THE GLOBAL BURDEN OF DISEASE FROM INDOOR AIR POLLUTION: RESULTS FROM COMPARATIVE RISK ASSESSMENT

KR. Smith,¹ S Mehta,¹ and M Feuz¹,²

¹School of Public Health, University of California, Berkeley, CA 94720-7360  
²Swiss Federal Office of Public Health, Bern, Switzerland CH-3003

ABSTRACT
Recent estimates (organized and coordinated by WHO) of the global burden of disease for some two dozen risk factors by age, sex, and region include, inter alia, malnutrition, hypertension, tobacco use, obesity, unsafe sex, and several environmental risk factors, including lead, climate change, and indoor and outdoor air pollution. Only two categories of indoor pollution were deemed sufficiently well characterized regarding both exposure and risk to attempt to make global estimates: environmental tobacco smoke and combustion products from household use of solid fuels (biomass and coal). We summarize here the approaches used to estimate the health impacts from solid fuel use, including exposure modeling and meta-analyses for major disease endpoints. Although all the risk factor studies are not yet completed, the results seem to place indoor air pollution as a major risk factor worldwide, perhaps fifth after malnutrition, tobacco, HIV, and poor water/hygiene/sanitation in attributable burden.

INDEX TERMS
risk assessment, solid fuels, households, meta-analysis, exposure modeling

INTRODUCTION
There is no question that concerns about health are major drivers of research and control efforts related to indoor air quality (IAQ). Melding as they do into concerns related to comfort and productivity, the known and potential links to health outcomes make up the primary justification for the work that has gone into the papers presented at a conference such as this one. Thus, health is important in IAQ. Less clear, however, is the strength of the inverse relationship, i.e., how important is IAQ in health? How does IAQ stack up against the wide variety of risk factors that affect health, from unsafe sex to fatty diets to dirty water? Should IAQ become a concern of researchers and organizations whose primary interest is in health improvement and who must evaluate the effectiveness of interventions across the spectrum of possibilities? How does its impact vary by population group and region of the world?

Burden of Disease Database
Until relatively recently, it would not have been possible to answer this question in a systematic manner for any risk factor. This is because the health community lacked a coherent, consistent, and comprehensive dataset describing the extent and distribution of ill-health. Simple questions such as how many died of what disease at which age in which part of the world could not be answered reliably. Just asking each of the expert groups how many deaths were caused by their particular disease produced irreconcilable results. The sum of all disease groups’ estimates invariably came to many more deaths than the known total. This is because of the natural tendency of interest groups to cite the higher end of uncertainty ranges, differences in treating evidence among groups, and true conceptual difficulties, especially...
with assigning deaths from multiple causes to one disease category, for example whether tuberculosis deaths in an HIV-positive population should be accounted to HIV or tuberculosis.

This is quite primitive compared to other major datasets used by modern society. We expect that import statistics will match export statistics by region and commodity. So with energy and food production and consumption, the net of births minus deaths and population growth, financial flows, etc. If any of these data do not balance, we send them back to be fixed. Until the mid-1990s, however, we had to live with a health database that did not balance.

It is more difficult with health than with physical objects, of course. First of all, there are no cross checks, i.e., we have no import statistics from heaven and hell. Secondly, although death comes to everyone eventually, people experience death at different times. If we only count deaths, the death in a young child counts the same as the death of his or her grandparent. And yet, we know that society does not consider these deaths to be equivalent. Thirdly, in many places, particularly developing countries, detailed information on cause of death is rarely noted. There are also major differences in how causes of death are tabulated in different parts of the world. Even in developed countries with highly developed health information systems, however, there were inconsistencies in the totals published by different sources.

Without such data, trying to determine the number attributable to any one risk factor was lost in a sea of inconsistent and competing claims. Imagine, for example, trying to determine what fraction of energy is produced by coal if we have neither a reliable number for total energy use nor an agreed upon way to distinguish coal from oil?

