ehp
ENVIRONMENTAL HEALTH PERSPECTIVES
AUGUST 2006
ehponline.org/science-ed

Making Sports Green

Cleaner Air and Water on the Fly

Getting the Lead Out

NIEHS
National Institute of Environmental Health Sciences

PUBLIC HEALTH SERVICE
U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES
NATIONAL INSTITUTES OF HEALTH
NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES
NIH PUBLICATION 2006-218

STUDENT EDITION

The minute you start talking about what you're going to do if you lose, you have lost.
George Schulz, U.S. Secretary of State

DRINKING WATER QUALITY

Taking the Lead and Copper Rule to Task

When testing in 2003 found higher-than-allowable lead levels in the District of Columbia's drinking water, it hit awfully close to home for some law makers, prompting three U.S. legislators to direct the Government Accountability Office (GAO) to evaluate how well the EPA regulates lead levels in drinking water. In January 2006, after a year-long investigation, the GAO reported that although the EPA says lead levels in drinking water systems have dropped since the early 1990s, the agency in fact has no data—which states are supposed to provide—to support that finding for about 30% of medium and large municipal systems. Additionally, although the EPA requires states to report on lead-in-water "milestones," or measures that must be met, the agency lacks those data for 72% of water systems.

The report centered around the question of how well the agency enforces its 1991 Lead and Copper Rule. This rule requires water utilities to sample lead levels in homes and, at certain trigger points, to notify customers and sometimes take remedial action.

The Lead and Copper Rule is unusually tricky to enforce, because the contaminants in question are out of the control of the water utilities. "What makes lead so unique is that it's picked up in the distribution system; everything else, like *E. coli*, is treated at the water treatment facility," says John Stephenson, director of natural resources and environment at the GAO.

Usually lead is introduced to drinking water in the service lines, which connect individual buildings to main water lines. These service lines are often owned by individuals rather than utilities. Lead may also be introduced within the house itself, from lead pipes or solder that connects copper pipes in the house. Because lead enters drinking water so late in the pipeline, samples must be taken from the taps of individual structures rather than from a central distribution point. Typically, building owners are asked to provide these samples.

Cloudy on the details. A GAO report on the EPA Lead and Copper Rule shows that enforcement is not a clear-cut outcome.

The Lead and Copper Rule stipulates that in the largest systems—50,000 or more users—only 100 homes have to be tested, says Stephenson. Generally speaking, testing is done every three years. "We didn't get into the reasonableness of the samples, but it isn't a very large sample in the first place," he says. "It's not until more than ten percent of those tests are above acceptable levels that you have to do anything about it."

That was the case in Washington, where 40,000 water service lines were replaced after the District of Columbia Water and Sewer Authority found drinking water lead above the action level of 15 parts per billion in 73% of the 4,613 homes tested. All of the homes tested had lead service lines.

One reason the EPA was short on data may have been that some states decided to concentrate their scant resources on lead management rather than lead reporting, says Steve Via, a regulatory engineer for the nonprofit American Water Works Association, whose membership is drawn from water utilities. "Would you rather see a state with limited resources spending a lot of time managing the data up the chain so that somebody can have a relatively simple time compiling a report? Or would you rather see them put the money into having their people in the field helping people who have problems either complying or trying to do a better job?" he asks.

An appendix to the report notes that the agency continued to assess penalties during the period in question. As for the future, the EPA has developed a plan to improve its enforcement of the rule, and is preparing revisions that will address some of the issues raised in the GAO report, says Veronica Blette, a special assistant to the director of the EPA Office of Ground Water and Drinking Water. The agency must also notify Congress as to how it will address the GAO's recommendations, and will periodically report on its progress.

For now, Stephenson says, the GAO has no further role to play in the process. "It's really up to the Congress to keep oversight pressure on the GAO to stay involved, to ask us again to look at it—and they may down the road." **–Scott Fields**

Muriel Lasure/ShutterStock

The Beat

edited by **Erin E. Dooley**

MERCURY

Cleaner Air on the Fly?

The coal industry represents more than half of America's energy production, and DOE estimates place the recoverable reserve at more than 250 billion short tons. Coal is notorious for its drawbacks, however, including emissions of sulfur (which in the form of sulfur dioxide can react with atmospheric water to form sulfuric acid) and mercury (a known neurotoxicant). Now scientists from the Energy Research Center at Lehigh University, led by Carlos Romero, have shown that it may be possible to reduce mercury emissions by up to 70% without a lot of costly modifications, simply by optimizing boiler operation.

The USGS report *Mercury in U.S. Coal: Abundance, Distribution, and Modes of Occurrence* states, "The mercury emitted directly from power plants is not considered harmful; however, in the natural environment, mercury can go through a series of chemical transformations that convert elemental mercury to a highly toxic form [methylmercury] that is concentrated in fish and birds." In large doses, methylmercury can cause mental retardation, seizures, cerebral palsy, and death in humans. Though some mercury is removed by cleaning the coal before burning, and more is recaptured in the stack, the EPA estimates that coal-fired power plants release 40 to 52 tons of mercury each year.

Cutting coal's costs. New boiler configurations may lead to fewer mercury emissions.

Currently, according to Romero, the industry relies on techniques such as injecting activated carbon into the flue gas stream to adsorb the mercury. One costly problem with this approach is that a typical 250-megawatt power plant can use significant amounts of activated carbon, at a cost of about 50¢ per pound.

The goal of Romero's optimization technique is to leave more unburned carbon in the fly ash, the residue left after combustion of pulverized coal. The more carbon the fly ash contains, the better able it is to capture oxidized mercury (formed when mercury combines with chlorine, also found in coal). It's not clearly understood why fly ash captures mercury, Romero admits, and more research is being done to explain this interaction.

"Our testing has shown that if you lower the amount of excess air in the boiler [and thus lower the flue gas temperature], you increase the level of unburned carbon," he explains. "You can also increase the level of unburned carbon by grinding the coal more coarsely." Results vary depending on the type of coal used and the boiler configuration.

Further tweaking will address a couple of potential drawbacks to the approach. Fly ash is used in Canada and the United States in the manufacture of cement, but due to the physical qualities of the unburned carbon, fly ash can contain only a certain amount (about 4–6%). Plus, flue gas temperatures must not be lowered too dramatically, says Romero, lest acids form in the gas, creating corrosion in the smokestack.

Under the Clean Air Interstate Rule of March 2005, the EPA has mandated a 23% reduction of mercury by 2010 and a 69% reduction by 2018. Romero thinks some boilers could achieve the first reduction through boiler optimization. "The sixty-nine percent [reduction] will be tough to achieve with combustion optimization," he says, "but I believe this approach can be a valuable tool in industry's efforts to reduce mercury emissions."

George Offen, senior technical leader for air emissions and combustion product management at the Electric Power Research Institute, says that while this may be a low-cost approach to achieving moderate reductions in mercury emissions, larger plants will retrofit with other technologies to meet the requirements of the Clean Air Interstate Rule. "However," he adds, "many smaller plants, or those located far away from locations that use fly ash in concrete, could find this process very attractive." **–Lance Frazer**

Easy Rider, Easy Polluter

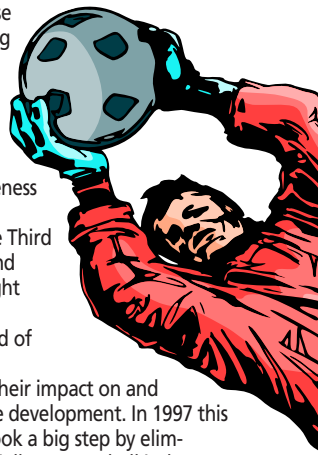
A Swiss study published in the 1 January 2006 issue of *Environmental Science & Technology* shows that motorcycles collectively emit 16 times more hydrocarbons, 3 times more carbon monoxide, and "disproportionately high" levels of other air pollutants, compared with passenger cars. Two- and three-wheeled vehicles are widely used in Asia. Because they are not a primary means of transportation in developed countries, however, not a great deal of attentionhas been paid to emissions from these vehicles. But a U.S. EPA rule that took effect in January 2006 requires manufacturers to reduce emissions of hydrocarbons and nitrogen oxides by 60%. By 2010 the EPA estimates the rule will save about 54,000 tons of emissions and 12 million gallons of fuel per year.

Beverages Doing Better

Last year, the EU commissioner for health and consumer affairs called on drink and food companies to take steps to fight the growing problem of child obesity. In response, the Union of European Beverages Associations (UNESDA) announced in January 2006 that it would limit advertising targeted at youth, control sales in schools, and improve nutritional labels. It further agreed to provide drinks, including sugar-free and low-calorie options, in smaller container sizes to limit intake. Also, vending machines in schools will carry images of a healthy, active lifestyle and a balanced diet, rather than brand logos. Global drink firms including The Coca-Cola Company and Cadbury Schweppes European Beverages are members of UNESDA.

Score for the Environment

In November 2005, sporting goods manufacturers from Sialkot, Pakistan, who produce 60% of the world's soccer balls, pledged to reduce and improve the use of water and energy during their manufacturing processes. They also agreed to introduce cleaner technology, reduce toxic wastes, and raise environmental awareness among their workers. This agreement was part of the Third Global Forum for Sports and Environment, which brought together more than 200 participants from the world of sports and sporting goods manufacturing to discuss their impact on and contribution to sustainable development. In 1997 this group of manufacturers took a big step by eliminating child labor in the Sialkot soccer ball industry.



Clockwise from left: Corbis; Juuce/iStockphoto; Vallentin Vassileff/ShutterStock

PHARMACEUTICALS

A Headache for Water Treatment

Acetaminophen is turned into at least two toxic compounds by chlorination treatment, researchers report in the 15 January 2006 issue of *Environmental Science & Technology*, raising concerns about the fate of this and other pharmaceuticals that end up in water supplies. Acetaminophen is one of the most widely used over-the-counter painkillers in the world—in the United States alone, some 37,000 metric tons are produced each year, says coauthor Mary Bedner, a research chemist at the National Institute of Standards and Technology. "Some of this is reaching the environment," she says, "but no one really knows what happens to it or what effect it might ultimately have on ecosystems or people."

Remedy or pain? The presence of toxic metabolites in water supplies makes you wonder.

Reports of acetaminophen in European rivers have appeared since the 1990s, and in the 15 March 2002 issue of *Environmental Science & Technology* a USGS team reported detecting it in nearly a quarter of the water bodies it sampled. "It gets there through wastewater [i.e., via human excretion] and in some cases through poor disposal practices," says Nick Voulvoulis, a senior lecturer in natural sciences at Imperial College London. Only 22% of Britons and just 1.4% of Americans return unwanted medicines to pharmacies, says Voulvoulis. More than 35% of U.S. nonreturners flush unused drugs down the toilet, while most British drugs end up in landfills, from which they can leach into water bodies.

Concerned that acetaminophen's structure renders it likely to react with chlorine, Bedner and colleague William MacCrehan used reversed-phase liquid chromatography to follow its interaction with the chlorinating agent hypochlorite. Under simulated treatment conditions in samples of distilled water and wastewater, 11 new compounds were formed from acetaminophen within an hour, the time the reactants would likely be in contact at any plant. Among them were 1,4-benzoquinone (a mutagen) and *N*-acetyl-*p*-benzoquinone imine (a hepatotoxicant also produced during acetaminophen metabolism that is responsible for overdose deaths). Together, these compounds represented the fate of nearly 27% of the original drug concentration.

"Fortunately, these are unstable compounds, especially in the presence of sulfite, which is sometimes used to dechlorinate treated water, so they are unlikely to persist long in the environment," Bedner says. "However, they could accumulate where treated wastewater is returned to rivers, and the effects of resupply over long periods are unknown." The results also raise the question of what other drug-derived toxicants are out there, she says.

"This work shows we need to know much more about the fate of the drugs that contaminate our water supplies," says Damià Barceló, a professor of environmental chemistry at Barcelona's Centre for Research and Development. "We also have to look for what they turn into. Searching only for the original compounds themselves will not reveal all the dangers these contaminants may pose." **–Adrian Burton**

CANCER

Genetic Basis of UVB Sensitivity

More than 1 million new U.S. cases of basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) will be diagnosed this year, according to the American Cancer Society, and most will be highly curable. New melanoma will be diagnosed in only about 62,000 Americans, but will be far more fatal if not caught early; five-year survival for melanoma that has aggressively spread is only 16%. A study in the 21 December 2005 *Journal of the National Cancer Institute* now shows a genetic difference between melanoma patients and those with other skin cancers: melanoma patients' chromosomal DNA (chromatin) suffers less damage than other skin cancer patients' when cells are irradiated with ultraviolet B (UVB) light, the part of UV that causes sunburn.

The work, led by epidemiologist Qingyi Wei of the University of Texas M.D. Anderson Cancer Center, examined how susceptibility to large-scale DNA damage in the form of chromosome breaks differed among patients with different types of skin cancer. "At the chromosomal level, BCC and SCC patients seem more sensitive in terms of the number of chromosomal breaks per cell," Wei says. In earlier work, his laboratory established that people with melanoma and BCC are less efficient at repairing UV-induced DNA damage than are cancer-free controls; he's now working on a similar study on SCC.

BCC and SCC have clear dose–response curves with sun exposure, says Nick Hayward, a human geneticist at the Queensland Institute of Medical Research in Brisbane. In contrast, melanoma is more associated with acute intermittent doses. "Instead of going out and getting sunlight every day," he says, "people who get melanoma tend to be those who go to the beach without a tan, stay out too long, and get absolutely cooked."

