

## Ports in a Storm: A Surge of Solutions

## The Name Game

## The Scientific Method: Adding Up to a Lot of Good



**NIEHS**  
National Institute of  
Environmental Health Sciences

PUBLIC HEALTH SERVICE  
U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES  
NATIONAL INSTITUTES OF HEALTH  
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# STUDENT EDITION

A harbor, even if it is a little harbor, is a good thing. . . . It takes something from the world and has something to give in return.

Sarah Orne Jewett, writer (1849–1909)

MARINE AND COASTAL SCIENCE

## U.S. Ocean Policy Report Card

If the U.S. government were a student, it would be on the verge of flunking Ocean Policy 101, to judge by the *U.S. Ocean Policy Report Card* issued 3 February 2006 by the Joint Ocean Commission Initiative. The United States has accomplished far too little in response to a health crisis in the nation's oceans, coasts, and Great Lakes, according to the report card. More than a dozen federal agencies have a say in setting and implementing ocean policy, and they often fail to work together. Policy makers need to repair this fragmented system of ocean governance, and they need to do it fast.

The 10-member initiative was created to track government response to two landmark ocean commissions. In September 2004, the U.S. Commission on Ocean Policy, a presidential panel chaired by retired admiral James Watkins, recommended that Congress boost ocean research funding, improve fisheries management, and consolidate federal oversight over ocean policy. A year earlier, the pri-

vately funded Pew Oceans Commission, chaired by Clinton White House chief of staff Leon Panetta, had reached many of the same conclusions.

Yet policy makers have done too little to fix the nation's confusing system of authority over coastal and marine ecosystems, says initiative member Andrew Rosenberg, a fisheries scientist at the University of New Hampshire. "A lot of the issues that the commissions talked about came true with Hurricane Katrina: wetlands loss, lack of planning, inadequate infrastructure, risk from natural hazards, continued fragmentation of ocean policy, major damage to fisheries in the [Gulf of Mexico]," he says. "We need a lead ocean agency to take a new direction internally and to cooperate with other agencies to consolidate and focus programs."

Initially, government leaders responded positively to the two commission reports, a response that earned an A– on the report card. In December 2004, Bush released an action plan that included the creation of a committee to oversee ocean policies (this committee will release a priorities plan and implementation strategy at the end of 2006). Congress and state governors also acknowledged the major recommendations of both commissions.

But momentum has stalled since then. Congress and the Bush administration have not done enough to create a national ocean policy and to strengthen NOAA to the point that it can serve as the lead ocean agency, according to the report card, which gives leaders a D+ in the category of national ocean governance reform.

Policy makers, moreover, receive an F in new funding for ocean policy and programs. The U.S. Commission on Ocean Policy called for a doubling over five years of ocean-related research funding. But federal ocean research received level funding in fiscal year 2006, and Bush's 2007 budget proposal would reduce NOAA's oceanic and atmospheric research support by 9%, to \$338 million. Important ocean programs such as the six NOAA Undersea Research Centers were severely cut for 2006 and would not be fully restored under the 2007 budget.

"We are very disappointed in the president's budget request for NOAA," says Ted Morton, federal policy director of the international nonprofit Oceana. "We were expecting to see more increases for critical ocean and coastal programs. The commissions were clear that significant increases were necessary to restore ocean health."

The report card gives government a C+ for fisheries management reform, noting the Senate's establishment of bipartisan support in an effort to reauthorize the 1976 Magnuson-Stevens Fisheries Conservation and Management Act, the primary federal law governing fisheries management.

Another bright spot is the ongoing reform of ocean management occurring in some states and regions. Among the most notable are efforts in California, Puget Sound, and the Gulf of Maine. These management efforts, which earned a B–, are using a broad ecosystem approach and include government at all levels. The idea is to work toward regional cooperation and across jurisdictional lines in new and existing programs. In the Pacific Northwest, for example, the Northwest Straits Commission addresses marine conservation in the region, the Shared Strategy for Puget Sound addresses salmon recovery in that water body, and the Puget Sound/Georgia Basin International Task Force addresses environmental problems associated with population growth. —John Tibbetts



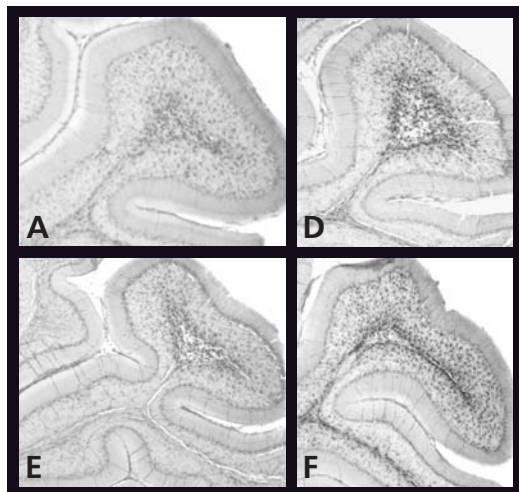
**Bright spot in a dim picture.** Although some regions such as Puget Sound (above) are earning good marks for ocean management, overall the United States is failing miserably when it comes to the nation's ocean policies, according to a recent report by the Joint Ocean Commission Initiative

## ENDOCRINE DISRUPTORS

## Bisphenol A and the Brain

Estrogens are known to trigger rapid cellular responses, including hormone secretion and cell permeability changes, in tissues as diverse as the pancreas, the pituitary gland, and the brain. Two studies published in the December 2005 issue of *Endocrinology* now present an intricate picture of how estradiol, the body's primary endogenous estrogen, acts in the cerebellum, with one study building on the other and including another layer of complexity: the addition of the xenoestrogen bisphenol A to the system.

The studies, conducted by researchers led by Scott Belcher at the University of Cincinnati College of Medicine, investigated an estrogen-mediated extracellular signal-regulated kinase system in developing rat cerebella neurons. The first study, conducted *in vitro*, identified the individual steps in a



**Are U surprised?** Compared to the control (A), bisphenol A exhibits a U-shaped dose-response curve in the rat cerebellum, increasing immunopositive cell numbers at low and high doses (D, F, respectively), but not intermediate doses (E).

cascade of cellular responses triggered by estradiol. The second study focused on this response following injection of estradiol and bisphenol A, alone and in combination, into rat cerebella. Effects were seen at very low doses of  $10^{-12}$  to  $10^{-10}$  moles per liter (M) and at higher doses of  $10^{-7}$  to  $10^{-6}$  M, but not at intermediate doses of  $10^{-9}$  to  $10^{-8}$  M. Paradoxically, when bisphenol A was injected alone, it mimicked estradiol; when injected with estradiol, however, it blocked estradiol action.

Bisphenol A is a known endocrine-active chemical. Low-level human exposure is widespread due to the chemical's presence in

polycarbonate plastic and epoxy resins, but understanding long-term consequences of exposure will be challenging. As illustrated in the *Endocrinology* papers, bisphenol A exerts an effect through a complex system at a concentration range that has not been evaluated in traditional risk assessment.

"It is a fundamental part of endocrinology, and it is beautifully demonstrated [in these papers], that stimulation at [the cerebellar] cell surface receptor is able to cause effects at doses below a part per trillion," says Frederick vom Saal, a professor of biology at the University of Missouri-Columbia. Not only are the doses many magnitudes lower than those considered in classic high-dose toxicity studies, but at extremely low doses both estradiol and bisphenol A demonstrate a response that disappears as the dose increases. "This absolutely challenges the fundamental assumption of risk assessment that once you start increasing dose you always see an increase in response," says vom Saal.

According to Belcher, an assistant professor of pharmacology and cell biophysics, labeling the effects observed in his group's studies as harmful or negative is not possible. "With the way it's been looked at, you can't say whether the observed actions are safe or harmful, but it is clear that the issue needs to be looked at more carefully and seriously," he says.

Although the plastics manufacturing industry, represented by the American Plastics Council in Arlington, Virginia, generally questions several aspects of bisphenol A research, they do agree that translating findings such as those in the *Endocrinology* papers to the sphere of risk assessment won't be easy. "It's not so straightforward to figure out what the results mean for human health, even if you take the results that are published at face value," says Steve Hentges, executive director of the American Plastics Council polycarbonate business unit. "Even to develop a testable hypothesis is not very simple at all. It's very complex systems that they're looking at. The mechanism is a long way from any kind of an adverse effect."

Belcher, too, believes that extending his work into risk assessment is premature. "You can't make a conclusion whether bisphenol A is going to be safe or harmful with current risk assessment models at these low doses," he says. Further, as shown by the paradoxical reaction to bisphenol A, responses to an estrogenic compound can depend on what else is in the system. —Julia R. Barrett

## PFOA to Be Eliminated

In January 2006, eight companies agreed to an EPA agreement to eliminate perfluorooctanoic acid (PFOA) from consumer products within the next decade. PFOA, used to make nonstick and stain-resistant materials, has been linked with cancer and birth defects in animals. The chemical has been detected in the blood of 95% of Americans and in marine organisms and polar bears. Currently, PFOA can be found in a wide variety of consumer products, including food packaging, nonstick cookware, and fabrics. Under the terms of the pact, companies will have to reduce manufacturing emissions of PFOA and trace amounts of the compound in consumer products by 95% by no later than 2010. PFOA should be completely eliminated by 2015.



## Mold Genomics

The 22 December 2005 issue of *Nature* featured information on the latest genomes to be cracked: *Aspergillus fumigatus*, the most common infection-causing mold; *A. oryzae*, a nonpathogenic mold that has been used for 2,000 years to make sake, miso, and soy sauce; and *A. nidulans*, widely used as a laboratory model organism. The work to sequence these mold genomes was an international effort, spanning three continents. Scientists working on the project hope their investment will yield insight into the workings of *A. fumigatus*, which could in turn lead to better treatments for serious asthma, allergies, and other conditions in which the fungus is implicated.

## Ahoy There, EPA!

In December 2005, the EPA formally introduced its new Ocean Survey Vessel *Bold*. A converted Navy vessel, the 224-foot ship is a floating scientific laboratory stocked with state-of-the-art equipment to support the EPA's ocean monitoring and educational tasks, and can accommodate 20 scientists. The EPA began using the *Bold*, its only coastal and ocean monitoring vessel, in August; by September the ship was involved in conducting water quality assessments in the Gulf of Mexico following Hurricane Katrina.

The *Bold* will also support enforcement and survey efforts, and function as a nautical classroom, where tours and demonstration events will educate the public about ocean and coastal environmental issues.



## AIR POLLUTION

## The Plaque of the Matter

Particulate matter measuring less than 2.5 microns ( $PM_{2.5}$ ) has been widely linked to heart disease. These tiny particles of dust, soot, and smoke accompany emissions from power plants and vehicle exhaust, and lead to an estimated 60,000 premature deaths per year in the United States. EPA standards limit average human exposure of  $PM_{2.5}$  to a maximum of 15 micrograms per cubic meter. Now a study published in the 21 December 2005 issue of *JAMA* shows that long-term exposure to  $PM_{2.5}$  even at levels within federal standards accelerates the development of atherosclerosis in laboratory mice by increasing plaque development, especially when the mice are also fed a high-fat diet.