In the early 1990s, however, through an exercise originally promoted by the World Bank at Harvard University but now incorporated into the statistical apparatus of the World Health Organization, a significant degree of order was brought to global health statistics in the form of the first C⁴ health database:

**Complete:** coverage of the entire world and all age and sex groups if not by actual data then by systematic and heavily reviewed extrapolation from relevant data.

**Consistent:** common definitions and conventions for disease conditions were developed and applied

**Coherent:** rows (deaths for each disease by age and sex) and columns (total deaths for all diseases) added to totals from population statistics and other sources.

**Comprehensive:** disability (disease and injury) as well as death was included.

To do so, it was necessary to bring together diagnosticians, disease experts, demographers, epidemiologists, statisticians, and others with relevant angles of view in a number of different fora around the world and impose a kind of consensual “discipline” never before attempted. No longer could one disease group claim large numbers of deaths unchallenged, because they would have to take into account the often directly conflicting estimates of other disease groups who also had evidence among the same populations. Since all the groups were engaged together and obliged not, in sum, to exceed the known number of deaths, coherence and consistency were enforced.

The first complete publication of the Global Burden of Disease (GBD-1990) database occurred in 1996 (Murray and Lopez 1996) using 1990 data. With such a database a broad set of analyses could be done that were not possible before. Among these are systematic
examinations of more distal risk factors for ill-health, as compared to the proximate causes such as particular diseases. IAP is a more distal cause of death than COPD, for example, and poor building ventilation would be more distal still. Even though only COPD would be listed on a death certificate and in the GBD database itself, some fraction nevertheless is attributable to IAP and, with appropriate data and modeling, the total burden of COPD and other diseases due to IAP can be estimated.

In the first GBD publication, preliminary estimates of the burdens in the form of Comparative Risk Assessments (CRAs) were conducted for 10 major risk factors worldwide. Outdoor but not indoor, air pollution was included, with a total burden estimated at about 0.5% of the global total (Hong 1996). By comparison, tobacco use and poor water/hygiene/sanitation accounted for 2.6% and 6.8% respectively.

The WHO has now prepared the GBD-2000 based on an extensive updating and review of the 1990 version. It is available on the web for review and will be published in final form in early 2003 (WHO 2001). In addition, the WHO commissioned teams around the world to prepare CRAs for the original 10 risk factors plus more than a dozen additional, including two types of indoor air pollution (IAP).

The GBD-2000 Comparative Risk Assessments for IAP

We were asked to conduct the CRA for IAP. Although a number of indoor air pollutants and their sources are known to affect health, the WHO CRA exercise required that to be included in the CRA a significant database must be available on the distribution of the risk factor worldwide (exposure) and the health risk (exposure-response relationship). Although these criteria might be met for radon, bio-aerosols, moisture, and a few other health-related indoor air pollutants in parts of North America, Europe, and the developed Asia-Pacific, we could not find sufficient data to extrapolate to exposures elsewhere in the world.

We were, however, able to find sufficient data to develop global exposure distributions for two major combustion-related indoor air pollutants, environmental tobacco smoke (ETS) and smoke from household use of solid fuels. In addition, there are now sufficient numbers of epidemiological studies in the peer-reviewed biomedical literature to conduct formal meta-analyses of the major health endpoints associated with each of these forms of IAP. Although having many common disease endpoints, because the causes, exposure distributions, and potential interventions related to these two sources are so different, the CRAs were conducted separately. The ETS CRA did not pass peer review in time to be part of the list in 2002 and is not discussed further here.

Under the principle of “consensual discipline,” the WHO CRA groups met together twice over a year period during their deliberations to hammer out agreements about the quality and quantity of evidence that would be expected from each. In between, the CRA management/editorial team at WHO maintained close contact with all groups and produced databases needed by all groups (e.g., GBD-2000, population projections). The differences in data available were substantial in many cases. The hypertension group, for example, had large surveys over many parts of the world for use in developing exposure distributions as well as dozens of large double-blind placebo-controlled randomized interventions (the “gold standard” of epidemiology) for determining exposure-response levels. The climate change group, in contrast, had none of either and, in addition, had to forecast forward in time. The IAP CRAs were intermediate in level of evidence available.
The first two draft CRAs from each group were shared among the groups and the third version was sent for extensive outside peer review. The final versions thus reflect not only “consensual discipline” among the groups, but also the disciplines imposed by blind peer review and strong editorial management. As much as possible, therefore, given the time, data, and other limited resources, the set of CRAs represent a comprehensive examination of the distal risk factors chosen.

