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Air Pollution and Child Health: Priorities for Action

Report of a Meeting of an EHP Technical
Advisory Group on Air Pollution,
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by
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Background

A four-person panel of experts on the health effects of ambient and indoor air pollution met for two days at the invitation of the Environmental Health Project (EHP) to advise EHP on what air pollution problems to address and how to address them, given USAID s emphasis on child health. The panel identified particulate matter as the air pollutant posing the greatest health risk to children, based on existing evidence of its association with acute respiratory infections (ARI), a principal cause of infant and child mortality, and suggested a number of key preventive interventions. This report summarizes the discussions and conclusions of the panel and its recommendations to USAID.

Purpose of the Panel

EHP is a five-year project initiated by USAID s Office of Health and Nutrition to provide technical assistance in environmental health to USAID missions and bureaus to achieve USAID s strategic objectives related to health, namely to reduce infant and child and maternal mortality. EHP approaches its mission from a preventive perspective, seeking to protect mothers and children from disease agents in their environment through behavioral change and household- and community-level interventions that complement traditional child survival efforts such as oral rehydration therapy and immunizations. EHP concentrates on three childhood diseases: diarrhea, malaria, and ARI. All three are causally related to environmental conditions and amenable to reduction through environmental improvements. While EHP has developed specific interventions to reduce mortality and morbidity from diarrhea and malaria interventions that build on the past success of its predecessors, the Water and Sanitation for Health (WASH) and the Vector Biology and Control (VBC) projects little guidance or experience is available on developing similar interventions for ARI.

The panel met for a day and a half in mid-July 1996 at EHP headquarters. The first day was devoted to examining two key questions: (1) which air pollution problems should EHP focus its efforts on, given USAID s commitment to reducing the disease burden on children, especially from ARI, and (2) what actions should EHP take or promote to address the selected air pollution problems, given that EHP s strength lies in interventions that emphasize changes in personal and institutional behavior, rather than high-cost investments in technology. On the second day, an audience of about 50 persons from USAID and other interested organizations gathered to hear and discuss the panel s conclusions and recommendations.

The panel based its conclusions and recommendations on several understandings regarding EHP s interest in air pollution and its role vis-à-vis USAID.

- EHP is most interested in health outcomes for children.
- EHP focuses its attention on health problems that constitute a significant portion of overall disease burden.
- To justify committing its resources, EHP must be assured that changing environmental conditions will be effective in averting morbidity or mortality, based on the best evidence available.
- EHP is not a research project.
- EHP s strengths lie in interventions that emphasize changes in personal and institutional behavior, rather than high-cost investments in technology.

Panel Members

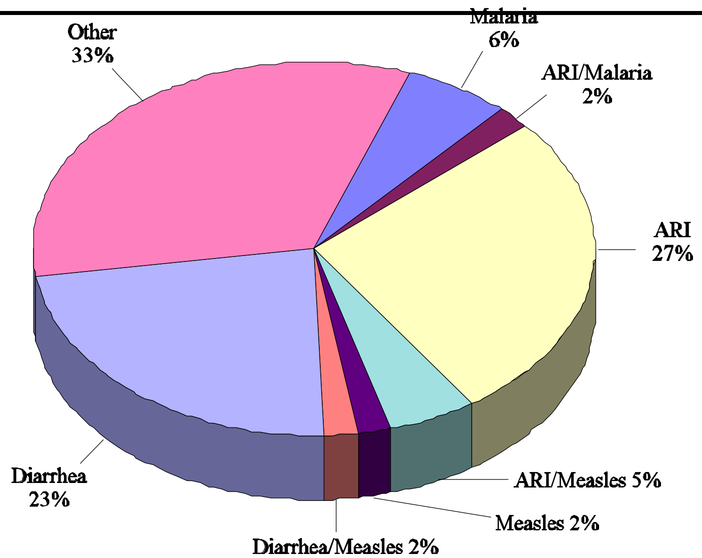
Panel members were Dr. Nigel Bruce, Liverpool University, Department of Public Health; Dr. Ruth Etzel, Chief of the Air Pollution and Respiratory Health Branch at the U.S. Centers for Disease Control and Prevention; Dr. Bart Ostro, Chief of the Air Pollution Epidemiology Division of the State of California Environmental Protection Agency; and Dr. Kirk Smith, Professor of Environmental Health at the School of Public Health, University of California at Berkeley. Drs. Bruce and Smith are members of the WHO International Study Group on Indoor Air Pollution and Childhood Pneumonia; Dr. Etzel is a recognized expert on environmental tobacco smoke; Dr. Ostro has developed several risk assessment models for air pollution and is an expert on the health benefits of reducing air pollution levels.

ARI The Leading Cause of Death in Children Under Five

ARI includes upper respiratory infections such as colds and sore throats and lower respiratory infections such as pneumonia and bronchiolitis. In the context of child survival programs, ARI refers mainly to pneumonias and is often called acute lower respiratory infection or ALRI.