Mice do not naturally develop plaque, a fatty deposit on the inner lining of arteries; the 28 mice used in the study were genetically modified to do so. The animals were divided into two subgroups, one fed a normal diet, the other a high-fat diet. Those subgroups were then divided again, with half breathing air containing concentrated  $PM_{2.5}$  at levels equivalent to 15.2 micrograms per cubic meter and the other half breathing particle-free filtered air. The air pollution group was exposed for six hours per day, five days per week, for six months.

Researchers found measurable changes in the extent and severity of plaque formation in the aorta as well as artery inflammation and reduced function of the arterial lining. In animals that breathed

polluted air and ate a high-fat diet, 41.5% of the arterial interior measured was filled with plaque, compared to 13.2% in animals that breathed filtered air and ate a normal diet.

In humans, high plaque levels can lead to heart attacks and strokes. “These results can be very applicable to the human population, especially in urban environments,” says coauthor Lung Chi Chen, an associate professor of environmental medicine at the New York University School of Medicine. “We found that the combination of air pollution and diet had a dramatic effect on plaque formation, leading to inflammation and heart disease.”

“It was surprising in this study to see the impact of exposure to a relatively low PM concentration on plaque development,” says Kevin Dreher, a principal investigator studying the cardiovascular effects of air pollution within the EPA’s National Health and Environmental Effects Research Laboratory. “While both dietary groups developed plaque when exposed to polluted air, the high-fat diet led to more consistent and statistically significant increase alterations of plaque development. Fat in the diet appears to be an important effect modifier when coupled with exposure to air particulate pollution.”

Chen and his group are now gathering results on heart rate and blood pressure changes in these same mice. In ongoing studies, they are also examining specific mechanisms that could link air pollution, diet, and heart disease. In particular, they are trying to better define which components in  $PM_{2.5}$  most likely promote plaque formation and atherosclerosis. —**Rebecca Clay Haynes**

## FOOD SAFETY

## Adding Up to No Good?

The safety of food additives is usually examined by varying the dose of a single additive administered to animal models or cell cultures. However, British researchers at the University of Liverpool and the University of Ulster report in the March 2006 issue of *Toxicological Sciences* that combinations of additives can produce neurotoxic effects at dosages that are safe when each additive is tested alone.

The authors examined four common food additives: Quinoline Yellow (FD&C Yellow No. 10), Brilliant Blue (FD&C Blue No. 1), L-glutamate (the major constituent of monosodium glutamate, or MSG), and aspartame. Quinoline Yellow is banned from foods in the United States, Japan, and Norway; Brilliant Blue was banned from foods in most European countries but has since been reapproved. Coauthor Karen Lau, a doctoral student, says these additives were tested because they are commonly used in foods targeted for consumption by children.

Neurotoxicity was measured by the relative growth of neurites from mouse NB2a neuroblastoma cells after exposure to the additives. Two combinations of additives stunted neurite growth: Quinoline Yellow paired with aspartame, and Brilliant Blue paired with L-glutamic acid. Other

pairings showed no effect. Lau hypothesizes that ingestion of the well-established neurotoxicants aspartic acid and L-glutamic acid as additives could lead to a high enough body burden to kill neurons by a mechanism called excitotoxicity.

Lau says young children may be especially at risk for the type of toxicity observed in the nerve-cell cultures, because effects were seen at concentrations of additives she says are theoretically achievable in plasma by eating foods and drinks typically consumed by children—for example, a snack of corn

chips, which may contain MSG, and a fruit juice drink, which may contain aspartame.

Scientists at the U.K. Food Standards Agency (FSA) question whether these results are relevant to the human consumption of these additives. “[The Lau study assumes] that both MSG and aspartame are absorbed one hundred percent in the gut, but [other studies] show that this does not seem to be the case,” says FSA senior press officer Shaun Whelan. “It is . . . extremely unlikely that the plasma levels predicted by the authors of this study accurately reflect the actual situations *in vivo*.”

Whelan says glutamic acid and aspartic acid occur naturally in many foods, and there is no evidence that they are treated differently in the body when they are ingested as food additives. Lau counters, however, that consumption of glutamic acid in its free form or as MSG has a more dramatic effect on plasma levels than that of glutamic acid in protein, and can lead to high concentrations in the body. More research is needed to clarify these effects.

Other studies have suggested that non-nutritive food additives are associated with behavioral disorders such as attention deficit/hyperactivity disorder. These effects are controversial, but Lau’s team believes their results warrant further investigation of such possibilities. Whelan says the FSA is currently funding research on the effects of ingested chemical mixtures, including color additives, on the behavior of young children. —**Michael Szpir**



**Food blues?** Certain food additives including common dyes may combine to cause toxic effects.

ehpnet

## International Maritime Organization

In 1948 an international conference in Geneva adopted a convention formally establishing what is today called the International Maritime Organization (IMO). The IMO initially worked mainly to ensure maritime safety, but after a 1967 spill of 100,000 tons of crude oil off the southern coast of England, the organization began focusing attention on alleviating the environmental impacts of the shipping industry. Today the IMO has devoted a section of its website at <http://www.imo.org/home.asp> to these environmental programs.

The Marine Environment section, accessible through the menu at the top of the IMO homepage, provides an overview of how the IMO works to regulate and prevent marine pollution by ships, with links to in-depth information on the applicable international treaties. The first such treaty is the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which was adopted in 1973 and modified in 1978. This treaty governs accidental and operational oil pollution as well as pollution by chemicals, packaged goods, sewage, garbage, and air pollution. The 1990 International Convention on Oil Pollution Preparedness, Response and Co-operation calls on parties to establish measures for reporting and handling oil pollution incidents. The IMO also serves as secretariat for the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, which was adopted in 1972.

A list of links on the Marine Environment page leads to other topics of interest. The Ship Recycling page has a detailed overview of the IMO's moves to govern the disassembly and recycling of ships. Although the organization adopted recommended guidelines on ship recycling in 2003, the IMO's senior technical body agreed in 2005 to develop legally binding regulations for the design, construction, operation, and preparation of ships to enable safer and more environmentally sound recycling, along with rules for enforcing the instrument. The Ship Recycling page also has links to an IMO article on ship recycling, to pages on the current guidelines for ship recycling, and to the website for the joint IMO/International Labour Organization/Basel Convention Working Group on Ship Scrapping.

The Prevention of Pollution section has links to pages on specific forms of pollution covered by the conventions that the IMO is responsible for (such as oil pollution, chemical pollution, sewage, and air pollution). These pages provide information on the specific protocols that govern each area, background on the pollution source and the problems it can cause, and details about how the treaties came about. Within this section there is also a page about shipboard pollution prevention equipment required under MARPOL 73/78.

The Ballast Water Management section includes information on the International Convention for the Control and Management of Ships' Ballast Water and Sediments, which was adopted in February 2004, as well as information in seven languages on other IMO guidelines covering this subject. There is also an external link to the site for the Global Ballast Water Management Programme, a partnership between the IMO, the UN Development Programme, and the Global Environment Facility that seeks to help developing countries understand the problem of ballast contamination and prepare to implement the convention. —Erin E. Dooley

## Zayed Prize Winners

In December the Zayed Prize Higher Committee announced the 2005 winners of this recently established international prize for environmental work. UN Secretary General Kofi Annan was honored for his efforts to catalyze global support for sustainable

development. The members of the expert panel of the Millennium Ecosystem Assessment were honored for cataloging the status of the world's ecosystems and the life-sustaining services they provide. Angela Cropper, co-president of the Cropper Foundation of Trinidad and Tobago, and Emil Salim, the former Indonesian State Minister for Population and Environment, were honored for their efforts to effect actual change in environmental policy. The prizes, worth \$1 million apiece, are awarded every two years.



## Testing New Mothers for Toxicants

In fall 2005, the North American Commission for Environmental Cooperation began a continentwide testing program to analyze the blood of 500 first-time mothers for environmental contaminants including dioxins, furans, PCBs, DDT, chlordane, lindane, arsenic, lead, and mercury. The study will give scientists a profile of population exposure to these pollutants and allow them to assess baseline values and potential areas of concern in Mexico. The testing, which is partially funded by the World Bank, will be conducted at 15 sites in Mexico and Canada; pre-existing data will be used for the United States. A report outlining the results of the study is expected in 2006.

## Breathing Easier at School

Now that many state laws allow students to carry asthma and anaphylaxis medications to school and administer these drugs to themselves, the Allergy & Asthma Network

Mothers of Asthmatics has launched a campaign to educate students, parents, health care providers, and school staff about these new laws and to help students

better manage their conditions. The campaign homepage at <http://www.BreatheAtSchool.org/> offers an interactive U.S. map showing state laws on permitting these medications in schools. Visitors can also download free educational materials such as the Allergies and Asthma at School Kit, which guides students and parents in talking to school staff about allergies and asthma.



## NIH Launches Genes and Environment Initiative

The NIEHS and its fellow NIH institutes and centers have joined forces to reveal still more connections between genes, the environment, and human health. On 6 February 2006 Health and Human Services Secretary Mike Leavitt announced that the Genes and Environment Initiative (GEI) would receive \$68 million in fiscal year 2007, a \$40 million increase above the funding already planned for these NIH research efforts. The GEI will seek to speed up research to uncover the genetic roots of common human diseases such as asthma, arthritis, and Alzheimer disease.

"This initiative would not have been possible a year or two ago," said NIH director Elias Zerhouni in an announcement of the initiative's launch. "This is a tangible result of the nation's increased investment in medical research over the past ten years. . . . We stand on the threshold of creating a future that will revolutionize the practice of medicine by allowing us to predict disease, develop more precise therapies and, ultimately, preempt the development of disease in the first place."

The GEI will be managed by a coordinating committee headed by NIEHS director David A. Schwartz and Francis S. Collins, director of the National Human Genome Research Institute.

The proposed federal funding will enable the GEI to perform genotyping studies for several dozen common diseases, which will be selected by peer review. The NIH also expects to invest in and develop four new environmental monitoring tests and devices each year to measure toxicant exposures, dietary intake, and physical activity, and to determine individuals' biological responses to those influences. Eventually these new tools may be applied to population studies to speed up data processing, enhance data accuracy, and reduce costs. The National Center for Biotechnology Information, a part of the National Library of Medicine,

will develop databases to manage the vast amount of genetic, medical, and environmental information that is expected to be generated from the initiative.

At a press conference announcing the GEI, Schwartz said the new monitors will focus on more precise measures of environmental exposure, giving researchers an edge in determining how risk factors interact with specific genotypes to either maintain health or lead to disease. "This is a whole program," he says. "This is a puzzle [of] understanding the relationship between genetic variation and environmental variation, and the more that we can inform environmental variation as the genetic studies move along, the more we'll understand why certain individuals develop disease."

Brenda Weis, senior science advisor at the NIEHS, sees great potential in the new research effort. "It is my belief that the GEI will accelerate the pace of discovery about the role of genes and the environment in the development of human disease," she says. "The GEI builds on the knowledge gained through the Human Genome Project and the HapMap Project, and will provide, for the first time, personalized measures of exposure with the same level of precision as we have for genomic analyses."

