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Arsenic Monitoring Using Microfluidic Hollow Fiber Membrane Extraction

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The Director's Chair

Joan G. Ehrenfeld, Ph.D

This issue highlights the range of research on water problems that are being conducted by researchers throughout New Jersey. The topics cover a variety of water resource problems – from the detection and remediation of toxics to the biology of restored wetlands to the economics of preventing nonpoint source pollution. We hope this issue illustrates the value of research in solving our water problems.

Kamilah Hylton and Dr. Somenath Mitra, New Jersey Institute of Technology

Arsenic (As) is a naturally occurring metalloid that has become a serious problem for drinking water supplies in many parts of the world, particularly in India and Bangladesh. At low concentrations, it is a known carcinogen and is responsible for adverse health effects such as spontaneous abortion and neonatal death [1]. Monitoring As at low parts per billion levels presents many challenges. Typical analytical methods for arsenic monitoring involve elaborate extraction steps followed by detection via hydride generation atomic absorption or ion chromatography. These techniques are relatively complex and expensive, and the development of simple and portable field methods will facilitate more widespread As monitoring.

The central core of this instrumentation is a device consisting of two 3 mm thick polymer chips that sandwich a hollow fiber membrane encased in a polymethylmethacrylate (PMMA) substrate. Micron-scale channels are etched into the PMMA substrate, allowing small volumes of water to flow through. It is compacted in a serpentine channel, as shown in Figure 1. The sample to be analyzed flows in the channels etched into the PMMA support, while an extractant fluid flows through the hollow fiber membrane. Arsenic moves through the membrane into the extractant fluid, and is concentrated there, facilitating measurement by inexpensive techniques. The arsenic extracted from the sample can be detected by a simple color-forming reaction using a molybdate reagent. The color is easily quantified using a portable spectrometer.

The device offers several advantages over current monitoring methods, such as simple design, higher active surface area per unit volume and inexpensive mass production [3,4]. The miniature As extractor is slightly larger than a US quarter, as shown in Figure 1 [2], making it highly portable and useful in field settings. Using this technique, we are able to detect low parts per billion levels of As in water. Currently, we are working to develop an integrated system for near-real time As monitoring.

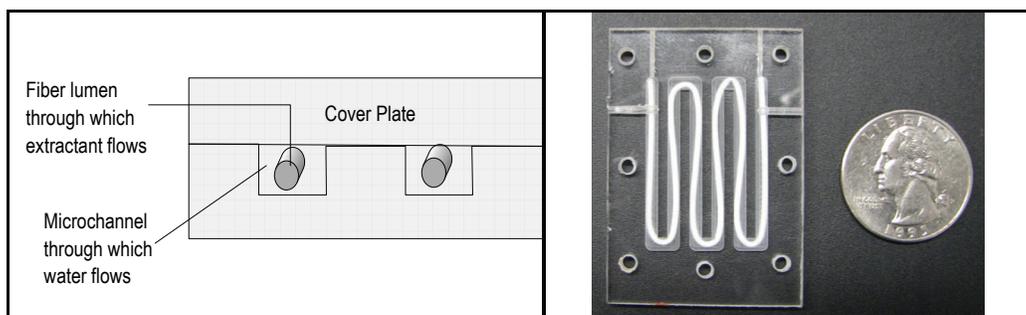


Figure 1. (a) Design of the Microfluidic Extractor. (b) Photograph of the device compared to a US quarter.

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Kamilah Hylton is a Ph.D. student and Dr. Somenath Mitra is a Professor in the Department of Chemistry and Environmental Science at the New Jersey Institute of Technology, <http://chemistry.njit.edu>.

From the NJ State Climatologist's Office...

Dr. David A. Robinson, NJ State Climatologist

As this is written, three weeks of November are in the record books, and statewide precipitation is running about 1-2" below average. Thus continues a fall that has seen the 3rd driest September and 20th wettest October since records were established in 1895. These precipitation ups and downs are certainly common to New Jersey: this past April was the wettest on record, which came on the heels of the record dry fall of 2006.

September 2007 rainfall averaged 1.06" across the state, leaving only 1941 (0.27") and 1914 (0.37") drier. This was 3.01" below the 1971-2000 average. Due to the longer-term dry conditions in the southern half of the state, by month's end the *US Drought Monitor* map depicted the southernmost counties of the state in "moderate drought: D1" and the counties northward to and including Ocean and Mercer as "abnormally dry: D0." Conditions were relieved somewhat in October when precipitation totaled 5.33", or 1.82" above average. It is interesting to note that five of the most recent six Octobers rank among the 25 wettest, with October 2005 the wettest of any month in any year at 11.98".

Precipitation departures of 25% over the past 180 days still place the southern counties in D0. While the worrisome downward spirals of ground water, river flow and reservoirs have ceased, it will be important to receive at least average precipitation during the coming months in order to return storage to its normal annual maximum next spring.

