National Water Research Institute
BRIEFINGS
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Project Uses Dendrimer Nanotechnology to Improve Water Treatment Processes

Dr. Mamadou Diallo

NWRI is funding an exciting, cutting-edge research project that will examine the feasibility of removing — and possibly recycling — metals from the leftover wastes of water treatment processes by using a groundbreaking technology that functions at the molecular level.

The project, called "Recovery of Metal Ions from Membrane Concentrates by Dendrimer-Enhanced Filtration," is a foray into Environmental Nanotechnology, a new field that addresses environmental issues through the use of functionalized nanomaterials.

In this particular instance, the project's principal investigator, Dr. Mamadou Diallo, and his collaborators are developing dendrimers — globular macromolecules with three covalently bonded components (a core, interior branch cells, and terminal branch cells) — to seek out and attach to specific metal ions with the goal of removing toxic metals like arsenic and copper from aqueous solutions.

An Environmental Engineer with a background in Molecular Physical Chemistry, Diallo is currently Director of Molecular Environmental Technology at the Materials and Process Simulation Center of the Beckman Institute at the California Institute of Technology (Caltech), as well as Visiting Assistant Professor of Civil Engineering at Howard University in Washington, DC.

"The purpose of this research," he said, "is to merge nanotechnology with water purification processes. It's a tall order, but it's also an opportunity to develop a new generation of water purification technologies that can help us remove some of the most difficult-to-remove contaminants."

According to Diallo, dendrimers have the potential to remove more than just metals from water, such as emerging contaminants like pharmaceuticals. So if his project is successful with metals, not only will it pave the way for water treatment facilities to pick and chose which contaminants to remove at will during the production of drinking water, but it will also help with the disposal of another product of the treatment process — hazardous waste.

Taking the 'Hazard' Out of Hazardous Waste

By definition, a hazardous waste is a substance that is potentially damaging to the environment and harmful to humans and other living organisms.

Utilities use membrane treatment technologies like microfiltration and reverse osmosis to separate contaminates from raw water to produce purified water. The separated contaminates are known as "membrane concentrates," which could include brines and backwash. Membrane concentrates are considered hazardous wastes because they contain toxins, such as metals.

According to Diallo, "The concentrate may have up to 10 times more metal than water." And because of the high levels of toxins, the concentrate cannot be disposed of like a normal waste product, which in some areas is released back into a river or ocean.

Landfills are the most common means to dispose of hazardous waste. Evaporation ponds are another option; they are basically containment areas where water is allowed to evaporate and then the metals are buried. A third tactic is deep well injection, in which the hazardous waste is pumped underground. None of these options are foolproof, and sometimes the toxins end up back in the water supply.

"The problem we're now facing," said Diallo, "is that hazardous waste continues to accumulate,

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In This Issue...

Properly Designed Dendrimers Can Bind to Toxic Metals in Membrane Concentrates

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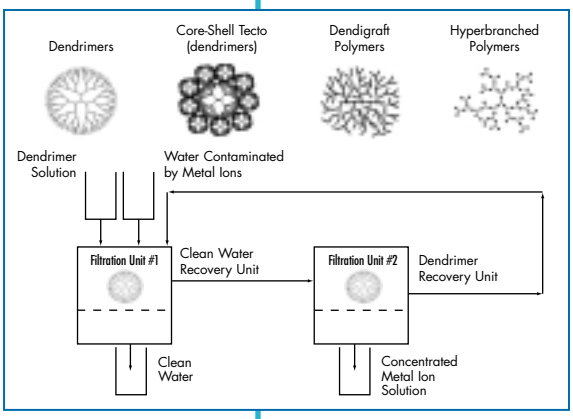
and people don't know what to do with it. But if you remove the toxins from hazardous waste, then it's no longer hazardous, and you don't have to worry about the costs and problems associated with disposing of it."



Recovery of metal ions from aqueous solutions by dendrimer-enhanced ultrafiltration. Reprinted with permission from Environmental Science and Technology, *2005, 39, 1366-1377. Copyright 2005 American Chemical Society.*

That's where Diallo's research project fits in. With funding support from NWRI, the National Science Foundation (NSF), and the U.S. Environmental Protection Agency, he will try to prove that dendrimers can recover metals from a broad range of membrane concentrates that result from membrane treatment processes.