-Tanya Tillett

## BEYOND THE BENCH Keeping Kids' Environments Safe

A safe home environment is the first line of defense in protecting children's health. And since many kids spend a great amount of time in schools and child care facilities, safeguarding their health in those places is also essential. The Community Outreach and Education Core (COEC) of the Environmental Health Sciences Center in Molecular and Cellular Toxicology with Human Applications at Wayne State University, in collaboration with the Detroit Head Start and the EPA, has developed the Healthy Homes = Healthy Kids Train-the-Trainer Program to ensure that parents and other caregivers receive information that allows them to create a hazard-free atmosphere for kids. These participants can then pass information along to other parents and caregivers. By training the trainer, the program ensures that a larger number of teachers and caregivers, and ultimately, children can be effectively reached and introduced to the basic concepts of environmental health science.



**Taking better care of kids.** The Healthy Homes = Healthy Kids Train-the-Trainer Program was developed to introduce parents and caregivers to environmental hazards in children's indoor environments and provide them with information on how to avoid such hazards and improve children's health.

Wayne State COEC/Detroit Head Start/EPA

Participants in the workshops are introduced to common household safety issues including toxic heavy metals (such as lead and mercury), indoor air pollutants (such as mold, asthma triggers, and combustion by-products), drinking water quality, food safety, pest control, and poisonous substances (such as medications, perfumes, and dish detergents) that children could mistake for food or drink.

Next, the participants learn about the health effects of these hazards, and are taught healthy practices to follow in the home, available methods for detecting and screening for poisonings, and ways to tap into additional local, state, and national resources. The program also provides hands-on activities for the participants that let them practice reacting to possible hazardous situations, such as finding a child playing with a toxic household cleaner.

The content of each workshop covers about six hours, but can be broken up over several days if needed. Program developers use pre- and post-tests to measure knowledge gained by participants, and also conduct follow-up surveys to gauge the effectiveness of the program and track how much the information is being used by workshop attendees. In addition to hands-on training, the program also provides a poster that highlights the hazards discussed in the sessions and a variety of fact sheets detailing common environmental hazards and prevention strategies. The fact sheets and poster are all available in English, Spanish, and Arabic.

The COEC recognizes the importance of community partnerships in providing effective outreach initiatives, and credits its outreach partners with helping keep the program responsive and successful. Train-the-trainer workshops have been conducted at Head Start in Detroit and the nonprofit Child Care Coordinating Council of Detroit/Wayne County.

“The COEC, through interactions and input from community groups . . . utilizes the scientific knowledge and research of center members to provide assistance to the community through education, prevention, and resource identification,” says COEC project coordinator Lisa Pietrantonio.

Materials for the program are continuously updated as new information becomes available, and new topics are currently being developed. A total of 174 caregivers have been trained so far, and additional training sessions are scheduled for this spring. **—Tanya Tillett**

## Headliners

NIEHS-Supported Research

## Environmental Tobacco Smoke



### Respiratory Effects Linked to Genetic Susceptibility

Wenten M, Berhane K, Rappaport EB, Avol E, Tsai W-W, Gauderman WJ, et al. 2005. *TNF-308* Modifies the Effect of Second-Hand Smoke on Respiratory Illness-Related School Absences. *Am J Respir Crit Care Med* 172:1563–1568.

Children are at special risk for adverse effects from exposure to secondhand smoke (SHS). Estimated population-attributable risks for SHS exposures in children range from 9% for asthma prevalence to 25% for hospital admissions due to lower respiratory symptoms. According to the Third National Health and Nutrition Examination Survey, 43% of children between the ages of 4 and 11 years are exposed to SHS at home. Now NIEHS grantees Frank D. Gilliland, Rob McConnell, W. James Gauderman, Louis Dubeau, Edward Avol, and Kiros Berhane, with their colleagues at the University of Southern California Keck School of Medicine, have shown that children with a particular genetic makeup are at a substantially greater risk for respiratory illness when exposed to SHS.

Using data from the Children's Health Study, the team examined school absences for 1,351 fourth grade students from 27 California elementary schools between January and June 1996. They categorized illness-related absences as being due to nonrespiratory or respiratory illness, then divided the latter into upper respiratory illness (runny nose/sneezing, sore throat, earache) or lower respiratory (wet cough, wheeze, asthma). They also gathered information on the students' health history, including history of asthma, and their exposure to smoking and allergens at home.

The researchers also collected buccal cells from each subject, to determine the student's tumor necrosis factor (TNF)- $\alpha$  genotype. TNF- $\alpha$  is an important cytokine in the inflammatory response to SHS. The *TNF* gene has a common variant in the promoter region G-308A that has been associated with TNF- $\alpha$  expression regulation in some studies.

Students who were exposed to SHS at home had a 51% greater risk of having a lower respiratory illness-related school absence compared with unexposed students. The association was clearest in students who had at least one copy of the variant A allele on *TNF-308*. Students who displayed the AA or AG genotype had a 75% increase in risk of illness-related absences of any kind. Those children possessing the A variant who were exposed to SHS at home had an even more pronounced risk for respiratory illness-related absences, especially absences due to lower respiratory illness. When compared to nonexposed children with the GG genotype, children with the A allele who were exposed to two or more smokers in the home were four times as likely to stay home because of lower respiratory illness.

The researchers postulate that variations in the *TNF* gene might intensify the body's inflammatory response to oxidative stress caused by cigarette smoke. They also note that since a significant number of people are exposed to SHS, future studies should focus on identifying genetically susceptible groups so actions can be taken to reduce their exposure. **—Tanya Tillett**

# PORTS <sup>IN</sup><sub>A</sub> STORM





The volume of global trade has been rising steadily in the past few years, fueled by free trade agreements and migration of manufacturing to destinations in Asia, particularly China. Nearly 90% of global trade is by sea, involving a fleet of 45,000 oceangoing merchant ships. U.S. ports and waterways move almost 99% of the country's international trade by volume and 61% by value, according to *America's*

*Ports Today*, a February 2006 brief from the American Association of Port Authorities.

This group estimates that the volume of cargo American ports currently handle—about 2 billion tons annually—will double over the next 15 years. Chinese ports, too, are seeing a spurt in traffic.

China currently has 1,430 ports and 34,000 docking berths, with a fleet of 210,000 inland and oceangoing vessels capable of handling more than 86 million tons of cargo, according to a 7 December 2005 news report from the official wire agency Xinhua. According to a 6 March 2006 report in *China Daily*, Shanghai is the world's largest freight port and the third largest container port. It handled 443 million tons of cargo and more

than 18 million TEUs (20-foot equivalent units) of containers in 2005.

While ports are major hubs of increasing economic activity, they are also increasingly becoming sources of local and regional pollution. And as nations around the world grapple with the health effects of shipping-related



**Wakeup call.** Ports, long bustling centers of industry, have become centers of pollution as well.



pollution, it becomes apparent that firm regulation is sorely needed.

### Sources of Pollution

For competitive economic reasons, ocean-going vessels typically use the least expensive (and often the dirtiest) fuels available. Large diesel engines propel these vessels, while auxiliary engines provide electric power for navigation, crew support, and other uses. Diesel-driven hauling equipment, trucks, and locomotives unload cargo and then ferry it to faraway inland destinations. Cruise ships idle at ports, adding to the load of diesel emissions and noise pollution.

The composition of diesel exhaust—a complex mixture of combustion products—depends on the type of engine, the speed and load at which it is run, and the composition of the fuel used. Diesel exhaust contains identified mutagens and carcinogens, and diesel exhaust particles are small enough to penetrate to the alveolar region. About 98% of the particles emitted from diesel engines are less than 10 microns in diameter ( $PM_{10}$ ), 94% are less than 2.5 microns in diameter ( $PM_{2.5}$ ),



**The great catch-all.** (left) The Chilean cargo ship *Vicuña* exploded and broke in half while unloading ethanol at a port in Paranaguá, Brazil, in November 2004. Cleanup workers found dead fish and dolphins in the toxic slick of fuel oil, diesel fuel, and methanol that leaked from the ship. (above) Ballast water pours into harbor waters, potentially carrying pathogens, fuel contaminants, and exotic species.

and 92% are less than 1 micron in diameter ( $PM_1$ ). As a result of incomplete combustion, the gaseous fraction also contains pollutants such as carbon monoxide, sulfur oxides ( $SO_x$ ), nitrogen oxides ( $NO_x$ ), volatile hydrocarbons, and low-molecular-

weight polyaromatic hydrocarbons and their derivatives, according to the National Toxicology Program.

As one example of the potential for pollution, the Los Angeles and Long Beach ports of Southern California together are responsible for daily emissions of 128 tons of  $NO_x$ , compared to 101 tons from all 6 million cars in the region, according to California's South Coast Air Quality Management District. Diesel PM emissions from the combined ports were estimated at 1,760 tons per year in 2002 by the California Air Resources Board (CARB).

This is approximately 21% of the total diesel PM emissions in the South Coast Air Basin, an area that includes Orange County and portions of Los Angeles, Riverside, and San Bernardino counties. Of this, 73% was emitted by ships in coastal waters extending 14 to 100 miles offshore from California, while commercial harbor craft accounted for 14% of the total. Other sources were cargo handling equipment (10%), in-port heavy-duty trucks (2%), and in-port locomotives (1%).

A projected tripling in trade at the Los Angeles/Long Beach ports between 2005 and 2020 would result in a 50% increase in  $NO_x$  emissions and a 60% increase in PM from trade-related activities, if no new preventive measures are taken, according to the *Goods Movement Action Plan* released by the California Business, Transportation, and Housing Agency and the California EPA in December 2005. The plan—basically a broad statement of the problem and the state's intention to take action to mitigate it—projects that port-related emissions are likely to account for 20% of total  $NO_x$  emissions in the South Coast Air Basin by 2020.

Emissions from ships engaged in international trade in the seas around Europe—the Baltic, North, Mediterranean, and Black seas, as well as the northeastern Atlantic—were estimated to be 2.6 million tons of  $SO_x$  and 3.6 million tons of  $NO_x$  a year in 2000, according to *Quantification of Emissions from Ships Associated with Ship Movements Between Ports in the European Community*, a 2002 study commissioned by the European Commission (EC). Although emissions from land-based sources are gradually coming down, those from shipping are increasing, the report said.

Dredging is a major cause of water pollution in port environments. Dredging is done routinely to create and maintain sufficient depth for safe navigation by ships. The dredged sediments are usually contaminated by industrial activities occurring in ports and through deposition of upstream sediments loaded with pollutants from other land-based sources.

Oil spills—both accidental and otherwise—also contribute greatly to water pollution. Most water pollution is a result of waste oil dumping, release of oily bilge water, washing of oil tankers (oil residue on hull walls is about 0.5% of the total load, according to the UN Environment Programme), engine operations, and the discharge of grease and oils used to maintain engines and shipboard machinery. Sometimes oily waste is illegally mixed into ship ballast water to avoid port fees. The contaminated ballast is then transferred to treatment plants that are not designed to handle the oily residue.

Ballast water itself is a cause for concern. The Global Ballast Water Management Programme of the International Maritime Organization (IMO) estimates that about 3–5 billion tons of ballast water are transferred internationally each year, often carrying exotic plant species and disease-causing organisms. A similar volume may also be transferred domestically within countries and regions each year. Invasive exotic species can alter the

local ecology, affecting fisheries and threatening endangered species, besides posing a risk to human health by contaminating seafood. Fresh- and saltwater ports bear the brunt of biological invasions introduced by ballast water. Such invasions are exacerbated when exotics spread from freshwater ports into rivers and inland lakes. According to the World Wide Fund for Nature, invasive species like the North American jellyfish in the Black Sea, the mitten crab in Europe, and Asian kelp in Australia have adversely affected commercial fisheries, local species, and marine habitats. [For more on this topic, see “Exotic Invasion,” *EHP* 105:590–593 (1997)].