A summary of all the CRAs is being published in the 2002 World Health Report, the annual report of the World Health Organization, and several book volumes with the detailed chapters on each risk factor are scheduled for publication by the end of the year. Here we report briefly on the methods and results of the IAP CRA (Smith, Mehta et al. 2002 (forthcoming)).

**CRA for Household Use of Solid Fuel**

A substantial and growing body of evidence demonstrates reasonably consistent and strong associations between the household use of solid fuels (biomass or coal) and a number of health endpoints. In households with limited ventilation, as is common in many developing countries, air pollution exposures to householders, particularly women and young children who spend a large proportion of their time indoors, have been measured to be many times higher than WHO Guidelines and national standards. Because of the limitations of the available epidemiological studies, strong evidence linking the use of solid fuels for cooking to health effects is only available for young children (less than five years of age) and adult women. Available data indicate that men are also affected, but apparently at lower risks, presumably because of lower exposures. Although few studies are available, school-age children (5-14) are probably also affected, also presumably at risks lower than women or young children.

We focus solely on solid fuel use in the household environment, as the largest fraction of time spent indoors occurs at home. We utilize the growing epidemiological literature on the health effects of household solid fuel use relying on binary exposure classifications (i.e. exposed vs. unexposed) to test for evidence of an association. Because the studies use binary exposure classifications, there is no need to extrapolate quantitative pollution exposures to determine risk at the population level. Since the studies have been done in the same populations and conditions of exposure in developing countries, many of the concerns about extrapolating exposure-response information from other settings are alleviated. We do not address indoor exposures resulting from outdoor sources, nor do we address how indoor sources can affect outdoor pollution levels.

The quality of evidence for each age and disease endpoint was evaluated. Burden of disease was estimated for the health outcomes classified as having Strong (defined below) or Moderate-I evidence (a few studies available and Strong evidence available for other age/sex groups for the same endpoint): acute lower respiratory infections in children under five, chronic obstructive pulmonary disease, and lung cancer (estimates for lung cancer are for coal use only). Although multiple exposure-response studies are available for endpoints with Moderate-II (a few studies available, but insufficient to characterize as Strong) evidence (TB, cataracts, lung cancer from biomass use, and asthma), to be conservative they are not presented in the main estimates. Potential health impacts not quantified at this stage include ischaemic heart disease, interstitial lung disease, and adverse pregnancy outcomes.
Exposure Distribution
We estimate exposure to solid fuel smoke by combining a number of national surveys of household fuel use into a model that predicts use according to independent, development-related variables such as income. The variance of the model is used as a measure of uncertainty. Since pollution emissions from use of solid fuel may not always indicate high exposures because of vented (chimney) stoves, cooking outdoors, or other, ventilation-related, characteristics of household cooking, we have adjusted exposure estimates by a second term, the ventilation factor.

We utilize binary exposure classifications (i.e. exposed vs. unexposed) similar to those used in the epidemiological literature on the health effects of household solid fuel use. In recognition of the fact that pollutant emissions and exposures from the use of solid fuel can be modified by ventilation characteristics, including vented stoves (chimneys), outdoor cooking, and other household cooking practices, we have included a ventilation factor into our risk factor estimates. The solid-fuel exposed population is thus defined as:

\[(\text{Proportion of households using solid fuel}) \times (\text{Ventilation Factor})\]  (1)

The result can be considered as “full-exposure equivalents,” thus allowing use of the relative risks from the meta-analyses of epidemiological studies. The proportion of households using solid fuel in each region was estimated as follows:

- A global database of household solid fuel use based on a review of national census data and other household surveys has been developed (Smith and Bailis 2000). This database provides information on household solid fuel use, expressed as percent of total population using each fuel type, for 52 countries.
- Using the database, a statistical model was developed to predict household solid fuel use from variables such as income, commercial energy use, and urbanization. Stepwise linear regression was used to build a model to predict solid fuel use on the basis of all of the above parameters. Known values of solid fuel use from the household fuel database were used to create the model. The model was then applied to countries where no household fuel data exist. This method also allows for the estimation of uncertainty surrounding each estimate. Using this model, household solid fuel use has been estimated for nearly 83% of the world’s population. The final model includes percentage rural population, location within the EMR region (Eastern Mediterranean), GNP per capita (log transformed), and per capita petroleum use. Several other potentially important variables, including fuelwood production per capita and electricity consumption per capita were not significant and thus did not survive in the final model.
- Known and predicted estimates of solid fuel use at the country level were aggregated into estimates for the WHO regions. Known values were used for all countries in the household fuels database. Solid fuel use estimates for countries in the household fuels database were arbitrarily assigned a +/- 5% uncertainty range. Regions with the least amount of coverage are the regions that have the highest levels of economic development, i.e. those regions that are least likely to have high proportions of household solid fuel use.

Ventilation is a function of climate and development. For example, in countries of Eastern Europe and the former Soviet Union, energy technologies with fewer indoor emissions were developed throughout a long history of household solid fuel use under cold climatic
conditions and relatively high standards of living. All countries classified as Former Socialist Economies of Europe (FSE) were assigned a ventilation factor of 0.2. As the widespread national improved stove program in China has disseminated cookstoves to more than 75% of rural solid-fuel using households in the past two decades, China’s ventilation factor is set to 0.25 for child health outcomes. Since current disease patterns for adults partly reflect pre-improved stove exposures, the ventilation factor is set to 0.5 for adult health outcomes. All countries with GNP per capita above $5000 are essentially assigned a ventilation factor of 0, i.e., any household solid-fuel use is assumed to be undertaken in fully vented appliances with no re-entry of the pollution back into households, a conservative assumption. All remaining countries, in the absence of further information, are assigned a ventilation factor of 0.75, to allow for a degree of outdoor cooking and other behaviors that reduce exposure. This conservative assumption affects about 45% of the world population.

Table 1 shows the percent of biomass-using equivalents among all households, i.e. the risk factor prevalence, by region. In addition, solid fuel has been disaggregated into coal and