Designer Dendrimers

So what, exactly, is a dendrimer?

According to Diallo, "A dendrimer is a 'smart' material in which you can design its size, structure, shape, and chemical properties to bind metals, organics, drugs, or whatever else you want to it."

Technically a globular polymer, a dendrimer has a structure similar to a tree. It has branches, and each branch has leaves. The key to a dendrimer is in those leaves, which have specific properties, depending on how you grow it, so that they can bind to specific substances.

Dendrimers were invented around 20 years ago, but their environmental applications have only recently begun to be investigated. Diallo is a pioneer in developing dendrimers for the water industry, though there are researchers who are currently developing the technology for medical purposes.

For instance, said Diallo, "If you look at cancer radiation therapy, radiation is used to kill the tumor, but it may also kill good cells at the same time. Imagine being able to have radiation that only kills bad cells. A dendrimer can be designed to do that. It's like a drug of sorts, in that it will ignore everything else but the cancer cell and release the radiation there only. We call it a 'smart cancer bomb.' That's what they are working on right now in the medical field. There's even a company using dendrimer-based HIV treatment. You can put any type of drug into the dendrimer and design it to bring that drug anywhere you want in the body."

For the purposes of the membrane concentrate, "a properly designed dendrimer can go inside waste and pick up the toxic metal," said Diallo. "It recognizes metal ions."

Dendrimer-Enhanced Filtration: Nanotechnology for the Twenty-First Century

It's pretty easy for metal to contaminate water. For instance, as groundwater flows through the subsurface, it picks up and carries whatever comes in its path, including contaminants like metal. It's a lot harder to remove these contaminants for drinking purposes.

The most common disinfection strategy is chlorination, but chlorine is most effective in killing organisms like bacteria and won't affect metals. Biological water treatment is another strategy in which microbes are added to water to eat organics, though they cannot eat metals. Membrane treatment, however, can remove harmful metals through the process of filtration, so it's been used as a popular treatment strategy.

Here's a brief summary of how Diallo will be testing dendrimers to see if they can be used as part of the membrane treatment process to improve water quality and prevent the creation of hazardous waste. He calls it "Dendrimer-Enhanced Filtration (DEF)."

The DEF process is structured around two unit operations: 1) a clean water recovery unit and 2) a dendrimer recovery unit. In the clean water recovery unit, contaminated water is mixed with a solution of functionalized dendrimers at a high pH (7 to 10) to selectively bind the targeted metal ions. Following completion of the reaction, the resulting solution is filtered to recover the clean water. The contaminant-laden dendrimer solutions are subsequently sent to a second filtration unit where the pH is lowered (3 to 5) to recover and recycle the functionalized dendrimers.

One of the possible outcomes and benefits of using dendrimers to recover metals is that not only will dendrimers solve a contamination problem, but they will also create a source of raw materials. It may be possible to recycle and/or resell cobalt, copper, platinum, silver, and other toxic metals — gold, even.

More importantly, though, dendrimers have a broad range of properties that can be harnessed to improve and advance water purification technology.

"Nanotechnology provides unprecedented opportunities to modernize water purification and to bring it into the twenty-first century," said Diallo. "And dendrimers are just one class of nanomaterials that can do it."

Progress Report

With a patent pending on the DEF process and a proof-of-concept article published in *Environmental Science and Technology* (2005, 39[5]), Diallo plans to develop a system to recycle the dendrimer, which

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Don't Miss the Water Treatment Technologies Workshop for Upgrading Water Quality

NWRI is pleased to announce that the *International Workshop on Novel and Enhanced Water Treatment Technologies for Upgrading Water Quality* will be held in September 2005 in Tianjin, China, to discuss the latest technological and scientific developments associated with drinking-water quality.

Topic highlights will include processes for upgrading drinking-water quality at relatively low cost and convenient operation, novel technologies such as advanced oxidation and membrane processes, and the recent development of multiple-barrier processes to upgrade water quality.

Other workshop topics include:

- Protection and remediation of drinking source water quality.
- Pretreatment technologies.
- Enhanced coagulation.
- Dissolved air flotation.
- Enhanced filtration.
- Activated carbon adsorption.
- Disinfection and by-products formation control.
- Water quality in distribution systems.

