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Wood: The Fuel that Warms You Thrice

Kirk R. Smith

'Wood is the fuel that warms you twice', goes an old New England expression: 'once when chopping and once when burning'. Unfortunately, however, wood seems to have the potential to generate heat a third time, because the smoke from its burning is a major risk factor for respiratory infections and the fever that often accompanies them. It is now believed that the burning of simple household biomass fuels – wood, but also fuels derived from trees, crops, animal dung, shrubs, grasses and root plants – is responsible for some 1.4 million (range: 1 million to 2 million) premature deaths annually, mainly in women and young children of developing countries (Smith et al, 2004). Household use of coal, another solid fuel that produces significant pollution, is responsible for another 200,000 premature deaths a year, mostly in China. This places indoor air pollution from household fuels as the second most important environmental risk factor globally, after poor water and sanitation, being responsible for a health burden well above that from all outdoor air pollution in cities, and tenth among risk factors of all kinds (Ezzati et al, 2002; WHO, 2002; Figure 5.1, overleaf).

When first hearing of the risks from woodsmoke, many people are sceptical because of our long-term association with this natural material. Indeed, it could even be said that the smell of woodsmoke from the hearth is exactly as old as humanity itself, since many anthropologists define the point at which we became 'human' as the moment when our ancestors learned to control fire. 'Natural', however, does not necessarily mean 'benign', and only a rather narrow view of global and historical environments would allow a conclusion that 'natural' is always good for health. Most of humanity has spent most of history trying to protect itself from environmental hazards. Nostalgia triggered by the sight and smell of an open wood fire in the hearth has tricked us into complacency about this source of risk in the past, and it continues to do so today.

Exposure to woodsmoke

Chemically, wood is nearly all carbon, hydrogen and oxygen and – unlike the other major solid fuel, coal – itself contains essentially no toxic materials (Smith, 1987). Thus, in special combustion conditions it can be burned completely to non-toxic carbon dioxide and water. Unfortunately, however, in simple household stoves, combustion is far from complete, and wood releases much of its carbon as products of incomplete combustion, respirable particles, volatile organic chemicals and carbon monoxide.

