International Expert Workshop on the Analysis of the Economic and Public Health Impacts of Air Pollution: Workshop Summary

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Forty-nine experts from 18 industrial and developing countries met on 6 September 2001 in Garmisch-Partenkirchen, Germany, to discuss the economic and public health impacts of air pollution, particularly with respect to assessing the public health benefits from technologies and policies that reduce greenhouse gas (GHG) emissions. Such measures would provide immediate public health benefits, such as reduced premature mortality and chronic morbidity, through improved local air quality. These mitigation strategies also allow long-term goals—for example, reducing the buildup of GHG emissions—to be achieved alongside short-term aims, such as immediate improvements in air quality, and therefore benefits to public health. The workshop aimed to foster research partnerships by improving collaboration and communication among various agencies and researchers; providing a forum for presentations by sponsoring agencies and researchers regarding research efforts and agency activities; identifying key issues, knowledge gaps, methodological shortcomings, and research needs; and recommending activities and initiatives for research, collaboration, and communication. This workshop summary briefly describes presentations made by workshop participants and the conclusions of three separate working groups: economics, benefits transfer, and policy; indoor air quality issues and susceptible populations; and development and transfer of dose–response relationships and exposure models in developing countries. Several common themes emerged from the working group sessions and subsequent discussion. Key recommendations include the need for improved communication and extended collaboration, guidance and support for researchers, advances in methods, and resource support for data collection, assessment, and research. *Key words:* **air pollution, economic valuation, human health, morbidity, mortality.** *Environ Health Perspect* **110:1163–1168 (2002). [Online 26 September 2002]** *http://ehpnet1.niehs.nih.gov/docs/2002/110p1163-1168bell/abstract.html*

Technologies and policies that reduce greenhouse gas (GHG) emissions also can promote social welfare and other environmental benefits unrelated to global warming, which may be explicitly intended or may incidentally arise as a consequence of mitigation policies (Davis et al. 2000). Such mitigation measures include increased energy efficiency, low emissions cooking stoves, improved land-use planning, electric and hybrid vehicles, renewable energy such as wind and solar power, reductions in agricultural production of methane, energy tax policies, and less carbon-intensive fuels (Metz et al. 1999, 2002).

One of the most important co-benefits, or ancillary benefits, associated with GHG mitigation is fewer health effects due to local air pollution. For example, certain policies that reduce the burning of fossil fuels decrease emissions of CO_2 and other GHGs, but also reduce the concentrations of ambient air pollutants that cause adverse health impacts, such as premature mortality, increased hospital admissions for respiratory and other causes, and increased frequency of asthma attacks. Therefore, such GHG reduction strategies can offer immediate public health benefits in addition to their long-term effects on climate change mitigation, in both industrialized and developing nations. Although most discussion of these GHG-reducing policies and technologies focuses on their potential to deter longer term climate change effects, such as temperature increase and sea-level rise, such measures can also achieve considerable short-term benefits of improving air quality and thereby public health. Thus, there is a need to improve and refine the methods by which these short-term impacts on public health and air pollution are quantified and assigned an economic value.

Most research on the ancillary benefits of GHG mitigation has explored the premature deaths and morbidity that could be avoided by enforcing policies that lower the levels of particulate matter in developed countries. A recent study evaluated the immediate public health benefits that might be achieved from GHG mitigation measures that would also reduce particulate matter and tropospheric ozone pollution, as compared to a business-as-usual strategy (i.e., one with no specific climate change policies), in four large cities: Mexico City, Mexico; New York, New York, USA; Santiago, Chile; and São Paulo, Brazil (Cifuentes et al. 2001). Researchers found that over the next 20 years, GHG mitigation measures in these four cities would reduce tropospheric ozone and particulate matter in sufficient concentrations to avoid approximately 64,000 premature deaths, including infant mortality, about 65,000 chronic bronchitis cases, and other effects such as work loss.

Full analysis of the public health benefits from GHG mitigation technologies and policies involves assessing the impact of GHG mitigation actions on air quality, exposure to air pollutants, health impacts of different levels of exposure, and economic valuation. Various agencies, such as the U.S. Environmental Protection Agency (U.S. EPA; Green et al. 2000), World Health Organization (WHO; 2000a), and Health Effects Institute (HEI 2000), have conducted significant research or planning activities on these issues, and

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additional research is ongoing. However, many methodological issues need further consideration, such as the transfer of concentration–response relationships from developed to developing nations with differing socioeconomic conditions, the impacts of indoor air quality, the analysis of susceptible populations, and the economic valuation of impacts. Many opportunities exist for research collaboration and exchange of information.