Although most skin cancers derive from either melanocytes or keratinocytes, the assay looks for physical breaks in the chromosomes of lymphocytes—nucleated blood cells—taken from skin cancer patients and cancer-free controls to estimate an individual's sensitivity to UVB. Blood cells are collected, grown in culture, irradiated under controlled conditions, and allowed to recover for a day for cellular repair to occur. Then researchers count gaps in the cells' chromatin. Cancer patients whose cells showed more chromosome breaks after UVB irradiation were 3 times more likely than the general population to have BCC or SCC, but were not more likely to have melanoma.

"One thing that's satisfying about this study is that it fits nicely with some of the known genetic and environmental causes, particularly of BCC, but also of SCC," says Graham Mann, a geneticist at the University of Sydney's Westmead Institute for Cancer Research. "It's been known for years that people with a severe familial form of BCC are very prone to BCC formation after ionizing radiation, presumably because they get much more chromosomal damage."

The assay is not on its way to development as a diagnostic, but rather adds to our understanding of the genetics of cancer. "If you want to diagnose patients," Wei says, "you have to have a thorough, specific assay. You don't want to make mistakes."

And in case sunbathers think they are safe against melanoma, they should remember that UVA radiation can still damage the DNA in melanocytes. **–Victoria McGovern**

Christian McCarty/ShutterStock

ehpnet

Global Sports Alliance

Sports speak a universal language, bridging class, nationality, and religion around the world. Many sports figures are better known than movie stars or prominent politicians. To capitalize on the importance of sports to billions of people around the world, the Global Sports Alliance (GSA) was formed in 1999 to serve as an international network of sports enthusiasts who care about the environment. The English version of the GSA website, available at http://www.gsa.or.jp/en/index.html, describes the work of this group.

From the GSA homepage, visitors can access information on the alliance's Ecoflag and Sports-eco.net projects. The Ecoflag, created by the GSA with the support of the UN Environment Programme (UNEP), is flown at sporting events around the world to symbolize the commitment of sporting enthusiasts to preserving the environment. Another component of Ecoflag is RECYCL'art, a movement to create works of art from used sports equipment, including balls, rackets, and shoes. The RECYCL'art website features a virtual gallery of such artwork. Sports-eco.net focuses on promoting the recycling of sports equipment. One alliance program collects used tennis balls and sends them to schools to put on the legs of school furniture to reduce noise in classrooms.

Another GSA project is the Global Forum for Sports and the Environment (G-ForSE), an archive of environmental action in sports from around the world. From a pull-down menu on the G-ForSE homepage, visitors can find information on how sports participants can protect the environment, as well as reviews of eco-friendly sporting goods such as battery-assisted bicycles, biodegradable fishing line, solar battery rechargers, and a portable ultraviolet measuring device.

As part of G-ForSe, the GSA sponsors Dream Camps in collaboration with UNEP, where children and teenagers are taught not only to play soccer and tennis, but also to be good environmental stewards. Camp activities include recycling and tree-planting projects. To date the camps have only taken place in Kenya, but the GSA is looking for other camp locations and organizers.

Through G-ForSE, the GSA also organizes global forums where world sport federation representatives, sporting goods manufacturers, athletes, and others join to discuss how the sports industry can bring environmental issues to the awareness of the global population and how to integrate sustainable practices into the industry itself. In July 2005, the Sports Summit for the Environment, held in Aichi, Japan, highlighted grassroots environmental initiatives through sports. Participants at the summit drew up the Joint Declaration on Sports and the Environment, which calls on the sports industry to become a partner in promoting sustainable development. **–Erin E. Dooley**

A "Cowabunga!" Moment for Farmers

Penn State researchers have come up with a cheaper, safer way to clean and disinfect milking equipment. Conventional cleaning systems use expensive acids and chlorinated chemicals that can burn the eyes and skin and damage the environment. The new process uses electrolyzed oxidizing water, produced when electric current flows through two electrodes immersed in a weak saline solution and separated by a membrane. Tests showed that the electrolyzed oxidizing water was as effective as conventional treatments at removing organic matter from a series of pipes set up to simulate real milking equipment. Electrolyzed oxidizing water is also effective for cleaning other agricultural products such as fresh produce and eggs.

Of Minors and Miners

Ghana's Institute of Journalism is objecting to a public relations campaign in a weekly children's newspaper, *Junior Graphic*, that focuses on promoting positive information about the gold mining industry. The campaign is funded by the mining company Newmont Ghana. The journalists decry the fact that the campaign targets children, and question its timing, months after the company was accused of knowingly dumping human waste into a river that provides drinking water for local communities. The Denver, Colorado–based mining company is the world's largest gold mining organization.

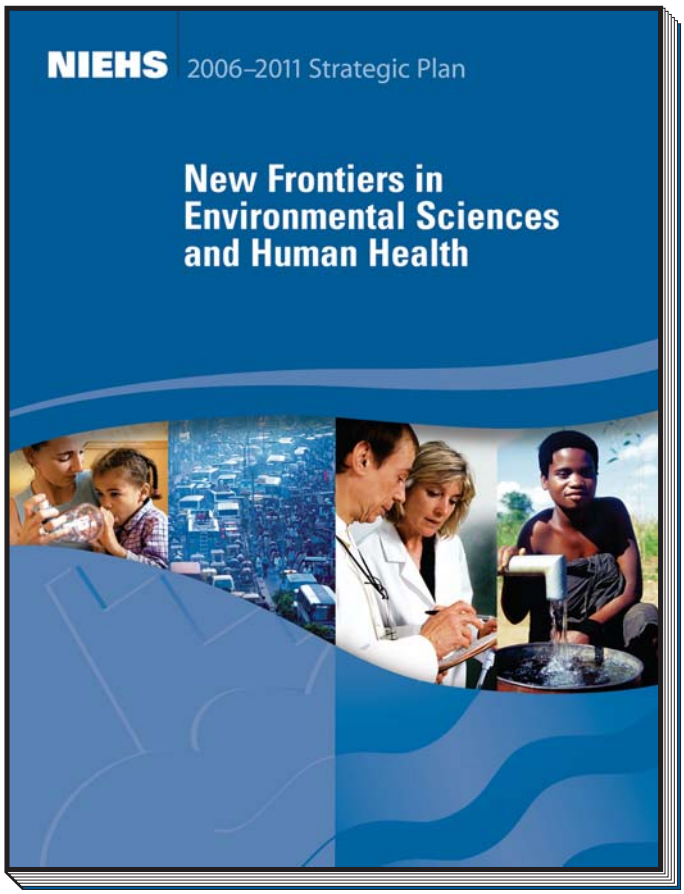
Arsenic and Old Decks

Two papers published by Florida researchers in the 1 February 2006 issue of *Environmental Science & Technology* highlight the threat posed by arsenic from treated lumber used in decks, utility poles, and fences. Though chromated copper arsenate (CCA)–treated wood was phased out of residential use in 2003, arsenic from wood already in use will likely leach into the environment for years to come, possibly threatening groundwater. One of the papers estimated that of 28,000 tons of arsenic used in Florida as of 2000 for CCA-treated wood, 5,000 tons had already leached to underlying soils. The paper added that over 12,000 more tons will leach from structures by 2040. Currently Florida law does not require that construction and demolition landfills be equipped with linings.

Clockwise from top right: Mark William Penny/ShutterStock; Aron Hsiao/ShutterStock; GSA (all EHPnet images)

NIEHS Strategic Plan: New Frontiers in Environmental Sciences and Human Health

The NIEHS has a rich history of scientific accomplishments and contributions to human health and well-being. As with any large-scale organization with far-reaching activities and widespread influence, however, it is advisable to take a step back periodically to critically examine mission, goals, objectives, strategies, and structure. With its recently completed strategic plan titled *New Frontiers in Environmental Sciences and Human Health: The 2006–2011 NIEHS Strategic Plan*, that is precisely what the institute has done. An intensive, inclusive process was designed to comprehensively and objectively reexamine, redirect, and in the end, reinvigorate the institute's trajectory. Leaders hope the new plan will guide evaluation and decision making as the NIEHS strives to achieve its vision: "to use environmental sciences to understand human disease and improve human health."



The plan lays forth an increased emphasis on leveraging scientific advances to benefit human health and longevity. "The plan will help us focus on the ultimate impact of our research in environmental health sciences," says NIEHS director David Schwartz. "This direction is consistent with that of [former director] Ken Olden, builds on our strengths in environmental health sciences, and keeps us focused on human health and disease."

In its final form, the plan is a blend of input from the many disparate stakeholders in the NIEHS research enterprise and Schwartz's views about the role of the institute. Most observers have seen this mixture of leadership and outreach as appropriate and healthy. "It's really important for the leader of an institute like the NIEHS to plant the flag, to lay out a vision of what he thinks is important, and [Schwartz has] done that in this strategic plan," says Bernard Goldstein, an NIEHS National Advisory Environmental Health Sciences Council member who recently retired as dean of the University of Pittsburgh Graduate School of Public Health.

William Greenlee, president and CEO of the CIIT Centers for Health Research in Research Triangle Park, North Carolina, agrees. "I think where the differentiator between the NIEHS and other institutes within the NIH really comes [in the strategic plan] is the emphasis on dose–response and the emphasis on biomarkers that are relevant to interpreting exposure data. . . . I was wanting the NIEHS to make sure that it doesn't appear to be another NIH disease institute, but that its environmental link is truly differentiated from the other NIH institutes. I think largely as I look through the plan, I see it there."

The working group that formulated and guided the extensive strategic planning process was co-led by Sheila Newton, director of the NIEHS Office of Science Policy and Planning, and institute deputy director Samuel Wilson. Wilson says the institute expended considerable effort to gain substantial input from diverse members of the research community—experts from a broad range of disciplines, fields, and perspectives. He also cites "the very deliberate and systematic process we used in identifying those experts, and identifying a format within which we could obtain the information." Adds Newton, "On the one hand, clearly the plan contains many of Dr. Schwartz's ideas, but on the other hand, those ideas are not unique to him, and they reflect a lot of the thinking that's been going on in our research community."

The Strategic Planning Process

The strategic planning process began with the formation of a working group consisting of more than 20 NIEHS staff members and local area investigators. The group, formed in June 2005, was charged with developing the procedures, format, and timetable for the overall process.

Following an announcement in the 21 June 2005 *Federal Register*, a six-question survey was posted on the NIEHS website, with a public comment period lasting until 5 August 2005. The survey generated more than 400 responses from academic and government scientists, advocacy groups, and individual citizens. After processing that input, and consulting with the NIEHS council, the group planned the next major event in the process—the Strategic Planning Forum, which was held 17–18 October 2005 in Chapel Hill, North Carolina.

More than 90 invited fundamental and applied scientists and public interest group members attended the event, which was cochaired by Frederica Perera, a professor of environmental health sciences and director of the Columbia Center for Children's Environmental Health at Columbia University, and Gerald Wogan, an emeritus professor of toxicology and chemistry at the Massachusetts Institute of Technology. Attendees were assigned to rotating breakout discussion groups, with each group asked to discuss one of six core topics related to future NIEHS priorities. Conclusions from each group were then presented to the entire assembly in periodic plenary sessions.

The deep and lively discussions at the forum generated an enormous amount of

NIEHS

I feel like I've been thinking about this strategic plan for the past twenty years of my research career.

–David Schwartz
NIEHS Director

Steve McCaw/Image Associates

input. "The meeting showed that all of the people who attended were engaged in the process," says Perera, "and really worked hard in the different sessions to help shape the strategic plan." After the forum, the input was analyzed by NIEHS staff and advisors, and a formal "proceedings" document was generated.

Newton describes the input gathered from the web survey as remarkably consistent, with many important themes articulated, including fostering training opportunities for future environmental health researchers at all educational levels and the critical need for validated biomarkers. "Many of those themes were reaffirmed, for the most part, by an entirely different group of people at the forum," she says. "In its own way, that's remarkable, and gives us a lot of confidence that we have a document that we can trust as we move forward."

Following additional discussions with members of the NIEHS Public Interest Liaison Group (which includes representatives of disease groups, at-risk groups, and environmental groups who meet periodically with NIEHS staff), a draft of the strategic plan was posted on the NIEHS website in December for public comment through 24 January 2006. Revisions were made to the document reflecting the comments received, and the updated plan was presented to the NIEHS National Advisory Environmental Health Sciences Council at its February 2006 meeting (this group advises the NIEHS on research issues and programmatic content). The final document, incorporating the comments and discussion generated at the council meeting, was completed in March.

A New Outlook

Wilson says the plan will have a large impact on the way the institute does business. "We are going through a period now of careful analysis of the existing programs and the potential for new programs," he says, "and the guidance that we can obtain from this strategic plan will be critically important in this process of planning and priority setting."

The new outlook described in the strategic plan involves an increased emphasis and sharpened focus on understanding how environmental exposures affect human biology, and on applying that knowledge to reduce morbidity and mortality. As stated in the plan, "Experience tells us that virtually all human diseases can be caused, modified, or altered by environmental agents. . . . The NIEHS is in a unique position to focus on the interplay between environmental exposures, vulnerable populations, human biology, genetics, and the common diseases that limit our longevity and quality of life." If the NIEHS is to take advantage of this position, however, it must meet three challenges, as identified in the strategic plan.

