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Looking for Pollution Where the People Are

KIRK R. SMITH

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SUMMARY For several decades developed countries have sought to protect the health of their citizens by monitoring and regulating outdoor air pollution. But are smog and other outdoor pollutants the gravest dangers to human health? A new way of looking at air pollution indicates that the danger is closer to home—in our homes, in fact, and in our cars and workplaces. About 90 percent of people's time in developed countries is spent indoors where cigarette smoke, household deodorizers and dry-cleaned clothes expose them to greater concentrations of pollutants than they will find outdoors in the most congested cities. The situation is even worse in developing countries where pollutants from household stoves help make respiratory diseases the chief cause of illness and death. Something less than 2 percent of global person-hours is spent in the urban outdoor settings of developed countries where 95 percent of pollution measurements have been taken. Measuring pollution where people are could result in dramatic changes in policy and funding priorities for controlling air pollution.

When we think about air pollution, we visualize the smog that envelops our cities or industrial smokestacks belching noxious fumes. Concern about these kinds of obvious pollutants has generated widespread support for controlling air pollution.

But if the principal goal of pollution control is to protect public health, this focus on outdoor air pollution, and on the largest outdoor sources of emissions, fails to do the job. For to affect health, we must reduce people's exposure to health-damaging pollutants *in the air they actually breathe.* These pollutants come, to a great extent, from relatively small localized sources that are, literally, right under our noses: cigarettes, spray cans and dry-cleaned clothes, for example. And, most often, these are indoors.

Most of our exposure to pollutants occurs indoors

In fact, most of our exposure to pollutants occurs indoors—inside homes, vehicles and workplaces. The growing awareness of the importance of small indoor sources reveals both another set of important pollutants and a new ordering of priorities for protecting public health. Indeed, acknowledging that health-damaging pollutants should be measured *where the people are* promises a revolution in the way air pollution sources, victims and control measures are evaluated.

Monitoring the Safety of the Air We *Don't* Breathe

In the United States, seven so-called "criteria" pollutants are widely monitored and regulated by the Clean Air Act. Included are particulates (solid or liquid particles suspended in the air that cause or worsen respiratory illness), carbon monoxide (a gas that damages the heart), and nitrogen dioxide (a gas associated with respiratory illnesses). A large national network of several thousand outdoor monitors measures compliance with the standards.

The United States has served as a model for other nations where similar standards have been established. But the current pattern of monitoring and regulation may not directly address the locations and types of pollutants with the most damaging health impact.

Current standards apply to outdoor levels of pollution where measurements are most easily made—typically the rooftops of public buildings. These locations are chosen for convenience, security, geographical spread and general congruence with population distribution. Most people, however, do not spend much time outdoors, particularly in temperate developed countries. In the United States, for example, less than 10 percent of the population's time is spent outdoors. Even in developing countries, 70 percent or more of the population's time is spent indoors.

How closely do the monitored outdoor concentrations of pollutants match the actual concentrations encountered by people in the indoor environments where they spend 70 to 90 percent of their time? Studies in developed and developing countries have shown that indoor and outdoor concentrations of most pollutants are often significantly different. Moreover, the local concentrations—both indoor and out—do not correlate well with concentrations measured at the nearest outdoor monitoring site. Thus, to understand the pollutant concentrations to which most people are exposed most of the time, it is necessary to monitor typical indoor environments.

Air Pollutants and Health

A pound of pollution released outdoors or in places where people do not spend much time is substantially less damaging to health than the same amount released near people.

For example, the major sources of benzene emissions (a known carcinogen) in the United States are automobiles and industrial plants, now under tightening controls through the Clean Air Act. The major sources of benzene exposure, however, are found indoors in household products and environmental tobacco smoke. Carbon monoxide, long controlled outdoors where it comes mainly from cars, reaches people primarily from

gas stoves and by leaking directly into the passenger compartments of cars. Emissions of p-dichlorobenzene, a probable cause of human cancer, come mainly from chemical manufacturing plants. Exposures to people, however, come mainly from household air deodorizing products. (See table.)

The major sources of air pollution exposures differ depending on a country's level of development. The primary air pollution health hazards in many developed countries are from cigarette smoke, motor vehicles and chemicals in household products. In developing countries, the greatest pollution-related threat to health comes from household and neighborhood use of dirty solid fuels, such as coal, wood, crop residues and dung, for cooking and heating. (See page 4.)