International Expert Workshop

To address these issues, 49 international experts met on 6 September 2001, in Garmisch-Partenkirchen, Germany, to discuss research on the economic and public health impacts of air pollution, particularly with respect to human health benefits from technologies and policies that reduce GHG emissions. The workshop was sponsored by the U.S. EPA, the World Bank, U.S. Agency for Internationial Development (USAID), WHO, the Organisation for Environmental Cooperation and Development (OECD), the United Nations Environmental Programme (UNEP), and HEI. The meeting was chaired by Devra Davis and held in conjunction with the 13th Conference of the International Society for Environmental Epidemiology (ISEE). Additional information about the workshop is posted on the National Renewable Energy Laboratory (NREL), UNEP, and U.S. EPA Web sites (see "References" for web addresses). The workshop aimed to address the public health benefits from improved air quality from GHG mitigation technologies and policies and foster research partnerships by improving collaboration and communication among various agencies and researchers; providing a forum for presentations by sponsor agencies and researchers regarding research efforts and agency activities; identifying key issues, knowledge gaps, methodological shortcomings, and research needs; and recommending activities and initiatives for research, collaboration, and communication.

Experts attended from a wide range of countries and diverse organizations. These included the Atomic Energy Commission of Bangladesh, California Office of Environmental Health Hazard Assessment, Center for Clean Air Policy (USA), the Deutscher Wetterdienst (Germany), HEI, Ministry of Environment and Forests of India, Ministry of Health of Indonesia, Mrigendra Samjhana Medical Trust (Nepal), the PA Consulting Group (USA), National Institute of Public Health of Mexico, NREL, Pan American Center for Sanitary Engineering and Environmental Sciences (Peru), Pelangi (Indonesia), Resources For the Future (RFF; USA), UNEP Collaborating Centre on Energy and Environment (UCCEE), USAID, U.S. EPA, World Bank, and WHO.

Participants also included researchers from many academic institutions such as Carnegie Mellon University (USA), P. Catholic University of Chile, Harvard School of Public Health (USA), Johns Hopkins University (USA), Kangwon National University School of Medicine (Korea), London School of Hygiene and Tropical Medicine (UK), London University (UK), Ludwig Maximilians University (Germany), New York University School of Medicine (USA), Peking University Health Sciences Center (China), Shanghai Medical University (China), Sri Ramachandra Medical College and Research Institute (India), Tata Energy Research Institute (India), Tribhuvan University (Nepal), University of Colombo (Sri Lanka), University of Basel (Switzerland), University of São Paulo (Brazil), and University of Washington (USA).

Presentations and Demonstrations

Sponsor agencies and related parties provided overviews of the agencies' activities and interests in air pollution, GHG mitigation, and health. Information on many of these programs and organizations can be found at the Web sites for the following agencies listed in "References" (HEI, NREL, OECD, UNEP, USAID, U.S. EPA, WHO, World Bank).

Myra Frazier (U.S. EPA) discussed the U.S. EPA's Integrated Environmental Strategies (IES) Program, which supports and promotes the analysis of the public health and environmental benefits of integrated strategies for GHG mitigation and local environmental improvement in developing countries. The program is country-driven, in that each country structures the project to meets its individual needs and goals. Participating organizations include governmental agencies and research institutions in Argentina, Brazil, China, Chile, South Korea, India, and Mexico.

Francesca Racioppi (WHO) provided an overview of the WHO Programme on Transport, Environment, and Health. This program facilitates the integration of health considerations in decisions affecting transport, promotes the implementation of strategies that simultaneously address the environmental and health impacts of transportation, informs on the health effects of transport, and provides tools and methods to assist member states in integrating health concerns into transportation-related decisions. She stressed the need for integrated strategies that address all the environmental and health impacts of transport, benefit from synergistic relationships, and can be implemented quickly.

Devra Davis (Carnegie Mellon University) outlined the goals of the workshop, discussing the need for expert's insights into this research and the need for improved collaboration among institutions carrying out this research. She elaborated on the complexity of these issues, such as the nature of transportation and energy systems, which differs substantially by country.