The variable fall precipitation regime was accompanied by some very warm weather until recent weeks. October warmth shattered the previous statewide monthly record. The average temperature of 62.4° was 8.2° above average. This exceeded the previous warmest October (1947 and 1971) by 2.3° and continued the early fall warmth (September ranked 7th warmest). November is likely to end one or two degrees below average.

Since I last contributed to this newsletter, considerable progress has been made within the Office of the NJ State Climatologist (ONJSC) toward providing state citizens and decision makers with timely weather and climate information. You are invited to visit the ONJSC web site (<http://climate.rutgers.edu/stateclim>), where you can access monthly precipitation information, some

back over a century, by clicking on links located toward the top right corner of the page. Look below the map of current weather conditions and you will find a link to our NJ Water Watch page. There you will find all sorts of information on NJ water conditions. Return to the main page and click on the map to access the NJ Weather and Climate Network (or head there directly: <http://climate.rutgers.edu/njwxnet>). This network of networks reports hourly observations of numerous weather variables from well over 100 electronic stations scattered throughout NJ. The ONJSC operates about 40 of these and data are also retrieved from NJDOT, NWS, USGS, IFLOWS and other networks.

Despite all of the great electronic stations out there, gaps exist in the coverage of precipitation observations across NJ, and quality observations of snowfall and snow cover are even more difficult to come by. Therefore, we are launching an ambitious volunteer observing network, known as NJ Co-CoRaHS. Yes, it's an odd acronym that stands for Community Collaborative Rain, Hail and Snow network (<http://www.cocorahs.org/>). This growing national network was born at Colorado State University in the late 1990s, after a deadly flash flood in Ft. Collins. Following some training (online or, preferably, in person), volunteers purchase a \$22 precipitation gauge and a piece of plywood to serve as a snow measurement board. They will then properly mount their gauge and begin taking daily observations of precipitation (rain and melted snow), snowfall, snow on the ground at the time of observation and, if they so choose, whether hail has fallen (some may even wish to build a hail pad to record the size and number of stones). Observations are taken every morning (with the option of taking them more often when the weather warrants), entered on a web page and at the push of a button sent off to Colorado and the ONJSC for quality control, archiving and display via tables and maps. NJ CoCoRaHS was launched on February 2 (Ground Hogs Day!). Should you wish to participate, or perhaps even be considered as a county coordinator, please get in touch with me (drobins@rci.rutgers.edu), or sign on via the web link provided above.

New Jersey High School Students to Study Aquatic Ecology and Chemistry of the Passaic River

Montclair State University, Passaic River Institute

Students and teachers from four New Jersey high schools in three counties will conduct scientific studies of the Passaic River under the guidance of professors and staff from Montclair State University under a new project, Passaic River Environmental Education and Monitoring Organization (or PREEMO), established through Montclair State University's Passaic River Institute (PRI). This program is supported by a grant of \$40,000 from the U.S. Environmental Protection Agency (EPA).

The EPA grant to PRI will support the program that will give high school students—from Barringer High School, Newark; Wallington High School, Wallington, (Bergen County); Passaic Valley High School, Little Falls, (Passaic County); and Newark Academy, Livingston, (Essex County)—hands-on training in the science of monitoring water quality along the environmentally-challenged river and its tributaries.

"The program has many benefits for the community. On an educational level, it is a very practical way of engaging high school students in biology, chemistry, math, and computer science

concepts that are taught in classrooms," says Kirk Barrett, Ph.D., PRI director. "It is also a way of encouraging young people to take an active role in taking care of their local environments, a trait that we hope will become a lifelong habit."

A highlight of the learning experience will be a year-end conference on the Montclair State University campus where students will meet to share and discuss their findings. "This project will culminate in a sharing of experiences between students and teachers from different learning environments," Barrett said. "It brings together a cross-section of young people who reflect New Jersey's diverse neighborhoods to study together waterways that we share in common."

Teachers from the schools are receiving advice, training and supplies in aquatic biological and chemical analysis procedures from PRI faculty and staff, and are leading their students to the Passaic River for monthly water-monitoring forays.

"Involving teachers and students in a study of the Passaic engages them in experiences that both educate and inspire them," EPA Regional Administrator Alan J.