Still other shipping-related pollution comes from ship-breaking/salvage activities. Out-of-service ships from developed countries are sold to traders for recycling of metal scrap. “Before Bangladesh, China, India, and Pakistan became the world’s leading ship-breakers, vessels were taken apart where they were built: in industrialized countries,” points out Paul

J. Bailey, a senior technical specialist with the International Labour Organization. “But high costs and environmental restrictions have driven ship owners to look elsewhere for a way of disposing of these vessels.”

The number of ships to be broken down will go up in the future, following IMO directives to phase out all single-hull oil tankers for environmental and safety purposes. In Europe alone, an estimated 2,200 ships will go out of service by the year 2010, according to Greenpeace International. About 1,800 ships from North America, Brazil, China, and other parts of Asia will go out of service in the same period.

“Ship-breakers seldom have access to basic personal protective equipment such as hard hats, gloves, and goggles for steel-cutting activities,” says Bailey. “Many are killed and thousands injured working in often torturous conditions. *Titanic*-sized vessels are floated ashore and cut up by workers who are often exposed to deadly toxicants, exploding gases, falling steel



**Herculean task.** Ship-breakers, like these workers near Chittagong, often lack even basic personal protective equipment, and may encounter hazards such as asbestos, toxic gases, and explosions.



**Cargo in, cargo out.** (top) Truckers wait to unload their cargo at the Port of Los Angeles, adding to the burden of diesel exhaust borne by port cities. (above) Hundreds of shipping containers move in a train at the Port of Los Angeles, just one way the cargo is moved inland.

plates, and other dangers.” In the December 2005 report *End of Life: The Human Cost of Breaking Ships*, Greenpeace and the International Federation of Human Rights Leagues estimated that the number of accidental deaths in ship-breaking yards of Alang in India and Chittagong in Bangladesh could exceed 100 every year. Furthermore, ships sent for breaking can contain large quantities of asbestos. Asbestos fibers were found not only at the ship-breaking yards at Alang, but in nearby living quarters, waste dumps, and places of worship. The report cites secondary data to estimate that 25% of workers in Alang will develop cancer.

Noise pollution poses further risks. Like air pollution, noise pollution can affect the cardiovascular system. Some researchers believe that air and noise pollution act synergistically. The EC has begun a project to develop a noise mapping and management system for European ports with the ultimate objective of reducing noise-related annoyance and health problems for people living around ports.

There are two aspects to the noise pollution problem. The first is the noise produced by diesel-run auxiliary engines as ships approach ports and idle at dock. In close proximity to auxiliary engines, noise levels can reach 80–120 decibels (in

comparison, a chain saw averages 110 decibels). Over the past three decades, ambient noise levels in a frequency band consistent with sounds produced by large vessels have increased at a rate of about 3 decibels per decade at a single location off Southern California, according to a study published in the April 2002 issue of *Acoustics Research Letters Online*.

The second aspect is the high level of low-frequency sounds produced by vessels while cruising in the sea. These sounds can travel long distances and may change local acoustic environments, impacting marine mammals that use sound in reproductive interactions and interference with predator/prey detection. In extreme cases, noise pollution may cause habitat avoidance in these animals.

### Air Toxics: A Particular Concern

The growth in trade and resulting increase in shipping is impacting the health of workers and people living in communities near ports and major transport corridors. Air toxics, in particular, are a source of great concern.

Exposure to diesel PM<sub>2.5</sub>, along with secondary particles formed when sulfur dioxide (SO<sub>2</sub>; a form of SO<sub>x</sub>) and NO<sub>x</sub> react with ammonia in the atmosphere, is known to cause or contribute to respiratory diseases, asthma, cardiovascular disease, lung cancer, and premature death. Emissions of NO<sub>x</sub> and reactive organic gases contribute to the formation of ozone, an oxidant that can damage the respiratory tract. In 1998, the State of California listed PM emissions from diesel-fueled engines as a Toxic Air Contaminant.

Current levels of ambient air pollution in Southern California have been linked to clinically important chronic health effects, according to a May 2004 study led by John M. Peters, a professor in the Department of Preventive Medicine, University of Southern California. The report, titled *Epidemiologic Investigation to Identify Chronic Effects of Ambient Air Pollutants in Southern California*, was prepared for CARB and the California EPA. “Our findings demonstrated effects of air pollution on both new-onset asthma and asthma exacerbations. Prior to this study, the prevailing scientific view was that air pollution made existing asthma worse but that it did not cause new cases to develop,” says Peters. “We have shown that air pollution is related to bronchitic symptoms and that asthmatics are more likely to be affected than nonasthmatics.” Evaluation of the longitudinal data implicated nitrogen

dioxide,  $PM_{2.5}$ , and organic carbon as being responsible for the observed effects, he says.

In a study published in the 9 September 2004 issue of the *New England Journal of Medicine*, present Southern California air pollution levels were also shown to cause chronic adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in lung function as the children reach adulthood. These deficits were associated with nitrogen dioxide, acid vapor,  $PM_{2.5}$ , and elemental carbon.

Recent findings suggest that chronic health effects associated with within-city gradients in exposure to  $PM_{2.5}$  may be even larger than previously reported across metropolitan areas. In a study published in the November 2005 issue of *Epidemiology*, researchers reported observing effects nearly three times greater than those seen in earlier studies in which all the individuals within a given metropolitan area were assigned the same level of exposure based on the average ambient concentration observed at fixed points in

that city. In examining specific cause of death,  $PM_{2.5}$  was associated more strongly with ischemic heart disease than with cardiopulmonary or all-cause mortality.

PM in air is also linked with postneonatal mortality, with respiratory causes having the greatest association. An *EHP* study published online 13 January 2006 found a relationship between postneonatal mortality from respiratory causes and long-term exposure to  $PM_{2.5}$  in California (although the study did not specifically address areas affected by port-related pollution, about a third of the infants studied were born in Southern California). Among respiratory deaths, the link was stronger in low-birth-weight infants as well as those with bronchopulmonary dysplasia, as an underlying cause of death. This suggests that these infants and those infants with underlying lung conditions may be at higher risk of ill effects from air pollution.

Elsewhere, other major shipping hubs also are realizing health impacts likely due to marine emissions. In Hong Kong—home of one of the largest container ports

in the world—marine emissions around Kwai Chung port are responsible for 36% of total  $SO_2$  pollution, compared to 6% contributed by local coal-fired power plants. This was one finding that researchers from Hong Kong University of Science and Technology and the University of California, Los Angeles, noted in a 2005 report titled *Significant Marine Source for  $SO_2$  Levels in Hong Kong*. “Since the health risks associated with  $SO_2$  and other pollutants such as  $PM_{10}$  are directly related to the concentration in which they reach sensitive receivers, the significance of the local marine sources is of considerable importance for policies to reduce the health impacts of local air pollution,” the authors wrote. “Yet, most attention has been focused on the power plant, while no controls are being imposed on the quality of fuel oceangoing cargo ships may burn while in port.”

The health risks and impacts due to shipping emissions from Shanghai’s port have yet to be assessed, though researchers have studied the impact of air quality in the city itself. According to an emission



**Cacophony of cargo.** Noise from large vessels approaching harbor and idling at the dock adds to the din of trucks and trains arriving to transport goods. Added to the ambient noise of an urban setting, the cumulative noise can cause health effects among the population living nearby.

Krista Niles/AP

inventory prepared by the Shanghai Environmental Monitoring Center, operations at the Port of Shanghai were responsible for 44,000 tons of  $\text{NO}_x$ , 39,000 tons of  $\text{SO}_x$ , and 6,000 tons of PM in 2003.

“We have developed spatial distribution of emissions, covering internal creeks as well as international lines along the East China Sea [and] Yangtze River,” says Dongqing Yang, a team leader at the center. “Since the air ventilation is so good around the creeks and river, the air quality

in ports is much better than the urban air quality in Shanghai. Though shipping emissions are so heavy, the air impact is not so bad around ports.”

Yang thinks the pollution effect from the Port of Shanghai is not as serious as it is in California, saying, “One major reason is large ports are located along the ocean in the estuary of the Yangtze River and East China Sea, which are far away from populated regions. People living near ports suffer more of noise rather than air pollution.”



**Working to contain the ill effects.** A draft plan by CARB aims to lessen ships' impact on premature deaths in California.

### Understanding the Impacts

In March 2000, the South Coast Air Quality Management District published results of the second Multiple Air Toxics Exposure Study, indicating an overall average cancer risk in the South Coast Air Basin of about 1,400 per 1 million due to diesel emissions. It indicated higher risk levels in industrialized areas such as the south-central portion of Los Angeles County, freeway interchanges, and areas near air- and seaports. Now official agencies are beginning to quantify health impacts of emissions specifically related to port-related activities.

Of the 9,000 premature deaths reported annually in California from ambient levels of ozone and PM pollution, CARB attributes some 8% to emissions from ports and international goods movement, according to the board's *Draft Emission Reduction Plan for Ports and International Goods Movement*. The draft CARB plan estimates cancer risk from diesel PM from all sources to be about 500 to 800 potential cancers per 1 million people exposed over a 70-year lifetime. A number of health effects—including heightened risk of heart disease, adverse birth outcomes, effects on the immune system, multiple respiratory effects, and neurotoxicity—were not quantified in the CARB plan due to lack of accepted burden estimates for those effects.

According to the draft plan, the largest contributors to cancer risk and other health effects are cargo-handling equipment and ships using diesel engines at dock. These emissions result in higher calculated risk due to the emissions' proximity to residential communities. Oceangoing vessels, while under propulsion power, produce far more in the way of emissions but do not result in a comparable cancer risk since their emissions are released many miles offshore. However, these vessels' emissions are still of considerable concern due to their potential for contributing to regional air pollution processes, says Edward Avol, a professor of clinical medicine at the University of Southern California Keck School of Medicine. These processes include photochemical formation of a number of pollutants of health concern, including ozone and PM.

CARB officials have sought peer review of their estimates of health impacts, and have identified areas in health assessment analysis that need revision. These areas include bounding estimates of health impacts of sulfates, ozone health impact assessment, and additional health end points such as chronic bronchitis.



**Seeking solutions in Shanghai.** In December 2005, Shanghai launched operations at the Yangshan deepwater port, a mammoth facility more than 20 miles offshore in the East China Sea. A study of the spatial distribution of emissions in Shanghai's air suggests that placement of ports farther from populated areas decreases the health effects of air pollution.

### Not Yet There

Scientists and action groups feel that CARB's health risk assessments are inadequate and narrow in scope. "It is difficult to measure chronic diseases epidemiologically," says John Froines, a professor of environmental health sciences at the University of California, Los Angeles. "Given the health end points including cancer, cardiovascular disease, neurological, immunological, and developmental disorders, and allergic airway disease including asthma, it will be extremely problematic to accurately assess the true impact of expanded goods movement in coming decades on the health of exposed populations."