ARI is the most important single cause of mortality in developing countries. It is now the number one cause of infant and child mortality, supplanting diarrheal diseases. Among children less than five years old in developing countries, 27% of the deaths are associated with ARI, and the presence of ARI can increase mortality from measles, malaria, other diseases, bringing the total up to 34% (see **Figure 1**). In 1993, over 4 million children under five died from ARI or ARI in combination with other diseases.

Figure 1. Distribution of 12.2 Million Deaths among Children under Five in Developing Countries



Percentages of deaths associated with:	
Acute Respiratory Infections (ARI)	34
Diarrhea	25
Malaria	8
Measles	9
One or more of these conditions	67

Source: WHO Division of Diarrhoeal and Acute Respiratory Disease Control, 1995.

ARI is not only the number one cause of mortality, but it is also the largest contributor to Disability Adjusted Life Years or DALYs lost, another measure of disease burden. According to the *Global Burden of Disease* (C.J.L. Murray and A.D. Lopez, Harvard School of Public Health, 1996) in developing regions lower respiratory infections are the leading cause of death, accounting for about 4 million deaths, close to 10% of all causes in 1990. In terms of disease burden, in the developing world 110.5 million DALYs per year are lost due to lower respiratory infections, making this disease the number one cause of disease burden. As these statistics indicate, ARI is a vast public health problem in developing countries a problem that panel members believe probably cannot be managed effectively using only curative interventions.

Effects of Air Pollution on Infants and Children

The U.S. Environmental Protection Agency regulates the ambient (outdoor) concentrations of six criteria air pollutants: ozone, carbon monoxide, lead, nitrogen dioxide, sulfur dioxide, and particulate matter. Particulates pose a risk to children because of their strong association with ARI. Epidemiologic studies have associated particulates with reduction in lung function, exacerbation of pre-existing asthma, acute bronchitis, emergency room visits, hospitalization, and mortality. In the last 5 to 10 years, numerous studies have shown an association between particulates and mortality, with children at a higher risk than adults. Also, mortality from pneumonia appears to be related to air particulates. While the negative effects of lead are well documented, and lead poisoning is unquestionably a serious health problem for children, causing neurobehavioral effects even at relatively low levels of exposure, lead is not associated with ARI and is being addressed in other EHP activities.

The Characteristics of Particulate Matter

Particulate matter ranges in size from a diameter of less than 1 μm (micrometer) (particles in smoke, for example) up to 100 μm (particles in mist, for example). It can consist of a variety of chemicals, and particles often change chemically once emitted. Major sources of particulates are combustion of fuel diesel trucks, wood- or coal-burning stoves and fireplaces; cigarette smoke; dust; and industrial operations cement plants, smelters, steel mills. Generally, the smaller the particle the more serious the health effect, since small particles reach deep into parts of the lung from which they are not expelled by the lung s natural defenses. U.S. regulatory efforts have focused on particles less than 10 μm in diameter (PM10), but recently more attention has been given to even smaller particles (PM 2.5).

Sources of Exposure

Children in developing countries are exposed to particulates in both ambient and indoor air in rural and urban settings. Particulates in ambient air, which originate from a variety of sources, pose a serious problem in some specific locations, such as Mexico City. However, indoor air pollution is a far more prevalent problem. Indoors, particulates are produced from tobacco smoke and the combustion of biomass fuels for cooking and heating. Environmental tobacco smoke is associated with ARI among children in developed countries, but fewer studies have documented this association in developing countries. In part, this may be because fewer studies have been conducted in the developing countries, but it also may be because smoking patterns are different in the developing world, children may spend less time in environments where smoking occurs, fewer women smoke (although this number is growing), and they may smoke fewer cigarettes per day, etc. The most significant source of particulates appears to be combustion indoors of unprocessed solid fuel (biomass and coal). Here the evidence of a reasonably strong relationship to ARI among children is convincing and consistent. In fact, there is a reasonably good case for believing this relationship is causal, although the lack of any direct exposure measures in most studies and the difficulty of taking account of associated (confounding) factors mean there is some uncertainty about the evidence.

Patterns of Exposure

The concentration of suspended particulates is measured in micrograms per cubic meter (μg m^3). According to recent estimates, in urban areas in developed countries, indoor levels of total suspended particles (TSP) average 100 μg m^3, whereas in developing countries the average indoor level is 250 μg m^3. In rural areas, the contrast is starker: an average of 80 μg m^3 for developed countries and 400 μg m^3 for developing countries. Urban ambient air pollution in developing countries is in the hundreds of μg m^3 but indoor air, where biomass fuels or coal are being burned for cooking and heating, may have concentrations of particulate matter as high as thousands of μg m^3. Such high levels are especially alarming given that health effects may be shown at less than 100 μg m^3. (These estimates need to be validated and updated by more detailed work.)

The magnitude of the problem becomes clearer when we look at where the pollution is and where the people are. **Table 1** compares average concentrations of particulate matter in indoor and ambient air in urban and rural areas in developed and developing countries and then indicates the corresponding population exposures.

The highest particulate concentrations are in indoor environments in rural areas in developing countries. Exposure, expressed as a percentage of the world total, is also highest in indoor rural environments in developing countries. In other words, that s where the pollution is and that s where the people are.