**Table 1:** Sample Estimates of Risk Factor Prevalence (Biomass Use) and Ventilation Factor

<table>
<thead>
<tr>
<th>WHO Region</th>
<th>Region Description</th>
<th>2000 Pop (millions)</th>
<th>Household Solid Fuel Use(^1)</th>
<th>Ventilation Factor(^1)</th>
<th>Point estimate</th>
<th>Low estimate</th>
<th>High estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFR D</td>
<td>Africa-Poor</td>
<td>295</td>
<td>73.4%</td>
<td>0.75</td>
<td>55.1%</td>
<td>51.1%</td>
<td>58.3%</td>
</tr>
<tr>
<td>AFR E</td>
<td>Africa-Very Poor</td>
<td>346</td>
<td>85.8%</td>
<td>0.75</td>
<td>64.3%</td>
<td>60.3%</td>
<td>66.9%</td>
</tr>
<tr>
<td>AMR A</td>
<td>Americas-Rich</td>
<td>325</td>
<td>1.5%</td>
<td>0.75</td>
<td>1.1%</td>
<td>0.7%</td>
<td>1.5%</td>
</tr>
<tr>
<td>AMR B</td>
<td>Americas-Mid-Income</td>
<td>430</td>
<td>24.6%</td>
<td>0.75</td>
<td>18.4%</td>
<td>14.1%</td>
<td>23.1%</td>
</tr>
<tr>
<td>AMR D</td>
<td>Americas-Poor</td>
<td>71</td>
<td>52.9%</td>
<td>0.75</td>
<td>39.7%</td>
<td>31.9%</td>
<td>47.4%</td>
</tr>
<tr>
<td>EMR B</td>
<td>Eastern Mediterranean-Mid-Income</td>
<td>139</td>
<td>6.1%</td>
<td>0.75</td>
<td>4.6%</td>
<td>1.5%</td>
<td>9.1%</td>
</tr>
<tr>
<td>EMR D</td>
<td>Eastern Mediterranean-Poor</td>
<td>343</td>
<td>55.2%</td>
<td>0.75</td>
<td>41.4%</td>
<td>37.4%</td>
<td>45.1%</td>
</tr>
<tr>
<td>EUR A</td>
<td>Europe-Rich</td>
<td>412</td>
<td>0.2%</td>
<td>0.73</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.4%</td>
</tr>
<tr>
<td>EUR B</td>
<td>Europe-Mid-Income</td>
<td>218</td>
<td>41.5%</td>
<td>0.51</td>
<td>20.5%</td>
<td>16.2%</td>
<td>24.5%</td>
</tr>
<tr>
<td>EUR C</td>
<td>Europe-Lower Mid-Income</td>
<td>243</td>
<td>22.8%</td>
<td>0.24</td>
<td>6.4%</td>
<td>4.3%</td>
<td>10.4%</td>
</tr>
<tr>
<td>SEAR B</td>
<td>South and SE Asia-Mid-income</td>
<td>294</td>
<td>66.5%</td>
<td>0.75</td>
<td>49.9%</td>
<td>45.8%</td>
<td>53.9%</td>
</tr>
<tr>
<td>SEAR D</td>
<td>South and SE Asia-Poor</td>
<td>1242</td>
<td>83.5%</td>
<td>0.75</td>
<td>62.6%</td>
<td>58.7%</td>
<td>66.2%</td>
</tr>
<tr>
<td>WPR A</td>
<td>Western Asia- Rich</td>
<td>154</td>
<td>0.2%</td>
<td>0.75</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>WPR B</td>
<td>Western Asia-Mid-Income</td>
<td>1533</td>
<td>78.1%</td>
<td>0.33</td>
<td>25.1%</td>
<td>23.5%</td>
<td>26.7%</td>
</tr>
</tbody>
</table>

\(^1\)Regional estimates are population-weighted estimates of national data.

\(^2\)Solid fuel using household equivalents have been calculated at the national level, and then scaled up to the regional level.
billion use for the separate quantification of the burden of lung cancer burden. To stay consistent with the epidemiological literature, we have used a binary exposure classification system. In reality, exposures to indoor air pollution from solid-fuel use results in a wide range of exposures. As the distribution of exposures is continuous, exposures would best be categorized into multiple exposure categories. A range of factors affects the degree of exposure: 1) emission characteristics differ with different types of fuel, cooking/heating methods, and season 2) indoor air pollution levels are influenced by household characteristics, including ventilation, size, stove type, quantity of fuel used, building material, and location with regard to other solid-fuel using households. Human exposure is also influenced by the amount of time spent within the household as well as proximity to the stove. Given the currently available information on indoor air pollution exposures associated with solid fuel use, the influence of most of the above parameters cannot be adequately quantified. We have, however, made a start by generating objective uncertainty measures in the fuel use model and using the ventilation coefficient to reflect variability in indoor air pollution.

**Health risk: Exposure-Response Relationships**

Relative risk estimates from recent extensive reviews of epidemiological studies (Bruce, Perez-Padilla et al. 2000; Smith, Samet et al. 2000) are combined in formal meta-analyses for the three disease endpoints with Strong evidence of an association with solid fuel use (see Table 2). Strong evidence is defined as more than six published studies in the peer-reviewed literature with standard methods of disease determination and quantified results along with supporting evidence from studies of outdoor air pollution, active and tobacco smoking, and laboratory animals.