The first challenge involves programmatic scope—the need to focus the research portfolio on those diseases and exposures that will optimize the future utility of the research for the greatest impact on human health. This prioritization will be pursued while the institute continues to fund innovative research efforts aimed at identifying new diseases with an environmental component as well as more classical research looking at the potential health implications of emerging environmental exposures. The second challenge involves the concept of integrative science, which the plan states will require a change in the institute's approach to basic research, "moving from our traditional science base of single investigators with a clear hypothesis to integrated research teams addressing the complex hypotheses associated with the interplay of environmental factors with many other factors (e.g., genetics, lifestyle, age, sex) on disease incidence and prognosis." The third challenge involves the public health impact of institute research findings, at both the individual and societal level. As the plan puts it, "How will we develop the scientific knowledge that empowers people to improve their environmental choices, [and] allows society to make appropriate public health decisions and results in our living healthier lives?"

None of these are new challenges for the NIEHS. But in seeking to maximize the benefits of research investments in improving the nation's health, the enhanced efforts described in the strategic plan are clearly directed at improving and accelerating the translation of new environmental health science knowledge to new therapeutic and preventive modalities. This more focused paradigm is embodied in seven broad goals, each supported by more specific objectives.

Statement of Goals

The first of the seven goals is to "expand the role of clinical research in environmental health sciences." Under that rather broad umbrella, the institute will seek to encourage clinical research that emphasizes the use of environmental exposures to understand and better characterize

common, complex diseases; develop improved models for human disease using our knowledge of environmental exposures and human biology; and enhance the role of the clinical investigator in environmental health sciences, bringing in both physicians and PhDs.

The institute is already taking steps to implement the goal of expanding clinical research. As noted in the strategic plan, it has established the Outstanding New Environmental Scientist (ONES) award to fund first-time R01 recipients who are using environmental science to understand a human disease. Also, the institute plans to establish a Clinical Research Unit within its Division of Intramural Research.

Goals II ("use environmental toxicants to understand basic mechanisms in human biology") and III ("build integrated environmental health research programs to address the cross-cutting problems in human biology and human disease") elaborate on the plan's overarching theme of the need for clinical research to more pointedly explore the relationship between environmental exposures and human disease, making full use of the new tools and technologies available, while encouraging the development of new ones. Some feel that the field is on the brink of a period of unprecedented and extraordinarily valuable discoveries. "My very strong view," says Schwartz, "is that environmental health science is poised to make incredibly important contributions to understanding very basic biological mechanisms that will have profound effects on human health and disease."

Goal III and its objectives encourage the promotion of integrative, interdisciplinary research models, with basic and applied investigators working together collaboratively on specific questions. This approach is seen as a way to increase the relevance, productivity, and impact of NIEHS research programs. "Ultimately, we want all of this research to lead toward something significant beyond a report in a journal," says Newton. "And a lot of the questions that we have now, that we really need answers to, require cross-fertilization and better collaboration between groups from different disciplines."

The strategic plan announced a concrete step in pursuit of Goal III—the development of a new program called Disease Investigation for Specialized Clinically Oriented Ventures in Environmental Research (DISCOVER). DISCOVER is designed to bring together basic, clinical, and population-based scientists to conduct integrative research programs on understanding the etiology and pathogenesis of human diseases influenced by environmental factors, using exposure to understand the interplay between genetic and environmental factors, and applying available state-of-the-art technologies and methods to improve human health.

Goal IV is "improve and expand community-linked research." The NIEHS has taken a lead role both in investigating environmental influences on disease in minority and socioeconomically disadvantaged populations and in developing tools and strategies to reduce health disparities. The report states, "We will continue to support research, both domestically and globally, that can offer important insights into how to reduce exposures and disease incidence in these community settings. . . . The likelihood of exposure to environmental toxicants increases in most economically disadvantaged communities and is associated with an excess disease burden in these communities."

Throughout the strategic planning process, the urgent need to develop new biomarkers of exposure, susceptibility, and effect, along with the technological advances in exposure assessment to allow their discovery, came through loud and clear. As expressed in Goal V of the plan, improvement in exposure assessment has to be one of the institute's top priorities. Says Wilson, "The need for quantitative measures of exposure is paramount in the environmental health sciences, and has been for many years. And certainly as we move toward more gene–environment type research, the quantitative measure of environmental exposure is absolutely fundamental."

The recently announced NIH Genes and Environment Initiative will be a first step toward achieving the goal of improved exposure assessment. The initiative constitutes a major federal investment in the development of innovative new technologies to measure environmental toxicants, dietary intake, and physical activity, and to determine an individual's biological response to those influences. The environmental arm of the project will be spearheaded by the NIEHS.

Goals VI ("recruit and train the next generation of environmental health scientists") and VII ("foster the development of partnerships between the NIEHS and other NIH institutes, national and international research agencies, academia, industry, and community organizations to improve human health") reflect common themes heard at all stages of the strategic planning process. The pursuit of partnerships, particularly to improve access to diverse subject populations and data sets, is widely endorsed, although some observers note that it is important that the NIEHS maintain its distinctive identity as it reaches out to other agencies. Nsedu Obot Witherspoon, executive director of the Children's Environmental Health Network in Washington, DC, summarizes this sentiment: "There's a fine line between what the NIEHS specifically brings as its own novelty versus what the overall NIH does. We need to make sure that we consistently work in a check-and-balance type of system, to ensure that we don't completely lose the unique entity that the NIEHS has [been] by leading environmental health research in the United States."

Kudos and Caveats

Observers contacted for their reactions to the strategic plan unanimously supported the overall goals and objectives outlined in the document. Several specifics also met with a warm reception. For instance, Greenlee was pleased to see the plan's emphasis on exposure assessment. "It's great to understand the biology," he says, "but you have to be able to put it in a . . . context of how external perturbations or exposures translate quantitatively into dose–response changes, and [then] target tissues, and then of course integrate that quantitatively with knowledge of biology to understand how that leads to potential health outcomes."

Witherspoon commended the plan's inclusion of continuing and expanding community-linked research as an individual goal. The question, she says, is how can stakeholders be effective resources for the institute, to assist the institute in being the most effective resource for various communities across the country?

John Balbus, director of health programs at the advocacy organization Environmental Defense, says, "I'm pleased to see the strategic plan developing in a way that reflects the importance of community-based research programs and basic toxicology, yet provides a sharper focus on diseases with the greatest public health burdens." While there are still details to be worked out, he adds, this plan provides a good framework for merging newer analytic tools with traditional ones in meeting the ultimate goal of the NIEHS in preventing disease due to environmental causes.

Deborah W. Brooks, president and CEO of The Michael J. Fox Foundation for Parkinson's Research, endorses the interdisciplinary approach of the plan, but adds a cautionary note. "It's not enough to [call them] interdisciplinary teams, and

then just continue the work as usual," she says. "To make interdisciplinary teams most powerful, you want a different kind of end point, which is a specific goal, a deliverable, an outcome. You want to empower those various experts at different points along a translational continuum to really think about how to problem-solve and get to an end point."

Goldstein also wants to ensure that the historic strengths of the institute in public health and prevention are not diminished by the new directions outlined in the plan. "The NIEHS in the past has made its major impact on human health through its translation to public policy, not through its translation to the bedside," he says. "I don't disagree with putting emphasis on clinical disease, but the question is, will the emphasis remain on what has basically been the glory of the NIEHS—what it's been able to do to prevent disease?"

A New Chapter

With the strategic plan now in place, the process of implementing its far-ranging ideas begins, and the eyes of the environmental health sciences community will be on the NIEHS to assess how effective that implementation will be, and what its impact will be upon the many constituencies served by the institute. "Certainly, we'll have to wait and see what happens once the new programs are put in place," says Fernando Martinez, a professor of pediatrics at the University of Arizona in Tucson. "With that caveat, I think the general ideas that were discussed and the specific strategies that have been proposed will move very strongly and very appropriately toward this new approach, this crucial new orientation for the NIEHS."

Although Schwartz says, "I feel like I've been thinking about this strategic plan for the past twenty years of my research career," he emphasizes that the plan is not fixed in stone. The process of seeking and incorporating input and assessment will continue. Wilson calls this "the lifeblood of how we do business—gaining advice, understanding, and perspective from a very broad range of scientists and others involved with the institute."

Schwartz stresses that "although the plan seems like a finalized process, it's really just the beginning—the beginning of a lot of exciting work, a lot of exciting program development, and a lot of opportunity. We view this as a way of communicating very clearly as to what we think are our priorities for growth in May 2006, but we encourage our constituents to help us identify new priorities and new opportunities as they evolve." **–Ernie Hood**

BEYOND THE BENCH

Environmental Health Nursing: Putting Knowledge into Practice

Training that delivers a complete picture of environmental dangers faced by communities is critical in helping environmental health nurses cultivate skills that go beyond basic health care. Now the Community Outreach and Education Cores (COECs) at the University of Wisconsin (UW)–Milwaukee Marine and Freshwater Biomedical Sciences Center and the Harvard NIEHS Center for Environmental Health have joined forces to take environmental health nurse training to the next level by combining didactic and onsite practice teaching methods into one integrated learning experience.

This learning experience includes a site visit within the larger context of a two-day conference. "These intense conferences are intended to provide some in-depth education for public health nurses who are on the front line of environmental health in communities everywhere, and for nursing faculty, who need to understand environmental health in order to incorporate that content into nursing education at all levels," says Jeanne Hewitt, director of the UW–Milwaukee COEC. Attendees receive continuing education units, which are authorized by the American Nursing Association and count toward the professional education that is required of nurses in some states.

The first conference was held in July 2005 at the Harvard School of Public Health (HSPH), and focused on helping academic and practicing nurses bring environmental health concepts into the classroom, practice, and policy arenas. With help from HSPH visiting scholar Stephanie Chalupka of the University of Massachusetts Lowell, the COECs designed a conference program that reflected the complexity and interrelationship of environmental health issues as well as the scope and nature of the practice of public health nursing. Activities included lectures, open discussions, hands-on computer work, and project development work group sessions focusing on the toxicology of organochlorines, the epidemiology of trichloroethylene, the existence of disease clusters, and the usefulness of geographic information system mapping technology in community health research and risk assessment.

The 2005 conference also included a teaching experiment that served as a bridge between the instructional segments and a site visit to the Wells G & H Superfund site in Woburn, Massachusetts (these two municipal wells were found to be contaminated with industrial waste in 1979). To illustrate the fate and transport of toxicants through different soils, the COECs used experiments created by staff from the Edgerton Educational Center at the Massachusetts Institute of Technology. One

Ann Backus/Harvard COEC

Field prep. Public health nurses study how contaminants travel through different types of soil in preparation for a visit to a Superfund site as part of a two-day conference.

The real deal. Health warnings mark the Wells G & H Superfund site visited by the conference participants.

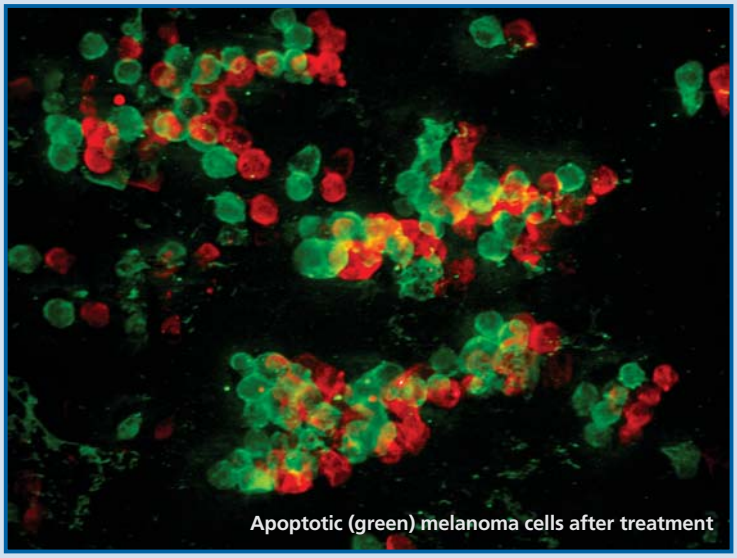
activity used simulated lake water, a surrogate "toxicant" (colored candy), and four containers, each layered with different amounts of clay and medium, coarse, and fine sand. The experiment revealed flow rates in various soils and showed how clay forms a barrier to flow. Once the nurses had an understanding of the properties of different soils, they visited the Superfund site to examine the contaminated soil there. The interactive design of the conference allowed them to apply the latest environmental health information directly to community analysis.

These conferences help nurses develop skills that respond to current environmental challenges that threaten the public's health. As Ann Backus, director of the Harvard COEC, points out, "Today's health problems stem not only from communicable diseases and other concerns such as nutrition, maternal and child health, disasters, and war-related injuries, but also from contamination of our water, soil, and air—the 'commons' we count on to keep us healthy rather than make us ill. We need now to usher in a new era of public health nursing which will be known for its application of the concepts and competencies in environmental and public health nursing to the prevention of illness in the population through stewardship of the environment. We need also to re-energize the demand for public health nurses who are competent in environmental health."

A second conference, scheduled for 1–4 August 2006 at UW–Milwaukee, will focus on the human health effects of mercury in the environment. For more information and online registration, see http://www.uwm.edu/Dept/MFB/nursingconference/. **–Tanya Tillett**

Headliners | Cancer

NIEHS-Supported Research



Apoptotic (green) melanoma cells after treatment

Inhibition of RLIP76 Causes Complete Regression of Melanoma in Mice

Singhal SS, Awasthi YC, Awasthi S. 2006. Regression of melanoma in a murine model by RLIP76 depletion. Cancer Res 66:2354–2360.