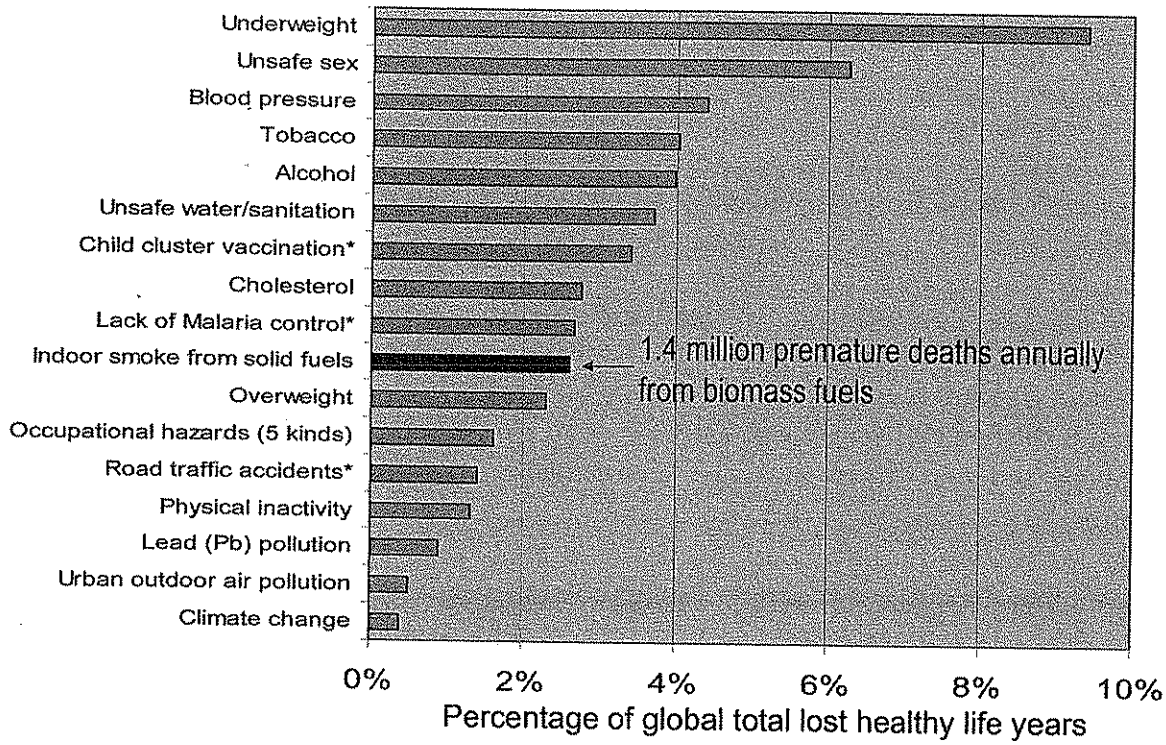

Figure 5.1 *Global burden of disease from major controllable risk factors*

Studies of typical Indian and Chinese biomass stoves, for example, show that 5 to 20 per cent of the carbon is diverted to such products (Smith et al, 2000; Zhang et al, 2000). Because of the complex chemistry created by the highly varying levels of temperature, oxygen and residence times in the flame zone of a simple wood fire, a vast range of compounds are routinely emitted. Thousands have been identified, many dozens of which are known from laboratory, animal or human studies to have toxic effects (Naeher et al, 2007). Box 5.1 lists major categories of materials found in woodsmoke, with a specific example of a major toxic chemical for each. Although there are differences in emissions from different species of wood and other biomass varieties, none burn without significant emissions of these substances in simple, small-scale combustion (Naeher et al, 2007).

The health burden created by a toxic material, however, is due not only to toxicity but also to exposure. No matter how toxic the mixture, if few people actually breathe it, the overall effect will be small. In the words attributed to Paracelsus, the Renaissance pioneer of toxicology and environmental health, 'the dose makes the poison' (Binswanger and Smith, 2000).

Besides containing noxious materials, woodsmoke is created by a process that is perniciously optimal for producing large human exposures. Nearly half the human race is thought still to rely on simple solid fuels for most of their household energy needs. Figure 5.2 shows estimates of the fraction of households using solid fuels in countries around the world, based on a combination of household survey data and econometric modelling (Smith et al, 2004). Only in China does any appreciable fraction (~25 per cent) of

BOX 5.1 MAJOR CHEMICAL CLASSES OF WOODSMOKE CONSTITUENTS

Examples of particular chemicals with known human toxic properties are shown in italics.

- Criteria air pollutants (national standards in most countries):

  small particles (PM2.5, those less than 2.5 microns in diameter), *carbon monoxide, nitrogen dioxide*

- Hydrocarbons

  25+ saturated hydrocarbons such as *n-hexane*
  40+ unsaturated hydrocarbons such as *1,3 butadiene*
  28+ mono-aromatics such as *benzene** and *styrene*
  20+ polycyclic aromatics* such as *benzo(α)pyrene**

- Oxygenated organics

  20+ aldehydes including *formaldehyde** and *acrolein*
  25+ alcohols and acids such as *methanol*
  33+ phenols such as *catechol* and *cresol*
  Many quinones such as *hydroquinone*
  Semiquinone-type and other radicals

- Chlorinated organics such as *methylene chloride* and *dioxin**

*Classified as Group I, 'known human carcinogen' by the International Agency for Research on Cancer.

Source: Naeher et al, 2007

solid-fuel-using households use coal; most households use biomass, with something like 50 to 60 per cent being in the form of wood (logs, branches, twigs) and most of the rest being agricultural residues.

Essentially all this wood fuel is used in simple household stoves, mostly for cooking but also for other tasks such as animal food preparation and, in temperate and highland areas, space heating. An unknown but high percentage of this burning is in unvented stoves – no chimney or hood – that release the smoke directly into the living area of the house. The result is indoor concentrations of many noxious pollutants that are high by any criterion: WHO guidelines, national health-based air pollution standards, urban pollution levels anywhere in the world, and any but the dirtiest industrial workplaces. Small particles, for example, are thought to be the best single indicator of risk for such combustion smokes. Typical long-term levels in households with open cookstoves are between hundreds of micrograms per cubic metre (μg/m^3) to 1000 or 2000μg/m^3, with peaks during cooking some five to ten times higher. The WHO's recent revision of its Global Air Quality Guidelines, by comparison, calls for a maximum of 10μg/m^3 for long-term exposure, and the new US Environmental Protection Agency (EPA) standard is 15μg/m^3 (WHO, 2005).