**Acute Lower Respiratory Infections (ALRI):** In terms of lost life years, ALRI seems to be the major disease associated with indoor air pollution (Smith 2000). The largest impact of ALRI is on young children, with 85% or more of the 3.9 million global ARI deaths annually occurring to children under five (WHO 2001). Severe childhood ALRI is rare in developed countries and as a result, relatively few air pollution studies there have focused on it through lack of interest or lack of sufficient cases for statistical significance. As documented (Smith, Samet et al. 2000), a number of studies have been done in the developing world that give quantitative estimates of the relative risk of severe ALRI for children living in biomass-burning households. The strength of the association was assessed by means of a series of meta-analyses of these studies.

A single statistical analysis of the whole set of studies is not appropriate because of the heterogeneous nature of the exposures and the diverse analytical strategies used by the investigators. Thus, several sub-analyses within groupings of these studies were conducted.

Eight studies reporting relative risks of acute respiratory illness for young children exposed to indoor smoke from solid fuel were included in the analyses. All but one study used binary exposure classifications of exposure. While this only indicates whether or not indoor smoke was present in households, one study with a slightly better indicator reported the average time the child spent near the fireplace. The three studies with the most precise indicator of exposure report whether or not children were carried on the mother’s back during cooking.

Cooking with wood or other biomass was associated with an odds ratio of 2.0 (95%CI: 1.4, 2.8). As expected, the highest odds ratio was found to be associated with the child being carried on the mother's back during cooking (OR= 3.1, 95% CI: 1.8, 5.3). The study with an
intermediately precise exposure measurement reports a relative risk estimate of 2.3 (95% CI: 1.8, 2.9).

Several confounding factors may have distorted our findings. As malnutrition is one of the major factors that increase ALRI risk, studies that did not control for nutritional status may have overestimated the association between indoor air pollution and ALRI. Three out of the eight studies considered nutrition as a confounding variable and found only a slight change in the strength of the association. Another distorting factor may be age. Since in almost all studies the potential confounding by age was accounted for, our results should be unaffected by age. In fact, a sub-analysis of the younger children versus the older showed a stronger effect in the young.

Finally, there are limitations inherent to the different types of study design. In most cases, however, authors took care to minimize bias either by the choice of the study population or during analysis. A more recent study has also shown a dose-response relationship for ALRI, further strengthening the evidence (Ezzati and Kammen 2001).

**Chronic Obstructive Pulmonary Disease (COPD):** COPD is usually not diagnosed until the second half of a lifetime but the exposure to indoor smoke often begins in early childhood. Today in developed countries, COPD is thought to be nearly all due to tobacco smoking. Undoubtedly its prevalence among men in developing countries is also significantly due to smoking. In addition, the results of the meta-analysis conducted here suggest that a sizeable proportion of COPD among men and more obviously among women in developing countries can be attributed to biomass smoke exposure. This analysis primarily included women as they comprise the population that is most frequently exposed to wood-smoke from cooking and thus at greatest risk for developing COPD if there is an association. Exposure in most studies was assessed by a binary measure that is likely to be imprecise. Use of a more precise measure such as the exact amount of years and hours of exposure, however, would be prone to recall bias that might well overestimate an effect if ill women over-reported exposure to indoor solid-fuel smoke.

Eight studies in six countries have actually determined the prevalence of COPD in ways that allow quantification. There is much less evidence available about the impact on men, but the effect seems to be lower presumably because of lower exposures.

As mentioned above, a great proportion of COPD in developed as well as in developing countries is likely to be due to smoking. It is thus of paramount importance to account for smoking status either at the design or the analysis stage. We were able to extract estimate of the relative risk adjusted for smoking from all but two studies. Those two studies were excluded from the sub-analyses. Not surprisingly, the combined risk estimate produced from those two studies alone, is much higher. Age as a proxy for cumulative lifetime exposure is a major factor that will influence the strength of the association. All studies included ill and healthy men and women of comparable ages thus there if an association is found it will very unlikely be due to variations in age.

**Lung Cancer:** Lung cancer in women due to cooking with open coal stoves in China is well demonstrated by at least 20 studies. There is less evidence of the association between lung cancer and biomass fuel use, however, even though biomass smoke contains a wide-range of chemicals, as gases and particles that are known or suspected human carcinogens and contains
particles mostly in the small sizes know to penetrate to the deep lung. We were able to include 16 studies in the meta-analysis, 14 from China.