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Cost-effectiveness of Targeting Critical Source Areas for Implementing Agricultural BMPs

Dr. Zeyuan Qiu, New Jersey Institute of Technology

The primary cause of water pollution in the United States is runoff from nonpoint sources. Controlling nonpoint source pollution is difficult because of its diffuse nature. However, recent studies argue that a significant amount of nitrogen, phosphorus and sediments come from relatively small areas in a watershed, called Critical Source Areas (CSAs). This concept is related to the idea that runoff is generated from relatively small areas within each watershed, which vary in size depending on mois-

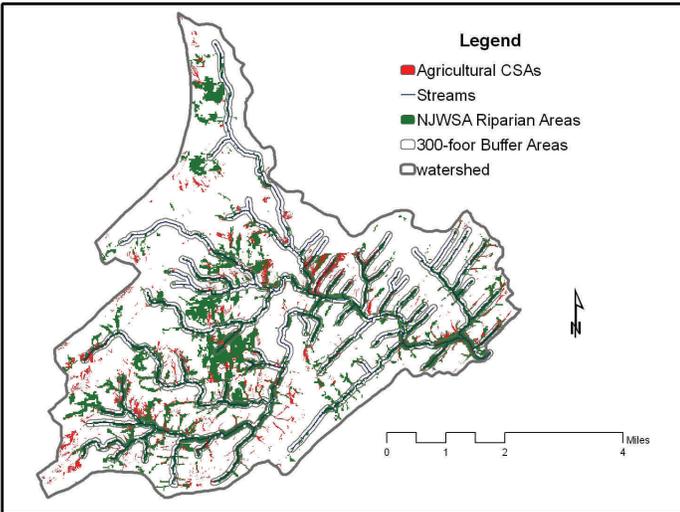


Figure 1. Distribution of agricultural CSAs vs NJWSA riparian areas and NJDEP 300-foot buffer areas in the Neshanic River Watershed.

ture conditions. These areas are in turn called Variable Source Areas (VSAs). By linking the runoff source areas (VSAs) to the sources of pollutants on the land, CSAs for nonpoint pollution can be identified. These areas – the intersection of runoff source areas and pollutant source areas – are called “hydrologically sensitive areas” or HSAs. In general, pollutant source areas are the areas in watersheds that have been actively used for agriculture. Implementing best management practices (BMP) in the CSAs of a watershed is an effective and efficient way to control nonpoint source pollution and improve water quality.

One common approach to reducing nonpoint pollution is to conserve and restore riparian buffers in degraded watersheds. Conventionally, these buffers are placed in the riparian zone along the streams. However, we have explored the possibility that it would be cost effective to focus buffer restoration on CSAs, rather than just the riparian zone, even if the CSA extends beyond the mapped riparian zone.

We evaluated the cost-effectiveness of three buffer restoration strategies when applied to the 31-square-mile Neshanic River watershed in Hunterdon County, NJ by assuming buffer restoration in agricultural lands was supported by the New Jersey Conservation Reserve Enhancement Program (NJCREP). The three strategies were an unconventional strategy of targeting buffer restoration in agricultural CSAs in the watershed, and two conventional riparian buffer restoration strategies (restoring buffers in agricultural lands within a 177-foot corridor of streams and a 100-foot riparian corridor of streams in the watershed).

We delineated VSAs and HSAs by using a modi-

fied topographic index model based on the 10-meter digital elevation model maintained by NJDEP and the SSURGO soils database by the Natural Resource Conservation Service (NRCS). The agricultural lands were extracted from the 2002 land use/cover database. CSAs for buffer restoration were identified as the agricultural lands in the HSAs. The 100-foot and 177-foot buffers were created along both sides of the streams in the watershed. The agricultural lands in the two buffer zones were targeted for buffer restoration in the two conventional strategies. Figure 1 presents the delineated agricultural CSAs. A significant portion of CSAs were distributed outside the active riparian management zones. NJCREP supports four types of buffer practices in agricultural lands: grass waterway, contour grass strips, filter strips and riparian buffer. Site-specific buffer types under each strategy were based on local conditions. The implementation costs, including sign-up incentive, installation and maintenance costs, and soil rental costs, were based on the average costs of existing enrolled NJCREP lands. The environmental benefits of different strategies were evaluated using the runoff potential of all sites measured by the modified topographic index. The cost-effectiveness was measured by the targeted average runoff potential divided by the average implementation costs. Table 1 presents the comparison of the cost-effectiveness of the three strategies. As we had predicted, the CSA strategy was more cost-effective than either conventional strategy, 57 and 61 percent more than the 177-foot and 100-foot riparian buffer strategies, respectively.

Several local conservation initiatives have incorporated the idea of targeting CSAs for agricultural BMPs. For example, a Cooperative Conservation Partnership Initiative grant, funded by NRCS and led by North Jersey Resource Conservation and Development Council (RC&D) with collaboration from New Jersey Institute of Technology and New Jersey Water Supply Authority, is adopting the CSA strategy to develop a riparian restoration plan for agricultural lands in the Raritan River Basin. The CSA concept is also adopted in North Jersey RC&D’s River-Friendly Farm Certification Program that promotes agricultural BMPs through recognition of well-managed farms that help to protect water resources in the Raritan River Basin. Our research demonstrates that combining knowledge of hydrologic sources areas and critical areas for pollutants and runoff can effectively direct the use of funds for buffer restoration to improve water quality.

