Cleaning Up Coal

Scientists and policymakers might debate the existence and causes of "global warming," but no one debates the need for clean air or the desirability of cleaning up emissions from coal-fired power plants.

Vanderbilt researchers David Kosson and Florence Sanchez want to make sure that new technology designed to remove mercury from power-plant emissions doesn't create an unintended byproduct of polluted ground water (please see photo and additional story about Sanchez on page 2).

The problem they're wrestling with is that taking pollutants out of the power plant smoke produces contaminants concentrated in the ash and other solid residues that have to be properly managed so they don't end up in our drinking water or in fish. Solving one problem can create another.

Kosson, professor and chair of civil and environmental engineering, and Sanchez, an assistant professor in the same department, have been collecting data to help the U.S. Environmental Protection Agency (EPA) regulate power-plant mercury-emissions control in ways that will protect human health at every stage of the process, from power production to waste disposal. The EPA issued its final Clean Air Mercury Rule on March 15, 2005, which the agency estimates will result in the reduction of mercury emissions from coal-fired plants by nearly 70 percent per year by 2018.

Indeed, the technology exists that can accomplish this feat. But Congress asked the EPA to research whether the mercury extraction technology might adversely impact groundwater, streams and rivers. Kosson and Sanchez were asked to provide technical management of this research in conjunction with ARCADIS, Inc, a contractor for the EPA Office of Research and Development.

The researchers found that doing a better job of removing mercury from smoke is not likely to result in dangerous releases of mercury into the groundwater after waste disposal. But there may be difficulties with arsenic and selenium.

"Leaching" is the action of a liquid passed over and through a solid. Kosson likes to use drip coffee as an example of a leaching process.

Research Assistant Professor Andrew Garrabrants worked with Professors Kosson and Sanchez to develop a leaching protocol which provides a powerful and adaptable tool for power engineers and environmental engineers.

Surprising Results

Arsenic is one of our most notorious toxins. However it takes a concentrated amount to have a deleterious effect on health, and most of us have trace amounts of arsenic in our bodies. Selenium, a highly beneficial mineral in small amounts, is poisonous in larger concentrations.

The arsenic and selenium results in the research were a bit surprising, Kosson says, and will require additional research.

He and Sanchez studied coal combustion residues from selected power plant facilities that use new mercury emissions reduction equipment, subjecting them to a series of tests to get a good sense of how much mercury and other contaminants might leach out into groundwater.

"What we found was that mercury concentrations remained below the mercury drinking water maximum contaminant level, but the arsenic and selenium concentrations present the potential for adverse environmental impacts with and without the new controls" he says.

The good news is that Kosson and Sanchez also found, much to their satisfaction, that the testing series and interpretation software they have developed to evaluate and predict how contaminants will behave under various environmental and waste-management scenarios is as valid as they had hoped it would be.

