to do what the policy intended."

Liu said a solution is to consider the interactive effects of various policies rather than individual policies in isolation. This approach places different demands on policy-making, forcing experts to look beyond their own fields and requiring various government agencies to work together.

"To meet the challenges of environmental policy in business and government, we need a new kind of scientist," said Thomas Dietz, director of MSU's Environmental Science and Policy Program (ESPP). "They will continue to need the scientific depth and rigor that comes from traditional fields. But they also need a breadth of understanding that the traditional fields don't supply.

"Environmental problems don't come in neat boxes. Students have to be trained to think out of their disciplinary boxes," he said.

"Understanding the complex interactions between people and their natural and built environments requires scientific analysis and synthesis that engage scientists and engineers to think more broadly and innovatively than they have had to think in the past," said Tom Baerwald, a senior science adviser and program director at the National Science Foundation and co-organizer of the AAAS symposium. "We have evaluated many exciting proposals in recent biocomplexity competitions and Michigan State researchers have been among the leaders in this process, both as researchers proposing projects and as reviewers evaluating them."

Also presenting at the symposium were Marina Alberti, University of Washington; Patrick Kirch, University of California, Berkeley; Timothy Kratz, University of Wisconsin; Peter Deadman, Indiana University; and Alice Pell, Cornell University.

MAES Scientist Leads Discussion on Major U.S. Environmental Policy at AAAS Annual Meeting

A major piece of U.S. environmental legislation is nearing its 35th birthday.

At home, the National Environmental Policy Act (NEPA) probably won't get a party for its 35th, and it's having something of a midlife crisis. Yet abroad it is revered and copied.

"Nobody's really revisited this statute since 1979; it's something of a forgotten environmental statute to many," said Daniel Bronstein, MAES resource development researcher. "But it really has changed everything, and it made us a leader in the world in environmental policy."

Bronstein led a panel discussion titled "The National Environmental Policy Act at 35 — Does it Have a Future?" at the American Association for the Advancement of Science (AAAS) annual meeting in Seattle in February. The group will examine how NEPA fits into current U.S. environmental policy.

NEPA was born in the Nixon administration in 1970 and gave the nation's citizens their first formal ability to have input in the decision-making process about projects that have environmental impact.

It was through NEPA that the environmental impact statement was born.

"Its original intent was to give the environment equal status to employment in the office of the president," Bronstein said. "It's never done that, but it has had major impact — it forces an explicit statement of the environmental trade-offs you're making."

On the surface, NEPA's major milestones now seem routine. Newer legislation, such as the Clean Air Act and Clean Water Act, seems to have more impact.

But across the globe, Bronstein said, NEPA is a powerhouse. The concept of full study of the environmental consequences of governmental actions has been adopted on a national level in more than 100 countries, according to the International Association for Impact Assessment. Similar requirements at less than national levels bring the count of legal requirements to more than 200 countries.

Bronstein said NEPA's strength is in the power it gives groups to oppose local projects that may threaten the environment, such as highway development.

"We need to take our position as a world leader seriously," Bronstein said. "We give advice when asked, and we want it to be good advice."

Scientist Organizes International Food Safety Experts to Offer New Methods to Assess Risk

New methods to improve the safety of the world's food supply are in the pipeline, and the need is imminent, said the director of the National Food Safety and Toxicology Center at MSU.

Scientist Ewen C.D. Todd organized the symposium "Food Safety and Risk Assessment: New Approaches to Microbiological Problems" at the American Association for the Advancement of Science (AAAS) annual meeting in Seattle. Todd emphasizes that microbiological food-borne hazards such as listeriosis are cause for concern today because of many changes:

- The globalization and urbanization of developing countries, some without adequate infrastructure systems to handle food and water safety.
- A growing number of countries reporting increased numbers of food-borne illnesses through better surveillance systems.
- Problems with produce contamination, extending the scope of food risk.
- Concerns about bioterrorism and possible threats to food security.
- New patterns of food production, distribution and consumption, including increased travel, more meals eaten away from home and increased demand for a wide variety of foods.
- Recent recalls and industry losses such as the Pilgrim's Pride *Listeria* outbreak of 2002 and mad cow disease affecting Canadian and U.S. beef supplies in 2003 and 2004.

"Scientific risk-based policy is overtaking the cultural and political debate about food," said Todd, referring to the recent single case of mad cow disease in the United States. "Countries are creating policies based on risk, not on culture. The current systems of testing and release of products have not proven very effective in reducing food-borne illness."