Program

The workshop will consist of key-note presentations, oral presentations, and discussions. Exhibitions will be available. In addition, technical field trips are being planned, as well as social and cultural events for delegates and their guests.

Language

The official language of both the workshop and the published proceedings will be English. Simultaneous translations will be provided.

Registration Fees

The registration fee is tentatively set at USD 300, which covers workshop attendance, proceedings, and meals and refreshments.

Date and Location

The workshop will be held September 6-8, 2005, in Tianjin, China. The venue has not yet been determined.

The *International Workshop on Novel and Enhanced Water Treatment Technologies for Upgrading Water Quality* will be held in September 2005 in Tianjin, China

The *International Workshop on Novel and Enhanced Water Treatment Technologies for Upgrading Water Quality* is jointly sponsored and organized by the following:

- China Water Association
- National Water Research Institute, USA
- National Natural Science Foundation of China
- Harbin Institute of Technology, China
- Tianjin Water Company, China

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Dendrimers and Metals May Be Recyclable

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would make it more cost-effective for water purification. He will also design his project to piggy-back on existing technology, so that no new hardware is needed.

At this moment in time, however, he is busy conducting experiments to see how well dendrimers bind to metal ions (e.g., copper, silver, and cobalt) when more salt than normal is added into the membrane concentrate. "Hopefully," he said, "the dendrimers will pick up the metals without also picking up any extra stuff we don't need."

Critical to these experiments is the fact that the formula for the membrane concentrate has an industrial source: secondary-treated effluent from the Orange County Water District (OCWD) in Fountain Valley, California.

"This is an exciting project," said Don Phipps, Research Director of OCWD's Research and Development Group, a world-renown state-of-the-art laboratory that focuses on testing and validating new technology. "Diallo's research is providing a practical solution to a real-world problem. Dendrimer technology has great promise, and there are a number of applications where I can see it taking a role in future contaminant removal processes. I think we are actually seeing just the tip of the iceberg right now in regards to what we can do with dendrimers."

Texas Student's Research Examines Precipitative Flocculation Processes

Who is Jeffrey Nason, NWRI's newest Fellowship recipient? Well, for one, he's a family man, father to a 16-month old daughter, with another on the way. Two, he's an outdoorsman, an avid camper and hiker who grew up in Idaho and who uses a bicycle to get around. Three, he's a go-getter whose curiosity is so huge it has led him all over the country. And finally, he's a student with a research project so innovative that NWRI had to support him.

Now in his third year as a Civil Engineering Ph.D. student at the University of Texas at Austin, Nason is currently exploring better ways to remove particles from drinking water during treatment processes to "ensure we all have clean water to drink."

Jeffrey Nason

Nason's fascination with water treatment processes began years ago while he was an undergraduate studying Chemical Engineering at Cornell University in New York. Two of the courses he took revolved around wastewater treatment, which intrigued him. "Most of us think that we can wash the dishes or flush the toilet, and the dirty water just disappears. The reality is that it goes back into the water supply, meaning it returns to the environment and eventually goes into our bodies. So it's in everyone's best interest to keep it clean."

After he graduated with his Bachelor's degree, Nason married and decided to pursue his interest in water and wastewater treatment processes by working for a small environmental engineering consulting firm in Washington State. There, he had the opportunity to work in wastewater treatment plant design, as well as pump station design. But, it was a desire to learn more that eventually drew Nason back to Cornell for a Master's degree in Environmental Engineering after working over 2 years in the consulting world.

Back at school, he discovered something new — a love for teaching. With the goal of becoming a Professor, Nason decided to pursue a Ph.D. in Civil Engineering under the guidance of Dr. Desmond Lawler, a member of the Academy of Distinguished Teachers at the University of Texas at Austin. It was through Lawler that Nason learned about the NWRI Fellowship for water research and decided to apply. He was one of two students to receive the Fellowship in 2004 from over 80 applicants for his graduate research on "Simultaneous Precipitation and Flocculation in Water Treatment: Modeling and Experiments."

"Any time surface water is used to produce drinking water," he explained, "there are particles present in the water, such as dirt or clay, bacteria, and plant material. One objective of drinking-water treatment is to remove particles before they reach the tap."