Studies have shown that inhibition or depletion of RLIP76, a glutathione-conjugate transport protein that helps cells defend themselves against toxicants, causes apoptosis in a number of cancer cell types. Now NIEHS-supported researcher Yogesh C. Awasthi of The University of Texas Medical Branch at Galveston and colleagues have confirmed that inhibition or depletion of RLIP76 causes apoptosis in malignant melanoma cells.

RLIP76 is implicated in the regulation of multiple signaling pathways. The clinical and physiological implications of RLIP76 extend to diverse processes, including stress resistance, chemotherapy drug resistance, radiation resistance, oxidative stress–induced disease, and even insulin resistance.

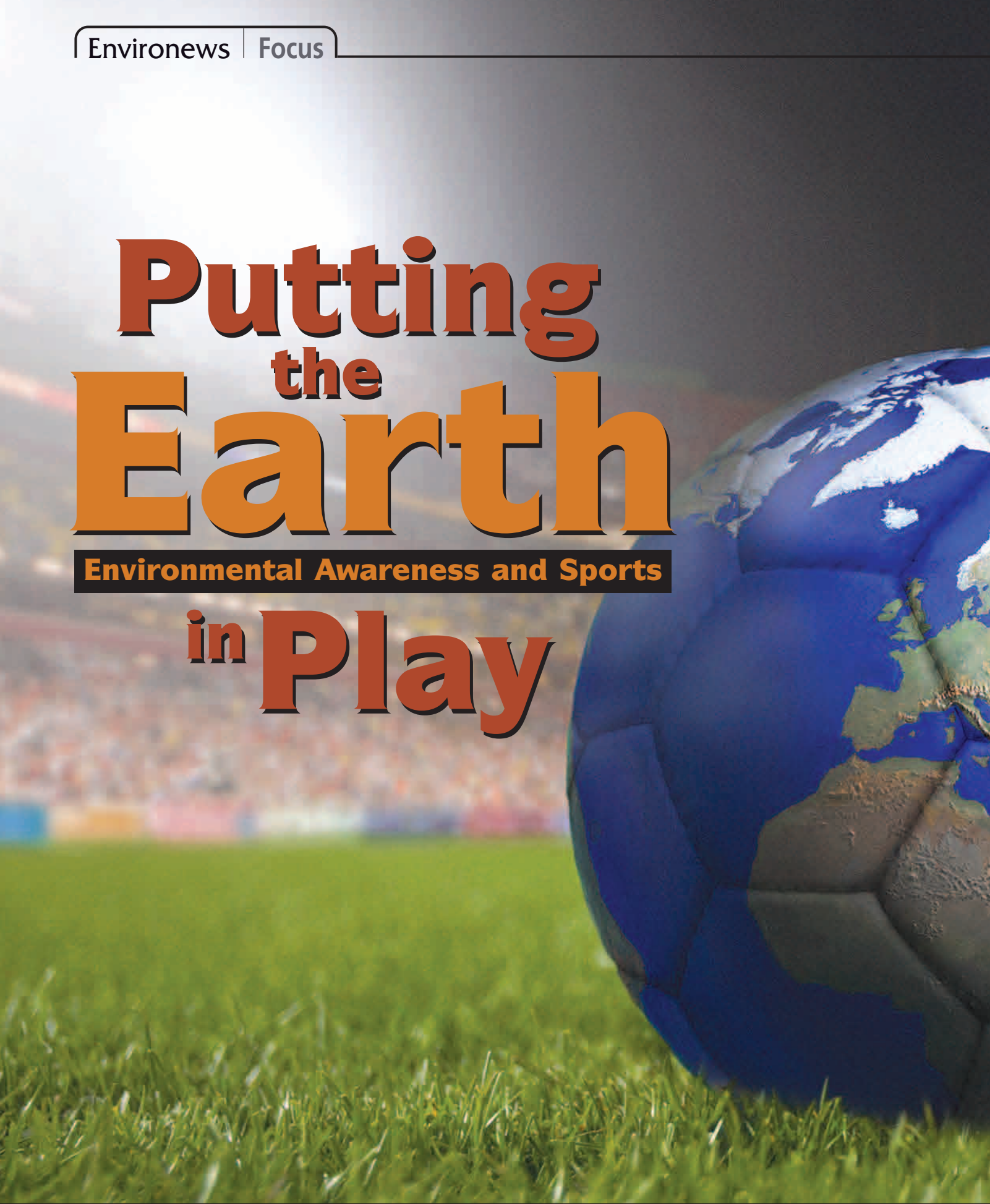
The Texas researchers compared the expression of RLIP76 in normal cells and several cancer cell lines to explore potential clinical impacts. Their studies also included techniques to determine whether depletion of RLIP76 would cause cancer-specific apoptosis. Expression of RLIP76 was found to be greater in malignant cells than in nonmalignant cells. Inhibition or depletion of the protein also caused preferential apoptosis in a variety of malignant cells in culture. Most importantly, in a mouse melanoma model, administration of a single dose of RLIP76 antibodies, short interfering RNAs, or antisense oligonucleotides caused complete tumor regression in 10 days.

These findings provide strong evidence that inhibition of RLIP76 through genetic engineering or by administration of antibodies may be a clinically relevant approach to treating cancer, especially melanoma. The dramatic results suggest advancing this technique to clinical practice. Further studies in melanoma and other cancer models and other susceptible cancer cell lines would be needed to show the general applicability of these results prior to human clinical applications. **–Jerry Phelps**

Left to right: Ann Backus/Harvard COEC; Sharad Singhal/University of Texas at Arlington

Putting the Earth in Play

Environmental Awareness and Sports



Blend/Getty

Since time immemorial, people have entertained themselves with sports. Sports are emblematic of health, with the best matches played by athletes in peak physical form. But ironically, even as sports promote health, they can also degrade the environment upon which good health depends. Whether played or watched, athletic endeavors have the potential to produce huge environmental "footprints" in terms of their use and abuse of natural resources. Ski slopes, for instance, disrupt fragile alpine ecosystems, while snowmobiles spew exhaust fumes into the air. Golf courses sprawl across the land, and consume large amounts of pesticides and water, while parking lots for stadiums and arenas produce vast paved surfaces. And major sports events use energy, emit greenhouse gases, and produce voluminous trash. The 2006 Super Bowl in Detroit produced 500 tons of the greenhouse gas carbon dioxide (from transportation and utility usage), while the 2004 Summer Olympics in Athens produced half a million tons in two weeks—roughly comparable to what a city of 1 million people would emit over a similar period. Each match during the 2006 World Cup this summer will use up to 3 million kilowatt-hours of energy (similar to the annual consumption of 700 European households), and produce an estimated 5–10 tons of trash.

These impacts have spawned an environmental movement with two broad goals: to reduce the ecological footprint of sports activities, and to exploit the popularity of sports to raise environmental awareness in general. "Like any other sector, sport has environmental consequences," says David Chernushenko, president of Green and Gold, a sports sustainability consulting firm in Ottawa, Canada, and author of the first book on the subject—*Greening Our Games*, published in 1994. "But sports are also heavily impacted by degraded environments, and that's important to an athlete

Doing the wave. The ecoflag, a symbol of environmental awareness in sports, flies at sports events.

who can't run on smog days, or to those in the golf industry who get told they can't build a new course because bad practices have tarred their image. So, sports create opportunities to produce leaders for better environmental practice."

UNEP at the Fore

The sports sustainability movement now encompasses numerous environmental groups, businesses, and nongovernmental organizations (NGOs). The UN Environment Programme (UNEP), a veteran influential player in this arena, was among the first to get involved. In 1994, UNEP created a Sports and Environment Program, and charged it with promoting environmental awareness through sports as well as the design of sustainable sports facilities and equipment.

Currently headed by Eric Falt, UNEP's director of communications and public information in Nairobi, Kenya, the program has fostered numerous initiatives. In 1994, the Centennial Olympic Congress of Paris established the environment as a "third pillar" of the Olympic charter, along with sport and culture. In a pivotal milestone, UNEP teamed with the International Olympic Committee (IOC) in 1995 to host the first World Conference on Sport and Environment, held in Lausanne, Switzerland. Participants there created a Sport and Environment commission within the IOC. The latest world conference, held in Nairobi in November 2005, yielded the Nairobi Declaration on Sport, Peace, and Environment, which calls upon the IOC and national Olympic committees to act as leaders in promoting environmental sustainability through sports.

UNEP has also organized three meetings of the Global Forum for Sport and Environment (G-ForSE) since 2001, in which sports stakeholders in and beyond the Olympic Movement review their contributions to sustainable development. At the July 2005 Sports Summit for the Environment, a G-ForSE meeting held in Aichi, Japan, participants signed the Joint Declaration on Sports and the Environment, in which they pledged to help address environmental problems and create a sustainable world society through sports.

UNEP has also worked with the IOC to develop an "Agenda 21" for the Olympic Movement based on environmental sustainability guidelines created by delegates at the 1992 UN Conference on Environment and Development. By adopting its own Agenda 21, the IOC committed itself to encouraging sustainability among its member nations and sports governing bodies. This agenda is being used by several National Olympic Committees for sustainable development work at the national level.

Failure to medal. From initial construction of facilities such as the Olympic Sports Complex (above) through the closing ceremony (left), the 2004 Athens Summer Olympics are widely viewed as an environmental failure, plagued by problems such as poorly designed venues and inefficient energy use.

Clockwise from top: Ecoflag; DigitalGlobe; Vincent Thian/AP

Competitive environment. Cranes add segments to the National Olympic Stadium, dubbed the "Bird Cage," being built in Beijing for the 2008 Olympics. China's bid to host the games included a strategic environmental assessment describing commitments such as sustainable construction.

AP

NGOs working in this area include the Global Sports Alliance (GSA), based in Tokyo. The GSA, which is supported by UNEP, partners with numerous sports groups including the IOC to help create an environmentally aware sports culture. GSA members try to spread environmental awareness in part by sending "ecoflags" to schools and sports clubs, which these organizations fly during games to affirm ecological commitments. The GSA also sponsors several projects and, with UNEP, the G-ForSE. [For more information on the GSA, see "EHPnet: Global Sports Alliance," p. A279 this issue.]

Greening of the Olympics

The 1994 Winter Olympics in Lillehammer, Norway, are now viewed as the first attempt to create a "green" Olympic Games. Local activists in Lillehammer successfully forced the country's Olympic Organizing Committee (OOC) to make changes based on environmental concerns. Because of their actions, a speed skating rink was redesigned to avoid impacts to a nearby bird sanctuary, and officials agreed to an environmental plan emphasizing renewable building materials and energy-efficient heating and lighting for facilities, trash recycling, and arena designs that harmonize with the local landscape.

Since Lillehammer, the IOC has tried to make the Olympics a showcase for environmental sustainability. With the 1999 adoption of the Olympic Movement's Agenda 21, any country that wants to host the Olympics has to produce a strategic environmental assessment to accompany its bid. David Crawford, a Winnipeg, Canada–based sustainability advisor to OOCs, says these assessments must describe environmental commitments around energy use, water consumption, waste generation, and sustainable building construction, in addition to social commitments to include local communities in the planning process. "If you look at who won the last three Olympic bids—Beijing in 2008, Vancouver in 2010, and London in 2012—you see environmental assessments played a major strategic role in that success," he says.

Intent and implementation aren't one and the same, however. Despite successful bids, some host cities have found their Olympic sustainability obligations hard to meet. The Athens Games, for instance, are widely viewed as an environmental failure, particularly with respect to sustainable construction and green energy. Despite Athens' commitment to use 100% renewable energy during the Games, almost all the energy expended there ultimately came from nonrenewable sources.

Beijing could also have trouble meeting its environmental obligations. The city's air quality ranks among the world's worst—indeed, the highest nitrogen dioxide levels in any city are found there. Exposure to Beijing's air can therefore irritate and damage the respiratory tract, posing an obvious hazard to competing athletes. To prepare its Olympic bid, Beijing promised to achieve 230 "blue sky" days per year, meaning days when air quality is "good or moderate." To achieve this, the city ordered the Shougang Corporation, a major steel maker, to move its coal-fired smelters—and some 120,000 employees—to a small island in neighboring Hebel province. City officials also imposed

On thin ice? The bobsledding track used at the 2006 Winter Olympics in Torino contains 48 tons of ammonia that could harm wildlife if leaked.

tighter auto emissions standards two years ahead of national implementation. These measures have produced some success: Beijing's air quality has improved, and the city claims it achieved 234 blue sky days in 2005. But air quality in January 2006 was the worst in six years, with only nine blue sky days reported.

Paying to play. Children plant trees in the Detroit area as part of a carbon mitigation project for Super Bowl XL.

The IOC's choice of Beijing underscores the notion that environmental sustainability—while important—isn't a deal breaker for host city selection. "Let's not kid ourselves," Crawford says. "The Olympic Movement is global, the Games can't always be held in the same continents. Beijing's air quality is bad, so the Chinese are using the Olympics for a public environmental education campaign. They are keenly aware they have a problem; the Olympics can be a positive catalyst for change."

As for the Torino Winter Olympics, a full picture of its environmental performance is now emerging. Falt acknowledges some problems at Torino: for instance, bobsledding created environmental and sustainability challenges, he says. The bobsled track, which Falt describes as a "huge fridge in the mountains," has a coolant system containing 48 tons of ammonia that could harm wildlife and human health if leaked. What's more, the track's annual maintenance cost of up to US$1.1 million will likely exceed visitor-generated revenue. On a more positive note, in a press release dated 1 March 2006, UNEP executive director Klaus Töpfer commended Torino for building skating rinks and other facilities in the city center to promote continued use. He also lauded efforts to limit erosion and runoff from ski slopes, and the use of renewable materials and energy-efficient systems in building construction.