Ross Anderson (London University) discussed efforts of an expert WHO working group to estimate the global burden of disease due to outdoor pollution, 1 of 20 factors whose impacts will be assessed as part of the WHO Global Burden of Disease Comparative Risk Assessment. The group will develop estimates of the annual average mortality impacts of combustion-related particulate pollution for all cities with populations greater than 100,000, using risk coefficients from a large U.S. study and from several developing country studies of respiratory disease mortality, to estimate reductions in life expectancy for adults and children under 5 years of age. Anderson reviewed the difficult problems posed by the lack of health and exposure data for many areas of the world and the considerable uncertainties entailed in extrapolating U.S. mortality risk coefficients to nonindustrialized countries.

Aaron Cohen (HEI) gave an overview of HEI's role in researching the health effects of air pollution, focusing on initiatives to strengthen the evidentiary basis for health impact assessment. HEI's efforts comprise three areas: funding international research on the health effects of air pollution to better understand inter-regional differences; developing methods for etiologic research and impact assessment; and exploring the impacts of changes in policy and technology. Cohen noted that HEI will seek funding in early 2002 for research on the health impacts of actions to improve air quality and will prepare a multiauthored monograph on that issue by early 2003. HEI also has established the Special Committee on Emerging Technologies to explore the potential health impacts of strategies used to mitigate GHG production.

Bryan Hubbell (U.S. EPA, on behalf of the United Nations Economic Commission for Europe; UNECE) provided a summary of key issues discussed at the UNECE Workshop on the Measurement and Valuation of the Health Effects of Air Pollution. Goals of that workshop included establishing the state-of-the-art in epidemiology and economic valuation and promoting collaboration between epidemiologists and economists. The workshop concluded that closer coordination and communication between epidemiologists and economists is necessary for defensible scientific benefits analysis. (Further information is available on the UNECE Environment and Human Settlements Division and Convention on Long-Range Transboundary Air Pollution Web sites; see "References" for addresses.)

Jorge Rogat (UNEP Centre) described the UN Environment Programme's financial initiatives for environment and sustainable development to promote integration of environmental considerations into all aspects of operations and services, and he gave several project examples. One project helps evaluate whether emissions reduction credits could make viable an otherwise stalled wind farm in Jamacia. The African Rural Energy Enterprise Development Initiative fosters renewable energy companies that serve the rural poor. Other projects aid the Malian Ministry of Energy in development of a crop-based community energy system and support the development of a subsidy reform package for renewable energy services in Ghana.

Cathy Allen (U.S. EPA) reviewed the U.S. EPA's mission to protect the environment and human health and shared a perspective on health, fossil fuel, and economic evaluation. This relates to the U.S. EPA's international goals addressing climate change, ozone, transboundary transport of toxics, shared ecosystems, and development of a global environmental capacity. Regina Ostergaard-Klem (USAID) described USAID's goal to promote economic growth and sustainable development, which is divided into broad categories, population health and nutrition, environment, democracy and government, women and development, economic growth, and humanitarian relief. She discussed USAID initiatives and activities that focus on air pollution and human health and its relationship to energy and environmental programs.

Todd Johnson (World Bank) reported that the World Bank has made human health a key issue of its environment and poverty-reduction strategies. He discussed the World Bank's activities in the area of air pollution and environmental health. These include research on dose–response functions in developing countries, the quantification of environmental health impacts; health benefits of various control strategies; country-level operations such as policy studies, technical assistance, and investment projects; and regional and global programs.

Luis Cifuentes (P. Catholic University of Chile) and Eva Wong (University of Washington) demonstrated integrated risk assessment and benefit–cost analysis tools that estimate the human health and related economic impacts of air pollution control policies. Cifuentes demonstrated a health impact assessment system originally developed for the analysis of Santiago as a case study. This system also has been used to conduct an integrated assessment of the health impacts of energy options in Shanghai and will be used in Buenos Aires and São Paulo as part of U.S. EPA–IES projects. Wong demonstrated the Fast Environmental Regulatory Evaluation Tool (FERET), a computerized template for benefit–cost analysis of regulatory actions (Farrow et al. 2001). FERET facilitates the analysis of regulatory alternatives to improve the environment, health, and safety. The current application (FERET version 1.0) can estimate the health impacts, costs, and benefits of changes in criteria air pollution, or direct changes in health outcomes. FERET provides a computational structure, access to peer-reviewed literature, and supporting documentation. Further information is available on the University of Washington FERET Web site (see "References" for address).