Zeyuan Qiu is an Assistant Professor in the Dept. of Chemistry and Environmental Science at New Jersey Institute of Technology, www.chemistry.njit.edu.

Table 1: Cost-effectiveness of three buffer restoration strategies

	Units	CSA Strategy	100-Foot Riparian	177-Foot Riparian
Total Areas	Acres	2,643	1,508	2,654
Agricultural Lands	Acres	692	321	705
Signing Incentive Payments	\$	69,207	32,138	70,475
Installation Costs	\$	1,514,526	926,924	2,032,640
Annual Land Rental Costs	\$	27,698	12,395	26,800
Annual Maintenance Costs	\$	3,045	1,864	4,088
Total Costs	\$	2,044,880	1,172,947	2,566,428
Average costs	\$ per acre	2,955	3,650	3,642
Targeted Runoff Potentials	per acre	500	409	393
Cost-effectiveness		0.169	0.112	0.108



NJDEP Water Research Project Summaries

Suzanne Shannon, Division of Science, Research and Technology, NJDEP

The information below summarizes six water research projects conducted by staff in the New Jersey Department of Environmental Protection (NJDEP) Division of Science, Research and Technology (DSRT). DSRT is the NJDEP's primary scientific research and technical support unit. The role of this division, through its studies, evaluations and monitoring efforts, is to provide NJDEP with a sound technical foundation upon which to base the department's policy and regulatory decisions. Additional DSRT research is available at <http://www.nj.gov/dep/dsr/>.

1) The NJ Toxics Reduction Workplan for NY-NJ Harbor (NJTRWP) and the NY-NJ Harbor Estuary Program Contaminant Assessment and Reduction Project (CARP).

Joel Pecchioli, M.S., NJDEP DSRT

The New York-New Jersey Harbor Estuary Program (HEP) has identified 15 toxic chemicals of concern, including polychlorinated biphenyls (PCBs), dioxins/furans, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and the metals cadmium, lead, and mercury. Responding to problems with management of contaminated dredged material, the HEP – in conjunction with the States of New Jersey and New York, and with funding from the Port Authority of NY-NJ – implemented the Contaminant Assessment and Reduction Project (CARP) in 1997. The NJTRWP is managed by NJDEP – DSRT, and is the New Jersey component of CARP.

The assessment phase of CARP has been completed, and sampling data collected by New Jersey and New York is available on the two CD-ROM CARP Database. The CARP samples (including ambient water quality; wastewater/POTW, combined sewer [CSO], and stormwater [SWO] discharges; biota; and bottom sediments) were collected and analyzed for the toxic chemicals of concern using state-of-the-science methods and protocols. This data was used to develop and calibrate the CARP sediment and contaminant fate and transport model. The CARP Database, the CARP Model technical reports, and a description of the CARP itself, can be found at www.carpweb.org.

Phase One of the NJTRWP has also been completed and project reports can be found at <http://www.state.nj.us/dep/dsr/njtrwp/>. This work included (1) hydrodynamic studies of the harbor conducted by researchers from Stevens Institute of Technology (SIT) and Rutgers University; (2) ambient water quality measurements and calculations of contaminant and sediment loads at the heads-of-tide of the Passaic, Hackensack, Elizabeth, Rahway, and Raritan Rivers (conducted by the U.S. Geological Survey); (3) ambient water quality measurements within the tidal reaches of these rivers and the estuarine areas of Newark Bay, the Arthur Kill, and the Kill van Kull (conducted by SIT researchers); and (4) measurements of contaminant concentrations in discharges from New Jersey POTWs, and selected CSOs and SWOs, that discharge to the harbor (conducted by the Great Lakes Environmental Center).

Based on the initial Phase One sampling data, researchers began limited Phase Two studies to gather additional data, focusing on specific areas where elevated concentrations of particular contaminants were identified. These areas included the Hackensack River (mercury), above the heads-of-tide on the Elizabeth and Passaic Rivers (PCBs, dioxins/furans, metals), and above the heads-of-tide on tributaries to the tidal Passaic River (the Saddle, Second, and Third Rivers). The Passaic Valley Sewerage Commissioners (PVSC) also initiated studies to track down sources of PCB11 within its service area.

The next step for the NJTRWP in 2008 is the development of the NJTRWP Implementation Plan. This will include an integration and detailed analysis of NJTRWP and NY-CARP data, the

CARP Model results, and available data from other studies to identify areas of the harbor with significant toxic contamination problems. The Implementation Plan will also contain recommendations for future source trackdown and reduction/elimination actions, and will identify data gaps and additional information needed to develop a better understanding of the toxic contamination problem in NY-NJ Harbor.

2) Mapping Water Resource Data using Advanced Modern Geostatistics.