The CARB assessment, he says, does not address issues such as occupational exposures, traffic accidents, psychosocial factors associated with travel, noise, and light with their implications for cardiovascular disease. Within air pollution too, the plan has not looked adequately at a



range of end points that are now known to be important, nor has it attempted to quantify risks where the end points are indirect.

Official projections significantly underestimate health impacts, says Diane Bailey, an engineer with the Natural Resources Defense Council. For example, the CARB plan quantifies health impacts of shipping containers as they enter or leave an international facility, while neglecting to assess pollution impacts of

containers traveling inland to distribution centers. "Future health assessments should cover all adverse public health outcomes, a wider array of pollutants known to cause adverse health impacts, and all significant sources known to emit these pollutants," she says. "Other issues that must be discussed and fully incorporated into future analyses are cumulative risk, increased vulnerability of sensitive populations, and risks to exposed workers, besides residential populations."

Meanwhile, the shipping industry has questioned the modeling techniques used to calculate health risks and maintains that CARB's risk estimates are flawed. "There are flaws in the methods used by CARB and in their application. But we want to make it clear that the discussion is over the magnitude of the impacts and not over the fact that there are impacts that need to be reduced," says T.L. Garrett, vice president of the Pacific Merchant Shipping Association. "We have some concerns on the use of modeling methods to diagnose health impacts in a population rather than use of the models to predict relative health benefits resulting from the implementation of control strategies."

### Regulatory and Technology Issues

Health impacts, including cancer risk, have provided evidence for stronger regulations aimed at cutting shipping-related emissions. The CARB plan targets a 20% reduction in diesel PM by 2010 from 2001 levels, which it claims will reduce health risks by 60% or more by 2020. "We estimate that one dollar spent on controls saves four to eight dollars in health costs," says Mike Scheible, deputy executive officer at CARB.

"Over half of PM<sub>10</sub> and PM<sub>2.5</sub>, almost ninety percent of the SO<sub>x</sub>, and over a third of the NO<sub>x</sub> emissions from port operations are traceable to oceangoing vessels," says Avol. "Clearly, substantive reductions in this source category would have a dramatic effect on regional air quality and health effects associated with ambient levels of these pollutants." He adds, "From the perspective of proximity to exposure and potential for noticeable improvements in local community pollution, trucks, rail, and cruise ships are significant port sources of pollution. This is because they are emitting directly in, near, or throughout the immediate community."

In its first major regulatory step to cut shipping emissions, CARB has targeted auxiliary engines on ships. The new rule requires ships to switch over to cleaner-burning fuels in their auxiliary diesel engines and diesel-electric engines once they are within 24 nautical miles of the California coastline. Another new rule targets cargo-handling equipment such as forklifts and cranes, calling for replacing or retrofitting their engines with those using "best available control technology." The new regulations, which come into effect 1 January 2007, are expected to cut diesel PM emissions by a total of 23,000 tons, NO<sub>x</sub> emissions by 15,000 tons, and SO<sub>x</sub> emissions by 200,000 tons by 2020.

"It is a good start to set goals and list possible mitigation measures, but as of yet there is really no plan or strategy," says Bailey. "For example, we need to see commitments to specific details such as mandatory emission reduction measures rather than voluntary incentives for industry. [CARB] needs to be an active regulator of pollution in our ports and with regard to goods movement throughout California."

The shipping industry has its own doubts about the CARB rules. Low-sulfur fuels are technically feasible and are being used by some vessels calling at West Coast ports, but switching of fuels while under way (as required under the new rule for auxiliary engines) raises operational and safety concerns, says Garrett. "The larger issue is, does the state of California have the authority to regulate international shipping beyond its traditional three-mile boundary?" he asks.

The U.S. EPA is working on reducing emissions from propulsion engines on oceangoing vessels. In 2003, the agency adopted emission standards for new Category 3 marine diesel engines installed on vessels flagged or registered in the United States from 1 January 2004 onward. Marine diesel engines differ from other diesel engines in terms of their exhaust, cooling, electrical, and fuel systems. Category 3 engines are large diesel engines used for propulsion power on container ships, tankers, bulk carriers, and cruise ships. These standards will apply until a second tier of standards for deeper emission reductions is developed; these standards should be finalized by April 2007. In the future, these standards may be made applicable to engines on foreign vessels entering U.S. ports. The EPA also intends to eventually set standards for fuels used by marine engines.

The federal agency estimates that these regulations—when fully implemented in 2030—will annually prevent up to 12,000 premature deaths, 15,000 heart attacks, and 6,000 child asthma-related emergency room visits throughout the United States.

Because issues such as engine emissions and fuel standards are international in scope, the IMO is also framing rules for cutting down shipping emissions. In May 2005, an IMO regulation on engine emission standards for NO<sub>x</sub> came into force for engines above 130 kilowatts, in the form of Annex VI of the International Convention for the Prevention of Pollution from Ships. The rule includes a global cap of 4.5% by mass on sulfur content of fuel oil and recommends monitoring of sulfur

content globally. (However, considering that the rolling average of sulfur content globally from 2002 through 2004 was 2.67%, the new cap may be too liberal.) The IMO is also encouraging countries to declare their coastlines as "SO<sub>x</sub> Emission Control Areas" (SECAs), where sulfur content in fuel must not exceed 1.5%. The U.S. EPA is exploring a potential North American SECA.

Under the marine fuel directive adopted by the European parliament in April 2005, all ships in the Baltic SECA and passenger vessels in European Union (EU) territorial waters will have to use fuel with a 1.5% sulfur limit after 11 August 2006. The 1.5% sulfur limit will apply to the North SECA (which includes the English Channel) after 11 August 2007. The sulfur limit will be 0.1% in fuel used by passenger vessels and seagoing ships at berth in EU ports after 1 January 2010. These measures are expected to reduce shipping-related SO<sub>2</sub> in the EU by over 500,000 metric tons a year from 2006.

Besides marine fuel regulation, the EC is encouraging research to assess the economic and technical feasibility of SO<sub>x</sub> and NO<sub>x</sub> abatement technologies such as shoreside electricity, seawater scrubbing, selective catalytic reduction, and the use of humid air motors. The EC also favors fiscal incentives and voluntary measures to encourage the use of low-sulfur fuels and green technologies by ship owners. But even after the implementation of SECAs in Europe, SO<sub>x</sub> emissions from international shipping are projected to grow by 42% and NO<sub>x</sub> emissions to grow by 60% by 2020. By then, emissions from international shipping around Europe will have surpassed the total from all land-based sources in the 25 member states combined, according to the 2005 report *Baseline Scenarios for the Clean Air for Europe (CAFE) Programme*.

Another emission reduction strategy is to cut idling time of vessels and tugboats by providing electric power on shore. The Port of Los Angeles has signed a lease with container terminal operator P&O Nedlloyd that would require the company to use shore power for ships at berth and alternative fuel yard tractors, and possibly employ low-sulfur fuel in vessel main engines. An additional benefit of using shoreside electricity is the elimination of noise and vibration from the auxiliary engines while they are at berth. At Sweden's Port of Göteborg, shoreside power is sourced from wind turbines, thus foiling criticism that the use of land-sourced power is merely switching from one dirty fuel to another.





**Night-owls reduce NO<sub>x</sub>.** The twin ports of Los Angeles and Long Beach have begun operating on weekends and evenings in a new initiative designed to cut freeway congestion and emissions.

Plugging in to onshore power requires retrofitting power systems on ships, and that involves new investments; it may not be economically viable for infrequent visitors. Nearly 20% of the ships visiting California ports will use shore-based power by 2010. This number would gradually go up to 80% by 2020, according to CARB. Avol points out this is only a proposed strategy at the present time, however, and it remains to be seen how realistic it would be in practice.

Reducing the speed of vessels as they approach a port can also help cut emissions. About 70% of ships calling at the ports of Los Angeles and Long Beach participate in a voluntary speed reduction program implemented since 2002. The plan requires ships to reduce their speed from 22 knots to 12 knots or less within a 20-mile radius of the two ports. The strategy is sweetened by a financial incentive; operators qualify for a 15% discounted dockage rate during the following 12 months if 90% of their vessels comply with the 12-knot speed limit for a year.

In the first six months of 2005, speed reduction at the Port of Los Angeles saved 266 tons of NO<sub>x</sub> emissions. The port now plans to extend the limit to 40 nautical miles. Authorities at the Port of Long Beach estimate that if all vessels comply

with the program, the amount of NO<sub>x</sub> produced by container ships would be cut by about 550 tons a year. One potential drawback to this scheme is that if ships are going to take longer to reach their destination ports, it can impact ship schedules.

Recycling of waste oil, oily bilge, and oil-contaminated waste can go a long way toward minimizing oil pollution at ports. In the 2000 report *Green Ports: Environmental Management and Technology at U.S. Ports*, researchers at the University of Massachusetts Boston Urban Harbors Institute recommended that ports provide facilities for oil collection and recycling that are easily accessible and inexpensive. Oil-dispensing facilities at ports can be encouraged to buy back used oil for recycling. Runoff from parking areas and roads that pick up oil and other wastes from land can be controlled quite effectively through filtration devices such as porous pavements, soak-away pits, and dry wells.

Main issues that need to be resolved to check shipping pollution are international and national consensus on fuel quality, emission standards, and a time frame for adoption as well as for onshore power systems. There is a need to enforce the same for other contributors to diesel emissions—cargo-handling equipment, trucks,

and locomotives. For this exercise to succeed, engine makers and oil companies also need to be involved.

In many parts of the world, shipping-related emissions have already exceeded or are projected to exceed those from land-based sources in the next few years, if no reduction measures are taken. Shipping emissions can be cut substantially by deploying some of the same technologies and fuels used for cutting emissions from land-based mobile and stationary sources. But doing so poses major economic, legal, and infrastructural challenges.

The emission reduction strategies currently on the table revolve around cleaner engines, cleaner fuels, exhaust control methods, and operational programs. And a variety of mechanisms are being explored or have been proposed to implement these strategies. The feasibility of these mechanisms is being tested at various ports with varying degree of success. What is needed is expedited decision making at all levels, from IMO to port city authorities, to ensure that our ever-increasing need to trade, transfer, and transport various things around the globe doesn't leave all of us stranded on an environmental ship of fools.

**Dinesh C. Sharma**



# Unfair Trade

## e-Waste in Africa



**Bad reception.** A boy hauls electronic waste from the Alaba Market in Lagos, Nigeria, to a nearby informal dump sitting atop a swamp. Imported televisions and computers that cannot be repaired get deposited here, and later burned.

©Basel Action Network, 2005

The bright and dark sides of Africa's information technology sector are both evident at the Ikeja Computer Village, near Lagos, Nigeria. Thousands of vendors pack this bustling market, one of three major hubs where imported used electronics are repaired and sold. Computers, fax machines, cell phones—if you want one, you can find it here, spruced up and ready to buy. But beyond the thriving storefronts and the piles of refurbished wares, a darker picture emerges. Up to 75% of the electronics shipped to the Computer Village are irreparable junk, according to the Computer and Allied Product Dealers Association of Nigeria, a local industry group. Nigeria has a thriving repair market, but no capacity to safely deal with electronic waste, most of which winds up in landfills and informal dumps. That's a problem, because this “e-waste” can be toxic: much of it is loaded with potentially toxic metals including lead, cadmium, and mercury. What's more, electronic components are usually housed in plastic casings that spew carcinogenic dioxins and polyaromatic hydrocarbons when burned.