Table 1: Particulate Concentrations (TSP) and Exposures in the Eight Major Global Microenvironments

	Average Concentrations		Exposures (%) of Global Total		
Region	Indoor (μg m^3)	Ambient (μg m^3)	Indoor (%)	Ambient (%)	TOTAL (%)
Developed					
Urban	100	70	7	1	8
Rural	80	40	2	0	2
Developing					
Urban	250	280	25	9	34
Rural	400	70	52	5	57
		Total (%):	86	15	100

Source: *Health and environment in sustainable development. Five years after the Earth Summit*, 1997, World Health Organization.

Note: Population exposures are expressed as a percentage of the world total. Here exposure is defined to equal to the number of people exposed multiplied by the duration of exposure and the concentration breathed during that time. By these calculations, the annual average for the entire world population is about 230μg m^3.

Both indoor and ambient particulate concentrations are also elevated in urban areas in developing countries, but it is only in the indoor urban environment that the level of population exposed is also high (25%). Although ambient concentrations are high, exposure levels are low. The pollution is there but the people aren t. It is ironic, given the picture that these figures paint, that the interest of most environmentalists is focused on urban ambient pollution in developed countries, when indoor pollution in developing countries is a more serious problem, particularly in rural areas.

WHO peak guideline recommends that a concentration of 230 μg m^3 of suspended particulate matter not be surpassed more than seven days of a year. However, the World Bank Development Report for 1992 presents data from several studies showing that that level is regularly exceeded. In India, a 1987-88 study showed levels 16 to 91 times that of the WHO guideline; in Kenya, a 1972 study of overnight use of space heaters showed particulate pollution levels 12 to 34 times the guideline. Studies in India and Nepal from 1982 to 1994 reported room concentrations for cooking ranging from 4,000 to 21,000 μg m^3. Twenty-four hour levels ranged from 2,000 to 3,000 μg m^3.

Dependence on Biomass Fuels

It is no surprise that particulate concentrations and exposures are high in rural indoor areas in developing countries. Fifty percent of the world s population depends on biomass fuels for cooking and heating: wood, agricultural residues, and dung. Mothers and their children spend an average of six hours per day in highly polluted indoor areas. When households advance economically, they inevitably move up the energy ladder and eventually graduate to the cleaner burning, more efficient fossil fuels; but poor economic conditions in developing countries and the rise in oil prices beginning in the oil crisis in the early 1970s have limited the ability of populations to make this climb. To reduce the pace of deforestation, coal has been used as a less-expensive alternative to imported oil in a number of countries. This makes sense economically and environmentally, but not from a health standpoint. For example, studies have shown that non-smoking women in China, where coal is used widely in homes, have high lung cancer rates as well as high rates of stroke, mouth and throat cancer, chronic lung disease, and other problems.

Evidence Associating Particulates with ARI

Dr. Bruce presented a review prepared for the WHO Division of Child Health and Development of 10 studies examining the association between exposure to indoor air pollution from particulates and ARI among children under five years of age (see **Table 2**). Although there are a number of methodological problems with the studies, they appear to demonstrate a relatively consistent association between particulate exposures and childhood ARI: the odds ratios are fairly consistent, there is consistency across different populations, and ARI is fairly well defined. The studies were carried out in South Africa, Nepal, Gambia, imbabwe, India, and Brazil. All used proxy measures of exposure: reported stove type, hours child exposed, etc. Four were case control studies, three were cohort, and one a cross-sectional survey. Confounding was addressed in six of the studies. Six of the studies showed odds ratios ranging from 2 to 5; one study showed a high odds ratio for girls (6.0) but not for boys (0.5). Three studies showed no significant result. One of the studies (Nepal) showed a positive dose-response relationship (i.e., the number and severity of ARI episodes per child increased with increased exposure, measured as reported hours near the stove) for moderate and severe cases of ARI (see **Figure 2**).

Table 2: Studies Examining the Association between Biomass Smoke and ARI in Children under Five in Developing Countries