Emissions of environmental tobacco smoke are a thousand times more dangerous than smoke emissions from power plants

Women—who do most of the cooking—receive the greatest exposure to particulates in developing countries. And infants, who are particularly subject to respiratory diseases, are exposed when their mothers are preparing food.

Similar examples can be found for the developed countries. Stringent pollution controls, for instance, are applied to coal-fired power plants in the United States, yet they still release about 500 thousand tons of particulate pollution each year. Tobacco smoking, which fortunately is declining, now releases only something like 20 thousand tons each year. From a particulate emissions standpoint, therefore, power plants are 25 times more polluting than cigarettes. When the comparison is based on actual human exposure, however, environmental tobacco smoke, sometimes called passive smoking, is found to produce some 50 times more exposure. This does not include the immensely larger exposure to the smokers themselves.

This means that from a particulate exposure standpoint, a 2 percent decrease in environmental tobacco smoke would be equivalent to eliminating all the coal-fired power plants in the United States. This could come from 2 percent cleaner, smaller or fewer cigarettes, of course, but could also come from better ventilation or more pressure to encourage smokers to smoke outdoors.

Perhaps even more striking is that, per pound released, environmental tobacco smoke is more than one thousand times more dangerous than the smoke from power plants. This is due not to any difference in their composition, assumed here to be identical, but simply to the differences in the place and time of release. Power-plant smoke is generally released from stacks high in the air and out of town, or at least in parts of town where few people live. Environmental tobacco smoke, however, is largely released indoors and often at the times when nonsmokers are present. Put another way, per pound released, the amount of environmental tobacco smoke actually inhaled

Table. Emissions versus exposures: The most important sources of air pollution in the United States

Pollutant	Health effects	Major emissions sources	Major exposure sources
Particulates	Respiratory diseases	Industry; automobiles; home heating	Environmental tobacco smoke
Benzene	Cancer, particularly leukemia	Industry; automobiles	Environmental tobacco smoke; household products
Tetrachloroethylene	Cancer	Dry-cleaning shops	Dry-cleaned clothes
Chloroform	Cancer	Sewage treatment plants	Chorinated water from showers
p-Dichlorobenzene	Cancer	Chemical manufacturing	Air deodorizers
Carbon monoxide	Heart disease	Automobiles	Driving; gas stoves
Nitrogen dioxide	Respiratory diseases	Industry; automobiles	Gas stoves

Where Are the People?

Let us consider the message of the accompanying article, *measure where the people are,* and ask, *"Where is this?"* As shown in the accompanying pie chart, the answer is surprising. On a global basis, only about 23 percent of the yearly person-hours are spent in developed countries such as the United States, and most of this is indoors. As a result, only about 2 percent of the world's person-hours are spent in the place where the vast bulk of air pollution research, regulation and control efforts have focused: outdoors in the cities of rich countries. Only about another 6 percent is spent in the next most well-studied location: outdoors in the cities of poor countries. The largest expenditure of person-hours is in the same place it has been for 10,000 years, indoors in farming communities in undeveloped parts of the world (fig. 1).

Now that we know the time spent in each of the eight major global microenvironments (indoors and outdoors in rural and urban settings in both developing and developed countries), what are the human air pollution exposures in each? This question cannot yet be answered in any precise way even for the major pollutants, for there are too few measurements, especially in the microenvironments with the most person-hours. Taking the single most important and most measured pollutant, particulates, however, there are enough data to obtain a rough idea of typical concentrations in the major microenvironments.

It may come as another surprise that the largest average concentrations of particulates probably also do not occur in cities, in spite of our association of air pollution with urbanization. Nor do they occur outdoors or in areas with high levels of fossil fuel combustion, as one might expect. Based on the admittedly small database of several dozen studies in rural areas of poor countries, the highest sustained concentrations apparently exist in the inverse situation, i.e., indoors in rural areas of developing countries where wood and other solid fuels are used. In the simple cooking and heating stoves relied upon daily by about half the world's households, unprocessed solid fuels burn relatively poorly, producing substantial particulate and other emissions.

We thus have what we need for a rough total particulate exposure assessment, which is found in fig. 2. This shows that less than 1 percent of total human particulate exposures occurs outdoors in the cities of rich countries, the location of most attention. More than half, however, would seem to occur indoors in the village households of the developing world, followed in size by indoor and outdoor exposures in Third World cities.