## Emerging Dumping Grounds

Hungry for information technology but with a limited capacity to manufacture it, Africa has become the world's latest destination for obsolete electronic equipment. Much of this material is more or less functional and provided in good faith by well-meaning donors. But the brokers who arrange these exports often pad shipping containers with useless junk, essentially saddling African importers with electronic garbage. In 2002, the Basel Action Network (BAN), a Seattle-based environmental group, made headlines with its investigation of e-waste exports to Asia [see "e-Junk Explosion," *EHP* 110:A188–A194 (2002)]. More recently, BAN explored Africa's e-waste problem, and described its findings in an October 2005 report titled *The Digital Dump: Exporting Re-use and Abuse to Africa*.

BAN coordinator Jim Puckett, who visited Nigeria as part of that investigation, saw enormous piles of e-waste throughout the countryside, much of it routed through Lagos, Africa's largest port. "We saw people using e-waste to fill in swamps," Puckett recalls. "Whenever the piles got too high, they would torch them. . . . Residents complained about breathing the fumes, but the dumps were never cleaned up. We saw kids roaming barefoot over this material, not to mention chickens and goats [which wind up in the local diet]."

Puckett says the dumps near Lagos could be the tip of an iceberg. No one knows for sure because there are virtually no data concerning the global e-waste trade—harmonized tariff schedules that dictate fees for export commodities don't assign codes to waste electronics other than batteries. There are tariff classifications for scrap (e.g., plastic, metal) and for new electronics by type (e.g., computer monitors, TV sets). Because the importers don't want to pay tariffs on a five-year-old computer based on the price of a new one, they often use scrap classifications, measured in pounds, says Robin Ingenthron, acting president of the World Reuse, Repair and Recycling Association (WR3A), a nonprofit group trying to establish fair trade standards for the practice. Consequently, the volume, characteristics, and destinations of e-waste exports are shrouded in mystery.

BAN's investigation—among the first of its kind in Africa—was limited to areas near Lagos, followed by a week-long foray into neighboring Niger, a landlocked country. Based on BAN's firsthand observations and other anecdotal reports, Puckett now believes e-wastes are passing

through African port cities that, in addition to Lagos, include Mombasa, Dar es Salaam, and Cairo. Puckett didn't encounter e-waste in Niger and speculates that this is at least in part because the inland country has no port.

An estimated 500 shipping containers loaded with secondhand electronic equipment pass through Lagos each month, BAN's investigation found. Each container can be packed, on average, with a load equal in volume to 800 computer monitors or central processing units (CPUs), or 350 large TV sets. Local experts cited by BAN estimate that anywhere from 25% to 75% of this material is useless. Assuming the low end of this range, one could hypothesize that volumes of e-waste equal to 100,000 computers or CPUs, or 44,000 TV sets, enter Africa each month through Lagos alone.

## The E-Waste Trade

Why do African importers pay for electronic junk they can't sell? If the contents of shipping containers are purchased by weight, not by the combined value of what's inside them, then waste can be transported by "averaging" the load. It costs an average of US\$5,000 to ship a 40-foot container full of used electronics from the United States to Africa, according to Jim Lynch, senior program manager for computer recycling and reuse at CompuMentor, a San Francisco-based nonprofit organization. Once there, some of this equipment can fetch a high price: Olayemi Adesanya, BAN's logistical coordinator in Nigeria, says a functional Pentium III computer sells for about US\$130 on Nigerian markets, while a working 27-inch TV might sell for US\$50. (Scrap components—especially working hard drives—can also be readily sold in Nigeria to supply an emerging reassembly industry.) Therefore, it doesn't take many working units to cover shipping costs. Indeed only 40 good Pentium III computers pays for an entire container, leaving a comfortable margin for profit even if the container is loaded with mostly unusable waste.

The question of who's selling e-waste to Africa is harder to answer. Used electronics travel murky routes populated by numerous recyclers and brokers working in an unregulated market, devoid of government certification programs. Electronics recyclers are at the top of the supply chain. These companies incur tremendous overhead expenses—to recycle a single monitor in the United States, for instance, can cost up to \$15.

Many recyclers run legitimate operations that absorb these costs and profit from refurbished equipment sales and fees charged for accepting old, unsalable material. But others are not so scrupulous. According to one anonymous recycler, it's not uncommon for companies to coordinate with exporters to ship junk overseas. In some cases, exporters negotiate with buyers in developing countries, who dictate the amount of junk they will accept in exchange for a specified number of high-value items. "I could come up with half a load of good stuff and say, 'If you want it, you have to take the bad,' and sell it all by the pound," the recycler says. "Then the guy in Africa will crunch the numbers and say, 'OK, if you put a few more Pentium IIIs in there, you've got a deal.'"

In other cases, the recycler adds, the deals are less defined—exporters simply load containers with junk, and sell it by the pound to inexperienced buyers who don't know to negotiate content from the outset. These cases are rare, however, and buyers stuck with containers full of worthless junk aren't likely to make the same mistake again, he says.

By the same token, says Ingenthron, some inexperienced exporters might unwittingly send a Cisco router worth \$15,000 in a container load of "mixed electronics." The WR3A refers to loads like those as "lottery tickets."

Ingenthron stresses that not all waste exports are bad. Asian importers, for instance, can sell working cathode ray tubes (CRTs), which contain up to four pounds of lead each, to electronics manufacturers who use them to make new products. Other importers may purchase broken CRT glass to be manufactured into new CRTs. "If you have containers full of cleaned, processed broken CRT glass going to Asian CRT furnaces, that's good for the environment," he says. "Otherwise, you have to mine for the metals."

Asia does, in fact, have a thriving electronics recovery industry that supplies manufacturers with recycled raw materials. While the practice does have its benefits, as noted above, it also exploits women and child laborers who cook circuit boards, burn cables, and submerge equipment in toxic acids to extract precious metals such as copper. BAN documented these practices, which have dire health and ecological consequences, during its 2002 and 2004 visits to China. However, BAN investigators didn't witness this type of activity in Nigeria. Puckett speculates this might be because waste volumes there aren't yet high

enough to realize profits from recovery. In that case, he suggests, it could be just a matter of time before the same hazardous e-waste extraction methods observed in China emerge in the Lagos street economy.

### Stemming the Tide

Numerous efforts to limit the flow of e-waste to developing countries are under way even as export volumes continue to grow. For its part, BAN has pushed for U.S. ratification of the Basel Convention, an international treaty drafted in 1989 that aims to prevent hazardous wastes from being dumped in the developing world (wastes exported for reuse and recycling are allowed under the treaty, however). The United States is one of the few countries in the world that have not yet ratified the convention. As it stands now, e-waste exports from the United States are illegal only



recyclable materials will be managed in an environmentally sound manner." No release date for the program was provided.

Meanwhile, a number of voluntary e-waste export reduction efforts are under way in the United States. In 2003, the EPA created the "Plug-In To eCycling" program, which promotes safe domestic recycling of electronic equipment by consumers and businesses. BAN has produced a document it calls the "Electronic Recycler's Pledge of True Stewardship," which can be signed by companies that promise not to send e-wastes to landfills, incinerators, or developing countries. And the WR3A has developed a new "e-certification program" to help e-waste generators find recyclers who can process their deliveries in an environmentally sustainable way.

All these programs have their work cut out for them—the electronics industry thrives on obsolescence. Computers, cell phones, and other gadgets go out of date quickly, sometimes within months of release. Indeed, e-waste is now considered the fastest growing segment of the municipal waste stream in the United States. But the United States is also



**Lots of trash, very little treasure.** (above) Thousands of Nigerians are involved in repairing and reselling imported used electronic equipment. Unfortunately, much of the imported electronics cannot be repaired and are instead dumped and burned. (left) Brominated flame retardants and heavy metals in plastics can yield toxic emissions when casings are incinerated.

Despite repeated inquiries, the EPA would not elaborate further on the U.S. position regarding e-waste

exports and their associated environmental impacts, except to say the agency has for several years negotiated with the Organisation for Economic Co-operation and Development on a program that will provide "greater assurance that exports of

weak in legitimate repair and reuse, discarding items that represent real income for educated repairpeople in other countries. And Africa, with its own economy dependent on the leftovers, is left picking through electronic trash. "There's just a lot more junk going to Africa now," Ingenthron says. "In Asia, the buyers tend to know more about the material than the sellers. But in Africa, it's the other way around."

**Charles W. Schmidt**

under the Resource Conservation and Recovery Act, and within that law, only if the exports wind up disposed of overseas. As long as the export goal is "recycling," U.S. shippers can legally send e-wastes wherever they wish.

# Safe Harbor

Protecting Ports with Shipboard Fuel Cells



**Cleaner cruising.** A rainbow arches over the guided missile destroyer USS *Gonzalez* (DDG 66) as it pulls into the Port of Mombasa, Kenya. The U.S. Navy is one of several groups investigating the use of fuel cells in its fleet. Fuel cells offer the advantages of being less polluting and quieter than diesel engines.

In September 2005, the city of Los Angeles announced a mandate to cut the air pollution from its harbor. The head of the city's harbor commission, S. David Freeman, gave the port managers a sobering direc-

tive: "Start acting like our lives are depending on it," he told them, according to the 29 September 2005 *Los Angeles Times*, "because our lives do depend on it." Three months later, the California Air Resources Board adopted rules that require ships within 24 miles of the state's coast to reduce diesel emissions to 2001 levels within the next four years. These developments have shippers scrambling to find a way to cut emissions. One of the main technologies attracting their attention is the use of fuel cells.

### The Full Import

Each year, the Port of Los Angeles—occupying 7,500 acres and 43 miles of waterfront—handles more than 162 million metric revenue tons of cargo (measured as 1,000 kilograms or 1 cubic meter, whichever is larger). With the increase in Pacific commerce, port diesel emissions have increased 60% since 2001, and the port complex has in 10 years become the single largest air polluter in the Los Angeles basin, according to the 25 September 2005 edition of the *Los Angeles Times*.

Nearby residents blame the port for illnesses ranging from asthma to cancer, according to Diane



Wes Epley/U.S. Navy

Bailey, head of the Health and Environment Program for the Natural Resources Defense Council (NRDC) in San Francisco. Studies have linked particulate matter from diesel fumes to respiratory illness and cancer.

In an August 2004 report titled *Harboring Pollution: Strategies to Clean Up U.S. Ports*, the NRDC noted that besides direct threats to human health, growing harbor traffic could increase regional smog, threaten water quality and public lands, and increase noise and light pollution. With three of the country's five largest harbors in California, Bailey says, cutting port pollution and the health impacts on surrounding communities is a "huge priority" for the state.

The source of most ship-related emissions is Bunker C fuel, a diesel that produces a thick, sticky residue. (Bunker C gets its name from the era when steamships were fired by coal stored in bunkers. When ships shifted to diesel, crews still used the term "bunker" to include liquid fuel tanks.) Ships in port can also use a kind of extension cord plugged in to land power supplies, but Scott Samuelsen, director of the National Fuel Cell Research Center at the University of California, Irvine, says these cords can be somewhat dangerous if they get tangled during loading or unloading. Therefore, most ships in port use diesel engines to provide "hoteling" power—basic lighting, heating, ventilation, and light electricity.

