changes in measures such as heart rhythm and white blood cells—even in asthmatics, whose damaged lungs contained up to six times as many particles as healthy people.

The explanation may be that it's not size or chemistry alone. The ultrafines used in the Rochester study were pure carbon black, but ultrafines in the real world are likely coated with metals and organic compounds, Frampton says. (Also, the researchers may need to test people with cardiovascular disease.) Likewise, sulfates may form the core of a particle that also contains nastier compounds such as metals, or they could change the chemistry of metals so they're more soluble in blood. Larger particles may irritate and inflame airways, exacerbating the toxicity of PM constituents such as organics and metals, says Costa. And particles may have different effects in the short term and after years of exposure. "It's far more complex than trying to decide which chemicals are toxic," says toxicologist Joseph Mauderly of Lovelace Respiratory Research Institute in Albuquerque, New Mexico.

Newer experiments are seeking to use more realistic mixtures. That became possible only a few years ago when researchers invented devices that can collect ambient air from outside a lab and concentrate the particles for use in experiments. Others are looking at pollutants from a range of sources. For example, Mauderly's group at Lovelace is conducting animal studies comparing particles from diesel engines, gas engines, wood smoke, cooking, road dust, and coal to pin down which type is most toxic. HEI, meanwhile, is sponsoring epidemiologic and toxicology studies that will take advantage of a new monitoring network at 54 sites that measures a finer breakdown of the chemicals in particles, such as sulfates, elemental carbon, and trace elements, than has been gathered previously. And EPA recently launched a $30 million, 10-year study led by University of Washington researchers that tracks correlations between these finer air pollution measurements and the health of 8700 people over age 50.

Down the road, this new information should help guide regulations—for instance, if carbon particles from wood burning were the main problem, or diesel engines, EPA could specifically target those sources. Controlling only mass, as EPA does now, might actually be counterproductive. For example, if larger $PM_{2.5}$ particle levels go down but levels of ultrafines do not, "that could make things even worse," Frampton says. That's because ultrafines tend to glom onto larger $PM_{2.5}$ particles, so they don't stay in the air as long when the larger particles are around.

Time to act

Those results won't be available for years, however, and EPA is under a court order to decide whether to tighten the current $PM_{2.5}$ standard by the end of 2005. EPA scientists in January recommended that the agency consider tightening the standards from the current annual average of 15 μg/m³ to 12 to 14 μg/m³, and the daily average from 65 μg/m³ to as low as 25 μg/m³. They also suggested replacing the PM_{10} standard with a new one for particles between PM_{10} and $PM_{2.5}$ to better target coarser particles between those sizes. In April, EPA's clean air advisory board will weigh in.

$PM_{2.5}$ levels have already dropped at least 10% since 1999 due to acid rain regulations and new diesel engine standards (see sidebar, p. 1860). They will fall further thanks to additional cuts in sulfates and nitrates from coal-burning power plants through new regulations issued this month and possibly the Administration's proposed Clear Skies program. But a tighter standard could trigger additional controls in areas with the highest particle levels, such as Los Angeles and the Northeast. Environmental and health groups as well as many scientists say that, as with tobacco smoke and lung cancer, policymakers can't wait for all the scientific answers before taking action to prevent deaths from dirty air.

–JOCELYN KAISER

U.S. Education Research

Can Randomized Trials Answer The Question of What Works?

A $120 million federal initiative to improve secondary math education hopes to draw on an approach some researchers say may not be ready for the classroom

When Susan Sclafani and her colleagues in Houston, Texas, received a $1.35 million grant from the National Science Foundation (NSF) to work with secondary math and science teachers, nobody asked them to demonstrate whether the training improved student performance. "All we had to do was produce qualitative annual reports documenting what we had done," she says. Sclafani thought that wasn't nearly enough and that NSF should be more concerned about whether the project helped students learn. Now, a decade later, she's in a position to do a lot more. And that's exactly what worries many education researchers.

As assistant secretary for vocational and adult education at the Department of Education (ED), Sclafani is championing a $120 million initiative in secondary school mathematics that is built in part on money shifted from the same NSF directorate that funded the Houston grant. The initiative, included in President George W. Bush's 2006 budget request for ED now pending in Congress, will give preference to studies that test the effectiveness of educational interventions in the same way that medical researchers prove the efficacy of a drug. Randomized controlled trials (RCTs) of new approaches to teaching math, Sclafani says, will help school officials know what works, and they can then scale up the most promising new curricula and teaching methods. "Randomized studies are the only way to establish a causal link between educational practice and student performance," she says.

CREDIT: U.S. DEPARTMENT OF EDUCATION

Prove it. The Department of Education's Susan Sclafani wants to see more experimental evaluations in math and science education.

But some researchers say that such trials won't tell educators what they need to know. And they believe their discipline is too young to warrant a large investment in experimental studies. "Rushing to do RCTs is wrongheaded and bad science," says Alan Schoenfeld, a University of California, Berkeley, professor of math education and adviser to both NSF and ED. "There's a whole body of research that must be done before that."

The proposed math initiative at ED would be a competitive grants program to prepare students to take Algebra I, a gateway course for the study of higher mathematics and the sciences. Applicants will be encouraged to use RCTs and quasi-experimental designs to measure whether the reform works, Sclafani

Published by AAAS