Perhaps these are the places that deserve the most air pollution attention.

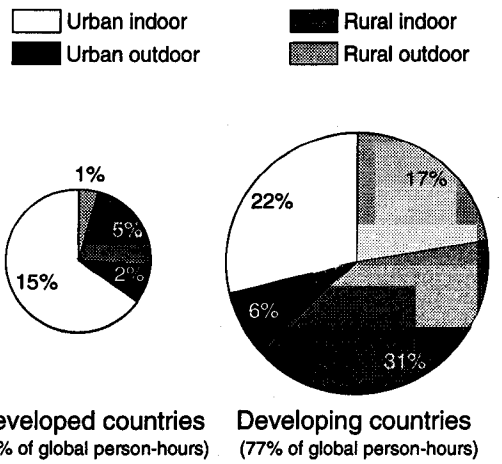

Fig. 1. Approximate distribution of global person-hours in 1990 into eight major microenvironments. Note that only 2 percent lie outdoors in cities of developed nations where the vast bulk of air pollution monitoring and control efforts have taken place.

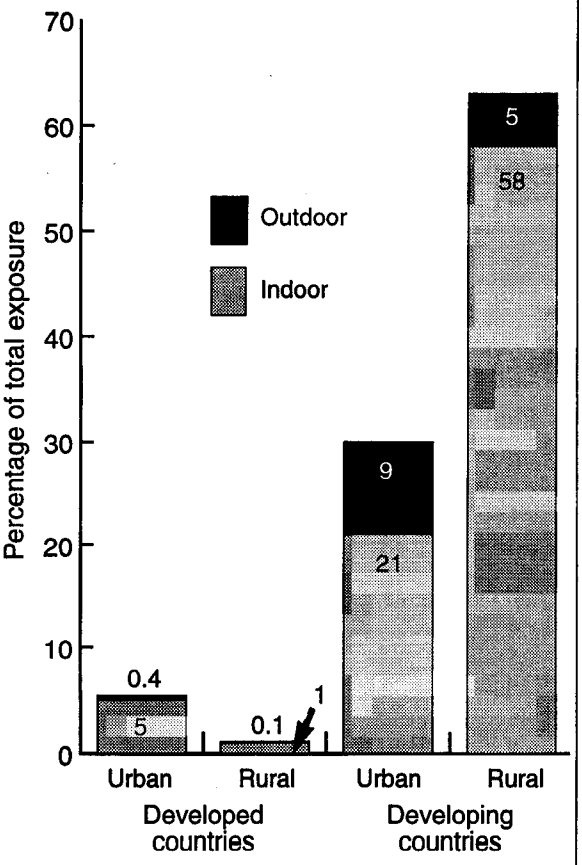

Fig. 2. Approximate distribution of human exposure to particulate air pollution. Note that more than 90 percent occurs in developing countries and that two-thirds of this seems to occur indoors in rural areas.

by people is more than a thousand times greater than what they inhale from power plant emissions. This difference is their relative "exposure effectiveness"—a comparison of how much of what is emitted actually goes into people's lungs.

This one comparison alone, if generally accepted, would have tremendous implications for air pollution control strategy in the nation. It implies, for example, that we ought to be willing to pay a thousand times as much to control environmental tobacco smoke as we are to control power-plant smoke. But this is only one example of how our current system of air pollution regulation and control tends to ignore the sometimes large differences in exposure effectiveness that can exist for the same pollutant in different situations.

A Pollutant Is a Pollutant Whatever Its Source

Some argue that indoor and outdoor exposures to pollutants are fundamentally different and so should not be compared. Power-plant smoke is imposed on people without their consent, the argument goes, and thus warrants greater public concern than indoor sources that people in some way bring on themselves. There are at least two major flaws in this argument, however.

Governments already have ways to control much inside our homes

First, it is only partly true that people make the decision to bring indoor exposures on themselves. How many members of the public are able to interpret the list of ingredients on a can of household cleaner or pesticide to decide how much exposure is warranted for their families? How is the householder able to judge what chemicals will be released from a carpet or piece of furniture they buy? Even exposure to tobacco smoke is clearly not entirely a matter of choice, because smokers still make up a significant part of the population.