Expert Working Group Conclusions and Key Workshop Recommendations

The experts divided into three working groups, each of which discussed separate issues, and then presented their conclusions. This section describes the outcomes of each working group, including discussion and recommendations.

Working group I: economics, benefits transfer, and policy. This group, led by Cifuentes, Hubbell, and Rogat, discussed methodologies for the economic valuation of health impacts from GHG mitigation strategies that lower ambient air concentrations. The discussion included differences between developed and developing nations, including valuation frameworks, consistency in epidemiological studies, and differences in the underlying populations. Consistent methodologies are needed to value health impacts in developed and developing nations, to apply best practices to transfer valuation estimates across countries, and to provide appropriate context for the interpretation of economic benefit estimates.

Most published literature on air pollution health studies involves Western European or North American populations. More recently, however, studies on urban populations from Mexico City, Santiago, São Paulo, and other cities in Latin America and Asia have provided evidence on the health effects of air pollution. Nevertheless, studies are not available for many areas, and the transfer of exposure, effects, or valuation deserves special attention. Air pollution may differ from region to region in terms of sources and composition. Population characteristics may also differ. In most cases, epidemiologic studies do not have an economic evaluation component. Furthermore, there may be inconsistencies among studies in the definition of health end points.

Most medical cost and value-of-life estimates are obtained in developed countries where incomes are higher, as well as the medical cost as a percentage of gross domestic product. There are substantial disparities in life expectancy, age distribution, and the importance of chronic diseases between developed countries and other nations. Transfer of valuation studies to other populations with different preferences and underlying characteristics could bias results. Estimates of health risks generally incorporate the averting and/or mitigating behavior of the affected populations. In countries where economic or institutional factors, such as access to health care, public information about high pollution levels, or public knowledge about the effects of air pollution, lead to lower levels of such behavior, the risks of air pollution may be larger than in countries where the behaviors are more widespread. Political and institutional structures, such as health systems and welfare programs, can differ widely. These can affect the distribution of income and burden of health costs in the population. Research is needed for areas that have thus far not been studied extensively. Studies should communicate the uncertainties incurred when valuation functions are transferred across countries, in addition to the uncertainties of the original study.

Air pollution data regarding both composition and exposure are often lacking for regions other than developed countries. Even crude measures of the spatial distribution of particulate matter, as well as important gaseous pollutants (NO_2, SO_2, CO, and O_3), across urban populations would benefit from the application of health-damage models. Studies in areas where uncertainties prohibit precise estimates would benefit from the development of tools and uncertainty analyses that can provide at least an order of magnitude estimate. For example, detailed personal exposure measurements may not be necessary where indicators of indoor exposures might be derived from housing characteristics (e.g., percentage air-conditioned, cooking fuels). A framework should be developed to aid in the assessment of health impact information where limited data are available, implementing a layered approach based on the availability of information for exposure, concentration–response functions, and valuation. Standardized methods for collecting relevant information on exposure, baseline population health status, and valuation components are needed as a first step to provide the background for any analysis.

Valuation studies should be conducted for various sets of end points and may be context and country specific. For example, in China better information on morbidity is very important, whereas in other countries a greater focus may be on mortality. Study replication is needed for both the physical effects of air pollution and their economic valuation. Gaps in current benefits analyses should be identified. Some studies omit many chronic health effects and focus on short-term end points, such as hospital admissions,

rather than on lifetime impacts. Studies focused on life-stage impacts in susceptible populations such as children are currently being performed and published. The full pyramid of effects should be communicated rather than mortality alone. Population burdens for morbidity and mortality should be reported as well as the monetary estimates of the value of these end points. Studies should provide for the appropriate context for interpreting monetary benefits. It may be more appropriate to use cost–benefit ratios as an ordinal ranking tool for within-country assessments rather than absolute measures for cross-country comparisons.