Risk assessment requires gathering quantitative data on the prevalence and concentration of food-borne illness for specific foods. Modules from farm to fork help create a mathematical picture of risk for contamination. The resulting models can predict how many illnesses can occur and how managers can change parameters — and food safety strategies — to control the risk. The concept is relatively new for the food industry, so it is imperative that the global community understand the issue and methods, Todd said.

Todd gathered world expert speakers on risk assessment of food to hash out approaches for countries as diverse as Malaysia and the United States, which currently have different approaches to assess risk for food-borne illness. In addition to Todd, the speakers were:

- Jorgen Schlundt, World Health Organization. The Food and Agriculture Organization of the United Nations, along with WHO, is drafting risk assessment strategies for 21 foods. (Todd co-authored the FAO/WHO assessment on *Listeria monocytogenes*.)
- Karen Hulebak, U.S. Department of Agriculture. Hulebak will represent the Codex Alimentarius Commission from the perspective of the Committee on Food Hygiene.
- Karen Dodds, Health Canada. Canada has a management system in place, but factors such as bioterrorism and mad cow disease may affect

food labeling and trade. (Todd was the head of the Contaminated Foods Section of Health Canada for many years.)

- Isabel Walls, International Life Sciences Institute (ILSI), Risk Science Institute. ILSI is drafting a final report that describes risk to various types of populations, including the immunocompromised persons. They might require messages not to eat certain foods on the basis of risk assessment findings. (Todd serves on the expert team to reduce listeriosis.)
- Leon Gorris, Unilever. Gorris provided an industry perspective on risk assessment and how it can aid in product development and design.

MAES Scientists Honored at Annual MSU Awards Convocation

An MAES entomology researcher was one of eight MSU professors receiving Distinguished Faculty Awards during the annual universitywide Awards Convocation in February.

An MAES agricultural engineering scientist received one of six Teacher-Scholar Awards at the ceremony.

Each Distinguished Faculty Award recipient receives a stipend of $3,000. The award is presented in recognition of a comprehensive and sustained record of scholarly excellence in research and/or creative activities, instruction and outreach.

Teacher-Scholar Awards, which carry a $2,000 stipend, are given for devotion to and skill in teaching and scholarly promise.

The Awards Convocation followed President Peter McPherson's State of the University speech.

Richard W. Merritt, MAES entomology researcher, received the Distinguished Faculty Award. One of only eight officially certified forensic entomologists in North America, Merritt conducts research in the biology and ecology of aquatic invertebrates, their roles in organic matter cycling and species of medical importance. He is dedicated to transforming fundamental research into technology that benefits society. Examples include his integrated stable fly management program for Mackinac Island and numerous mosquito and black fly control initiatives and Lyme disease projects.

Merritt is the author of *An Introduction to the Aquatic Insects of North America*, frequently referred to as the bible of aquatic entomology. His forensic entomology course, "Bugs and Bodies," is renowned, and his students find positions throughout the world as respected scientists, teachers and outreach specialists. Merritt's own outreach contributions include programs for communities and consultation to government and industry. He is in great demand by the legal profession for his expertise in forensic entomology and is valued for his thorough assessment of forensic entomological evidence in high-profile homicide cases.

Bradley P. Marks, MAES agricultural engineering researcher, received the Teacher-Scholar Award. Marks is nationally recognized for his teaching and research in biosystems engineering and food safety. His colleagues and peers appreciate his blend of high standards and great caring manner. He is the departmental leader in curriculum improvement and instructional innovations and has been called "a teacher of teachers."

Water Scientist Appointed to Michigan Environmental Science Board

Joan Rose, an MAES-affiliated scientist who holds the Homer Nowlin Chair for Water Research at MSU was one of four people appointed to the Michigan Environmental Science Board by Gov. Granholm in February.

According to the governor's statement, Rose was appointed to represent individuals with expertise in microbiology for a term expiring Aug. 6, 2006. She succeeds Ronald H. Olsen whose term expired.

The other appointees are:

- Michael Barcelona, professor and chairperson of the Department of Chemistry at Western Michigan University, who was appointed to represent individuals with expertise in chemistry for a term expiring Aug. 6, 2006.
- Gerald Keeler, professor of environmental health sciences at the University of Michigan, who was appointed to represent individuals with expertise in atmospheric sciences for a term expiring Aug. 6, 2006.
- Nicholas Mercuro, professor in residence at MSU-Detroit College of Law, who was appointed to represent individuals with expertise in economics for a term expiring Aug. 6, 2006.