Measurement of exposure to indoor-air pollution was done by a multitude of methods. Some studies assessed exposure in terms of years of cooking; others merely asked whether coal and/or biomass were generally used for cooking or heating. The resulting odds ratios of this analysis refer to the risk associated with the longest exposure compared to no or very short exposure. The effect taking into account both history of chronic respiratory disease and smoking was a substantial increase in the summary estimate of the risk for lung cancer. All studies included in the meta-analysis either adjusted for smoking or included only non-smokers.

<table>
<thead>
<tr>
<th>Illness</th>
<th>Population</th>
<th>Point Estimate</th>
<th>Low</th>
<th>High</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Lower Respiratory Infections (ALRI)</td>
<td>Children &lt;5</td>
<td>2.3</td>
<td>1.9</td>
<td>2.7</td>
<td>Strong</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disease (COPD)</td>
<td>Women ≥30</td>
<td>3.2</td>
<td>2.3</td>
<td>4.8</td>
<td>Strong</td>
</tr>
<tr>
<td>Lung Cancer –coal only</td>
<td>Men ≥30</td>
<td>1.8</td>
<td>1.0</td>
<td>2.8</td>
<td>Moderate-I*</td>
</tr>
<tr>
<td></td>
<td>Women ≥30</td>
<td>1.9</td>
<td>1.1</td>
<td>3.5</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>Men ≥30</td>
<td>1.5</td>
<td>1.0</td>
<td>2.5</td>
<td>Moderate-I*</td>
</tr>
</tbody>
</table>

* Lower limit of RR with Moderate-I evidence taken as no risk, RR=1.0.

**RESULTS**

The precise results of this as well as the other CRAs are embargoed until the release of the *World Health Report* in October 2002. It can be said, however, that well over one million of the world total of 55 million premature deaths can be attributed to the indoor pollution from solid fuel use worldwide in 2000. Because most of these deaths occurred in children under five (from ALRI), however, the fraction of total lost life years as measured in DALY’s is substantially greater than the fraction of total deaths.

Several potentially important health outcomes of IAP exposures for which quantitative evidence is available, including adverse pregnancy outcomes, tuberculosis, cataracts, asthma, and ischaemic heart disease, have not been addressed in this analysis, due to the conservative approach imposed by consensual discipline among CRA groups. Also not included are major related pollution sources: cooking oil smoke and toxic elements in coal smoke, a serious problem in China. In addition, since the counterfactual level considered, use of liquid and gaseous fuels, also produces some exposure, total burdens compared to truly clean fuels such as electricity would be higher than indicated here. On the other hand, the method used to derive exposure estimates, particularly the ventilation factor, and the observational studies used in the ALRI meta-analyses may result in some overstatement of burdens. Although trends are highly uncertain, the attributable burden in 2000 is likely to be greater than the actually avoidable burden from feasible interventions because the exposures and background disease rates are likely to decline slowly on their own, depending on population shifts and the way economic growth is distributed to the world’s poor households that now rely on solid fuels.

Nevertheless, it seems that cooking and heating with solid fuels may be responsible for a significant proportion of the global burden of disease, perhaps a few percent. This puts it at or
above the level of most other major risk factors, including cholesterol, hypertension, traffic accidents, and outdoor air pollution, although somewhat below the top four: malnutrition, tobacco, unsafe sex (HIV), and poor water/hygiene/sanitation. As with many important risk factors, IAP from household solid fuel use is a strong function of poverty. Just as with other such risk factors, however, it does not mean that we have to wait until people are rich to solve it. Just as the international health community has come to accept programs to improve household water and sanitation as ways to help people become healthy before they become wealthy, programs to improve household fuels and ventilation can be serve the same purpose. Indeed, just such recommendations are starting to come from the international agencies concerned with health in poor countries (UNICEF, UNEP, WHO 2002).

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REFERENCES