Precipitation, coagulation, and flocculation are processes used in conjunction to help remove particles from water by increasing particle size. What precipitation does is create insoluble particles (think, metals) from a soluble solution (water) by adjusting pH and/or adding chemicals (like lime or aluminum salts) to the solution. In other words, the chemical precipitants produce fine particles. Then everything is mixed together in a big tank called the flocculation basin so that the particles bump into one another and lump together. Now, because the particles are so much bigger and heavier, they either settle on the bottom (of a subsequent sedimentation tank) or can be filtered out.

For decades, these processes have been used together as a means to treat drinking water before it is piped out for human consumption.

As part of his research, Nason will conduct precipitation/flocculation experiments to determine what parameters control how particle size distributions change during flocculation when new solids are formed (as in lime softening and alum or iron coagulation). These parameters include mixing intensity and time in the rapid mix and flocculation basins, chemical dose, water chemistry, and the properties of existing particles.

His goal is to create a mathematical model that can be used as a tool to examine what process parameters are important and how the parameters may be altered (or tailored) to make flocculation and downstream treatment processes more efficient.

This is a unique project because, said Nason, "There's never been a detailed investigation of what's really happening to the particles in precipitative flocculation processes, how the particle size distributions are changing, and what's governing those changes."

Added his advisor, "Jeff has chosen an extraordinarily difficult problem, but one of great importance. It is nearly impossible to find a subject that impacts almost every operating water treatment plant and that has not been fully and virtually completely understood. Jeff has done so, trying to push the envelope of the understanding of precipitative flocculation, an old process that needs new understanding."

At this stage in his research, Nason is "just getting into the meat of his experimental work." He is busy developing the experimental apparatus and sampling procedures, and since he loves working with his hands and building things, he says this has been a lot of fun, even though "things don't always work on the first try."

Nason expects to graduate in 2006.

Education Video on the Value of Water Now Available

NWRI's newest educational video brings together economists, water experts, and Native Americans to explore one of the most basic, yet controversial, questions in the water industry: what is the value of water?

Released in early 2005, "The Value of Water" is the sixth program in NWRI's "Water From Water" series, an outreach effort meant to inform the public about significant water issues facing the nation.

"What do gasoline, lipstick, hamburgers, and a pair of shoes have in common," the 23-minute video begins. "We know what they cost — along with the hundreds of other things we need or want, important or not. But when it comes to something we need to stay alive, day after day, we have no idea what it costs or, more importantly, what it's worth. What is the value of water? It's a simple question that's very hard to answer."

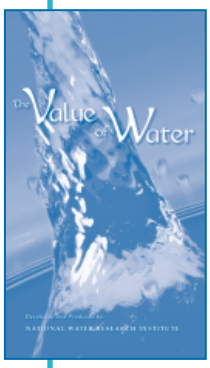
Hard to answer, says the video because, too often, water is viewed as a limitless and free resource that no one should have to pay for.

But that is the wrong type of thinking, says commentator Dr. Sandra Archibald, an economist at the University of Washington in Seattle. "We need to stop looking at water as a free good and look at it in its more economic values. Water has different values for different uses."

"People are willing to pay very high values to provide for drinking water and sanitation and to take care of their health needs," she says. "They're not willing to pay as much necessarily for water to wash their cars … Values for drinking, values for swimming, value for boating, and a willingness to pay for these different uses of water is the paradigm shift that we need."

To do this, the video suggests that water be viewed as an asset that provides services that require investments to maintain it for the people who consume it.

"We need to start valuing water as a commodity much like a stock," says commentator Michael Rudinica, Executive Vice President of RBF Consulting. "You buy stock at a cost but, in reality, you invest in stock for the long-term for the valuation that's going to come out of it. We haven't done that for water yet."



The video shows two different examples in which water is treated as an asset to be invested in. In the first instance, it explores the value of water to the Hopi Indian tribe in Northern Arizona, where water is a limited resource in the desert.

"Water is our lifeblood," says Wayne Taylor, Chair of the Hopi Tribal Council. "We are a farming people, so we depend on the rain. Because we are in a water-short area, everyday, everything we do — our activities and prayers — has to do with moisture and bringing out the rain. Water is very sacred to us."

So not only does water have a physical and economic value to the Native American people, but it also has a cultural and spiritual value as well.

The second major example of the value of water — and highlight of the video — is a short, in-depth look at the Tres Rios Wetlands project in Phoenix, Arizona, which uses natural biological processes to treat wastewater diverted into a man-made wetland. Therefore, the Tres Rios Wetlands not only provide services beyond aesthetic value, but they also provide flood control and wildlife habitat, as well as naturally remove harmful nitrates (via the plants) from water supplies.