Gail Carter, M.S., P.G., NJDEP DSRT

Over the past four years, DSRT, in conjunction with Dr. Marc Serre of the University of North Carolina in Chapel Hill, has worked on the development of modern geostatistical methods and their application to water resource issues. Modern geostatistical methods integrate spatial, temporal, and Bayesian equations to predict and map water quality in locations between sampling stations.

Using these methods, temporal trends in the data are now formally part of the mapping equations. The Bayesian equations allow mixing of "hard" and "soft" data sets in a single analysis. Hard data is a typical data set of specific measurements, for example water quality values from different sampling stations along a stream, in a reservoir, or in an aquifer. Soft data can be a set of data with different detection limits, upper or lower concentration limits instead of specific values, or distribution characteristics. Now, historical data with obsolete detection limits can be combined with current data to improve the accuracy of water quality predictions. An example of the method is shown in Figure 1.

Two earlier research projects have been completed and a third project will be completed in the spring of 2008. There are three research objectives: 1) to pilot test modern geostatistics on several "real world" New Jersey water data sets to prove that these mapping methods are more accurate than other methods; 2) to tailor modern geostatistics for NJDEP water resource applications, by developing a river metric so that the methods can be used along streams, and; 3) to make the modern geostatistical methods easily available to NJDEP staff by transparently embedding user-friendly prototype code into ArcGIS. Sixteen NJDEP staff from nine different programs have been trained to use the prototype Bayesian Spatio-Temporal Geostatistical code (BME-GIS).

The prototype code is being used to evaluate contamination in rivers, lakes and aquifers. Modeled contaminants include radiologicals, nutrients, Dense Non-Aqueous Phase Liquids (DNAPLs), and volatile organic compounds. One significant advantage of modern geostatistical methods is that accurate mapping can be done with much less data, which is valuable in a time of limited monitoring budgets.

Like most existing methods, modern geostatistics is very good at predicting how much contamination to anticipate in a waterbody. But unlike other methods, it provides significantly

more information about precisely where contaminants are likely to be found and how often they will rise above legal standards.

Maps produced using modern geostatistics cannot be made without specifying a level of scientific confidence. Therefore, each map includes a companion map displaying the probability that the given solution is correct for each spot on the result map. This is rarely done in classical water quality mapping projects. The companion error maps are also very helpful if additional sampling locations need to be selected.

At this time, no additional funds have been awarded for this project. However, if additional funding becomes available, eight specific areas should be pursued to enhance and improve the mapping method: 1) add the downstream River Metric to the prototype code; 2) improve the internal error management portion of the prototype code; 3) enhance the amount of data the code can process; 4) develop the mathematics so that covarying indicators and surrogate parameters can be incorporated into the map interpolation; 5) provide user assistance in the prototype code; 6) re-

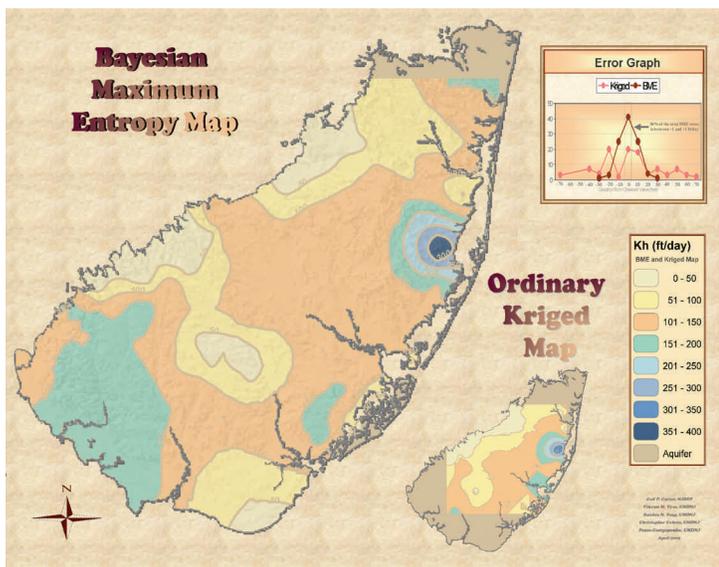


Figure 1. Two maps detailing variations in horizontal conductivity in the Kirkwood-Cohansey Aquifer in the New Jersey Coastal Plain. Both maps were produced with the same “hard” data set. The large map used advanced modern geostatistics methods, while the small map used traditional kriging.

verse and beta-test the code to run in Arc version 9.2; 7) expand the Bayesian soft data component of the code to include additional forms of soft data, and; 8) expand the mathematics to perform fully 3-dimensional spatio-temporal analysis. For more information on this research or suggestions where additional funding may be available, please contact Gail Carter at gail.carter@dep.state.nj.us.

3) Treatment of Arsenic from Water by Nanocrystalline Titanium Dioxide (TiO₂).

