Photo: Michael Goss

Herek Clack

CLEARING THE AIR

A New Approach to Mercury Remediation

Mercury, often linked in antiquity with alchemical transformations, is used today in such broad-ranging applications as thermometers, liquid-mirror telescopes, and for medical and dental purposes. Herek Clack, IIT associate professor of mechanical and aerospace engineering, however, would like to get rid of the stuff.

While useful, mercury is a highly poisonous substance that can permanently damage the central and peripheral nerves, lungs, kidneys, skin, and eyes. It is particularly hazardous to developing fetuses.

As Clack explains, mercury enters the environment through certain natural events, including volcanic eruptions and forest fires, which liberate mercury stored in plant matter. The largest anthropogenic source is the burning of coal, particularly from coal-fired power plants, and it is here that Clack has focused his efforts.

In a power plant, the combustion process produces flue gases that contain gaseous pollutants, including mercury, and incombustible ash. At any given power plant, various processes may be used to remove pollutants that contribute to acid rain and smog, and whose emissions are regulated. In addition, the ash may be captured either by a large set of fabric filters or by electrostatic precipitation, where the ash particles are charged and extracted from the flue gas by an electric field. Clack describes the popular Ionic Breeze type of home air purifiers as miniature versions of industrial electrostatic precipitators (ESPs).

Historically, far fewer fabric filters have been installed on large, coal-fired power plants than ESPs. Currently, the leading strategy for reducing mercury emissions is to inject a powdered adsorbing material into the flue gases, just before they enter the ESP. "My research is looking at how we improve the removal of mercury within these ESPs that are so prevalent around the world," Clack says.

Tests conducted by the Department of Energy (DOE) at actual power plants have examined the effectiveness of this approach. Clack revisited the DOE's data and assembled a detailed computer model of mercury capture by suspended particles, with emphasis on the fluid dynamics. "To our knowledge, it's the first model of its kind," Clack states.

Reviewing the performance of the model and comparing it with the DOE's data, Clack found something interesting. While the model accurately duplicated experimental results under certain conditions, elsewhere it deviated from laboratory results, over-predicting the amount of mercury removal. "Our theory as to why the model was not agreeing with the data under certain conditions was that as you increase the injection of powder you increase the likelihood that those particles stick together—the process is called coagulation or agglomeration," Clack explains.

Compared to a fine powder, these larger, agglomerated particles are less effective at removing mercury from the flue gas, resulting in lower-than-predicted performance.

Clack was able to verify the process of agglomeration in the lab, comparing the signature of a powder irradiated by laser light before it was fed into a length of tubing and after it emerged at the other end—thereby replicating on a smaller scale the process used to inject activated carbon particles into an ESP.

Beyond the intellectual challenges, Clack emphasizes the increasing value to society of such research, as energy requirements skyrocket and coal use rapidly proliferates, particularly in China, India, and South Africa. In the last year and a half, Clack has begun addressing mercury emissions globally. The United Nations Environment Programme (UNEP) has formed a Global Mercury Partnership, whose objective is to progressively eliminate sources of mercury emission into the environment.

Through UNEP, representatives from governments, industry, academia, and non-governmental organizations around the world have partnered to develop a comprehensive strategy for mercury emissions reduction that addresses the often disparate needs of developed and developing nations. Part of that strategy is to develop, disseminate, and maintain a reference document of established best practices for reducing mercury emissions that is relevant to each source category, with Clack playing a key role in the coal combustion source category. This initiative promises to significantly broaden the scope and reach of Clack's work, as other sources of mercury emission—including artisanal gold mining, a significant issue in the developing world—are evaluated.

Additionally, Clack stresses the importance of finding mercury alternatives and praises United Nations efforts to buy up existing stores of mercury and remove them from global circulation.

—Richard Harth

MORE ONLINE

EPA overview of controlling emissions: **www.epa.gov/hg/control_emissions/index.htm**
Basics of mercury emissions: **www.mercuryanswers.org**
Mercury contamination in North America: **www.sciam.com/article.cfm?id=mercury-hot-spots-found-i**

Harvesting the Future

Alireza Khaligh

To fulfill our energy needs, we mine coal from the earth, pump oil out of ever-deepening wells, and even split atoms in atomic reactors. But **Alireza Khaligh** (Ph.D. EE '06), IIT assistant professor and director of the Energy Harvesting and Renewable Energies Laboratory, is tapping new sources of energy much closer to home.

Khaligh is interested in wellsprings of energy that surround us but are often overlooked. Using innovative techniques in electrical engineering, he examines ways of harnessing these bits of free energy through strategies variously referred to as energy harvesting, power harvesting, or energy scavenging.

Energy harvesting is at least as old as waterwheels and windmills. Recently, however, the idea has received renewed interest, as squeezing every droplet of available energy from the surrounding environment has become critical. The excitement over energy scavenging is also due to the proliferation of small, mobile devices, many of which can survive on a minute trickle of energy.

Khaligh seeks to scavenge energy from both environmentally friendly sources such as wind, ocean, and solar energy, as well as biomechanical sources. While the latter often generate comparatively small amounts of energy, Khaligh and others are working on ways to mobilize it and put it to use for a variety of applications including hybrid cars, health care devices, and portable electronics like cell phones and MP3 players.

One gadget Khaligh describes is a self-powered, shock-detection device that can scavenge kinetic energy from body movement. "When someone suffers a strong jolt, such as hitting the ground, the device turns on and sends a signal to a wireless receiver to call for help," he explains. The life-saving potential for such devices has already been established. But scavenging enough kinetic energy to power the critter is tricky.

Khaligh proposes a hybrid energy-harvesting approach using electromechanical and piezoelectric mechanisms. The resulting device falls into the category of a MEMS—MicroElectroMechanical System—small enough to be implanted under the skin.

Electromechanical energy is produced in devices where a magnet moves through a coil or winding, inducing a current according to Faraday's Law. In contrast, piezoelectric materials respond to pressure or vibration, inducing a current across a pair of electrodes. Khaligh has mathematically demonstrated that while each of these energy sources may be insufficient for the needs of small devices, a hybrid of electromechanical and piezoelectric energy can do the trick.

One of the most exciting applications will be in battery-free cell phones. As a user walks, his center of gravity moves up and down from 4 to 7 centimeters—enough, Khaligh has demonstrated, to allow the kinetic energy to be scavenged to power the phone.

Khaligh notes that the effect of replacing batteries with biomechanical energy harvesters in the 220 million cell phones in use in the United States would be dramatic. Some 220,000 kilowatts of energy, equivalent to the output of a medium-sized power plant, would be saved.

Recently, Khaligh created the Energy Harvesting and Renewable Energies Lab at IIT, where a broad range of energy-scavenging technologies are being investigated and developed. Such fully renewable and completely clean energy sources will be a vital part of the world's energy portfolio.

—Richard Harth

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Nano-sized machines:
www.sciam.com/article.cfm?id=how-self-powered-nanotech-works
Energy scavenging in China and India:
www.businessweek.com/globalbiz/content/oct2008/gb20081022_212298.htm
Free energy and mobile devices:
www.pcworld.com/article/155063/intel_hopes_to_bring_free_energy_to_mobile_devices.html