The decision-making context should be understood in various cultural and political systems. The applicability of benefit–cost analysis must consider whether such a framework fits within the decision-making process in place and whether the government system facilitates or hinders consideration of these issues. Analysis must consider existing institutional structures, especially those responsible for environmental and public health decision-making. Other areas of concern include the relative importance of local and global environmental issues on the public agenda and whether environmental and public health initiatives have support. There is a need to evaluate how policies are made, why worthwhile interventions are not adopted, and how to identify and promote strategies that provide short-term improvements to public health and long-term benefits of global warming mitigation. Policies that jointly reduce local air pollution and GHG emissions should be identified and reviewed, accounting for differences between countries. Comparative risk assessments, in which air pollution-related mortality and morbidity are contrasted with other social problems, should be a complementary input to benefit–cost analysis for policy discussions, and the impacts of policy interventions outside of air pollution health effects should be assessed. Benefit–cost analysis and health impact analysis is only one point in the decision-making process.

Communication and standardized reporting of results and methods for case studies from a variety of countries and policy interventions would provide information to allow comparison across regions and policies. Guidance documents with case studies and alternative approaches to the economic valuation of health impacts from air pollution policies would aid researchers, policy makers, and other stakeholders. Ideas and results are understood more easily if they are put into the parlance of consumers and decision-makers. Information should be disseminated through multiple media outlets (e.g., Internet, print, newspaper, conferences, and journals). A World Wide Web site should be created to disseminate information about case studies, methodologies, and other documents. Better coordination is needed among the exposure, risk assessment, and valuation components. The development of guidance documents, a Web site, a network of experts and institutions, and local and regional workshops would foster much needed communication and create a forum for the development of joint projects and proposals.

Working group 2: indoor air quality issues and susceptible populations. This group, led by Majid Ezzati (RFF), George Thurston, and R. Uma (Tata Energy Research Institute), discussed the morbidity and mortality effects of indoor air pollution and populations who are more susceptible to the adverse effects of air pollution, such as infants, children, the elderly, and people with pre-existing respiratory conditions. Those who suffer from poverty are also particularly susceptible, due to poor access to health care, lack of safe drinking water, and malnutrition, among other risk factors.

New research is needed to discern fully how some subpopulations are more adversely affected by air pollution than others, to gain a better understanding of the health benefits of GHG mitigation strategies. Persons in certain occupations may suffer from disproportionate exposure. Women and men can differ in their exposures and health responses (Ezzati and Kammen 2001; Ezzati et al. 2000). Until recently, most studies used data that were aggregated over time and space. Such analysis excludes the impact of high-concentration episodes and individual exposure profiles, which may greatly affect susceptible persons. Projecting air pollution health effects requires estimates of the underlying prevalences of specific disease conditions. Prevalence for many chronic cardiovascular and respiratory diseases varies greatly among ethnic and economic groups. Although genetic susceptibility might explain some of these differences, quite often housing factors, behavior, and access to medical care play a substantial role. In most countries, health statistics are inadequate to provide analysis of air pollution inequalities. Pilot studies of exposure, health, and intervention in various geographical settings would help identify policies that successfully protect susceptible populations. Shared research objectives for susceptible populations should be promoted for developed and developing nations (e.g., studies of pollution's effects on the urban poor and infants).

Indoor air pollution significantly damages public health, especially in developing countries. Women and children may be particularly susceptible or particularly exposed through proximity to cooking stoves, which can emit high concentrations of indoor air pollution. For example, more than 75% of household energy in India is produced by burning biomass fuels such as wood in inefficient stoves. This process emits GHGs such as methane, as well as particulate matter and other pollutants. It is estimated that about 500,000 premature deaths are caused annually by indoor air pollution in India. If this source of indoor air pollution were replaced by more efficient and less polluting stoves, immediate local health benefits would accompany a reduction in GHGs (Uma et al. 2001).

Key issues for the study of indoor air pollution include ventilation (e.g., housing type) and source factors (e.g., fuel type). Further research is needed to assess indoor air pollution exposure, including air and ventilation monitoring and interactions among technology, behavior, and emissions. The source and composition of the pollution and its toxicity should be appraised, as the toxicity of various source emissions may differ. Shifts from more to less carbon-intense fuels will affect indoor air pollution and will vary by region. Research on intervention strategies may be limited by a lack of analysis under real-world conditions and long-term monitoring. In addition, a greater emphasis is needed on personal preferences and behavior that will influence the adoption and correct use of new technologies such as more efficient stoves. The lack of sufficient dose–response relationships for the developing world applies particularly to indoor air pollution. Assessment of indoor air pollution requires a multidisciplinary approach, incorporating local institutional structure and behavior and cultural factors. Exposure from indoor air pollution should be included in integrated environmental strategies and other benefit analysis.