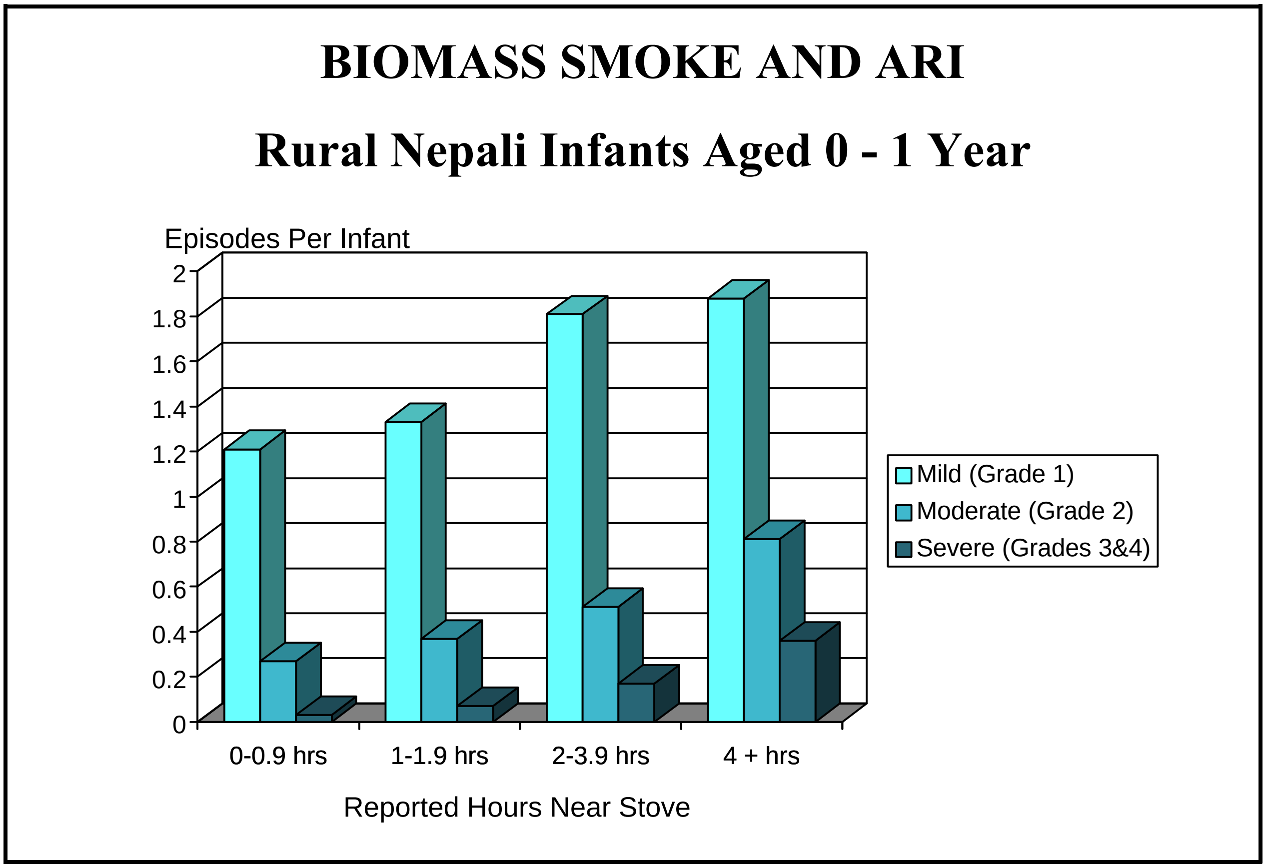
Study	**Design**	**Case Definition**	**Exposure**	**Confounding**	**OR (95% CI)**	**Comments**
Armstrong JR, Campbell H. Indoor air pollution exposure and lower respiratory infections in young Gambian children. *International Journal of Epidemiology,* 1991, 20(2): 424-429.	Cohort rural Gambia. Age < 60 mo. 500 (approx.)	Weekly home visits: ALRI clinical and X-ray	Questionnaire: Carriage on mother's back while cooking	Questionnaire: - parental smoking - crowding - socioeconomic index - number of siblings - sharing bedroom - vitamin A intake - no. of wives - no. of clinic visits. Adjusted in MLR.	Approach (i) (All episodes) M: 0.5 (0.2, 1.2) F: 1.9 (1.0, 3.9) Approach (ii) (1st episode) M: 0.5 (0.2, 1.3) F: 6.0 (1.1, 34.2)	Boy/girl difference not really explained, but could be due to greater exposure. Acknowledged risk of confounding where risk factors highly interrelated. Report carriage on back quite a distinct behavior so should define the two groups fairly clearly with low level of misclassification.
Menezes AM, Victoria CG, Rigatlo M. Prevalence and risk factors for chronic bronchitis in Pelotas, RS, Brazil: a population based study. *Thorax*, 1994, 49(12): 1217-1221.	Case control urban Brazil. Age <24 mo. 510 cases 510 controls	**Cases:** ALRI admitted to hospital, clinical and X-ray. **Controls:** Age matched, neighborhood.	Trained field worker interview: - any source of indoor smoke (open fires, woodstoves, fireplaces) - usually in kitchen while cooking	Interview: - Cigarettes smoked - housing quality - other children in hh - income/education - day center attendance - history of resp. illness - (other) Hierarchical model/MLR.	Indoor smoke: 1.1 (0.61, 1.98) Usually in the kitchen: 0.97 (0.75, 1.26)	NB: only 6% of children exposed to indoor smoke. Urban population with relatively good access to health care. Not representative of other settings in developing countries.
Shah N, Ramankutty V, Premila PG, Sathy N. Risk factors for severe pneumonia in children in south Kerala: A hospital-based case-control study. *Journal of Tropical Pediatrics*, 1994, 40(4): 201-206.	Case control urban and rural Kerala, India. Age 2-60 mo. 400 total	Hospital: **Cases:** Admitted for severe/very severe ARI (WHO definition). **Controls:** Outpatients with non-severe ARI.	History taken, including: - type of stove with "smokeless" category - outdoor pollution.	History: - smokers in house - number of siblings - house characteristics - socioeconomic conditions - education - birth weight, etc. Adjusted in MLR.	"Smokeless" stove: 0.82 (0.46, 1.43)	NB: This is a study of the risk factors for increased severity, as the controls have ARI (non-severe). On MLR, only age, sharing a bedroom, and immunization were significant. Exposure assessment very vague.