The Carbon Counting Game

Two of the environmental programs employed by Torino's OOC are particularly notable. One is its use of the European Union's Eco-Management and Audit System, through which registered organizations in Europe evaluate, report on, and improve their environmental performance. Twenty-nine Olympic sites in Torino, including training facilities and buildings in the Olympic village, were built by companies registered with the system. The other notable program is Heritage Climate Torino, which strives to offset the estimated 300,000 tons of greenhouse gases released during the two-week event. According to Ugo Pretato, the Torino OOC head of environmental programs, the Regional Public Administration in Piedmont (the Italian province of which Torino is the capital) allocated approximately US$6 million for carbon credits linked to several greenhouse gas mitigation projects, including a reforestation project in Mexico, renewable energy projects in India and Sri Lanka, and an energy efficiency scheme in Eritrea. "The expectation is

Top to bottom: Andrew Medichini/AP; NFL Environmental Program

. . . And the crowd goes wild. South Korean soccer fans gathered in Seoul to watch a live broadcast of the 2002 World Cup quarter final match. The 2006 World Cup is striving for zero impact on the environment through greenhouse gas emission offsets, recycling, and traffic mitigation.

Ahn Young-joon/AP; inset: Vincent Thian/AP

that Heritage Climate Torino will become more developed over time," says Pretato. "We hope our example will be followed by other big sports events in the future."

Offsetting carbon emissions from spectator events is a noble gesture, but also one that's new and untested. An obvious question concerns the amounts of greenhouse gases that events like the Olympics actually produce. Quantifying them is no easy task, says Mark Bain, director of Cornell University's Center for the Environment. "Do you count the extra flights, hotel stays, and changes in personal habits?" he asks. "It's not just the spatial boundaries you have to consider, it's also the downstream and upstream consequences to the carbon cycle. I think lots of organizations want to say they're making up for their environmental effects, but most haven't fully considered what this actually means."

For his part, Pretato says the Torino OOC counts all transportation to and from the Olympics, including air travel, in addition to energy consumption by all Torino venues and stadiums. Data collection is still ongoing, he says.

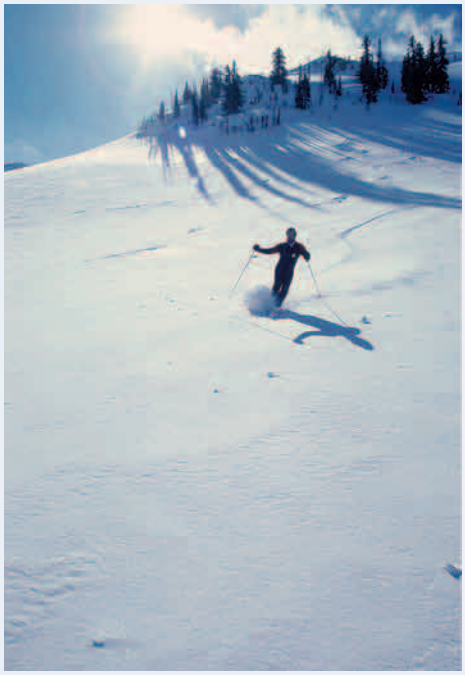
The U.S. National Football League (NFL) also plays the carbon counting game. Seeking to offset the greenhouse gas emissions of Super Bowl XL, played 5 February 2006 in Detroit, the NFL consulted with scientists at Oak Ridge National Laboratories and Princeton University, who concluded that an acre planted with 250 native Michigan trees would absorb 75 tons of carbon over the trees' life span. The NFL ultimately planted 2,500 trees over 10 acres in Michigan to offset the Super Bowl's carbon emissions, a number that Jack Groh, director of the NFL Environment Program, says far exceeded what was necessary to mitigate the game's climate impact.

Meanwhile, organizers with the 2006 World Cup, which overtakes Frankfurt, Germany, in June, are striving for "climate neutrality" (i.e., zero impact), which they hope to achieve by offsetting the expected 100,000 tons of greenhouse gas emissions with investments in renewable energy and energy-efficient technology. Climate neutrality is just one aspect of the World Cup's extensive environmental agenda, however. As described in *Green Goal: Environmental Goals for the FIFA 2006 World Cup*, published by the Institute for Applied Ecology in Berlin, additional objectives are found in the areas of water use, recycling, energy efficiency, and traffic mitigation. World Cup organizers and The Coca-Cola Company have agreed to use recyclable cups at the event. And rain will be channeled into storage systems designed to provide water for cleaning playing surfaces and parking lots, in addition to toiletry needs. Indeed, organizers plan to save as much as 10,000 cubic meters of drinking water by installing the latest in water-free urinals.

Major sports events like the Olympics, the Super Bowl, and the World Cup generate large environmental footprints over short durations. But what of the day-to-day sports played by billions of ordinary people? Many are environmentally benign. But others do have potentially serious environmental consequences. Here are some examples.

Skiing: A Slippery Slope

Skiing—a sport whose very existence is in some places threatened by global warming—can produce substantial environmental impacts. Ski slopes disrupt the natural landscape, sometimes harmfully so, according to



Snowball effect. With greater attention focused on the impacts of skiing, perhaps more resorts will sign on to—and honor—eco-friendly programs such as the Sustainable Slopes Initiative.

Ryan Bidwell, executive director of Colorado Wild, a Durango-based environmental group. "Downhill ski terrain typically gets carved into ecologically sensitive high-alpine environments," he explains. "And these areas have short growing seasons, so they aren't quick to recover." Trail building contributes to erosion because it removes trees and shrubs that anchor soils. Other negative impacts come from snow making, which could become more prevalent in some areas because of global warming. Snow making diverts natural waters, altering the normal flows of rivers and streams that supply the necessary water, and resulting in dry stream beds, effects on irrigation, and consequences for species that depend on stream flow.

Some streams in Colorado and other western states are contaminated with acids and metals such as cadmium, copper, lead, and zinc—a legacy of the region's mining industry. Snow made from these sources might contaminate otherwise pristine areas, Bidwell says. In one high-profile case, owners of the Arizona Snowbowl Ski Resort will soon make snow from treated wastewater. Their announcement of doing so drew a sustained outcry from the local Navajo population, which views the surrounding San Francisco Peaks as a sacred natural shrine. But these objections were overruled by U.S. District Court judge Paul Rosenblatt in January 2006, clearing the way for wastewater snow making to begin. Snowbowl officials say the wastewater poses no health risks, but caution skiers against eating the snow, which—according to the resort's website—contains residues from "animals, litter, boots, saliva, petroleum products, etc."

Another key issue concerns the ongoing expansion of western ski resorts on public lands. In these cases, resorts expand until they buttress private land boundaries, attracting the development of multimillion-dollar homes built by those who can pay for residential slopeside access. Construction of these homes in delicate high-alpine areas brings numerous problems, however, including erosion, air emissions, impacts to endangered species, and water withdrawals.

To improve their environmental performance, 178 U.S. resorts have endorsed the National Ski Areas Association's Sustainable Slopes Initiative, a collection of environmental best practices for ski owners and operators that was adopted in June 2000. The initiative promotes 21 principles in areas such as planning design, water and energy use, recycling, air quality, and forest management. A total of 71 resorts also participate in "Keep Winter Cool," an initiative sponsored by the National Ski Areas Association and the Natural Resources Defense Council that promotes energy efficiency in ski operations and also supports anti–climate change legislation.

While notable, these initiatives have critics who counter that they don't go far enough. Bidwell, for instance, blasts the Sustainable

Missing the green. Golf courses are huge consumers of water and pesticides, raising environmental concerns for both those who play and those who live near them.

Clockwise from top right: Hamish Trounson/Alamy; Digital Stock; iStockphoto

Slopes Initiative, suggesting it does little to address secondary impacts from land development and the destructive consequences of snow making, which he says pose the greatest environmental damage from skiing. "The charter has no accountability and no system to document whether resorts follow through on any of their proposals," he adds.

To counter these perceived gaps, the Ski Area Citizens' Coalition, also based in Durango, produces an annual "Ski Areas Environmental Scorecard," which grades 77 resorts on their performance in areas such as energy efficiency, reduced habitat impacts, and efforts to expand operations within existing area boundaries. In the 2005/2006 scorecard, the coalition reported that only 50% of resorts supported legislation to combat climate change. Just 21% used alternative fuels such as biodiesel, 31% used wind or solar power, and 60% supported mass transit programs.

Teed Off at Golf

Many golfers prefer their courses to be blanketed in velvety green grass, regardless of where the course is sited, be it the beach, the desert, or a naturally lush locale. Golf courses thus must be intensively coddled with lots of water and lots of pesticides. Each of the more than 17,000 golf courses in the United States alone can consume hundreds of thousands of gallons of water per day. And according to Stuart Cohen, president of the Wheaton, Maryland–based consultancy Environmental & Turf Services, golfing greens are among the most intensive nonagricultural users of pesticides.

Cohen says approximately 50 pesticide active ingredients are commonly used by the golf industry, although the number typically used on any one course is much lower, ranging from 4 to 12 per year, depending on location. Among the chemicals used are chlorpyrifos, an organophosphate insecticide whose residential uses are banned by the EPA due to developmental hazards; carbaryl, a carbamate insecticide; and chlorothalonil, an organochlorine fungicide.

Despite high-level use, documented cases of environmental harm from pesticides on golf courses are rare. In one instance, dating back to the mid-1980s, hundreds of Canadian geese were found dead on the Seaway Harbor fairways in Hempstead, New York—apparently poisoned by diazinon, an organophosphate insecticide that was subsequently banned from golf course applications in 1990 and from all residential uses in 2005. Another organophosphate pesticide—fenamiphos—has produced fish kills when washed into waterways from golf courses after heavy rains. Fenamiphos is now being phased out in Florida, where these fish kills have occurred, and a nationwide ban will be complete in 2007, Cohen says.

Cohen has conducted the largest survey to date of water quality impacts from U.S. golf courses, which was published in the May–June 1999 issue of the *Journal of Environmental Quality*. This review of 17 studies performed on 36 golf courses found little evidence of environmental harm, however. Cohen wrote, "None of the authors of the individual studies concluded that toxicologically significant impacts were observed," but he also concluded that "there are major gaps in this review, particularly in the mid-continent area." He is now updating and expanding this survey with funding from the U.S. Golf Association and the Golf Course Superintendent Association of America.

Cohen believes that when properly applied, golf course pesticides pose a low risk of exposure to players and nearby residential populations. This is in part, he says, because turf is a dense "living filter" with a thatch underlining that not only grips pesticides but also prevents them from leaching into groundwater. The turf system is also microbially active, and thus tends to degrade pesticides.

J. Marshall Clark, a professor of entomology at the University of Massachusetts Amherst, agrees. He and PhD student Ray Putnam have performed extensive risk assessments as part of Putnam's thesis showing that dermal exposure—particularly through the lower legs, thighs, and lower arms—is the main way that players are exposed to golf course pesticides. Clark says his additional dosimetry studies, which measured excreted pesticides and metabolites in urine, have shown that the doses

Matt Sayles/AP

Fast track to cleaner air. Under pressure from environmental groups to phase out leaded gas, NASCAR will require stock cars to use a lead-free fuel made by Sunoco beginning in 2008.

absorbed by players are far beneath any hazardous level. "People used to think hand-to-mouth was the main exposure route—for instance, golfers putting golf tees in their mouths," he says. "But studies have dispelled that notion; the amount of hand-to-mouth activity on golf courses is small. Also, we find that hands are often well protected, and players are always wiping their hands off when they play, which removes the residues."

Some environmentalists aren't convinced, however. Jay Feldman, executive director of Beyond Pesticides, a Washington, DC–based environmental group, believes the exposure scenarios considered by the EPA thus far are incomplete, particularly as they apply to young golfers and chlorpyrifos. "The EPA's view is that children don't play golf, so golf courses can continue using chlorpyrifos," he says. "But if you look at the U.S. Golf Association's own statistics, you see kids are playing golf more and more. We think childhood risks should be taken into account by the EPA for all turf chemicals and for chlorpyrifos in particular."

Water conservation is perhaps a more pressing problem for golf courses, and many facilities are trying to conserve. According to the 2001 report *Water Right: Conserving Our Water, Preserving Our Environment*, published by the International Turf Producers Foundation, the U.S. Golf Association has spent more than $18 million since 1982 seeking solutions to environmental issues related to golf, including the development of new grasses that require less water and pesticides, improved irrigation techniques, and use of alternative water sources, such as treated wastewater and storm runoff collected in storage ponds.

NASCAR: The New Baseball

NASCAR racing is the fastest growing sport in America. In 2004, a total of 3.5 million fans watched races sponsored by NASCAR (the National Association of Stock Car Racing). Once concentrated mainly in the Deep South, NASCAR now lays claim to audiences throughout the United States, and even in Mexico. While a day at the races might seem like good clean fun, NASCAR can also produce significant environmental problems, including noise pollution, polluted runoff from tracks and parking lots, and reliance on an old health villain: leaded gas.