The board is an independent state agency established in 1992 to provide scientific and technical advice to the governor on matters affecting the protection and management of environmental and natural resources.

MAES Scientist Honored

Brenda Sternquist, MAES merchandising management researcher, is the first professor to be honored as Retail Educator of the Year by the National Retail Federation, in partnership with J.C. Penney Co. and the Center for Retailing Studies at Texas A&M University.

Witter Named Interim Chair

Scott Witter, MAES scientist, has been named interim chairperson of the Department of Community, Agriculture, Recreation and Resource Studies (CARRS). He was chosen following a process that included input from faculty and staff members, students and stakeholders of the new department. He replaces Janet Bokemeier, who was named chairperson of the Department of Sociology.

Witter has more than 10 years of college-level administrative experience in the MSU Institute of International Agriculture. He served as associate chairperson of the Department of Resource Development and as acting chair since 2000. Witter also has more than 20 years' experience conducting research, outreach, consulting and teaching activities related to international and domestic watershed management issues. He holds a doctorate from MSU in resource development/watershed management, a master's degree from the University of Alberta in watershed management and a bachelor's degree from South Dakota State University in urban planning.

A national search will be conducted to select a permanent chairperson.

Research *in the news*

Agriculture and Natural Resource Leaders Receive MSU Distinguished Service Awards

Four Michigan leaders in agriculture and natural resources have been honored with Michigan State University College of Agriculture and Natural Resources Distinguished Service Awards.

Dennis Grinold, of Lansing; Amy Frankmann, DeWitt; and Duane and Velmar Green, Elsie, received the awards for their leadership of and success in agriculture or natural resource fields and their dedication to community affairs.

Peter McPherson, MSU president, and Jeff Armstrong, dean of the College of Agriculture and Natural Resources, presented the awards March 11 during Agriculture and Natural Resources Week at MSU.

Grinold has served as president and vice president of the Michigan Charter Boat Association (MCBA), a non-profit organization serving more than 300 charter boat captains in Michigan. He serves as U.S. adviser to the Great Lakes Fishery Commission, chairperson of the Lake Michigan Task Force and external adviser for the Michigan Sea Grant College Program.

Frankmann has developed educational programs addressing the needs of every segment of the state's green industry. She also organized and coordinated the Great Lakes Trade Exposition and the Michigan Nursery and Landscape Association Summer Field Day. Additionally, Frankmann serves as a member of the FFA Foundation board of directors.

Duane and Velmar Green have been active in several state and national organizations. Duane has been active with Holstein Association USA, serving as national board member, vice president and president. Velmar has been active with the Michigan Milk Producers Association and currently serves as director and treasurer.

Integrated Manure Management Systems Provide New Opportunities for Dairy Producers

Integrated manure management systems that reduce nutrients and possibly eliminate pathogens in the manure stream will change the way dairy farmers handle manure on the farm. What was once a relatively simple task of hauling and spreading manure on farm fields is evolving into a highly sophisticated process involving treatment and other operations that grant farmers flexibility and generate the potential for new profit centers.

MAES agricultural engineering researchers have been at the forefront of developing manure management systems in this country. The first component they developed for dairy farms was a sand-manure separator to take sand used for bedding out of the manure. Removing the sand allowed more flexibility in manure handling. And because the separator also rinses the sand, farmers can reuse it.

"Michigan dairy farmers have identified manure management as one of the most important challenges they face today and expect to face in the future," said William Bickert, MAES agricultural engineering scientist. "We are continuing to look at new ways to help farmers meet these challenges."

A component of the integrated manure management system being investigated by MAES researchers is a fixed-film anaerobic digester, which is used to convert the biomass into an energy source. The fixed-film digester has the advantage of a shorter retention time — four days compared with 21 or more days in a plug flow system — so it requires a substantially smaller digester volume and can be built at a lower cost.

"Unlike the plug flow systems operating in Michigan 20 years ago, the fixed-film digesters offer new opportunities for treating animal manure, especially manure streams with higher moisture contents," Bickert said. "When used in conjunction with other manure treatment processes, the digester reduces odors and pathogens, generates energy and sets the stage for removing nutrients from the manure stream."

In spring 2004, Bickert and his colleagues in the MSU Department of Agricultural Engineering will install the first anaerobic digester on a Michigan dairy farm in 20 years.

Funding for the digester comes from the Animal Agriculture Initiative and the Michigan Biomass Energy Program. In addition, Wirth and Fedewa Construction and MPC Cashway Lumber have provided a building for laboratory equipment and instrumentation. Green Meadow Farms in Elsie, Mich., is providing facilities and assistance with construction.