Study	Design	Case Definition	Exposure	Confounding	OR (95% CI)	Comments
Aswathi S, Glick H, Fletcher R. Effect of cooking fuels on respiratory diseases in preschool children in Lacknow, India. *Am. J. Trop. Med. Hyg.* 1996, 55: 48-51.	Cross sectional survey, random population, urban India. Age < 60 mo. Sample of 650	Presence of symptoms and some signs on day of interview (see comments).	Type and duration of use of cooking fuel in last week.	Interview: - child indoors while cooking - number sharing bedroom - family income - father's indoor smoking - use of other fuel. Adjusted in MLR.	Dung: 2.69 (1.37, 5.31) wood, kerosene, coal: NS	Definition of respiratory disease would include upper and lower respiratory infection and wheezing. Runny nose and noisy respiration (incl. wheeze, stertor) most commonly reported.

Note: ALRI acute lower respiratory infection; AURI acute upper respiratory infection; COHb carboxyhemoglobin; TSP total suspended particulates; MLR multiple logistic regression.
NS not significant

Source: Summary prepared by Nigel Bruce on behalf of the WHO Division of Child Health and Development. Information highlighted and comments are the result of his analysis.

Figure 2



Source: M.R. Pandy *et al.*, Domestic smoke pollution and acute respiratory infections in a rural community of the hill region of Nepal, *Envionment International*, 1989, 15: 337-340.

The single strongest recommendation of the panel was that enough is known now from previous studies to justify a large-scale intervention study that would provide better information not only on the dose-response relationshiop but also on the practical improvements in health that could be achieved through exposure-reduction interventions. Nevertheless, the panel agreed that existing evidence is adequate to spur action to reduce exposures to particulate matter as an approach to reducing ARI.

Health Effects

What health improvements might be expected from pollution reduction interventions There are six potential intervention areas for reducing pneumonia morbidity and mortality among children under five years of age: (1) case management and chemoprophylaxis (e.g., of severely malnourished children or high-risk neonates), (2) immunization (e.g., new vaccines for Haemophilus influenzae and pneumococcus), (3) improving nutrition and encouraging breastfeeding, (4) reducing transmission of pathogens (e.g., reducing crowding), (5) improving childcare practices (e.g., promote effective care-seeking behavior), and (6) reducing environmental pollution of the indoor and ambient air.

The WHO Division of Child Health and Development has estimated the potential impacts on mortality from ARI from these interventions. According to these calculations, a 20% reduction of indoor air pollution from biomass combustion could reduce mortality from ARI by 4.3% to 7.8%; a 60% reduction could yield decreases in mortality ranging from 13.0% to 19.5%. These estimates compare favorably with the expected impact of other types of interventions, such as reducing the incidence of low-birth-weight babies by 20% (expected reduction in mortality   2.6% to 6.7%); or achieving a rate of 60 55 50 in the three-dose vaccination for pneumococcus (expected reduction in mortality   7%).

Options for Action

The panel reviewed the many preventive interventions available, both long- and short-term and ranging from technical fixes to behavior change or policy revisions. The panel organized its examination of options around the three sources of airborne particulates to which children in developing countries are regularly exposed: (1) indoor air from cooking stoves, (2) indoor air from environmental tobacco smoke, and (3) ambient air.

Reducing Indoor Air Pollution from Stoves. Designing appropriate interventions to reduce indoor air pollution from cooking and heating stoves calls for an understanding of the fuels used, the use to which they are put, the combustion conditions, housing patterns, temporal and spatial behavior of the population, socioeconomic conditions, and physiological status of the population. **Table 3** lists the possible points of intervention for reducing indoor air pollution from cooking and heating stoves.

Table 3
Possible Points of Intervention for Reducing Air Pollution from Cooking and Heating Stoves

Use cleaner fuel.
- Move up the energy ladder to kerosene or liquified petroleum gas.
- Use clean modern fuels.
- Use processed biofuels such as charcoal (in some locations) or biogas.

Lower emissions.
- Improve combustion through secondary air
- Use more fuel-efficient stoves.

Lower household concentrations.
- Improve ventilation.
- Install chimneys or flues.

Lower exposure.
- Improve kitchen design: move kitchens outside or establish communal kitchens.
- Change behavior.
  - Reduce time children are in kitchen.
  - Reduce cooking duties of women during pregnancy.
  - Stop lying close to the fire.

Influence policy.
- Humanitarian arguments.
- Human capital arguments.
- Economic arguments.