Working group 3: development and transfer of dose–response relationships and exposure models in developing countries. Dose–response relationships can be used to estimate the human health benefits from reductions in air pollutants that result from GHG mitigation. This group, led by Lester Grant (U.S. EPA), Paulo Saldiva, and John Sung (Kangwon National University), explored the adaptation and transfer of dose–response relationships within and between countries, with different economic structures, air pollution composition, and populations.

Dose–response relationships and exposure models derived from ambient air pollution and health studies do not exist for many countries. In some cases they are available in limited form, for only a few select pollutants and for a few health effect end points. Estimates of air pollution impacts in areas without established dose–response relationships can be estimated by applying studies from other countries, usually those with more advanced economies. However, such an approach is problematic

given the different demographics of the population (e.g., socioeconomic status, underlying health of the population, diet, lifestyle, and age distribution) and composition of pollution (e.g., different sources and chemical composition). Such deviations in the target population should be considered in the analyses (WHO 2000b, 2000c). Hypotheses regarding the modifying effect of socioeconomic status should be developed and researched. Area-specific information is needed to better characterize socioeconomic status and exposure.

The populations of the young and elderly who survive in developing countries may be more robust than those in countries with more advanced economies. In developed nations, neonatal and geriatric medical care can create populations that include proportionally more frail members. There are differences in vaccination requirements, childhood exposures, and the use of antibiotics, among many other factors that distinguish susceptibility or insensitivity across the world's population. Methods for estimating the potential impact of changes in medical technologies and care need to be developed and validated.

Transfer of dose–response relationships may involve extrapolating beyond the range of pollutant concentrations originally studied. The background level of pollution may differ greatly from that of the original region of study. Not only are the levels of pollution different, but the relative proportions of various pollutants can play a modifying or confounding role. For example, differences in the prevalence of air conditioning and source of particulate matter partially explains discrepancies among observed exposure–effect relationships for hospital admissions for heart and lung disease in several U.S. cities (Janssen et al. 2002). Mortality and air pollution associations can be affected by the distribution of different sizes of particulate matter, housing characteristics, climate, and other factors (Levy et al. 2000). In much of the West, SO_2 has been greatly reduced, and health effects are attributed more significantly to particulate matter concentrations. But in many countries, local SO_2 pollution can still be quite high. In some regions pollutant concentrations can be high because of background levels alone. In some areas, indoor air pollution can be significantly higher than ambient concentrations. This is important when health assessments from other areas are used because of the modifying influence of factors affecting the penetration of ambient pollution. Similar difficulties arise when transferring dose–response relationships within a given country, if the pollution or population of application differs from that of the original study.

Inadequate information on exposure and the baseline rate of health effects is a significant problem. Some regions lack air pollution monitoring networks to sufficiently measure ambient air pollutant concentrations, which hinder determination of exposure. Additionally, monitoring measurements vary in quality. Data collection is sometimes inconsistent, even for a given area, and the location of monitors may not be ideal to ascertain exposure. Political barriers and the cost of obtaining information can impair research. The lack of exposure data could be aided by use of mobile monitoring equipment that measures NO_2, fine particles, CO, and other pollutants. These lightweight instruments can assess local environments, such as subway systems. Such monitoring kits and training on their operation could help alleviate the lack of air pollutant concentration data.

Bioindicators are plants or animals that respond to environmental factors, such as air pollution, in ways that allow estimates of air pollution levels and the impact of such pollution. For example, lichens have been used as bioindicators of air quality in Italy (Conti and Cecchetti 2001). The use of bioindicators should be explored to correlate these indicators with human health data. Surveillance of health outcomes also may be incomplete, inconsistent, or absent. An inventory should be developed of what information is present and lacking in different regions (e.g., exposure assessment and health outcome data).

The working group stressed the need to expand the expertise base for studying developing countries and performing studies in areas without previous research experience. Tutors could be provided to various regions, using resources from agencies such as the World Bank, USAID, and other donors. Guidelines on how to assess socioeconomic status, possibly using U.S. data as an example, would aid researchers. Other recommendations include training courses on how to perform health assessments and demonstration projects to teach researchers how to compile environmental and health data from different centers within a region.