Although the EPA phased leaded gas out of the consumer market more than 30 years ago, its use in stock cars has gone on with the agency's blessing—an exemption was written into the Clean Air Act. Lead lubricates engines, helping them run smoothly, but it's also a neurotoxicant that can lower IQ, particularly among young children. In December 2005, a draft EPA document titled *Air Quality Criteria for Lead* stated that leaded fuel may pose a serious risk to residents living in the vicinity of racetracks, fuel attendants, racing crew and staff, and spectators.

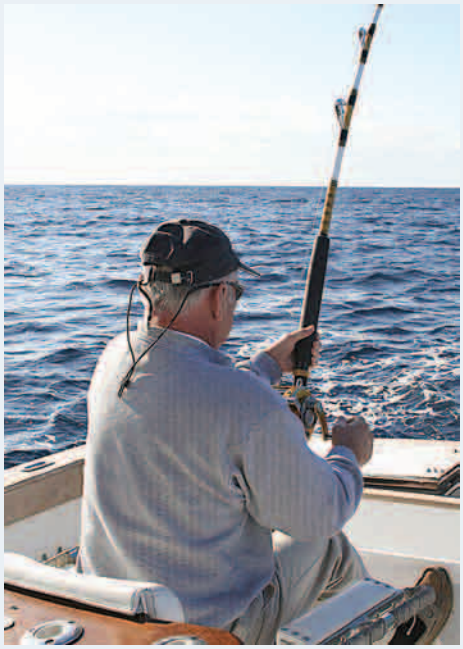
In a pilot study published in the February 2006 issue of the *Journal of Occupational and Environmental Hygiene*, Joseph O'Neil of the Indiana University School of Medicine and colleagues found elevated blood lead levels among some mechanics and crew members of a NASCAR race team. Specifically, the median blood lead level in 47 tested individuals was 9.4 micrograms per deciliter, which approaches the EPA's own risk threshold of 10 micrograms per deciliter, over which toxic effects can be expected. Nineteen of those individuals had blood levels at the EPA threshold.

For years, the EPA has urged NASCAR to quit leaded gas voluntarily. The industry claimed it was trying to find replacements, but also insisted the ones that were available lowered performance and harmed engines. But in January 2006, under pressure from Clean Air Watch, a Washington, DC–based environmental group, NASCAR finally relented. The industry will begin using a lead-free fuel made by Sunoco called 260 GTX by 2008.

Other Impacts

Golfing, skiing, and stock car racing are not the only sports that present problems for the environment, however. Fishing, considered a competitive sport by some and a recreation by others, is being shown to have significant impacts on fish populations. A study in the 27 August 2004 issue of *Science* showed that recreational catches represented almost a quarter of catches of fish species identified by the U.S. government as species of concern for declining populations. Other water sports also have significant environmental impacts. Conventional outboard motors and personal water craft may release as much as 30% of their fuel into the water unburned. Recreational marine engines contribute a high percentage of hydrocarbon emissions to the air. And boating activities can have dire effects on estuaries that serve as nurseries for many fish species. [For more information on these impacts, see "The Environmental Pain of Pleasure Boating," *EHP* 111:A216–A223 (2003).]

One group is trying to bring awareness to these issues. On 3 April 2006, the *Earthrace*,



Reeling in a big one for the Earth. Sport fishing and boating have had many negative ecological impacts, but the *Earthrace* project (above), which is attempting to break the record for circumnavigating the globe in a boat run on renewable fuels, aims to show that marine sports can be less damaging to the environment.

Left to right: Tim Costar Photography; Shutterstock

an 80-foot trimaran billed as the "world's coolest boat," was launched in Auckland's Waitemata Harbour. The *Earthrace* project is a bid to break the world record for circumnavigating the globe (24,000 nautical miles) in a powerboat, using only renewable fuel. The project includes an 18-month tour calling at 60 major cities, promoting biodiesel and raising awareness about sustainable use of resources along the way. Sponsored by more than 200 marine supply companies, the boat is a showcase of environmentally friendly technologies such as low-emission engines, nontoxic antifouling paint, and efficient hull design. *Earthrace* skipper Paul Bethune said in a February 2006 press release, "By racing an awesome-looking boat on this fuel around the world, we hope to raise public awareness of the need to take alternative fuels seriously, as well as [display] incredible advances in the ways marine technology now coexists harmonically with marine ecology."

The environmental footprint of sports extends beyond the activities themselves. The manufacture of sports clothing and equipment also exerts potential environmental impacts, mainly worker exposure to production chemicals and plant releases of dyes and wastewater, says André Gorgemans, secretary general of the World Federation of the Sporting Goods Industry (WFSGI) in Verbier, Switzerland. Of particular concern, Gorgemans says, are uses of polyvinyl chloride (PVC)—a type of plastic linked equivocally to testicular cancer and more definitively to many other health effects—for making soccer and cricket balls, footwear, bats, helmets, gloves, shin pads, and other sports items. Many countries around the world have been phasing out PVC (which also has numerous other uses in construction and plumbing) since toxicity issues first arose in the 1980s.

Today, the WFSGI discourages the use of PVC and hundreds of other toxic chemicals—including metals, dyes, and ozone-depleting chemicals—by sports manufacturers. All these chemicals are listed in the organization's 2003 policy document titled *Guidance on Restricted Substances in Sports Footwear, Apparel, and Accessories*. Restricted substances, as described by the WFSGI, include chemicals that have been either legally banned by national governments in the European Union and elsewhere, or subjected to voluntary restrictions by nongovernmental ecolabeling schemes.

Frank Henke, global director of social and environmental affairs at adidas-Salomon and vice chairman of the WFSGI Committee for Corporate Social Responsibility, which produces the restricted substances list, says most "branded companies," such as Nike and adidas, adhere to it. But he acknowledges that PVC and other restricted substances are still used by smaller manufacturers in developing countries. Henke declined to identify these manufacturers, however.

In addition to issues of the components of sports equipment, the manufacture of such equipment also plays into issues of obsolescence and waste. As any parent with a cluttered garage knows, used sports equipment can pile up quickly. Multiply one garage by all the others out there, and it's easy to get a picture of how much waste sports activities can produce. Although equipment is occasionally passed down to siblings or resold, seldom is it recycled. Two projects of the GSA are working to remedy this situation. Sports-eco.net is a grassroots initiative to reduce, reuse, and recycle sports equipment, particularly the 30 million tennis balls that are manufactured every year. The program collects the balls and distributes them to schools for use on chair and table legs to muffle noise. The GSA website states, "By sending used tennis balls to primary and junior high schools around the country, we are reducing noise levels and creating a better atmosphere to learn, we are helping hearing impaired children (hearing aids are sensitive to sudden loud noises), and we are teaching a valuable environmental lesson."

Similarly, the Igfy Corporation in Japan has pioneered a program to carry out the GSA mission. Called RECYCL'art, the program offers information and workshops on how to turn used sports equipment—including tennis rackets, balls, and shoes—into art. The program supplies special boxes that can be set up at schools, stores, and sporting events for collecting old or unused sports equipment for recycling.

Some sports manufacturers themselves seem to be catching on to the idea. Nike offers a program called Reuse-A-Shoe in which used athletic shoes are collected, deconstructed, and turned into "Nike Grind," actually three different materials, each used in a different way to resurface soccer and football fields, basketball and tennis courts, tracks, and playgrounds.

Aman Sharma/AP

A sticky wicket. Although many large companies voluntarily restrict or ban the use of toxic chemicals in their sporting equipment, smaller manufacturers in developing countries still use chemicals, such as the PVC used in cricket balls, that may harm human health.

A Sporting Chance

In many ways, the emerging environmentalism in sports is highly collaborative, says Falt. "We don't think it's useful to blame specific sports or federations for environmental problems," he says. "Confrontation doesn't work. We need to engage these entities directly."

Meanwhile, the sports and environment movement continues to grow. Falt points out that during the early 1990s, the linkage between them had barely been made. But now, sports and the environment are indelibly linked—from the glitziest athletic spectacles, played out on the world stage, to the everyday games played by billions of ordinary people—and from this current generation of sports enthusiasts, a new generation of environmentalists may be emerging.

Charles W. Schmidt

The Regulation Equation

Factoring In the Price of Health

Controversy erupted early in 2003 after the U.S. Office of Management and Budget (OMB) proposed that the lives of older people were worth less in dollar terms than those of younger people. The idea was included in a plan published in the 3 February 2003 *Federal Register* by the OMB's Office of Information and Regulatory Affairs (OIRA) that was designed to improve how the federal government determines the benefits and costs of proposed regulations, including environmental regulations. A revised version issued 17 September 2003, called Circular A-4, stipulates that specific age-adjustment factors should not be used. But it still includes a number of calculation processes that many perceive discount the value of health as people age.

To help address the controversy that still simmers over how, or whether, to assign a specific value to effects such as degraded human health, OIRA and several federal agencies asked a committee of the National Academies' Institute of Medicine (IOM) to weigh in with guidance on one type of cost–benefit analysis, called cost-effectiveness analysis (CEA), which can include calculations of the dollar value of human life and which was included in Circular A-4. After an effort spanning about two years, the committee issued its report, *Valuing Health for Regulatory Cost-Effectiveness Analysis*, on 11 January 2006.

The committee concluded that the techniques advocated by the OMB, including CEA, have their place, but also have important deficiencies, which could be addressed to some extent by following the committee's main recommendations. In addition, the committee—whose 16 members represent several U.S. and Canadian universities, health care systems,

Corbis

and state and federal agencies—cautions that CEA likely will remain an imperfect tool that should be balanced with other objective and subjective considerations of a regulation's impact.

Uncertainties about the future use of CEA, as well as the OMB's overall regulatory review approach, continue to stir sharp divisions among critics and supporters. All sides are closely watching the OMB to see how it proceeds.

Calculating All Effects

OIRA oversees the implementation of many governmentwide policies, including the adoption of new regulations. For regulations, its emphasis is on impact analysis, particularly of economic impacts, as well as interagency coordination of regulations and consideration of alternative rules and regulatory approaches.

Under former administrator John Graham, the OIRA emphasized the importance of cost–benefit analysis when reviewing proposed federal agency regulations that had to funnel through his office. Cost–benefit analysis looks at dollars gained and spent in both the public and private sectors as the result of a regulation.

However, some regulatory impacts—such as effects on human health—are difficult, if not impossible, to express in dollars. As a result, OIRA also began to emphasize CEA, which attempts to account for effects like these by assigning a number, tied to some kind of synthetic index, to the benefit side of the equation. This number reflects impacts such as tons of pollutants reduced or years of life gained. CEA has been evolving for several decades in the medical field, but is in its relative infancy when applied to other areas.

OIRA laid out its version of CEA requirements in Circular A-4, and said its analytical process had to be used for any proposed regulation estimated to have an annual effect on the economy of $100 million or more. The IOM committee found that only 18 regulations meeting that standard were finalized in the period from January 2000 to June 2004, out of thousands of federal rules proposed every year. Among these were the EPA's efforts to address diesel engine emissions and arsenic in drinking water, an FDA regulation on juice processing contaminants, and a Food Safety and Inspection Service regulation on *Listeria* contamination in meat and poultry. The committee says a number of upcoming regulations likely will need to complete a CEA.

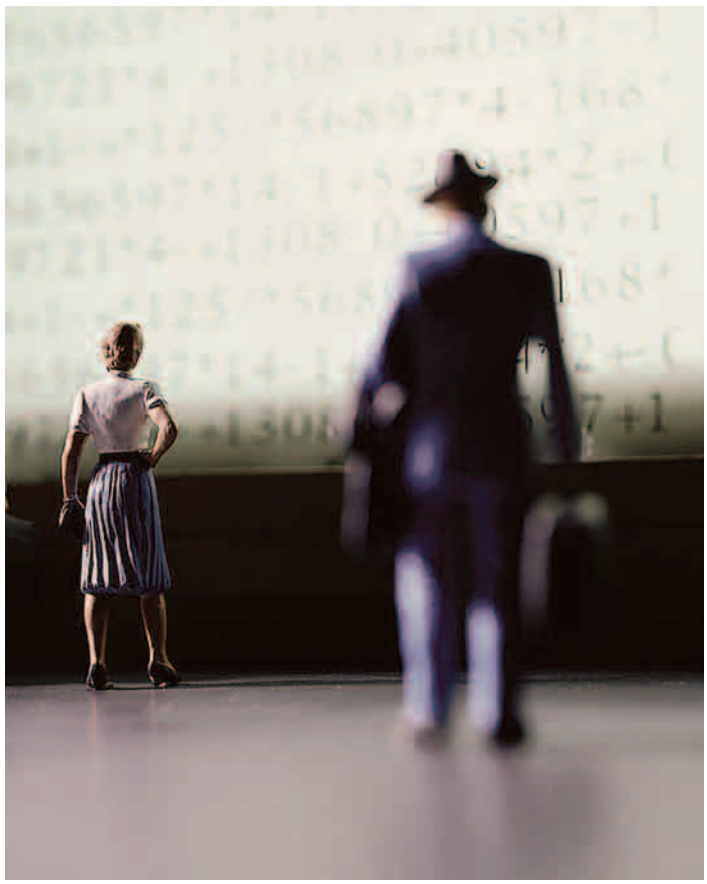
New Ways to Crunch the Numbers

The committee made a dozen primary recommendations to improve the use of CEA. Many of these address exactly how a CEA should be conducted. For instance, the committee recommends the use of a measure called a quality-adjusted life year, or QALY, to create the most viable measure of human health impacts. Calculations of QALYs address both length of life and degradation of health to create a score. However, the committee says even this widely used tool has limited data supporting it, and much more information must be developed to improve it.