The digester will be one component of a complete integrated manure management system installed on the mid-Michigan dairy farm. If the trial is successful, researchers expect to see more digesters in place around the state.

"Anaerobic digestion is the cornerstone of an integrated manure management system in which successive treatments may lead to a zero effluent discharge manure system," Bickert said. "For example, phosphorus separation technologies and other innovative manure treatments benefit from the stable and consistent effluent stream produced by an anaerobic digester."

The anaerobic digester also can destroy pathogens such as E. coli and Salmonella that may be present in the manure.

The first step in the process is the removal of sand and grit from the manure. The digesters used in the past were unable to handle manure with sand in it. The development of the sand-manure separator makes the digester a viable concept again.

From the sand separator, the manure stream travels on through a grit removal system that removes fine sand and grit particles, further reducing problems in the digester. Once the grit is removed, the manure stream goes through a grinder, then through a heat exchanger and then to the anaerobic digester.

"Through this process, all the biosolids in the manure will be included in the digestion process, increasing biogas production and reducing the stream of unprocessed biosolids," Bickert explained.

The liquid and biosolids leaving the digester will then pass through a struvite reactor, where the phosphorus is removed in a sludge that can then be land applied or composted. The sludge and resulting compost can be sold as fertilizer. The struvite reactor is being constructed with a grant from the National Center for Manure and Wastewater Management.

Research *in the news*

The liquid leaving the struvite reactor, with very low concentrations of biosolids and nutrients, will then be directed to a constructed wetland.

A team of researchers from the departments of Agricultural Engineering and Civil and Environmental Engineering will evaluate the integrated manure management system at each step in the process. Samples from each process will be collected and tested to determine the effectiveness of the complete system.

Jim Wallace, a graduate student in biosystems engineering, is studying the use of an anaerobic membrane as a part of the system to determine the impact on digester efficiency and reduction of pathogens.

"Integrated manure management systems can be tailored to individual farms, depending on the needs and goals of the operation," said Dana Kirk, graduate assistant in biosystems engineering. "Individual farm operations may not need every possible treatment component but may implement those that are useful on their farm."

Michigan Tourism Industry Projected to Rebound in 2004

After declining in 2001 and 2002 and experiencing lackluster growth last year, Michigan's tourism industry can look forward to healthy growth in 2004, if a forecast presented at the Michigan Tourism Outlook Conference proves to be correct.

A research team headed by Don Holecek, MAES scientist and director of the Michigan State University Tourism Resource Center, projects that the number of travelers will increase by 3 to 4 percent in 2004 over last year and travelers' spending will increase by 4 to 5 percent. The team reviewed a multitude of factors known to influence travel activity in Michigan and surveyed industry leaders across the state.

Travel prices are projected to increase only slightly — 1 to 2 percent — so Michigan travelers can expect to receive a high value at a very reasonable price again this year. But, with demand building, Holecek recommends booking preferred accommodations early to avoid possible disappointment.

Gaming, shopping market segments and outdoor recreation are expected to show the largest increases at 4 to 6 percent, Holecek noted.

Other projections include:

- The Upper Peninsula is expected to show the largest increase in tourism volume — 4 to 5 percent.
- The northern Lower Peninsula and southeastern Michigan will show a 3 to 4 percent increase.
- The southwest region will show the smallest increase — 2 to 3 percent.

The projected growth for Michigan's tourism industry is in line with average industry growth over the past 20 years. Holecek noted that the economy, consumer confidence, stock markets and international political climate have all improved since last spring and will boost travel activity in 2004.

The weaker U.S. dollar should also benefit Michigan's tourism industry because it will discourage residents from traveling to other countries while making traveling to Michigan less expensive for international travelers, especially those from Canada, the most important source of foreign travelers to Michigan.

On the other hand, a continuing high rate of unemployment in the state, relatively high gasoline prices and scarce funding to promote travel to Michigan are expected to weigh negatively on the rate of travel growth this year. Industry profits will improve but not keep pace with growth in travel volume because high-margin business and conference travel has not fully recovered from the recession, and both business and leisure travelers are maintaining a tight rein on their travel expenditures.

Holecek said that consumers have become wedded to discount shopping necessitated by the recession, and the emergence of the Internet greatly makes shopping for the best prices easier.

This year and beyond, Michigan's tourism industry faces mounting competition for travelers' dollars, a challenge even though the travel market is expanding. Participants in the Michigan Tourism Outlook Conference last year concluded that Michigan would need to invest in its travel products to maintain and grow its travel market share.