### The Beauty of Fuel Cells

Fuel cells are cleaner than diesel turbines and other internal combustion engines. Samuelsen explains that fuel cells convert energy from hydrogen directly to electricity without combustion; the only residues are water and heat.

A fuel cell works using the same electrochemical reaction as the battery under a car hood, Samuelsen explains. But whereas the battery in your car primarily stores energy while the engine is turned off, a fuel cell reaction provides energy continuously as hydrogen fuel encounters oxygen. Compared to internal combustion, says Samuelsen, "the fuel cell is more of a one-stop shop, one reaction." And with fewer moving parts, there's the prospect of reduced maintenance.

The NRDC recommended fuel cells as a quieter, cleaner, more efficient power source for ships in *Harboring Pollution*. Since the report appeared, Bailey says other technologies have gained momentum, at least in the short run. Among them are diesel-electric hybrids, more efficient versions of the



**Hot box.** The 625 Molten Carbonate Fuel Cell Reformer System (fuel cell stack is out of view) produces methane from high-sulfur logistics fuel to power the fuel cell stack with an expected efficiency of 47–50%. The system is being land-tested by the Office of Naval Research, and will be installed at the Naval Sea System Command's engineering facilities in Philadelphia in 2007 for extended testing.

locomotive engine, which can cut emissions by 90% compared with the old diesel engines used to assemble freights in port rail yards. Another alternative is the gas turbine engine, which has strong marketplace advocates.

In Los Angeles, though, says Samuelsen, "the fuel cell will probably be the preferred choice." He adds that California's regulatory action will likely point the direction for maritime energy use elsewhere. As in the drive toward greater fuel efficiency in automobiles, Samuelsen suggests, the state's regulatory process will likely drive national technological advances.

### Contemplating Naval Studies

The U.S. Navy has been exploring shipboard use of fuel cells for some time,

according to Anthony Nickens, a program officer with the Office of Naval Research (ONR) in Arlington, Virginia. Nickens says the Navy is very interested in the technology for its efficiency and low emissions. "There's no [nitrogen oxide emissions] coming out, there's no flame," he says. Fuel cells also permit a "distributed" power system design; they can be located at different points in the ship, away from the ship's principal exhaust stack system, unlike conventional power-generation and propulsion engines. This flexibility can improve ship survivability in the event of an accident or enemy attack, according to an ONR press release from February 2004.

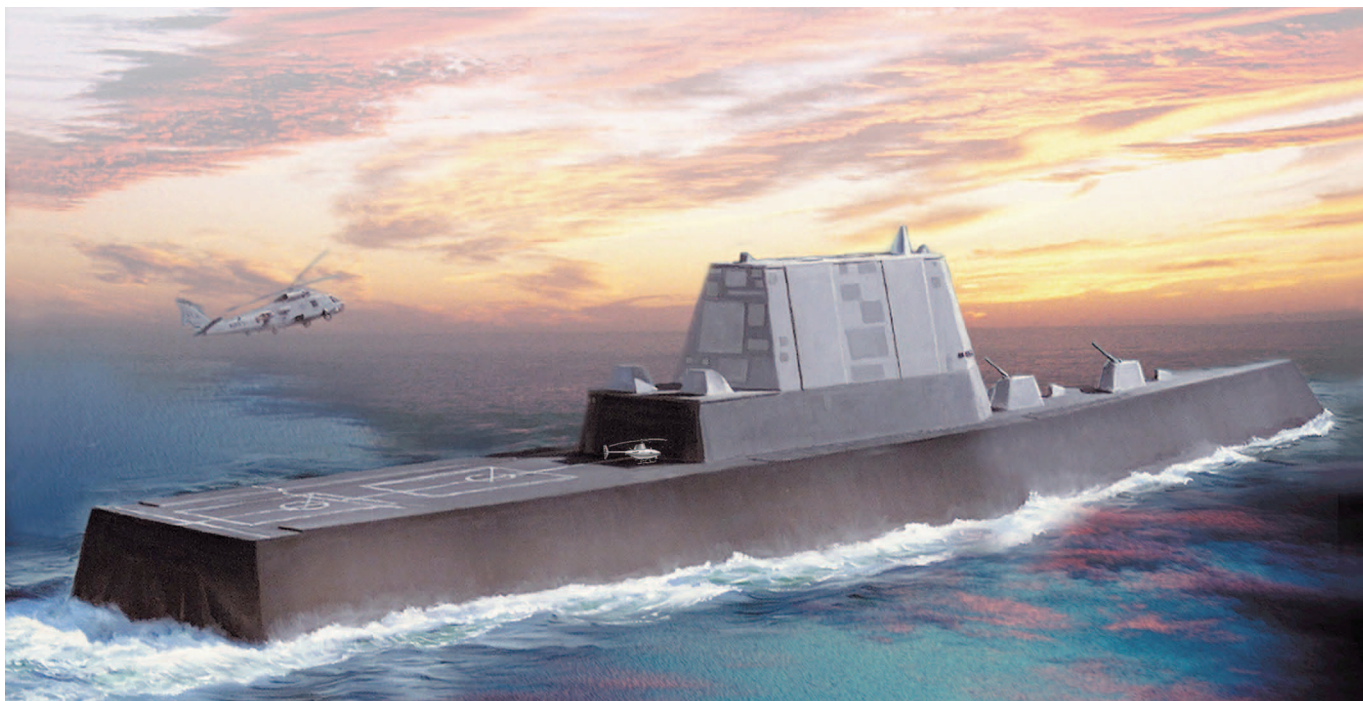
So far, fuel cells are still in a demonstration phase supervised by ONR's science and technology staff. "I think we can get there in five, seven years," says Nickens of the Navy's plans for fuel cell-powered vessels. One demonstration for the Navy by Sandia National Laboratories and Plug Power, a company based in New York, was completed in August 2005. The project tested 20 fuel cells at naval support sites in California, New York, and Hawaii, and proved their ability to provide heat and power for land-based functions. Abbas Ali Akhil, Sandia's energy analyst on the project, says a final report on that demonstration will be completed later this spring. Meanwhile, test results from locations in three states are available at the Sandia website [see Suggested Reading below].

Steven Eschbach, director of investor relations and communications for FuelCell Energy, based in Danbury, Connecticut, says his company, too, has been working for several years to provide the Navy with a land-based demonstration of shipboard fuel cells for providing hoteling power to stealth destroyers. Eschbach says the silence of fuel cells is an important benefit for stealth destroyers, but it also helps that these power

## Suggested Reading

- Bailey D, Plenys T, Solomon GM, Campbell TR, Feuer GR, Masters J, et al. 2004. *Harboring Pollution: Strategies to Clean Up U.S. Ports*. New York, NY: Natural Resources Defense Council. Available: <http://www.nrdc.org/air/pollution/ports/ports2.pdf>.
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- National Fuel Cell Research Center, University of California, Irvine. Fuel cell information [website]. Available: <http://www.nfrcr.uci.edu/fcresources/index.htm>.
- Sandia National Laboratories. Navy fuel cell demonstration sites [website]. Available: [http://www.sandia.gov/fuel\\_cell/index.htm](http://www.sandia.gov/fuel_cell/index.htm).





**Picturing the future fleet.** Artist's concepts of two potential ships that may use fuel cells in the not-too-distant future: (above) a design by a Northrop Grumman Corporation–led team of the U.S. Navy's 21st century surface combatant, and (right) Calá Corporation's fuel cell–powered luxury cruise ship.



sources are more efficient (47% electrical efficiency—the portion of total energy in the reaction that is translated into usable electrical power—compared to 30–40% for diesel engines) and 99% cleaner, especially in terms of nitrogen oxide, sulfur oxide, and particulate emissions. The company is currently testing peripheral components of the fuel cell power plant and will soon integrate those with a fuel cell stack for complete system verification.

Another key advantage to the fuel cell approach is that the hydrogen needed for the electrochemical power generation is internally purified in the fuel cell module. “We don’t need a hydrogen infrastructure for our fuel cells to operate,” Eschbach says. The company plans to continue testing this spring, followed by delivery of the fuel cell system later this year pending funding from the Navy.

The German Navy also is exploring fuel cells and in October 2005 commissioned two new fuel cell–powered submarines from Siemens KWU, according to a 23 January 2006 report by the online industry publication *Fuel Cell Today*. The Siemens model uses a solid polymer electrolyte membrane (PEM) fuel cell to direct hydrogen ions to a cathode for reaction with oxygen inside a pressurized housing. PEM cells, operating at temperatures less than 80°C, are reportedly 60% efficient,

according to *Fuel Cell Today*.

### Commercial Applications

For commercial ships, Samuelsen expects to see design prototypes in about five years, spearheaded by one or two shipping companies that pave the way. He also expects the shift to be gradual, with “a few decades before the momentum grows,” he says. After all, the new laws dictate reduced ship emissions, but they don’t dictate fuel cells as the only way to get there.

For cruise operators wanting to spotlight an environment–friendly fleet and give passengers a quieter cruise experience, fuel cells may be especially appealing. Calá Corporation, a cruise line operator based in Titusville, Florida, has plans to build three cruise ships equipped with fuel cells, says CEO Joseph Calá. The fuel cells will provide hoteling power for electricity as well as power at low speeds (under 8 knots). Calá expects the first vessel to be ready by 2008. Each will be equipped with about 20 cells providing 500 kilowatts apiece. Calá estimates that the cells will save perhaps \$1 million in fuel each year. Cruising at 16 knots, he says a ship can burn up to \$35,000 in fuel a day.

Calá, who became interested in fuel cells’ promise 12 years ago, maintains that nautical

engineers aren’t moving fast enough in furthering the technology. “They need to bring in people with vision,” he says. “They need to expand their minds and imagination.”

Several technical challenges remain, notes John Weidner, a chemical engineering professor at the University of South Carolina. Unlike other forms of energy, fuel cells don’t offer economies of scale for making the large units needed for ships. This is due to the simplicity of the fuel cell chemical reaction. There are no moving parts you can accelerate for a bigger bang; the energy output is strictly related to the size of the cell. “You can make them big, but if you make it ten times bigger, it costs ten times as much,” says Weidner. Furthermore, in some applications, durability of the fuel cell’s electrolyte is still an issue. For some types of fuel cells, including molten carbonate cells, the high temperatures involved decrease cell life.

Despite these challenges, the technology is promising for maritime use. As more research comes online, we can likely expect to see fuel cells surging full steam ahead.

**David A. Taylor**

## Ozone Overload

### Current Standards May Not Protect Health

Ozone is a common urban pollutant that has been linked to health effects such as reduced lung function, increases in respiratory symptoms, and development of asthma. Now a team of researchers reports that ozone may pose a danger to human health even at levels far below the limits set by current U.S. and international regulations [*EHP* 114:532–536; Bell et al.]. The team conducted a study of 98 U.S. urban communities between 1987 and 2000 to investigate whether there is a threshold below which ozone does not affect mortality, and report that they were unable to identify such a threshold.