One way to do this is to acquire better baseline information by adding appropriate questions to and coordinating better among existing national surveys, such as the National Health Interview Survey and the Medical Expenditure Panel Survey. This would provide a better perspective on how the general public judges various health outcomes. For example, how would someone score the effects of short-term arthritis versus long-term arthritis that waxes and wanes but never resolves?

Some research is already under way on the half dozen most commonly used questionnaires designed to gauge individual judgments on health impacts. A team led by IOM committee member Dennis Fryback, a professor of population health sciences at the University of Wisconsin–Madison, is trying to develop a "Rosetta stone" that will aid comparison between the sometimes-disparate results from different questionnaires, increasing their statistical power. Based on three studies of about 3,900 U.S. residents, Fryback hopes to begin presenting results late in 2006, with journal publication through 2007 and early 2008.

The committee also recommended that improved regulatory analysis should include clearer and more prominent explanations of the many uncertainties inherent in CEAs; should better address differences in impacts on various geographic areas and groups, such as infants, the elderly, and those of different races and economic classes; should be standardized so that all federal agencies use a common approach; and should be more transparent and open to public involvement and review.



A League of Their Own

Even with these recommendations, a CEA unavoidably has to put a price on the health impacts and regulatory costs involved in saving a QALY—that is, how much are we, as individuals and as a society, willing to pay per unit of gained healthy life? Controversy over that concept may increase in the future, since one OMB goal has been to use CEA and cost–benefit analysis to develop tools called "league tables."

Similar to sports league standings, league tables could provide a simple way to compare regulations, even if they cover diverse topics. A regulation to cut *Escherichia coli* in food might be reduced to a score of 27, while a regulation to slash auto accident fatalities might have a score of 39, and a regulation to throttle sulfur dioxide pollution might have a score of 62.

Corbis

(These numbers are purely hypothetical, for the sake of example, since the OMB has not yet developed accepted scales for scoring.)

This strategy fits within OMB's broader objective to adopt "regulatory budgeting," which includes the idea that when all public and private parties meet a preset dollar figure assigned to regulatory expenditures each year, no more regulations can be passed. These approaches are desirable, says Angela Logomasini, director of risk and environmental policy at the Competitive Enterprise Institute, a free enterprise advocacy group, since government needs a tool to decide where best to spend limited resources.

However, the IOM report specifically warns against computing league tables across regulations or areas of regulation, noting that what is considered a benefit and what should be counted as a cost differs from analysis to analysis. "It is analogous to looking at prices of cars where one does not know whether they are comparably equipped, have similar efficiency, and so on," says Fryback. "We can say that the price per car varies, and that one looks more expensive than another, but without the details these comparisons may be misleading."

Furthermore, such important determinations can't rely solely on a tool such as a CEA, says Amy Sinden, an associate professor at Temple University's Beasley School of Law and a member scholar of another advocacy group, the Center for Progressive Reform. "There's just not enough data," she says. "Important aspects of ecological and human health impacts that can't be quantified get left out. A CEA produces numbers that create an aura of scientific objectivity but that may be misleading. The numbers tell only part of the story." The worry, she adds, is that when agencies use methods like these, often all the public sees are the numbers, not the nuances.

The Unknown Factor

The future of OMB's approach is uncertain. Graham left OIRA and assumed the role of dean of the Frederick S. Pardee RAND Graduate School on 1 March 2006. His permanent successor had not been named as of mid-April 2006. Robert Shull, director of regulatory policy at the nonprofit OMB Watch, suspects the general direction of OMB and OIRA won't change much, regardless of who is administrator, given that the general direction has already been set by the Bush administration.

IOM committee chairman Robert Lawrence, a professor of preventive medicine at the Johns Hopkins Bloomberg School of Public Health, says that, although initial response by OMB and numerous federal agencies to the report has been good, prospects for specific revisions to current efforts and policies are unclear. Much will be determined by the new OIRA administrator, he says, and many of the affected agencies told him it would be difficult in this budget climate to get additional money to proceed with the committee's recommendations.

Whatever the outcome, even supporters of the OMB approach realize such measures are less than perfect. "All of these things are highly subjective," Logomasini says. "Such regulatory reforms are often not as effective as we would like them to be. Ultimately, deciding whether or how to regulate is a policy decision."

Bob Weinhold

BIOGAS
a Bright Idea for Africa

Ibadan, the second largest city in Nigeria, is the center of a large agricultural region in Oyo State. Since the nineteenth century, fierce intertribal rivalries and other political unrest have pushed large influxes of refugee and military populations into the city. This chaotic growth has discouraged the kind of municipal infrastructure that is taken for granted in the developed world. Soon, however, Ibadan's power needs, at least, will get a boost from a relatively simple but extremely effective source of energy that is increasingly finding favor across Africa: biogas.

Biogas technology, which converts biological waste into energy, is considered by many experts to be an excellent tool for improving life, livelihoods, and health in the developing world. Worldwide, about 16 million households use small-scale biogas digesters, according to *Renewables 2005: Global Status Report*, a study by the Worldwatch Institute. The Ibadan plant will be one of the larger biogas installations in Africa, providing gas to 5,400 families a month at around a quarter the cost of liquefied natural gas.

The Ibadan digester will take advantage of the city's Bodija Municipal Abattoir, where nearly two-thirds of the animals in Oyo State are slaughtered, according to a study in the January 2002 *African Journal of Environmental Assessment and Management*. The wastes from the slaughtering process are rinsed into open drains that connect to surface water; they also percolate into groundwater. About 60% of Ibadanians get water from hand-dug wells vulnerable to contamination from surface sources, and about 15% have private wells tapping a deep aquifer, according to Tijani Moshood, a geologist at the University of Ibadan.

Abattoir waste carries high levels of microorganisms that cause disease in humans and animals, such as *Salmonella* and *Escherichia coli* bacteria, Rift Valley fever virus, and parasites that cause toxoplasmosis and trichinellosis. Pesticides, antibiotics, metals, industrial chemicals, and the agents responsible for bovine spongiform encephalopathy (BSE) may also enter the human food chain at an abattoir if they are present in the animals. Furthermore, decomposing organic material releases methane and carbon dioxide (CO_2). CO_2 is a primary culprit in climate change, but methane is even worse—23 times more potent than CO_2, according to the Intergovernmental Panel on Climate Change report *Climate Change 2001: The Scientific Basis*.

Fortunately for the people of Ibadan, the new plant should mitigate many of these hazards. The project, dubbed Cows-to-Kilowatts, is a joint venture among the Nigerian branch of the Global Network for Environment and Economic Development Research, a nongovernmental organization (NGO); the Biogas Technology Research Centre of King Mongkut's University of Technology in Thonburi, Thailand; the Centre for Youth, Family and the Law, a Nigerian NGO; and the Sustainable Ibadan Project, which is part of UN-HABITAT. Cows-to-Kilowatts was a 2005 winner of the Supporting Entrepreneurs for Environment & Development (SEED) Awards, which honor outstanding new entrepreneurial ideas for sustainable development worldwide.

Joseph Adelegan, a civil engineer and project director for Cows-to-Kilowatts, estimates the project will cost around US$300,000. Startup funds have been procured, and construction of the new plant is expected to begin by July 2006. The Ibadan system will employ a sophisticated design known as an anaerobic fixed-film digester, in which the active microorganisms are attached to an inert medium. The fixed-film technique shortens the time it takes for complete digestion, which enables the digester to be more compact.

Nuts and Bolts

Biogas is one of many biomass energy sources, which include anything that was once alive and that can generate energy (except for fossil fuels, which are not renewable). In addition to direct use of wood and charcoal, biomass energy sources include ethanol and biodiesel. But these forms require considerably more investment, advanced technology, and/or resources than basic biodigesters provide. Ethanol, for example, requires advanced technology, whereas biodiesel, although relatively easy to produce, requires the availability of plant oil. Biogas technology simply formalizes the natural decomposition process.

A biogas digester consists of one or more airtight reservoirs into which a suitable feedstock—cow dung, human waste, abattoir waste—is placed, either in batches or by continuous feed. Small-scale digesters for household use are commonly made of concrete, bricks, metal, fiberglass, or plastic. Larger commercial biogas digesters are made mainly of bricks, mortar, and steel.

Digestion is accomplished in two general stages. First, acidogenic bacteria turn biomass into volatile fatty acids and

Kemie Guaida/iStockphoto, Matt Ray/EHP

acetic acid. Then methanogenic bacteria metabolize these compounds into a combination of methane-rich gas and an odorless phosphorus- and nitrogen-laden slurry, which makes excellent fertilizer. Depending on temperature and moisture content, it takes about 6–25 days to fully process a batch, according to a fact sheet from WASTE, a development NGO based in the Netherlands. Simpler digesters may take longer.

The end product is about 60–70% methane and 20–30% CO_2, with small amounts of hydrogen sulfide and other impurities. The gas can be connected to a household stove for cooking, to a light fixture with a gauze mantle for lighting, or to other appliances with simple natural gas plumbing; it burns like liquefied petroleum gas. Depending on the design and size, prices for small-scale biodigesters run from US$100 to US$1,700.

It takes 1–2 cows, 5–8 pigs, or 4 adult humans to supply adequate daily feedstock for a single-household biodigester, according to a UNDP–Global Environment Facility fact sheet. The daily input of dung and urine from a single cow produces 1–2 kilowatt-hours of electricity or 8–9 kilowatt-hours of heat. Over a year, this is just about enough to run a refrigerator. In most African applications, a household biogas installation provides sufficient energy for cooking and some lighting.

The Environmental Health Payoff

Properly designed and used, a biogas digester mitigates a wide spectrum of environmental undesirables: it improves sanitation; it reduces greenhouse gas emissions; it reduces demand for wood and charcoal for cooking, and therefore helps preserve forested areas and natural vegetation; and it provides a high-quality organic fertilizer. A well-maintained digester can last over 20 years and will pay for itself in one-fifth that time. But for the developing world, biogas's greatest benefit may be that it can help alleviate a very serious health problem: poor indoor air quality.

Some 2 billion people around the world, including 89% of the sub-Saharan African population, use biomass for cooking and heating, according to *Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals*, a report stemming from a 2004 conference of the same name organized by the Dutch government. Where combustible biomass is the chief energy source, life often revolves around an indoor cookstove or open fire that likely has no vent to the outdoors. Just gathering the fuel takes several hours a day—work that, in sub-Saharan Africa, is done almost entirely by women and children, according to *Energy for Development*. Since women also do most of the housework, including cooking, they and their children are exposed to cookstove smoke far more than men.

From abattoir to energy. A biodigester converts slaughterhouse waste into energy and solves two environmental problems—unhealthy waste and a need for power—at once.

Their respiratory health suffers accordingly. In 2000, burning solid fuels caused 1–2 million deaths, comprising 3–4% of total global mortality, according to *Renewables 2005*. Indoor air pollution such as that stemming from biomass burning may increase the risk of acute lower respiratory infections in children, chronic obstructive pulmonary disease in adults, tuberculosis, low birth weight, asthma, ear infections, and even cataracts, according to the 2002 WHO report *Addressing the Links between Indoor Air Pollution, Household Energy and Human Health*. The Global Health Council, an international group of health care professionals and organizations based in Washington, DC, states that of all infectious diseases worldwide, those in the lower respiratory tract are the leading cause of death.

Clearly, biogas—being free of smoke—offers dramatic improvement of this particular health problem. Even so, concerns among potential users about other health risks of biogas generation have impeded more widespread adoption of the technology.

The Question of Sanitation

A biogas digester can function well on human and animal waste. A quantity of liquid also is necessary; usually water is used, but urine works, too. Different kinds of waste can be mixed, although the cellulose and lignins in plant waste resist decomposition and may cause problems in the digester.

Some potential users are thus reluctant to try the digesters out of concern about sanitation, according to Dhananjay Kunte, a researcher in the Department of Internal Medicine at Evanston Northwestern Healthcare in Illinois, who has conducted several biogas pathogen reduction experiments funded by the government of India. In the developing world, this is no small worry. According to the Global Health Council, almost 40% of deaths in Africa are due to diarrheal diseases; the figure is even higher in Southeast Asia.

There is no question that human and animal waste is loaded with pathogens—*Salmonella*, *E. coli* O157:H7, *Campylobacter jejuni*, *Yersinia enterocolitica*, *Giardia lamblia*, and several types of *Cryptosporidium*, among others. Most of these pathogens are transmitted via the oral–fecal route and can cause diarrhea, abdominal cramps, dehydration, fever, vomiting, and—in vulnerable populations such as infants, children, the elderly, and immunocompromised persons—death. Even though the biodigestion process naturally reduces the pathogen load, handling biogas feedstock and using biogas slurry as fertilizer does carry some risk of infection.

It is not entirely clear whether digester slurry can still harbor enough pathogens to infect humans who handle it or eat crops fertilized with it. In several experiments using human waste as a feedstock, Kunte studied *Salmonella*, *Shigella*, and *Vibrio cholerae*, pathogens common in India that produce symptoms similar to those cited above. Kunte found that separating the overall digestion process into discrete acidifying and methanogenic stages—thereby isolating the acidogenic bacteria in their own tank—resulted in complete eradication of live pathogens. (Biodigesters probably can not

Top to bottom: Sam Roberts/iStockphoto; SEED Initiative

break down the prions that cause BSE, although this is not known to have been tested. However, the risk of BSE is probably low in Africa because most cattle there are free-ranging and not fed cattle parts.)