The second flaw in this argument is the hidden assumption that the emissions from outdoor sources are somehow different from those originating indoors. If we are serious about controlling benzene exposures for health reasons, should not we view each benzene molecule as our enemy and work to stop as many as possible from reaching people? What sense does it make to spend hundreds of millions of dollars controlling stationary outdoor sources, which cause relatively little human exposure, while ignoring the indoor sources that cause the most? Will the parents of a child afflicted by benzene-triggered leukemia be less upset if they are assured that the benzene probably came from indoor sources?

The leadership of Surgeon General C. Everitt Koop during the mid-1980s is a model for the approach being promoted here. When AIDS became a problem, he attacked it everywhere he could: at the blood banks, in the bath houses, among the prostitutes, at the schools, and so on. His target was the disease and he did not let himself be sidetracked by issues about who had brought it upon themselves—that some AIDS cases were somehow of less concern than others. Although taking courage at the time, his approach is actually the classic route to better public health. Ignoring some exposures because they are indoors, "voluntary," or otherwise less worthy of attention is the route to wasting resources. Wasting resources is the route to protecting fewer people than we can, resulting in greater ill health than necessary.

Another criticism of efforts to bring indoor exposure considerations into regulatory frameworks is that this will result in an infringement of individual rights—that big government will place electronic monitoring devices in every home. This is ridiculous, for total exposures can be determined by statistical sampling techniques analogous to the way the Nielsen ratings of TV viewing habits are done.

A variant on this Big Brother argument is that regulating indoor pollution will require the government to impose its will on the individual householder, meaning that pollution fines, limits and other controls would be imposed on the "castle" that is each householder's home. It is useful to note, however, that the infamous London smog of 1952, which killed 4,000 people in a few days and instigated air pollution control legislation around the world, was largely due to household coal heating stoves. Just such a belief that an

Englishman's home is his castle had held back efforts to control household sources even though outdoor sources had started to be controlled in London. The stove smoke's release at breathing level right in the neighborhoods where people lived gave it a tremendous exposure effectiveness during the windless foggy days of the smog.

Exposure to pollutants often depends more on people's activities than on where they live

In fact, governments already have ways to control much inside our homes. Fuel quality is regulated by the government as is the performance of stoves and other combustion devices. Building and fire codes already affect ventilation rates, although aimed primarily at other issues. Household chemical products are subject to regulation, some substances being banned, for example. Radon gas inspections are mandated in many states. Taxes, public education and controls on advertisements have had clear impacts on tobacco consumption. There would seem to be little need to invent any other policy tools to control indoor air pollution, but rather to adjust the existing ones to address concerns about people's exposure to pollutants.

Total Exposure Assessment

The increasing, if tentative, attention being given to indoor air pollution is an indicator of a more fundamental shift occurring in the environmental health sciences: recognition of the need for total exposure assessment (TEA). The idea behind TEA is that if we are to understand how a particular pollutant affects humans and what the most effective control measure is, it is necessary to account for all routes of exposure. To do this, we must study the various microenvironments in which people spend time. This can be done by measuring pollutant concentrations separately in each microenvironment and then taking the sum weighted by the person-hours spent in each. Another approach is personal exposure monitoring in which the air in the breathing zone of individuals is sampled during normal daily activities. A range of portable devices and techniques for both kinds of monitoring has been developed.

A complete TEA would involve summing exposures across all routes of entry into the body, that is, ingestion, inhalation and skin absorption. For many of the major air pollutants, however, exposure by routes other than inhalation is insignificant. And small changes in indoor conditions affect total exposures more than do large differences in outdoor concentrations, even though indoor levels are affected by outdoor pollution. Attempts to accurately correlate health effects with outdoor concentrations alone may, therefore, be foiled.

Indeed, the U.S. Environmental Protection Agency has itself conducted a set of Total Exposure Assessment Methodology (TEAM) studies in different parts of the country. The TEAM studies provide ample evidence that outdoor measurements are often nearly useless in determining actual human exposures to air toxics (volatile organic chemicals) as well as for the more traditional pollutants, such as particulates and nitrogen dioxide. The studies show that, in the United States, people's exposure to harmful pollutants depends far more on their activities (for instance, whether they work or live with a smoker) than on whether they live in an urban or industrial setting or near a chemical plant or oil refinery. The EPA has apparently not, however, taken these findings to heart. There is a serious lag between science and policy as only a tiny fraction of the EPA's budget is set aside for total exposure assessment and research on indoor pollution.

Policy Implications

How might governments begin to address the problem of indoor air pollution? And how can we even begin to quantify the effects of the thousands of potential sources of indoor pollution?