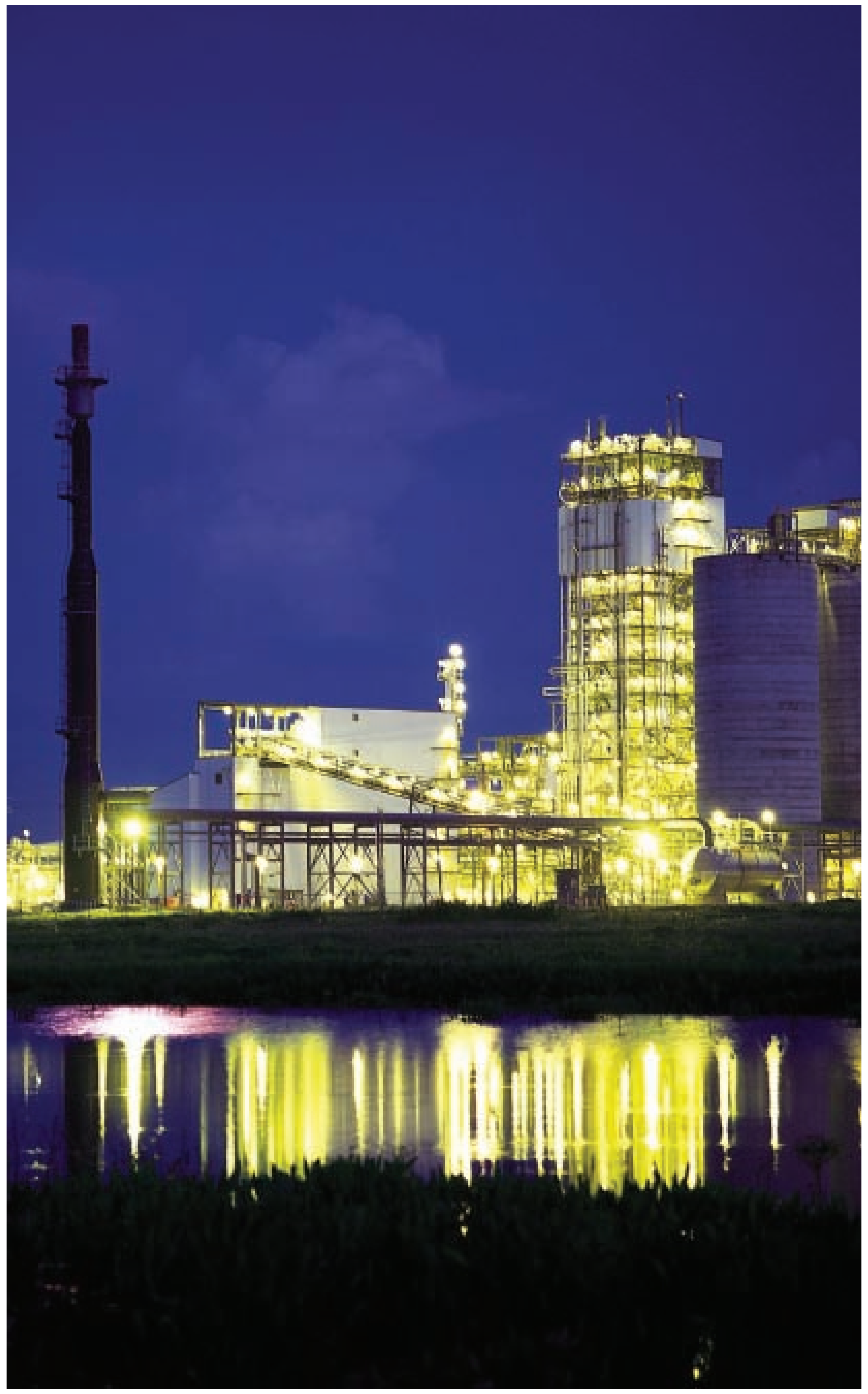
"The protocol is very solid," Kosson says with a smile.

Napkins and Coffee Grounds

Kosson and Sanchez have reason to be proud. The leaching protocol they developed, along with Vanderbilt colleague Andrew Garrabrants and H.A. van der Sloot of the Netherlands Energy Research Foundation, is a powerful, highly adaptable tool for power engineers and environmental engineers.

"The protocol considers the range of known coal combustion residue chemistry and management conditions," Kosson says. "The method also permits development of data that are comparable across U.S. coal and residue types. The approach has also been demonstrated to be applicable for evaluating potential environmental impacts from a wide range of solid materials for beneficial use and disposal."

Published in *Environmental Engineering Science 2002*, the protocol had its beginnings in the 1980s, when Kosson was on the faculty at Rutgers and was trying to help the state of New Jersey figure out what to do with solid waste residue after incineration. Kosson happened to meet van der Sloot during a conference in Europe, and they discovered they had similar frustrations with the existing frameworks for assessing leaching.



A nighttime view of a large coal-gasification plant. Vanderbilt researchers are studying coal-combustion residues to help the Environmental Protection Agency regulate power-plant emissions in ways that will protect human health.