Greg Austin, director of AGAMA Energy, a Cape Town, South Africa–based alternative energy company, says that once people see a digester in action and are trained in proper hygiene, such as washing their hands while working with it, they realize that health risks associated with operating a biodigester are relatively minor. Austin himself has installed a number of biogas systems in rural areas.

Attitudes and Applications

Beyond concerns about sanitation, successful adoption of biogas in the developing world is highly dependent on political, economic, logistical, and social factors. Again, a key to successful adoption of biogas technology appears to be direct observation and experience. "The problem for anaerobic digester technology is that it is seen as complicated, but it really can be very simple," says Paul Harris, an agricultural engineer at the University of Adelaide in Australia. "And because it is seen as complicated, it is regarded as hard and expensive, but many thousands of rural units worldwide show that this is not true."

In 1982 Tanzania started distributing concrete-and-steel digesters that cost about US$1,400; by 1991 there were only 200 functioning biogas units in the country, according to an article by Innocent Rutamu in the July 1999 issue of *Livestock Research for Rural Development*. Rutamu, a development officer with the Tanga Dairy Development Programme in Tanzania, was testing a plastic unit that cost only US$50. He surveyed 72 farmers in the Tanga region and found that about half had heard of producing biogas from cow dung, but none were already using a digester. Three-quarters thought digesters would be expensive, but most of them could easily pay half the estimated construction cost of $50. Nearly all looked forward to not having to gather wood in the rainy season and no longer risking injury from snakes and thorns during firewood collection. Rutamu's team distributed and installed 46 of the plastic digesters in several villages. After the digesters had been running for five months, respondents said they were doing an average of five fewer hours of housework per day.

Somewhat larger-scale biogas plants also operate successfully in a number of African locations. Biodigesters in five of Rwanda's largest jails provide more than half of the prison kitchens' energy, according to a 30 June 2005 BBC report. And a 30 November 2005 article in the Rwandan newspaper *The New Times* states that the Institute for Scientific Research and Technology in Kigali plans to install some 1,500 biogas digesters by 2009 in the *imidugudu* settlements, villages where rural Rwandans were relocated after the genocidal wars of the mid-1990s.

Other regions, too, have seen a reasonable amount of adoption, says Harris. Nepal celebrated the construction of its ten-thousandth unit a few years ago, and there are thousands of polyethylene digesters operating in Vietnam, as well as a huge number of Chinese and Indian gobar gas units.

In regions where there is already a mature electrical grid, there is limited incentive to use simple biogas digesters because they are not easily scaled up to produce energy comparable to hydropower and coal. Likewise, large farms and dairy operations need appropriately scaled treatments for the mountains of dung and waste their animals and crops generate. In developed markets, energy companies are seeking to convert 100% of biomass to energy, says Mark Kendall, an energy specialist in the renewable resource division of the Oregon Department of Energy. Using biogas alone has an energy conversion efficiency (the proportion of energy produced to that consumed) of about 10% or less, according to *Solid Waste Conversion: A Review and Database of Current and Emerging Technologies*, a 2003 report by the University of California, Davis, Department of Biological and Agricultural Engineering. By comparison, nonrenewable natural gas has an energy conversion efficiency of 55%. Austin counters, however, that this figure depends on conversion technology and energy type (for example, thermal or electrical). When used in a combined heat and power configuration, he says biodigester efficiency can approach 88%.

Still, with its sulfur compounds and other impurities, biogas is too dirty to feed directly into natural gas systems driving motors or to be used as transport fuel in place of gasoline. And in many African countries, bottled liquefied petroleum gas is used rather than natural gas due to lack of both infrastructure and large markets to justify investment in piped gas supply systems. Biogas is not easily bottled and thus must be used near its sources.

The Bright Side

Basic biogas technology is therefore probably limited to places like sub-Saharan Africa—but in those places, it can make a big difference. In those environments, says Austin, the cost per unit of energy over a digester's 15- to 20-year life cycle is lower than both solar electrification and the cost of extending a conventional electrical grid.

There is plenty of scope for biogas technology to expand in Africa. An AGAMA Energy fact sheet estimates that in South Africa there are 400,000 households with two or more cows and no electricity that could make use of biogas digesters. The fact sheet further notes that 45% of schools in South Africa have no electricity, 66% have poor sanitation facilities, 27% have no clean water, and 12% have no sanitation at all. Biogas installations could help mitigate all of these problems.

According to *Renewables 2005*, global energy demand nearly doubled between 1971 and 2002. Whether developed or developing, nations are caught between a rising population generating massive amounts of waste and the impending arrival of hard limits to nonrenewable energy sources. The need for clean, renewable energy is especially acute in the developing world, where few efficiencies have been introduced. In this context, biogas technology is a very good solution to local energy needs, and provides significant benefits to human and ecosystem health. Further expansion of biogas solutions via relatively inexpensive policy initiatives and the development of new technology combinations offers one very bright spot in the diminishing constellation of energy choices, wherever in the world they must be made.

Valerie J. Brown

Suggested Reading

Adeyemo OK. 2002. Unhygienic operation of a city abattoir in south western Nigeria: environmental implication. Afr J Environ Assess Manag. 4(1):23–28.

Flavin C, Aeck M. 2005. Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals. Washington, DC: Worldwatch Institute.

Intergovernmental Authority on Development. Biogas digesters [website]. Available: http://igadrhep.energyprojects.net/Links/Profiles/Biogas/Biogas.htm.

REN21 Renewable Energy Policy Network. 2005. Renewables 2005: Global Status Report. Washington, DC: Worldwatch Institute.

Diving Hazards Unmasked

Estimating Infection Risk from Pathogen Exposure

Most recreational water quality standards are aimed at protecting beachgoers against accidental ingestion of or skin contact with water contaminated by fecal material. But the increased popularity of water sports such as kayaking, surfing, and diving, which often occur far from regulated bathing beaches, raises the question of the water-related health risks these sports entail. Now two researchers at the National Institute of Public Health and the Environment in the Netherlands have attempted to answer this question for divers [***EHP* 114:712–717; Schijven and Husman**]. The study is the first to establish estimates of how much water divers swallow, figures that can be used in calculating health risks involved with waterborne pathogen exposure during diving.

What lies beneath. A new study estimates divers' risk of developing infections when diving in fecal-contaminated waters.

The researchers used detailed questionnaires to ask occupational and sport divers about the number and duration of dives they made in ocean, coastal, and freshwater areas; whether a known pollution source was nearby; the type of diving mask worn (which affects the amount of water swallowed); and the amount of water typically swallowed per dive. Five equivalents enabled divers to estimate how much water they swallowed: nothing, a few drops (an average of 2.75 milliliters [mL]), a shot glass (25 mL), a coffee cup (100 mL), or a soda glass (190 mL). The questionnaire also asked respondents to detail past health complaints, including diarrhea, vomiting, nausea, and eye, skin, and ear problems.

Then the researchers calculated the risk of infection per dive and per year based on the volume of swallowed water reported and pathogen concentrations. *Campylobacter jejuni* and enteroviruses were used for the analysis; concentrations for these organisms in different kinds of surface waters were taken from the literature, and concentration distributions constructed.

The infection risks for *C. jejuni* were generally an order of magnitude higher than those for enteroviruses. For occupational divers, the greatest per-dive mean risk of infection was calculated at 2.8% in coastal waters near a sewage discharge. For sport divers wearing ordinary diving masks, the greatest mean risk was seen in freshwater recreational waters, where there was a 1.5% per-dive risk and a 25% per-year risk of getting an infection. The risk was about 10 times lower when sport divers wore full face masks.

Although occupational divers usually have the protection of a full face mask or diving helmet, they are far more likely than sport divers to dive in contaminated conditions—for example, to assess damage to underwater sewage pipes. They also tend to stay underwater longer. Thus, the chance for exposure goes up.

These relatively high infection risks may explain why 80% of the divers surveyed reported at least one of the health complaints listed on the questionnaire during the course of one year. The authors recommend that divers wear full face masks or helmets when diving in potentially contaminated waters, and that they stay informed about fecal contamination in diving areas. **–Nancy Bazilchuk**

A Fine Differentiation

Chlorpyrifos and Neuronal Development

Although chlorpyrifos has been restricted for use in the home, it is still permitted for agriculture and remains the most widely used organophosphate pesticide in the world. Animal studies and *in vitro* models have indicated that chlorpyrifos has direct and indirect effects on fetal and neonatal neural cell replication and differentiation. These effects include cholinesterase inhibition as well as immediate and delayed-onset changes in synapse formation, neurotransmitter release, neurotransmitter receptor expression, and intracellular signaling. Moreover, chlorpyrifos can exert simultaneous, opposite effects on axonal and dendritic growth. Now researchers from Duke University Medical Center show that chlorpyrifos has direct effects on the differentiation that determines the phenotypic fate of developing neuronotypic cells [***EHP* 114:667–672; Jameson et al.**].

One problem with *in vivo* animal studies is the difficulty of teasing out the indirect effects mediated by mother–fetus or mother–neonate interactions, as opposed to the direct effects of chlorpyrifos on the developing brain. Accordingly, attention has increasingly come to focus on *in vitro* models that simulate the development of two basic types of brain cells, neurons and glia.

The Duke researchers set up such a model using PC12 cells, a tumor cell line that originates from a neuronal phenotype and that can recapitulate all the major phases of neurodevelopment thought to be targets for chlorpyrifos. With the addition of the peptide known as nerve growth factor, differentiation begins: PC12 cells cease dividing and develop the characteristics of neurons, including axonal projections and specialization into either cholinergic or catecholaminergic transmitter systems.

Cholinergic systems have shown immediate and lasting damage when exposure to chlorpyrifos occurs during periods of rapid cell replication (when the neuronal cells are dividing) and differentiation. In contrast, chlorpyrifos exposure initially enhances the development of catecholaminergic systems, increasing the expression of the proteins characteristic of this system and enhancing synaptic activity;

Daniel Gustavsson/ShutterStock

nevertheless, long-term brain function deficits eventually appear, mainly in the form of disruption of synaptic connectivity. The current study was aimed at answering three basic questions about *in vitro* exposure to chlorpyrifos: Does chlorpyrifos alter the ability of developing neurons to express a specific neurotransmitter phenotype? If so, at what stage of cell maturation does this occur? And do such changes occur at chlorpyrifos concentrations below those that affect cell viability?

The researchers evaluated PC12 cells in the undifferentiated state, at the initiation of differentiation, and at mid-differentiation. They contrasted the effects on cell viability, DNA synthesis associated with cell replication, and increased expression of enzyme markers that characterize cholinergic or catecholaminergic phenotypes: choline acetyltranferase (ChAT) and tyrosine hydroxylase (TH), respectively.

Chlorpyrifos exposure at the start of differentiation significantly reduced ChAT but not TH activity. With chlorpyrifos addition during mid-differentiation (four days after nerve growth factor pretreatment), ChAT was unaffected, but TH was increased slightly. Chlorpyrifos reduced DNA synthesis in the undifferentiated state, thereby impairing general neuronal cell development, whereas at the start of differentiation, it specifically impeded development of the cholinergic phenotype.

Chlorpyrifos administration *in vivo* is known to cause deficits in the number of neurons and cholinergic function. Because the researchers were able to reproduce these effects reliably *in vitro*, they suggest that chlorpyrifos directly influences the phenotypic fate of neuronal precursors. In addition, they suggest that their cell culture model could become useful for the rapid screening of neurodevelopmental outcomes with related, or even disparate, neurotoxicants. **–Julian Josephson**

The Freeway Running through the Yard

Traffic Exhaust and Asthma in Children

Since its inception 13 years ago, the Children's Health Study has indicated that air pollution in Southern California communities reduces lung growth and development, raises the risk of developing asthma, and increases school absences due to respiratory illnesses. The latest finding from the study team zeroes in on the impact of exposure to traffic-related pollutants at home, and shows that kindergarten and first-grade students who lived near busy roads experienced a higher prevalence of asthma [***EHP* 114:766–772; McConnell et al.**].

Peter Chen/iStockphoto

Life on the streets. Children who live within a block of major roads are one and a half times more likely to report asthma or wheezing than those living four or more blocks away.

The researchers evaluated the respiratory health of 5,341 children relative to the distance that they lived from major roads, including highways, arterial roads, and freeways. The children, aged 5 to 7 years, lived in 13 communities. The team used detailed information about roadway type and traffic volume collected by the California Department of Transportation to develop a proxy for fresh traffic exhaust—the gases given off immediately around cars—at each child's home.

Children who lived within 75 meters of a major road (about the length of a city block) were approximately 1.5 times more likely to report asthma or wheezing compared to those living 300 meters or more from a major road. Among children with no parental history of asthma, those who had resided at an address close to heavy traffic since before age 2 experienced even higher risks (2.5-fold for asthma and 2.7-fold for wheezing), suggesting that a cumulative lifetime exposure to traffic pollutants may raise health risks. Girls showed a greater association between living near a major road and the health outcomes measured, for unknown reasons.

Few studies in the United States have looked at the connection between traffic and the prevalence of childhood asthma, but the results are consistent with emerging evidence from European studies. Smog and other regional pollution is slowly being brought under control by legislation. However, traffic exhaust represents a form of local pollution with public health consequences that is largely unregulated. As a start toward curbing the effects of exhaust, California recently passed a law that prohibits the construction of new schools within 500 feet of freeways. Locating playgrounds, parks, and sports fields a safe distance from busy roads may be another way to prevent children from inhaling exhaust fumes. **–Carol Potera**