More than 100 million Americans live in areas that exceed the EPA's National Ambient Air Quality Standard (NAAQS) for ozone of 80 parts per billion (ppb) ozone averaged over a peak 8-hour time period. The EPA is currently reviewing scientific evidence to determine whether that NAAQS should be revised in order to meet the 1997 Clean Air Act's goal of protecting human health with an adequate margin of safety.

The researchers embarked on this project to better identify that margin. Data were gathered from the National Morbidity, Mortality,



**Smog alert.** A new study was unable to identify a threshold below which ozone no longer affected premature mortality.

and Air Pollution Study, a project launched in 1996 to address questions about the degree to which particulate matter is responsible for changes in daily mortality rates. They also used ozone data from the EPA and weather data from the National Climatic Data Center. Then they applied a Bayesian hierarchical model to mortality data from the National Center for Health Statistics to evaluate the relationship between ambient ozone levels and mortality rates within each community over a 14-year period.

The key finding of their research is strong and consistent evidence that daily increases in ambient ozone exposure were associated with daily increases in premature mortality. This was true even at very low pollution levels, including an idealized scenario in which every community always met current ozone regulations. In that scenario, each daily 10-ppb increase of 8-hour ozone was associated with a 0.30% increase in mortality.

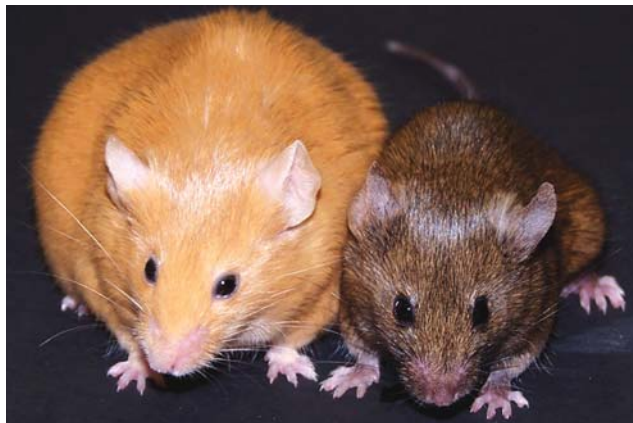
"All results indicate that any threshold would exist at very low concentrations, far below current U.S. and international regulations and nearing background levels," the authors write. They conclude that any reduction in ambient ozone levels, such as through transportation planning in urban areas, could be expected to yield important benefits to public health, even in areas that already meet current regulatory standards. —Richard Dahl

## Color by Soy

### Genistein Linked to Epigenetic Effects

There is substantial evidence that a pregnant mother's exposure to environmental substances can affect her young. Now researchers have uncovered the first direct evidence that maternal exposure to a phytoestrogen in soy can cause lifelong epigenetic changes—that is, changes in gene activity from processes other than changes in the DNA sequence—in mouse offspring [*EHP* 114:567–572; Dolinoy et al.]. If the findings hold up, there eventually could be repercussions in several important arenas, including recommendations about what pregnant women and infants should eat.

The researchers made their observations in genetically identical yellow mice. The mothers in the test group ate a diet modified to include a concentration of genistein typical of what people eating a



**Telltale traits.** Differences in the size and color of offspring are epigenetic effects of genistein consumption (via a high-soy diet) by mouse moms.

high-soy diet would consume, while the control group mothers ate the same food without the genistein. The diets began two weeks before mating and continued through pregnancy and lactation. At 21 days after birth, the offspring were weaned to a stock maintenance diet, which they ate for the rest of the study period.

The researchers assessed offspring coat color and body weight, traits that can vary with methylation (a mechanism in which methyl groups attach to DNA where cytosine bases occur consecutively). The offspring exhibited wide color differences, ranging from yellow to brown, with varying degrees of mottling in between. The researchers found that these differences corresponded closely with methylation in a DNA region upstream of the offspring's *Agouti* gene, which determines coat color. The 44 genistein-fed offspring were more than twice as likely as the 52 controls to have brown fur and to have much higher methylation, while they were only one-third as likely to have yellow fur and much lower methylation. Animals that had a blend of yellow and brown fur had progressively increased methylation as brown became more dominant.

For weight gain, the brown mice showed by far the least propensity to become overweight. The other groups, with yellow or various combinations of yellow-brown fur, had roughly the same trend toward becoming significantly overweight. The researchers also found that methylation was evident in many parts of the body, including the brain, liver, kidney, and tail.

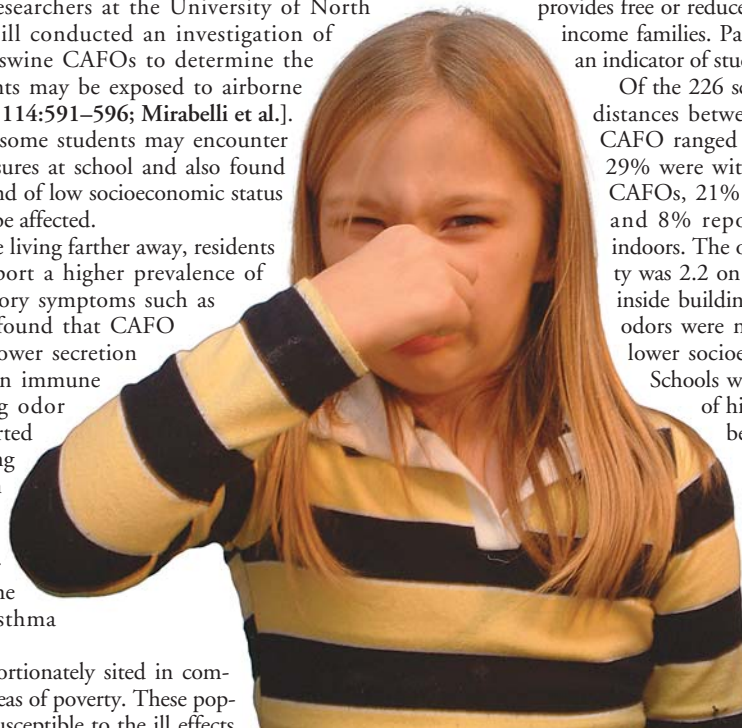
The team speculates that the ability of genistein to increase DNA methylation provides a plausible explanation for the lower incidence of certain cancers in Asians compared to Westerners. Nevertheless, the pathway by which these changes occurred suggests there could also be significant adverse interactions between genistein and common dietary supplements such as folic acid, which is added to many foods and recommended for pregnant women. Soy-based infant formulas might also be a concern because of the high levels of genistein present in these products. More research is needed to determine if these worrisome possibilities are correct. —Bob Weinhold

## Hogging the Air CAFO Emissions Reach into Schools

Confined animal feeding operations (CAFOs) can pollute the surrounding air with malodorous compounds, bacteria, fungi, and endotoxin. CAFO-related health impacts have been investigated primarily in adults, but children may be at greater risk because of their size and developmental stage. Since children spend considerable time at school, researchers at the University of North Carolina at Chapel Hill conducted an investigation of schools' proximity to swine CAFOs to determine the extent to which students may be exposed to airborne CAFO emissions [*EHP* 114:591–596; Mirabelli et al.]. They determined that some students may encounter CAFO-associated exposures at school and also found that students of color and of low socioeconomic status were the most likely to be affected.

Compared to people living farther away, residents living near CAFOs report a higher prevalence of headaches and respiratory symptoms such as coughing. One study found that CAFO neighbors experience lower secretion and concentration of an immune system protein during odor episodes; another reported livestock odor as having a negative impact on adult levels of tension, depression, and anger. For children, the closer they live to a CAFO, the greater their risk of asthma symptoms.

CAFOs are disproportionately sited in communities of color and areas of poverty. These populations may be more susceptible to the ill effects of airborne exposures owing to existing health challenges such as higher-than-average disease rates and inadequate health care access.



**Sniffing out inequalities.** New data show that minority and lower-income students are most likely to encounter odors from swine feedlots near schools.

The study findings are based in part on the geographic locations of swine CAFOs and 339 public schools in North Carolina, a state with significant hog, cattle, and poultry industries. Additionally, personnel from 267 schools completed a 21-item survey that included questions about the frequency and intensity of livestock odors in the schools' indoor and outdoor environments. Publicly available records detailed schools' racial and ethnic composition and the proportion of students participating in the National School Lunch Program, which provides free or reduced-price meals to students from low-income families. Participation in the program served as an indicator of students' socioeconomic status.

Of the 226 schools included in the final analysis, distances between a school and the closest swine CAFO ranged from 0.2 to 42.0 miles. Of these, 29% were within 3 miles of one or more swine CAFOs, 21% reported livestock odors outdoors, and 8% reported noticeable livestock odors indoors. The overall average rating of odor intensity was 2.2 on a scale of 1 to 5; the average rating inside buildings was 2.8. Schools with noticeable odors were more likely attended by students of lower socioeconomic status, regardless of race.

Schools with more white students or students of higher socioeconomic status tended to be farther from a swine CAFO.

Although the researchers did not characterize the composition of swine CAFO-associated air pollution or identify specific health-related effects, they conclude that livestock-related odors in and around schools may indicate the presence of hazardous airborne contaminants from nearby CAFOs. Their results confirm and expand previous research describing racial and economic disparities in exposure to CAFO emissions.

—Julia R. Barrett

## One Less Lead Link? Exposure–Hypertension Association Not Replicated in Young Children

For two decades, scientists have known that lead exposure can induce hypertension in lab animals. More recent studies suggest it might also promote hypertension in adults. But little was known about the metal's effects on blood pressure in children. Now researchers who studied 780 lead-exposed children for five years report seeing no indication that lead raises blood pressure in young children [*EHP* 114:579–583; Chen et al.].

Lead's most widely documented effects are neurological. Exposure diminishes intelligence and alters behavior. Young children are particularly vulnerable to these effects because their nervous systems are still developing. Children are exposed primarily through paint particles in household dust and outdoor soil contaminated with lead from paint and industrial and motor vehicle emissions. Lead exposure in the United States plummeted after the 1978 ban on lead paint, when the CDC reported that 88% of children aged 1 through 5 had blood lead levels above the level of concern of 10 micrograms per deciliter ( $\mu\text{g}/\text{dL}$ ). By 2000, that rate had dropped to 2.2%.

The researchers originally set out to determine whether treatment with the oral chelating agent succimer would improve

lead-exposed children's scores on behavioral and cognitive tests. They recruited 780 children at clinics in Baltimore, Cincinnati, Philadelphia, and Newark. All were between 12 and 33 months of age and had moderately high blood lead levels of 20–44  $\mu\text{g}/\text{dL}$ . Succimer was given to 396 children in the randomized, double-blind study. The remaining 384 children were given a placebo.

Succimer lowered blood lead levels dramatically, but there was no change in test scores. So the researchers opted to examine the data for blood pressure changes.

Clinicians had measured the children's blood pressure every time they tested blood lead—immediately before the study and 7, 28, and 42 days after the start of each of three 26-day rounds of treatment. Measurements also were taken every three to four months for five years following treatment.

The only difference noted was a 1-mmHg increase in systolic blood pressure between one and five years after treatment—but only in the succimer group. The researchers considered this change insignificant. Diastolic pressure remained unchanged for both the succimer and placebo groups.

The team acknowledges that lead exposure might still cause hypertension years or even decades after exposure. This, combined with lead's known neurological effects, renders the metal an important contributor to the global burden of disease. —Cynthia Washam