Lee Lippincott, Ph.D., NJDEP DSRT

Xiaoguang Meng, Ph.D., P.E., Center for Environmental Systems, Stevens Institute of Technology, Hoboken, NJ

Elevated arsenic (As) concentrations are found in groundwater in many countries, such as Bangladesh, China, India, Vietnam, Chile, and the United States, due to naturally-occurring As in aquifer sediment. It is estimated that arsenic in drinking water may have affected more than 100 million people worldwide. A nanocrystalline TiO₂ has been developed for treatment of inor-

ganic and organic As in drinking water. The chemical interactions between arsenic species and TiO₂ and filtration treatment of As using the granulated TiO₂ adsorbent, will be reported. Experimental results indicated that the adsorption capacity of TiO₂ for arsenate [As(V)] increased dramatically when the size of TiO₂ decreased from 134 to 7 nm. As(V) and arsenite [As(III)] interactions at the solid-water interface of nanocrystalline TiO₂ were investigated using electrophoretic mobility (EM) measurements, Fourier transform infrared (FTIR) spectroscopy, extended X-ray absorption fine structure (EXAFS) spectroscopy, and surface complexation modeling. As(V) and As(III) are adsorbed on the solid surface mainly through the formation of (TiO)₂AsO₂⁻ and (TiO)₂AsO⁻ surface complexes, respectively. Granular adsorbent has been produced from the nanocrystalline TiO₂ for filtration treatment of As in water. The nanocrystalline TiO₂ is also an effective photocatalyst for demethylation of monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). Superoxide (O₂^{•-}) and hydroxyl radicals (HO[•]) are the primary reactive oxygen species for the photodegradation of MMA and DMA. The methyl groups in MMA and DMA are transformed into organic carbon, including formic acid and possibly methanol, also through photochemical reactions.

4) Kinetics of Biological Perchlorate Reduction and pH Effect.

Lee Lippincott, Ph.D., NJDEP DSRT

Chao Wang and Xiaoguang Meng, Center for Environmental Systems, Stevens Institute of Technology, Hoboken, NJ

Batch experiments were conducted to investigate the kinetics of biological perchlorate reduction and the effect of pH on the reduction process. The kinetic parameters were determined with the substrate-utilizing model and cellular maintenance model. The result indicated that perchlorate could be steadily reduced to 15 µg l⁻¹ in a completely mixed and continuous flow system. The half saturation constant, K_s, was 261 µg l⁻¹, which suggests that perchlorate-reducing bacteria were effective at utilizing low concentrations of perchlorate. Perchlorate-reducing bacteria are neutrophiles that had maximum activity for perchlorate reduction at pH of about 7.0. The rate of perchlorate reduction was reduced dramatically at pH below 5.0 or above 8.8.

5) Determination of Configuration of Arsenite-Glutathione Complexes Using ECSTM.

Lee Lippincott, Ph.D., NJDEP DSRT

Mei-Juan Han and Xiaoguang Meng, Center for Environmental Systems, Stevens Institute of Technology, Hoboken, NJ

Inorganic arsenicals such as arsenite [As(III)] and arsenate [As(V)] are known human carcinogens. The interactions of As(III) with sulfhydryl groups of peptides and proteins are very important mechanisms for the toxicity and metabolism of arsenic in mammals. The present study was designed to investigate the interactions between As(III) and glutathione (GSH), an ubiquitous tripeptide in nearly all known aerobic organisms, by using electrochemical scanning tunneling microscopy (ECSTM), UV-Vis spectra and electrospray ionization-mass spectrometry (ESI-MS). ECSTM was applied to image the GSH and its complex with As(III) and configuration change of GSH after the complex formation in a 0.1 M NaClO₄ solution on the Au(111) surface. High-resolution STM images revealed that the As(III) and GSH formed an As(GS)₃ com-

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Cranberry farms' ecological function and restoration in the Pine Barrens of New Jersey

Ai Wen, Dept. of Ecology, Evolution and Natural Resources, Rutgers University

Cranberry (*Vaccinium macrocarpon*), as a native perennial crop, has brought enormous commercial and social value to growers and the public in New Jersey. As a unique wetland agricultural product, cranberry has been cultivated in the Pine Barrens for over 150 years. The 3,600 acres of active farms and innumerable abandoned farms are an important component of the Pine Barrens wetland system. Dams and reservoirs have been constructed along rivers to direct water into the cranberry farms, where water is further controlled by ditches and their tributaries to supply various cranberry bogs within the farm. Water from the bogs then returns to the wetland via downstream ditches. The reservoirs and ditches enable an elaborate water level control during different seasons in the farm, which is critical for cranberry cultivation. In the winter and early spring, the cranberry bogs are submerged under water for frost control; during the growing season, bogs are watered by sprinklers to avoid the damage of sun scald; in the fall, the modern wet-harvest technique requires flooding in the bogs in order to float the berries for collection. Because of cranberry cultivation's dependence on fresh water, the quality and quantity of cranberry production relies on the quality of water input and the integrity of the surrounding wetland system.