"What is the value of water at the Tres Rios Wetlands?" Asks the video. "Hundreds of millions of dollars, and counting."

The video finishes by pointing out that if we don't understand and invest in the value of water, we are at great risk of mismanaging our limited water resources.

"The costs of cleaning polluted water supplies become greater," concludes Kris Lindstrom, a water quality expert. "There could be a lack of water in drought. The ability to grow food will be diminished … There's already a lot strife over water supplies. China and other growing countries have experienced huge shortages of water and won't be able to sustain themselves. So there will be major consequences in the next 20 to 50 years worldwide for our lack of stewardship of our water resources."

The video is now available to purchase for $24.95. Please visit www.nwri-usa.org to order.

The Tres Rios Wetlands. Photo courtesy City of Phoenix (Arizona) Tres Rios Demonstration Constructed Wetland Project.

Workshop First Step in Improving Public Response to Hurricane Warnings

In an effort to better understand how and why people respond the way they do to hurricane forecasts and warnings, NWRI hosted a workshop in February on behalf of a national weather agency to examine means of integrating social science research with atmospheric science.

The purpose of a hurricane forecast and warning system is to prevent death and injury, as well as to reduce vulnerability to winds, storm surges, inland flooding, and other hazards.

According to Dr. Jeff Lazo, Director of the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information at the National Center for Atmospheric Research (NCAR), the number of people in the U.S. injured or killed by hurricanes has gone down in recent years, and that's largely due to improved forecasting and warning systems (as a point of comparison, nine hurricanes affected the U.S. in 2004, killing 59 people, versus nearly 3,000 people killed in the Caribbean nation of Haiti by only one of those hurricanes). However, there is still potential for significant loss of life in the U.S., especially in a city like New Orleans, Louisiana, where worst-case scenario projections estimate that tens of thousands of people could die during a major hurricane event due to geographic and transportation problems if there is not enough lead time to evacuate.

Dr. Jeff Lazo (center) helped organize the Hurricane Forecasting and Warning System Workshop, held in February 2005.

At issue is how do people respond to and make decisions based on information provided by the hurricane forecasting and warning system, such as when urged to evacuate.

"The data shows that only 30 to 50 percent of the people who should evacuate during a hurricane actually do," said Dr. Lazo. "This is a 'social problem' that social science research can address. Improving the actual forecast and warning system won't necessarily help. Improving communication with the public and understanding the public's response to the forecast and warning system may make a world of difference."

One of the first efforts toward accomplishing this was to bring together a group of experts at a workshop in Pomona, California, to begin developing a social science research agenda for the hurricane forecasting and warning system. NWRI organized the workshop, which was sponsored by NCAR and indirectly funded by the National Oceanic and Atmospheric Association (NOAA).

"The hurricane forecasting and warning system," said Dr. Lazo, "benefits people and society as a whole. If we do not research how society deals with it, then we're missing the point of the system. If we don't know what people are doing with the information, then how can we know if the information is doing them any good?"

Thirty-two experts participated at the workshop, including social scientists, meteorologists, geologists, psychologists, economists, and various hurricane specialists. Together, they represented a myriad of agencies, from the National Weather Service to the Federal Emergency Management Agency to representatives from several universities renowned in these fields of study.

The following are examples of priority issues determined at the workshop:

- Improving the understanding of how people make decisions during hurricanes (for instance, figuring out why people go to work, open for business, and conduct their daily lives despite a hurricane threat or how they might modify their behavior).
- Estimating the economic benefits of hurricane forecasts and of improving forecasts (this can help justify current forecast expenditures and help support research for improving forecasts).
- Determining how forecasts and warnings are affected by the information age (how to effectively send out messages via the Internet, television, radio, and so on).
- Focusing research on helping socially vulnerable populations during hurricane events (the handicapped, hospitalized, and poor are among those who have difficulties in evacuating or in even receiving warnings).

These issues and more were flushed out in detail in a 155-page preliminary report prepared by the workshop participants.

"The workshop was helpful in that it allowed us to get a cross-disciplinary discussion going," said Dr. Lazo. "We were able to focus on what we needed to do to develop a research agenda."

