"A SHORTAGE OF WATER RESOURCES COULD SPELL INCREASED CONFLICTS IN THE FUTURE. POPULATION GROWTH WILL MAKE THE PROBLEM WORSE. SO WILL CLIMATE CHANGE. AS THE GLOBAL ECONOMY GROWS, SO WILL ITS THIRST. MANY MORE CONFLICTS LIE JUST OVER THE HORIZON."

– United Nations Secretary General Ban Ki-Moon

WATER

CRISIS OF QUANTITY AND QUALITY

The global water picture is definitely troubling. Many millions of people around the world do not have access to safe drinking water and contract deadly diseases as a consequence of lacking this basic resource for life and health.

Even where water is safe, supplies are dwindling in many areas. Devastating drought continues in the U.S. Southwest, with California enduring the worst drought conditions in centuries. And while there's an abundance of water in the Northeast, concern is mounting over the challenges of maintaining purity due to contamination from industrial, agricultural and other sources.

The reality is that the total amount of water in the world is estimated to be the same as it was in the era of the dinosaurs. The demands of our civilization could lead to violent international conflict over this vital finite resource.

But there are positive steps that can be taken on various fronts to meet the global water crisis – steps such as those involving research under way at NJIT in the area of membrane-based technologies for providing pure water.

ILLUSTRATION: MARK SMITH

Some of the membrane units at a commercial-scale reverse-osmosis desalination plant.

MAST MEMBRANE PROGRESS

NJIT is host to the Membrane Science, Engineering and Technology Center (MAST), a National Science Foundation Multi-site Industry/University Cooperative Research Center. Kamalesh Sirkar, distinguished professor of chemical engineering, and Boris Khusid, professor of chemical engineering, are, respectively, the director and co-director of the MAST Center. MAST academic affiliates include the University of Arkansas and the University of Colorado at Boulder, and some of the world's largest membrane-products companies are MAST Center sponsors.

For two decades, MAST and NJIT initiatives have advanced membrane-technology progress to produce pure water by recycling and desalination, as well as for other applications in the medical, petrochemical, chemical, food and beverage industries. Essentially, all of these applications are based on the process of membrane separation, which depends on creating molecular-level gaps, or minute pores, in a membrane. The membrane is placed in a housing to make a membrane module. The size of the membrane gaps/pores is the key to determining which molecular or macromolecular components in a liquid or gas will pass though the membrane from a region of high concentration to a region of much lower concentration, even blocking the passage of particular molecules almost entirely.

The approximate diameters of the pores in microfilter, ultrafilter and nanofilter membranes are, in descending order, .02 to 10 microns, 1 to 100 nanometers, and 0.5 to 2 nanometers. A micron is a millionth of a meter, and it would take some 1,000 microns to equal the thickness of a U.S. dime. A nanometer is a billionth of a meter, or the equivalent of 10 hydrogen atoms in a row.

Increasingly, reverse osmosis (RO) is the membrane technology used for desalinating seawater and purifying what is known as "produced water" that results from extraction of petroleum and natural gas. In reverse osmosis, the pressure differences on the two sides of a membrane having molecular-level gaps of 0.3 to 0.5 nanometers cause the separation of salt or other molecules.

Today, desalination plants based on membrane technology are part of the landscape in regions such as the Middle East and North Africa, where they produce millions of gallons of fresh water daily. Plants of this type are also operating in coastal areas as well as in arid regions of the United States.

A MAGNETIC CHALLENGE

At NJIT, Khusid is working to improve reverse-osmosis purification technology, an effort that has involved addressing the internal buildup of a type of scale, or precipitate, that compromises membrane performance and is difficult to remove from RO systems. His work has been funded by the U.S. Bureau of Reclamation, which assists the Western States and Native American Tribes with water-resource management.

One project is testing the claim that passing water entering an RO unit through magnets will inhibit the formation of an undesirable heterogeneous precipitate consisting of salt and other material as an alternative to treatment with costly chemicals that also present a disposal problem. Khusid explains that this has required developing bench-scale methodology for assessing the claims made for large-scale systems operating over long periods.

DISTILLING ANOTHER OPTION

Sirkar's wide-ranging membrane-separation research includes development of membrane distillation (MD) as another technological option for increasing the world's supply of pure water. MD is a thermally-driven process that could be an attractive alternative to reverse osmosis under certain conditions.

Although it requires more energy in the form of heat, the internal pressure in an MD system would be much lower. Potentially, that translates into significantly lower costs for the membranes needed, as they would not have to tolerate the thousands of pounds of pressure per square inch typical of RO systems used to purify highly saline water.

“MEMBRANE DISTILLATION COULD BE A VIABLE, COST-EFFECTIVE OPTION WHERE THE WATER TO BE PROCESSED IS HIGHLY SALINE AND THERE IS SUFFICIENT GEOTHERMAL OR SOLAR ENERGY OR WASTE HEAT AVAILABLE.”