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Leaching is a very important thing to consider when planning what to do with wastes, because most waste disposal properties, such as landfills and impoundment ponds, are subjected to rain. The amount of rain water will vary from place to place and from day to day, which is one reason why predicting how much pollutant might leach out from the waste can get a little tricky.

Another factor complicating the prediction process is the wide variety of pH levels in the disposal site soils and in the waste material itself. The degree of acidity or alkalinity affects the rate of leaching and hence the amount of contaminant released.

Add those difficulties to the variations in waste management techniques and blending of materials, and it gets, well, messy.

Kosson and van der Sloot put their heads together to design a more comprehensive and adaptable protocol than the traditional method. "A lot of the initial design work was sketched out on napkins while riding the train to and from Washington, D.C.," Kosson says.

Their idea was to determine the intrinsic leaching properties of contaminants of interest and to develop computer simulation models that use the intrinsic properties to predict contaminant behavior under various conditions in the field. The traditional protocol attempted to mimic conditions in the field, which basically required "re-inventing the wheel" for each facility. The new protocol is based on intrinsic data and known dynamics, and variations from site to site are accounted for using the simulation modeling.

"The leaching protocol we developed, and continue to refine, is based on characterizing fundamental parameters of leaching dynamics of contaminants and then modeling them to predict outcomes in different field scenarios," Kosson says.

As part of this project, Kosson and Sanchez ran tests to check the validity of their protocol in predicting actual results in the field.

"The Leaching Framework was able to fully satisfy our quality assurance and quality control requirements," Sanchez says.

Mercury rising

The protocol, which is being adopted in Europe and is being used by the EPA in several situations, can be employed in a variety of industrial and public utility situations. Kosson and his associates have been working with the agency to replace the traditional method with the new protocol, so this summer's research that validates the approach represents a welcome milestone.

This summer's research teamed Vanderbilt with ARCADIS of Durham, N.C., to sample fly ash and sludge from power plants to test the waste for mercury, lead, cadmium, selenium, arsenic and other pollutants.

The team ran a battery of tests of sample fly ash produced both with and without new mercury emissions control technology. Tests included assessments of alkalinity, solubility and release as a function of pH; solubility and release as a function of the liquid-to-solid ratio; electrical conductivity; surface area and pore size distribution; carbon content; moisture content; mercury content; and content of other metals. These and other tests gave the researchers the raw data they needed to feed into software models that can give a comprehensive analysis and prediction of contaminant behavior across a range of waste management and environmental conditions.

"We found that leaching of arsenic may be of concern for some land disposal scenarios, independent of whether activated carbon injection is in use," Kosson says. Activated carbon injection is the new technology used to reduce mercury and other contaminant emissions.

"We also found that leaching of selenium may be a concern for some facilities using activated carbon injection," Sanchez says.

Future research will delve further into the problematic areas and will examine wastes produced by other types of coal-fired power plant facilities, using other types of coal.

—*Vivian F. Cooper*

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Professor David Kosson is working with Assistant Professor Florence Sanchez to determine whether mercury, arsenic and selenium are leaching into the groundwater from new emission-control technology for coal-fired power plants.

Monitoring Mercury

The EPA announced its intention to require reduction of mercury and other contaminant emissions from coal-fired power plants in December 2000. Reduction of mercury emissions was a primary goal of the new regulations to be developed.

Mercury, as an element and as part of various compounds, has known adverse health effects, particularly on neurological development. Most people in the U.S. are exposed to mercury through eating fish and shellfish containing methylmercury.

Mercury is one of the metals in coal that do not burn and are released as coal combustion residues. Coal-fired utilities produce approximately 105 million tons of coal combustion residues per year. The some 1,250 coal-fired power plants in the U.S. provide more than half of all electrical power generated in the U.S.

Coal combustion constituents that do not remain in the bottom of the boiler are released in fly ash or are removed by a wet scrubbing process using sulfur dioxide. Some 68 million tons of fly ash were produced in 2001.