As mentioned earlier, EHP focuses on environmentally based preventive activities, particularly, though not exclusively, on those that can be implemented on the household and community level. Thus, the interventions in Table 3 of greatest interest are (1) the use of cleaner burning or better vented stoves, (2) improving ventilation, and (3) behavioral changes. These are interim measures to decrease the severity of the problem; the long-term solution is to move away from highly polluting fuels. The eventual long-term goal is for clean fuels to be available to all.

Improved Stoves. Stove programs have had mixed success. Programs that arose out of the appropriate technology movement in the 1980s were generally not very effective. Such programs promoted stoves constructed by users out of readily available local materials. Unfortunately, these improved stoves were often quite similar to what people were already using: if they had been able to construct a better stove with materials available to them, they probably would have. Genuinely improved stoves are more likely to be manufactured not in a home by a family member, but in a village workshop by a skilled artisan. Another difficulty is that some new stove designs may be more efficient in fuel use, but they may not be designed to reduce smoke and, therefore, may be equally polluting, or even more polluting, than traditional models.

Many types of improved stoves are available. **Figure 3** is an advertisement for one such stove used in India. The Chinese National Improved Stove Program introduced 145 million improved stoves in rural areas of China. The stoves are purchased and installed at residents expense with few subsidies. In most countries, a campaign to introduce the use of improved stoves would have to have a credit component. Also, a lesson learned from the experience of stove programs is that such programs are most promising in areas where stoves and fuel are purchased, not where stoves are constructed at home to burn fuels gathered by the family.

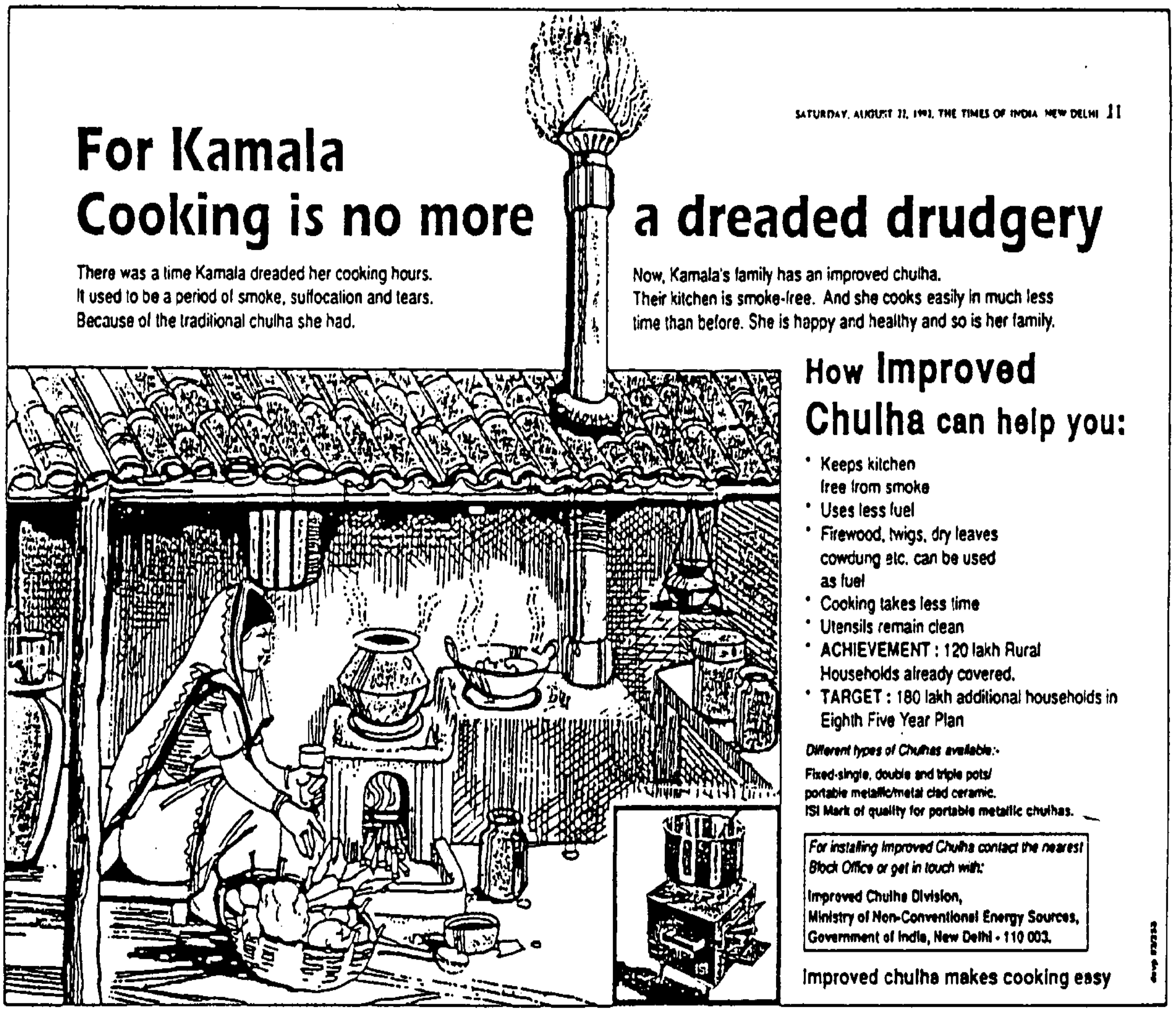
The difference between a traditional and improved stove in terms of total suspended particles emitted can be striking. A longitudinal study comparing traditional and improved stoves in Nepal showed a difference of 5.2 mg m^{3} in particulates concentrations (traditional 8.2 mg m^{3}; improved 3.0 mg m^{3}) (M. Pandey *et al.* 1989. Domestic smoke pollution and acute respiratory infections in a rural community of the hill region of Nepal, *Environment International* 15: 337-340.). It should be noted, however, that the particulate concentration level with the improved stove is still extremely high by developed country standards. The results of similar studies are shown in **Table 4**: for example, a cross-sectional study also in Nepal showed a difference of 2.01 mg m^{3} between the two types (traditional 3.14 and improved 1.13 mg m^{3}). In Guatemala PM10 levels ranged from just under 2.5 mg m^{3} for open stoves, to just over 1 mg m^{3} for improved, to less than 0.25 mg m^{3} for gas, according to a 1993 study prepared by Kirk Smith and Janice Lu.