"This was a complex topic," he added, "but an important one that needed to be addressed. What we're doing will have long-term impacts on improving the hurricane forecasting and warning system for the benefit of society."

The workshop was just the first step in moving this effort forward. In fact, since then, biweekly conference calls have been organized with a number of workshop participants to continue with and build on issues discussed at the workshop. One of the next steps, Dr. Lazo said, is to "write a summary paper" based on the workshop report.

For more information on this ongoing effort, please contact Dr. Lazo at lazo@ucar.edu or through the Societal Impacts Program website at www.sip.ucar.edu.

Meet Our Research Advisory Board: Mark A. Thompson

Mark Thompson is a hands-on type of guy. As a boy, he mixed chemicals and things together to see what would happen. As a teenager, he spent his summers living in the forest and catching rattlesnakes for fun. As an expert in the operation, design, and management of water treatment facilities, he's literally built membrane system units from scratch — in his own garage.

Thompson says he's a water process person. Basically, he figures out how to get the quality of raw water from Point A to Point B, with B being safe to drink.

A country boy, Thompson grew up in a small town in the mountains of rural Pennsylvania. He'd always dreamed of being a scientist, so he decided to attend Duquesne University, one of only two major Jesuit universities in the U.S., where he earned a Bachelors degree in Chemistry, with a minor in Environmental Biology.

It was there that he met a Professor of Ecology whose personal philosophy so impressed him, he's incorporated it into his own life.

"Most of our teaching is taught through convergent thinking," said Thompson, using an example of a pond. "Convergent thinking describes the pond — the color of the water, its temperature, its chemical make-up, etc. This professor taught us divergent thinking. In other words, you look at the pond and determine how it affects and is affected by the environment around you. Did the recent rains cause runoff into the pond? What did the runoff do to the quality of the water? How does the quality affect the organisms and animals that depend on the water? Based on the characteristics of the pond, what type of animals can be supported by it and how does it affect ecosystems downstream of it? With this way of thinking, you try to maintain a balance with the ecosystem without disrupting the greater good of the pond in that region, but also meet the needs of the people that use the pond. We are part of the ecosystem, too."

A catch-and-release fisherman, Thompson is no stranger to the great outdoors. In fact, while he went to college, he supported himself by working summers as a state park ranger. Those first two summers, he lived entirely out of a tent.

It was as a park ranger that he first had the opportunity to work with a water and wastewater plant (the water came directly from a mountain spring, with only a little chlorine added to it). Another interesting side-job of his as park ranger eventually earned him the nickname "Snake Man."

Thompson had become good friends with a naturalist at the park, and the two of them would work together to capture snakes, sometimes "just for fun" and sometimes to protect visitors. They'd keep the snakes in pens for a few weeks, and during that time, they'd pull them out and teach people how to identify and handle both poisonous and nonpoisonous species (fortunately, Thompson's never been bit).

His funniest rattlesnake experience, he said, happened when he was hiking with a group of high school athletic instructors. "Most were jocks, trying to outdo each other to see who could walk faster or hike longer. One female had to use the facilities, so she decided to go back behind a tree. The next thing we know, she turned as white as a ghost and started slowly walking from behind the tree without looking back."

It turns out she was answering nature's call right next to a rattlesnake. Luckily, the snake wasn't aggressive, albeit noisy, and she was able to walk away unhurt — though "there were a lot of puns and jokes after that."

Mark Thompson

Fresh out of college, Thompson was hired by the City of Chesapeake, Virginia, to start-up a new surface water treatment plant. He'd had nominal experience with water treatment in school, so he said "it was learning under fire." But it was something he had a knack for, and 2 years later, he moved on to the City of Suffolk, Virginia, where he was also hired to start up and manage a new plant that was still under construction.

Thompson moved up in rank with the City of Suffolk and eventually served as Director of Public Utilities for 2 years, in which he was responsible for water supply, treatment and distribution development, and wastewater collection. But a new opportunity soon came his way, and he joined the Newport News, Virginia, office of Malcolm Pirnie, a national environmental engineering firm, where he ended up working with membrane facilities around the world (membranes are a growing technology used to treat water).

Then, one day in 1998, a friend came up to him and asked him if he'd like to test out an ultrafiltration membrane prototype for a membrane supplier. Thompson thought "why not?" and found the prototype had potential, but the system was useless for proper operation of the membrane. So the supplier asked him to design and build a system that would work.