Cranberry farms are a human-dominated component in the Pine Barrens, usually found between natural wetlands and human residential areas. With proper management, active cranberry farms can provide valuable wetland habitat for the surrounding Pine Barrens' wildlife, buffering the impacts of agricultural activities on wildlife. Monitoring wildlife distribution in the farms and their association with habitats within the farm will indicate the critical habitat components that accommodate wildlife. From spring 2006 to fall 2007, 122 bird species were observed in habitats within and along the boundaries of cranberry farms. Their distribution along the farm boundaries varies with the vegetation composition. Further analysis shows bird density is positively correlated with grass density and vegetation coverage along the boundary. This is especially important in the winter, when the remaining dead grass provides seeds and shelter along the farm boundary. Cranberry farms therefore can serve as an important winter food source for the Pine Barrens bird community because the farms' openness encourages the growth of herbaceous species.



Cranberry farm at the Whitesbog, Burlington County.

In addition to active farms, there are also numerous abandoned cranberry bogs imbedded in the Pine Barrens landscape. After a farm is abandoned, natural succession begins as plants sprout from the remaining soil seed bank and new seed inputs from the surrounding habitat. However, because the construction of cranberry farms has drastically changed the hydrology of the landscape, leaving the abandoned farms solely to natural succession could result in unexpected plant communities, such as exotic invasive weeds or upland forest. Even if the original wetland could be restored by natural succession, it might take centuries to reach a stable community. Therefore, active restoration in the cranberry farms is helpful to direct and accelerate recovery after abandonment. The New Jersey Conservation Foundation is planning to restore the Franklin Parker Preserve, which includes about 800 acres of abandoned cranberry bogs. After seven years of abandonment, the bogs already contain different plant communities, with some bogs dominated by upland plants rather than wetland species. The difference is hypothesized to

be due to different hydrologies and different propagule availabilities in the bogs. To better understand how hydrological conditions and propagule availability influences restoration, a seed bank germination study was conducted from May to October 2007. Soil cores were taken from bogs with low and high water tables, and then artificially treated with different flooding regimes. Each soil core was also divided by depth into three layers to observe the difference in seed bank composition at different soil depths. The result shows frequent flooding is necessary for the germination of *Juncus* and *Carex* species, while flooding inhibits the germination of *Drosera rotundifolia* (sundew) and other upland species. The seed bank close to the bog surface contains more upland species, while the deeper layers (deeper than 5cm) contain more wetland species. The results suggest that successful restoration may require a well-designed flooding regime to encourage germination of wetland species, as well as either sowing seed or turning the soil over to expose seeds of wetland species in the lower soils. Together, these steps will encourage the successful restoration of wetland plants.

Ai Wen is a Ph.D. student in the Dept. of Ecology, Evolution and Natural Resources at Rutgers University, <http://rci.rutgers.edu/~deenr/>.

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Steinberg said. "This program gives educators and young people the knowledge and skills they need to understand their environment and take action to improve it. They will know how to meet an important challenge, being environmental stewards of the Passaic River."

Using kits purchased by the grant, students are measuring water quality variables such as dissolved oxygen, water clarity, and phosphorus concentration. They are also collecting small bottom-dwelling animals, like snails, that indicate pollution levels.

Students enter their collected data into a Web-based program

(www.premmo-msu.org) that allows them to analyze data and compare it with data from other sites. The website also provides links to educational materials and other data sets about the river, and will provide a forum for students to post their impressions and questions about ecology and environmental science.

One sampling site is the lake in Essex County's Branch Brook Park, which flows to the Passaic River. "We are pleased the EPA and Montclair State will utilize Branch Brook Park as an environmental classroom and help students learn about and gain an appreciation of nature," Essex County Executive Joseph N. DiVincenzo, Jr. said.

Potential Ecological Impacts to the Delaware Bay from a Non-Indigenous Isopod

Sean Boyd, Dept. of Ecology, Evolution and Natural Resources, Rutgers University

In 1999, a non-indigenous marine isopod was discovered in the Maurice River, a tributary of Delaware Bay, by a research technician working at Rutgers University Haskin Shellfish Research Laboratory in Bivalve, NJ. Specimens collected from the river were originally identified as *Synidotea laevidorsalis*, however, recent molecular analyses suggest that the *Synidotea* species found in Delaware Bay and elsewhere in the United States is *S. laticauda*. *Synidotea laticauda* is a member of the Isopoda suborder Valvifera, and is endemic to the shallow intertidal waters of California where it is believed to have been geographically and ecologically segregated in the San Francisco Bay system. The isopod was likely introduced to Delaware Bay through the discharge of ballast water from ships visiting the region.