Dr. Smith made some rough estimates of the extent to which exposure to suspended particles could be reduced given various technical fixes. His estimates were scaled by defining a traditional biomass stove with no venting to be 100% and an electric hotplate to be 0%. He estimated that exposure could be reduced by 25% with room vents or through the use of less-smoky fuels. A possible 66% reduction might be expected through use of a hood with passive ventilation. A traditional stove with mechanical ventilation could possibly reduce exposure by 25% to 75%. Switching to an improved stove will generally reduce exposure significantly, except that low-cost improved versions may be worse from the pollution perspective, as mentioned above. An improved, relatively high-cost, biomass-burning stove with a flue could reduce exposure by as much as 90%. These rough estimates do not take into consideration emissions from the food being cooked, for example, products from frying with oil, or possible reductions due to behavioral change.

Generally speaking, improving ventilation has limited impact on the concentrations of particulate matter because it is not possible to increase ventilation enough to make an appreciable difference.

Guatemala Stove Trials. A stove trial study in Guatemala has been proposed by WHO for a number of years, but funding for it has not been made available. The study would involve 1,600 households in several rural communities; 800 would receive improved wood-burning stoves; 800 would continue with their

Figure 3. Advertisement for an Improved Stove



Source: Advertisement in the *Times of India* (New Delhi) August 22, 1992.

traditional open fires. Households would be recruited when women first report that they are pregnant. They would be assigned to the treatment or control group, and the new stove would be installed before the child s birth. Children born in the households would be the study cohort. ARI incidence would be measured by health workers in weekly visits until the infant reached 18 months. (At that point the control group households would be offered the improved stoves also.) The study would take four years: two years to recruit the cohort, 5 to 6 months of remaining gestation, and 18 months surveillance. The improved stove, which costs 50 to 100, is already being produced in the study area and is in demand.

This randomized intervention study would be the first to systematically evaluate the health impact of an improved stove. It would provide definitive information about the potential of improved stove programs as a way to effect reductions in ARI and would begin to fill the information gap on the dose-response

Table 4
Smoke Exposures and Concentrations
Due to Traditional and Improved
Cookstoves with Flues in South Asia

(Measurement of TSP by Use of Personal Monitoring Equipment)

Location	Traditional stoves		Improved stoves		*p*	Reference
	n	Mean	*n*	Mean		
Nepal: two mid-hill villages	22	3.14 mg/m^3	27	1.13 mg/m^3	<0.5 %	Reid H *et al*. Indoor smoke exposures from traditional and improved cookstoves: comparison among rural Nepali women. *Mountain research and development*, 1986, 6(4): 293-394.
India: two Gujarat villages	21	6.4 mg/m^3	14	4.6 mg/m^3	n.s.	Smith KR. *Biofuels, air pollution and health* (New York: Plenum Publishing Co., 1987).
India: four Gujarat villages	21	3.6 mg/m^3	23	3.9 mg/m^3	n.s.	Smith KR, Durgaprasad MB. Difficulties in achieving and verifying exposure reductions in village households with improved biofuel-fired cookstoves. Siefert B *et al*. (eds) *Indoor Air 87* (Berlin: Institute for Water Soil and Air Hygiene, 1987).
India: one Haryana village	51	3.2 mg/m^3	36	2.8 mg/m^3	n.s.	Ramakrishna J. Cultural, technological, and environmental factors influencing indoor air pollution in rural India. Seifert B *et al*. *op cit.*
India: two Karnataka villages	39	3.5 mg/m^3	40	2.6 mg/m^3	n.s.	Ramakrishna J. *op cit.*

Source: Smith KR. Dialectics of improved stoves. *Economic and Political Weekly*, March 11, 1989, pp. 517-522.

relationship across the range of exposures typically encountered among rural populations using open fires and improved stoves.