Taking up the challenge, Thompson did — building the system in his own garage at home. The supplier liked it so much that he was asked to build a half-dozen more. It was then that Thompson realized he was having fun building units. So he decided to go into business on his own. Thus, Advanced Membranes

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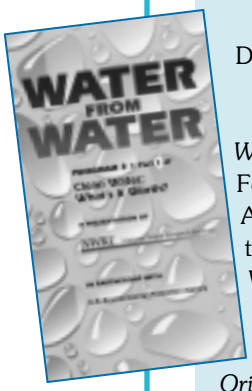
NWRI Products Now on Sale



Water from Water Video, Programs 3 & 4: *Clean Water – What's It Worth?*

DHS Video Only (both programs sold together)
40 minutes

A public education video, *Clean Water – What's It Worth?* examines the impacts of the Federal Water Pollution Control Act Amendments of 1972 ("Clean Water Act") on today's environment and economy. The Clean Water Act established a national agenda with a clear goal: to make our lakes, rivers, and coastal waters "fishable and swimmable" once again.

Original Price: $39.95 *50% Discount:* **$19.98**

Treatment Technologies for Removal of MTBE from Drinking Water: *Air Stripping, Advanced Oxidation Processes, Granular Activated Carbon, Synthetic Resin Sorbents,* Second Edition (2000)

410 pages ◆ Softbound

This document presents the results of feasibility and economic analyses of the most promising and/or widely accepted technologies for removing methyl tertiary butyl ether (MTBE), a volatile organic compound, from drinking water — namely, air stripping, advanced oxidation processes, granular activated carbon, and synthetic resin sorbents.

Original Price: $42.00 *25% Discount:* **$31.50**

Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse, Second Edition (2003)

64 Pages ◆ Softbound

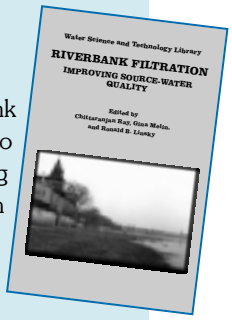
Developed by a team of international experts, these guidelines are intended to provide guidance to state and federal regulatory agencies who review applications for the use of ultraviolet disinfection (UV) systems in potable (drinkable) water and water reuse, and to water utilities who are interested in using UV for disinfection purposes.

They have been revised to:

- Reflect needed changes resulting from the experience gained in the application of the 2000 guidelines.
- Clarify application issues.
- Incorporate additional guidance on UV lamp storage.

Original Price: $27.00 *25% Discount:* **$20.25**

Riverbank Filtration: Improving Source-Water Quality (2002)



364 pages ◆ Hardbound

For more than 100 years, riverbank filtration (RBF) has been used to produce drinking water by inducing surface water to flow downward through sediment and into a pumping well. During this process, potential contaminants are filtered from the water, significantly improving water quality.

Written by over 30 experts from the United States and Europe, this book explores three themes:

- The mechanics behind RBF
- RBF's ability to remove contaminants from surface water
- Critical research needs

Its purpose is to show that RBF is a low-cost and efficient alternative water treatment process for drinking-water applications.

Original Price: $88.00 *25% Discount:* **$66.00**

These items and more are available at www.NWRI-USA.org!

Thompson Hand-Designs Membrane Systems

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Systems, Inc., was born.

With a main office in Virginia and a field office in Florida, Thompson's company provides extensive service in the operation, evaluation, and fabrication of water process systems, including the custom design and fabrication of membrane filtration and desalting systems for water and wastewater applications. Recently, the company rebuilt a seawater desalination unit in Italy, helped start up water treatment plants in both Virginia and Florida, and shipped a custom-built ultrafiltration system to Russia.

Thompson joined the NWRI Research Advisory Board (RAB) over 7 years ago to represent the American Desalting Association (now known as the American Membrane Technology Association [AMTA]). Typical of his hands-on approach, he didn't wait to be invited on the RAB; rather, he elected himself to the position, since he was President of AMTA at the time. In NWRI, he saw an organization that was focused and productive, an organization that "has done a lot of positive things for the industry" (especially by promoting cutting-edge technology) and that looks at issues "holistically."

An organization that, in many ways, is very much like himself.

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