Anecdotal reports from fishermen and scientists working in Delaware Bay indicate that *S. laticauda* has been present in the bay for several years, conspicuously abundant on ropes and buoys in the water column with extremely high localized seasonal abundances. Its ecological impact and overall distribution within Delaware Bay and adjacent waterways was initially unknown. Consequently, an ecological assessment was warranted and provided the impetus for a study conducted during the summer of 2006.

A presence-absence survey conducted as part of the study indicated *S. laticauda* at present occurs only in mesohaline and



Synidotea laticauda

oligohaline regions of the bay. It does not occur in the adjacent Atlantic coastal waters or in the freshwater portions of tributaries that drain into the bay. In general, isopods were associated primarily with anthropogenic structures, particularly submerged buoy lines and marinas, showed a slight preference for biological fouling, and became less abundant as the water became fresher. It is unlikely that the range of *S. laticauda* will expand further into the estuary. Acute temperature-salinity challenges found that isopods died quickly in the freshwater. However, they were able to survive at higher salinities which may allow for the expansion of their range farther south into portions of the bay where higher salinities are prevalent. Juvenile isopods were also found to be more sensitive to acute temperature-salinity exposure than adult isopods.

Several trophic interactions between *S. laticauda* and the biota of Delaware Bay were identified through this study. Single-choice feeding trials identified nine different native fauna and flora that were readily consumed. This established *S. laticauda* as an omnivore capable of exploiting multiple food resources within the Bay. Cannibalistic behavior and the ability to scavenge food resources was also observed. Furthermore, gut content analysis of fish collected from the Maurice and Nantuxent Rivers indicate that at least four predatory species may consume *S. laticauda*, although the isopod did not appear to be an important component of their diets.

Synidotea laticauda is likely to persist in Delaware Bay because it possesses temperature and salinity tolerances that are suitable for much of the bay. Broad dietary preferences and limited predation pressure are additional qualities that favor *S. laticauda* as a successful biological invader.

Sean Boyd recently received an M.S. from Rutgers University for research performed with Dr. David Bushek at the Haskin Shellfish Research Laboratory, <http://vertigo.hsrl.rutgers.edu/>.

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plex. The orientation and packing arrangement of the molecular adlayers were also seen clearly from the images and molecular models constructed using the Chemical Window and Hyperchem software package. The configuration of GSH in $As(GS)_3$ was found to be different from single GSH. UV-visible spectra indicated the emergence of an absorption shoulder in the range 250-280 nm for the aged $As(III)$ -GSH solution, compared to the spectra of single $As(III)$ and GSH solutions. MS spectra showed the presence of a new peak for the aged $As(III)$ -GSH solution at m/z 992 corresponding to the $As(GS)_3$ complex. The results obtained by the last two methods verify the compound imaged by using STM is $As(GS)_3$. Study on the interactions of $As(III)$ and peptides are an important step toward a better understanding of interactions between $As(III)$ and proteins.

6) Adsorption of $As(V)$ and $As(III)$ by Nanocrystalline Titanium Dioxide.

Manish Patel and Lee Lippincott, Ph.D., NJDEP DSRT

Maria E. Pena, George P. Korfiatis, Xiaoguang Meng, Center for Environmental Systems, Stevens Institute of Technology, Hoboken, NJ

This study evaluated the effectiveness of nanocrystalline titanium dioxide (TiO_2) in removing arsenate [$As(V)$] and arsenite [$As(III)$] and in photocatalytic oxidation of $As(III)$. Batch adsorption and oxidation experiments were conducted with TiO_2 suspensions prepared in a 0.04M NaCl solution and in a challenge water containing the competing anions phosphate, silicate, and carbonate. The removal of $As(V)$ and $As(III)$ reached equilibrium within 4h and the adsorption kinetics were described by a pseudo-second-order equation. The TiO_2 was effective for $As(V)$ removal at $pH < 8$ and showed a maximum removal for $As(III)$ at pH of about 7.5 in the challenge water. The adsorption capacity of the TiO_2 for $As(V)$ and $As(III)$ was much higher than fumed TiO_2 (Degussa P25) and granular ferric oxide. More than 0.5 mmol/g of $As(V)$ and $As(III)$ was adsorbed by the TiO_2 at an equilibrium arsenic concentration of 0.6 mM. The presence of the competing anions had a moderate effect on the adsorption capacities of the TiO_2 for $As(III)$ and $As(V)$ in a neutral pH range. In the presence of sunlight and dissolved oxygen, $As(III)$ (26.7 μM or 2 mg/L) was completely converted to $As(V)$ in a 0.2 g/L TiO_2 suspension through photocatalytic oxidation within 25 min. The nanocrystalline TiO_2 is an effective adsorbent for $As(V)$ and $As(III)$ and an efficient photocatalyst. (Water Research 39 (2005) 2327-2337)

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