Behavioral Change Interventions to Reduce Indoor Air Pollution. Behavioral change interventions to reduce indoor air pollution from stoves may have an impact but would be difficult to implement. For example, mothers could put their children in another room or area away from the smoke while they are cooking, but the children might be exposed to other health hazards. Or mothers could cook outdoors or arrange to share cooking and child care so that children are kept out of smoky areas. However, such changes may be impractical and unacceptable culturally. Educational programs may have some potential. For example, in Kenya, a school curriculum on reducing the use of fire and smoke in cooking is in use. Much remains to be learned and tried in this area.

Reducing Environmental Tobacco Smoke. Environmental tobacco smoke makes up a smaller proportion of the total indoor air pollution burden in developing countries. While the contribution of environmental tobacco smoke may be smaller than that of indoor combustion of biomass fuels (tens of $\mu g\ m^3$ compared to thousands of $\mu g\ m^3$), it is reasonable to expect that exposure to environmental tobacco smoke will become a much larger problem in years to come, and it would be wise to keep abreast of smoking trends as well as developments in country-level policy and health promotion. (There is conclusive evidence from developing countries of a link between exposure to environmental tobacco smoke and ARI incidence.) The panel recommended a number of preventive interventions: training caretakers not to smoke around children, promoting smoke-free public facilities, anti-smoking advertisements, and training medical personnel to deliver anti-smoking messages when children are receiving treatment for ARI and when parents are receptive to such messages.

Reducing Ambient Air Pollution. Reducing people s exposure to particulates in ambient air depends heavily on technological interventions, such as control of stationary sources of emissions, conversion to cleaner fuels, improvements in vehicle fleets, the use of catalytic converters, and discontinuing the use of diesel-fueled buses. Nevertheless, some community- and household-level interventions are feasible. These include banning open burning of solid wastes and agricultural refuse, street sweeping, and keeping children from being too active on high-pollution days. The latter depends upon the presence of an air quality monitoring and health advisory system something that most developing countries do not have.

In many instances, developing countries set ambient air pollution standards unrealistically low, on a parallel with developed country standards. The panel advised that it would be preferable for countries to develop strategies for reducing pollution step-wise over a number of years, during which standards would be reached incrementally in accord with industry s capacity to meet them and the country s ability to enforce them. The panel suggested that USAID design such an evolutionary sequence of activities for meeting acceptable long- or medium-term goals for strategies for reducing particulate levels in three or four cities. These site-specific designs could serve as models for other countries.

Conclusions and Recommendations

The panel recommended a focus on air pollution from particulates, which is clearly related to the incidence of ARI. The three major sources of particulates are given in **Table 5** with an indication of the magnitude of the exposure and the strength of evidence connecting it with ARI. Of the three sources indoor sources, ambient sources, and environmental tobacco smoke indoor sources, mainly from cooking and heating, are the greatest contributor to particulates in the air that most children in developing countries breathe. However, the strength of the evidence goes in the opposite direction: the evidence linking environmental tobacco smoke with ARI is strong and extensive; that linking indoor sources is weak because it is limited. The panel agreed, however, that it is not necessary to wait for further studies to take action.

Table 5
Particulates in Air Linked to ARI

Source	Magnitude of Exposure	Strength of Evidence of Link to ARI
Environmental tobacco smoke	10s of $\mu g/m^3$	Strong and extensive
Ambient sources	100s of $\mu g/m^3$	Moderate and limited
Indoor sources	1000s of $\mu g/m^3$	Limited range and quality of evidence, but consistent

In summary, the panel made six recommendations for EHP activities related to ARI prevention:

1) **Focus the effort on airborne particulate matter**, because particulate matter has been closely linked with health outcomes of concern to USAID, namely ARI in young children.

2) **Develop interventions to reduce exposure to smoke from indoor solid fuel combustion**, because the resulting particulate exposures are much greater than those resulting from outdoor exposures. A first step will be to gather and summarize existing information from diverse sources. For example, programs to reduce fuelwood consumption may have an impact on smoke exposure and health outcomes without having these as primary objectives.

3) In three or four different urban settings, **apply a methodology to prioritize among outdoor ambient particulate problems and promote focused activities to address the highest priority problems.**

4) **Adapt protocols for monitoring indoor and ambient particulate levels** appropriate for USAID-assisted countries, which could be used to monitor the impact of interventions pursued under other recommendations.

5) **Develop a strategy for limiting the growing exposure of children worldwide to environmental tobacco smoke.** While this problem may be limited within the most vulnerable USAID-assisted populations, it is growing and will probably be affected by changing smoking behavior patterns, including gender-based differences.

6) **Investigate childhood ARI/pneumonia as a health outcome of ambient air pollution in less-developed countries**. Childhood ARI has not been the focus of studies in developed countries because it is not a major health problem there. However, the situation is quite different in developing countries.

Next Steps

The next step for EHP is to use the panel's recommendations to develop a realistic plan of action, perhaps culminating in developing a results package on the prevention of ARI similar to the existing results packages on diarrhea and malaria prevention.