– Kamalesh Sirkar, distinguished professor of chemical engineering

“We are at a formative stage in the practical development of membrane distillation,” Sirkar says. “We are studying the fundamentals, such as defining basic characteristics of the membranes that will be needed so that manufacturers will be able to provide them for commercial units. But membrane distillation could be a viable, cost-effective option where the water to be processed is highly saline and there is sufficient geothermal or solar energy or waste heat available.”

THE NANOTUBE ADVANTAGE

The potential of membrane distillation could also be enhanced by introducing carbon nanotubes into the pores of MD system membranes, as demonstrated by Somenath Mitra, distinguished professor of chemistry and environmental science. One atom thick and about 10,000 times smaller than a human hair in diameter, carbon nanotubes are already used in numerous consumer products ranging from packaging to cosmetics and medicines.

With respect to membrane distillation, Mitra's innovation of immobilizing carbon nanotubes in the pores of the membrane increases water-vapor permeation and prevents liquid water from clogging the pores. Tests have shown dramatic increases in the amount of salt removed from the feed-water stream and overall production of pure water, increases achieved at an operating temperature substantially lower than that required when using a membrane without the nanotubes.

“Together, these benefits add up to a greener process that could make membrane distillation economically competitive with other desalination technologies as a way to provide people with pure water where it is most needed,” says Mitra.

JUST PART OF THE SPECTRUM

Advances in membrane-based water-purification technology comprise just one aspect of research at NJIT dedicated to confronting the water crisis in the U.S. and other countries. Faculty in diverse departments and disciplines, joined by undergraduate and graduate students, are engaged in environmental-monitoring, water-resource management, and civil-engineering initiatives focused on solutions for this growing global challenge. ■

Look for more about work at NJIT across the spectrum of these leading-edge water initiatives in future issues.

mastcenter.org
chemicaleng.njit.edu
chemistry.njit.edu

Author: Dean L. Maskevich is editor of NJIT Magazine.

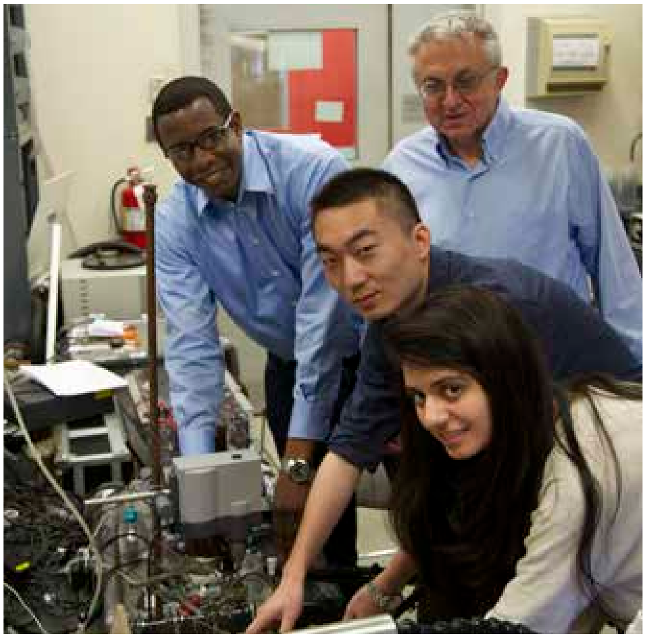

PHOTO: DERIC RAYMOND

Engaged in bench-scale tests at NJIT to improve reverse-osmosis membrane water-purification technology are (from left) Ezinwa Elele MS ’06, Ph.D.’11, research scientist; Boris Khusid, professor of chemical engineering; Qian Lei, master’s candidate and laboratory assistant; and Dana Qasem, undergraduate senior.

BY THE NUMBERS

GLOBAL WATER WARNING

A sampling of current statistics and projections clearly signals the need for more pure water worldwide:

1.2 BILLION • An estimated **1.2 billion** people live in areas with inadequate water supplies.

3.4 MILLION • More than **3.4 million** people die each year due to a lack of pure water and proper sanitation.

• Nearly **one out of every five** deaths of children under the age of five worldwide results from a water-related disease.

400 MILLION • Water-related diseases cause young students to lose over **400 million** school days every year.

• **Half of the hospital beds** in the world are filled with people suffering from water-related diseases.

80 PERCENT • In developing countries, as much as **80 percent** of all illness is linked to impure water and poor sanitation.

• Inadequate water and sanitation have cost Sub-Saharan African countries more in **lost GDP** than the entire continent received in development aid.

• **Water use is increasing** much faster than the world's population.

• It's projected that people in **two-thirds of the world** will live under conditions of water scarcity by 2025.