Perhaps the easiest way is to establish broad classes of emission sources and then determine the average exposure effectiveness of each. Examples of classes of emission sources might include vehicles, stoves vented indoors, stoves vented outdoors, aerosol cans, cigarettes, power plants, gas stations and dry cleaners. Exposure effectiveness is the percentage of the pollution from each emis-

sion source that actually reaches people's breathing zones.

This task is not as daunting as it may seem. There is already a great deal of information about the characteristics of pollution sources. We do, however, need more information about the distribution of the population's time in the principal microenvironments.

Of course, no individual aerosol can is used exactly the same way as any other and thus each actually has a unique exposure effectiveness. It might be argued, therefore, that since it would clearly be impractical to determine an exposure effectiveness separately for each device, the whole procedure should be abandoned. Again, the answer is in statistical sampling techniques, which can be used to determine the average and range of exposure effectiveness for each class of devices. Even if some sources are used in a much different way than the average, we would still be much better off than with the present system, which ignores exposure effectiveness.

Priority should be given to controlling emission sources that produce the most human ill health

Once exposure effectiveness figures are determined for each important class of emission sources (a calculation that would have to be periodically updated), air pollution control decisions could be based on the emissions of each source weighted by the exposure effectiveness of its class. This would give priority to those sources that produce the most human ill health and not to those that just produce the most outdoor emissions.

One difficulty with this suggestion, at least for the United States, is that no single agency has a wide enough mandate to regulate the wide range of sources revealed by total exposure assessment. Several agencies, including the Environmental Protection Agency, the Food and Drug Administration, the Occupation Safety and Health Administration, the Consumer Product Safety Commission and the Department of Energy have jurisdiction over areas that would need to be effectively coordinated for total exposure assessment. As a start, however, the Environmental Protection Agency could consider the exposure effectiveness of the classes of sources that already lie within its mandate.

Fundamental Questions

In considering policies based on the principle that controlling people's exposure to pollutants should take priority over controlling emissions, we need to address several questions about current air pollution policy on the United States:

- Is public health the real concern behind current regulations? Or have other hidden priorities—such as aesthetics, property values and simple outrage at industrial polluters—shaped our policies?
- Since there is no qualitative difference among exposures of the same pollutant in different situations, such as indoor and outdoor or "voluntary" and "involuntary," why should one be of public health concern and one not?
- Would a new emphasis on controlling exposure rather than emissions create politically unacceptable control strategies in which some population groups receive little benefit because it is too expensive to reduce their exposures? Would this be seen as the majority unfairly benefiting at the expense of a minority?
- Why hasn't the Environmental Protection Agency translated the findings of its own studies on total exposure assessment into policies and programs to reduce people's exposures to pollutants. Is institutional inertia contributing to the survival of outmoded pollution control strategies?
- How do we map a public health strategy that recognizes that by controlling too much in one place we waste resources that could have been used to achieve greater health benefits overall?

Let me tackle the last question in this way. We can perhaps agree that our goal is the day when there are no human-generated toxins circulating in the environment. Unfortunately, we neither have the resources nor the knowledge to make tomorrow be that day.

What we can do, however, is design a pathway so that at the end of each day we can tell ourselves that we have moved as far as possible

toward our goal with the time and other resources available. Thus, we do not say that anyone's favorite hazard is not important, only that it will be put on a priority list that starts with the control measure that brings the most benefit. Eventually, everything is to be controlled. How much to spend each day is a political decision, with scientific, economic and social inputs.

The design of the best pathway to follow, however, can proceed even at times when overall movement along the path is slow. Although there exists no perfect way to make the comparisons needed to design such a pathway, total exposure assessment is the best for a broad range of pollutants.

The bottom line, again, is that when ill health is the outcome of concern, it is necessary to look for pollution where people are; most people do not spend much time outdoors, let alone on the roofs of post offices. Put another way, total exposure assessment gives us a much better indicator of the real factor of interest, health effects, than do outdoor concentrations. It is thus exposure that should be the focus of our attention.

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About the Author

***Kirk R. Smith** is a senior fellow in the East-West Center's Program on Environment and coordinator of the World Health Organization's Collaborating Centre for Studies of Risk and Development. In 1984 Dr. Smith was selected as one of the 100 outstanding young scientists of America by* Science Digest.
Telephone: (808) 944-7519
Facsimile: (808) 944-7298