Common Themes among Working Group Recommendations

Several common themes emerged from the working group sessions and subsequent discussion on health benefits from improved air pollution resulting from GHG mitigation. The experts' observations and suggestions overlapped, emphasizing the importance of these recommendations. The themes here reflect long-term goals that will require extensive research, cooperation, funding, and time.

Increased communication and collaboration. Workshop participants stressed the need to encourage communication and collaboration among different disciplines (e.g., economists and public health researchers) and regions (between developed and developing nations and among developing nations). Recommendations included standardization of results and methods (e.g., standardized reporting of case study results); a network of experts and institutions to develop better coordination; workshops and Internet forums to facilitate joint proposals (e.g., joint work between economists, epidemiologists, and sociologists); development of multidisciplinary approaches and studies; and the development of shared research objectives for developed and developing countries. A Web site could publicize research results; distribute standardized methods; supply documents on the impacts of air pollution on human health and the benefits of air pollution control policies; provide access or links to information databases; facilitate coordination among agencies, academic institutions, and other organizations; promote funding opportunities; and provide a forum for discussion for researchers, decision-makers, and others.

Support for researchers and increased expertise base. Another theme was the need for guidance, funding, and other support for researchers and an increased expertise base, especially for developing nations. The working groups recommended guidance documents (e.g., for the collection of information on exposure and populations); guidelines for the economic valuation of benefits; and guidance documents with case studies and alternative approaches to analysis, tutors, workshops, demonstration projects, and training groups. These activities would help researchers better perform health assessments, monitor environmental indicators, compile environmental and health data, and assess and account for socioeconomic status (e.g., income and education levels).

Data collection and assessment. The experts stressed that data gaps should be addressed through measures such as a framework for assessing limited information (e.g., limited morbidity data), mobile air pollutant monitoring kits, and an inventory of what information is needed in each region (e.g., characterization of socioeconomic status, exposure assessment, and human health data). To conduct a first-level assessment of the mortality and morbidity associated with air pollution, it is necessary to have access to pollution data, such as annualized concentrations, including measures for particulate matter, SO_2, CO, and O_3; information on spatial distribution of pollution across the population of interest; distribution of deaths within a population by age along with the overall age distribution; disease-specific causes of death with focus on cardiovascular and respiratory disease and (with new evidence emerging) lung cancer; age-specific prevalence rates for chronic bronchitis and asthma; measures of health

care utilization such as emergency room visits (or equivalent) and hospitalization rates; and infant cause-specific mortality, if life-years loss is included in the evaluation.

Support for research. A recurring theme throughout the workshop was the need for support for additional research and related funding. Further research was recommended for many areas including pilot studies in geographical settings without many existing studies, differing exposure levels and susceptibility of various occupations and populations, health impact assessments of policies and technologies, the transfer of dose–response curves and valuation functions and methodologies from developed to developing nations, toxicity of different emissions sources, exposure from indoor health pollution and related health impacts, approaches to assess health impact information, and value of information studies for different end points. The transfer of study results between developed and developing regions was an important topic of discussion in all three working groups. Research is needed to explore the appropriate transfer of dose–response curves and valuation functions and the problems that may arise and to establish dose–response curves for developing regions.

Internet-Based Information System Initiative

Workshop participants recognized the need for a central information source and discussion forum for policy makers and researchers. In response to workshop recommendations, a joint effort by UCCEE, USEPA, UNEP, the World Bank, WHO, OECD, NREL, HEI, Carnegie Mellon University, Peking University Health Science Center, P. Catholic University of Chile, and Shanghai Medical University established a Web site (www.airimpacts.org) to increase global awareness and research collaboration regarding the health and economic impacts of air pollution. UNEP has provided initial funding for the site. The Web site hosts and disseminates information, thereby providing a resource for the advocacy of integrated environmental policy at local, regional, and international levels for policy makers and agencies. This facilitates information exchange among experts, the media, and decision makers. The site also aims to promote collaboration among scientific researchers by providing a forum to share methodologies, results, and discussion. Website content includes information for policy makers at various levels, including local and global interests, with case studies and information for diverse sectors (e.g., energy, transportation, health, and sustainable development), and specific information and links to policy measures and technologies that mitigate GHG emissions and improve local air quality and human health. The Web site is coordinated and hosted by UNEP/UCCEE and is operational, although still under development.

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