The 2004 Michigan Tourism Outlook Conference was designed to set the scene for the first Michigan Tourism Investment Forum, May 26-27 in Dearborn. The forum, co-hosted by the MSU Tourism Resource Center and the School of Hospitality Business, will provide more in-depth information about tourism development opportunities in Michigan, as well as an opportunity for investors, developers and others to come together.

For more information about the May 26-27 Michigan Tourism Investment Forum, visit <www.tourism.msu.edu/forum/> or contact Alex Nikoloff at 517-353-0793 or nikoloff@msu.edu.

MAES Scientist Honored by Alexander von Humboldt Foundation

Alvin J. M. Smucker, MAES crop and soil sciences researcher, received a Humboldt Research Award from the Alexander von Humboldt Foundation in Germany. He was nominated for the award by German scientist Rainer Horn. The award recognizes Smucker's lifetime achievements in science. In addition, he was invited to carry out research projects in cooperation with specialist colleagues in Germany. Smucker will be honored with an award ceremony in July.

As part of the cooperative research associated with the award, Smucker is working with four doctoral students and three post doctoral students in Germany, as well as two international programs at the Kiel Soils Institute in China and Brazil. The scientists also are writing joint proposals and manuscripts to support future multinational research at the International Long-Term Ecological Research (ILTER) site, the international branch of the Long-Term Ecological Research (LTER) site at the Kellogg Biological Station.

The Alexander von Humboldt Foundation grants up to 100 Humboldt Research Awards annually to scientists and scholars from abroad with internationally recognized academic qualifications.

Evangelyn Alocilja
Assistant Professor of Biosystems Engineering
204 Farrall Hall
517-355-0083
alocilja@egr.msu.edu

Jon Bartholic
Director, Institute of Water Research
Professor of Community, Agriculture, Recreation and Resource Studies
115 Manly Miles Building
517-353-9785
bartholi@msu.edu

Carole Bolin
Professor of Pathobiology and Diagnostic Investigation
A3A Veterinary Medical Center
517-355-8533
bolinc@ahdl.msu.edu

Stephen Boyd
Professor of Crop and Soil Sciences
532 Plant and Soil Sciences Building
517-355-0271, ext. 252
boyds@msu.edu

Tom Fernandez
Assistant Professor of Horticulture
A216 Plant and Soil Sciences Building
517-353-3765
fernan15@msu.edu

Tim Harrigan
Assistant Professor of Biosystems Engineering
220 Farrall Hall
517-353-0767
harriga1@msu.edu

Syed Hashsham
Assistant Professor of Civil and Environmental Engineering
A126 Engineering Research Complex
517-355-8241
hashsham@egr.msu.edu

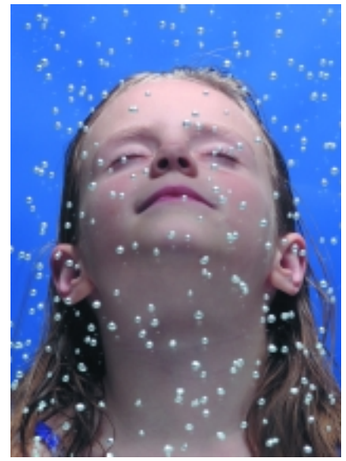
Ruth Kline-Robach
Outreach Specialist, Institute of Water Research
115 Manly Miles Building
517-355-0224
klineror@msue.msu.edu

Dave Lusch
Senior Research Specialist; Remote Sensing and GIS Outreach Services
308 Manly Miles Building
517-355-8497
lusch@msu.edu

Bill Northcott
Assistant Professor of Agricultural Engineering
218B Farrall Hall
517-432-7702
northco2@egr.msu.edu

Joan Rose
Homer Nowlin Chair in Water Research
13 Natural Resources Building
517-432-4412
rosejo@msu.edu

Clayton Rugh
Assistant Professor of Crop and Soil Sciences
516 Plant and Soil Sciences Building
517-432-6159
rugh@msu.edu



Orlando "Ace" Sarnelle
Associate Professor of Fisheries and Wildlife
163 Natural Resources Building
517-353-4819
sarnelle@msu.edu

James Tiedje
Professor of Crop and Soil Sciences and Director, Center for Microbial Ecology
540 Plant and Soil Sciences Building
517-353-9021
tiedjej@msu.edu

Robert von Bernuth
Professor of Agricultural Engineering
213 Farrall Hall
517-432-6379
vonbern@egr.msu.edu