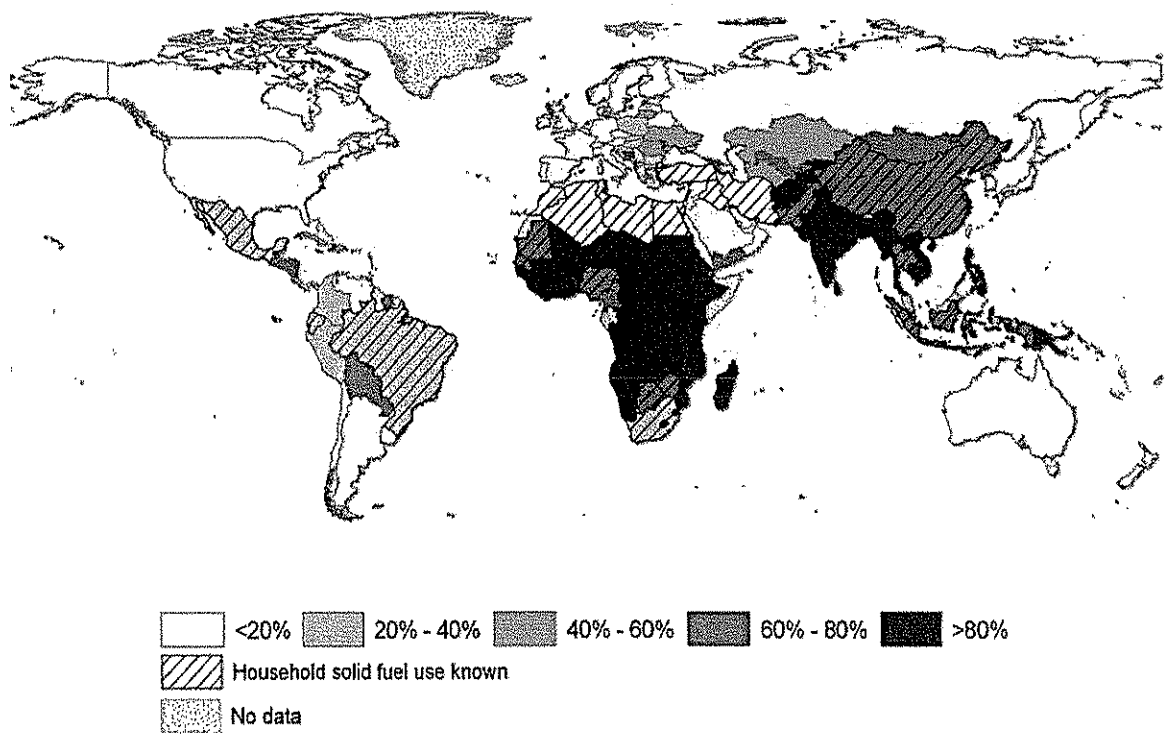

Figure 5.2 *Estimated national fractions of households dependent on solid fuels*

Here, then, is the 'perfect storm' combination for producing exposure: an essential task done two or three times every day in half the world's households releases a toxin-containing mixture directly into the households just at the times when people are present. When one considers also that it is women in nearly all cultures who are responsible for most cooking and for most care of small children, it follows that two of the most vulnerable population groups are most heavily affected. Given that it is the urban and rural poor who are most dependent on solid fuels and simple stoves, it also most heavily exposes populations with among the lowest socioeconomic (and political) status globally (Wilkinson et al, 2007).

NEED FOR EPIDEMIOLOGIC EVIDENCE

In a developed country, toxicological and exposure evidence of the sort noted above would be more than enough in themselves to warrant major and urgent protective action, even without detailed direct evidence on human health effects. Hundreds if not thousands of epidemiologic studies in Europe, Asia, North America and Latin America detail the health impact of the same pollutants in urban outdoor settings. These studies are remarkably consistent around the world (Cohen et al, 2004; ISOC, 2004; PAHO, 2005) and show major health effects even at particle levels as low as 10μg/m^3. A recent review by the WHO, for example, found that a long-term drop from 25 to 15μg/m^3 produces a 6 per cent drop in non-accident-related mortality rates (WHO, 2005).

Woodsmoke particles are somewhat different from the fossil fuel particles that pollute the atmosphere in developed-country cities, where these studies have mostly been done, and thus might be thought to have less effect. Although studies of pure woodsmoke exposures in outdoor settings are difficult to do, current toxicological, controlled human exposure, occupational and epidemiologic evidence is not supportive of treating woodsmoke particles as significantly different (Samet and Brauer, 2006; Naeher et al, 2007).

Seeing the high exposures in developing-country households, air pollution specialists may wonder why more research would be needed. After all, we know that particle levels 10 or 100 times lower cause significant effects in healthy populations (WHO, 2006b). Rather than waste time pinning down the effects precisely, it could be argued, the needed interventions could be deployed now. Indeed, it has even been argued that it would be unethical to do intervention trials because we already know that there must be important impacts (Last, 1992).

Perhaps paradoxically, however, in developing countries where health and environmental conditions are worst, the need for strong evidence is greatest. This is because of the extreme scarcity of resources for addressing health problems. In 2003, for example, India spent just US$7 per capita on health (WHO, 2006a), and thus those who decide on its allocation must be extremely pragmatic and highly critical of the evidence to ensure that available funds will be spent well. To argue within the health community that funds should be reallocated to improved fuel or stoves and, consequently, away from antibiotics, vaccines and clean water/sanitation, for example, requires much more than just evidence from laboratory studies and extrapolation of human health studies in developed countries. It requires the highest-quality biomedical research done directly with the populations of concern: developing-country households that depend on biomass.

CURRENT EPIDEMIOLOGIC EVIDENCE

Current epidemiologic evidence can be divided into three categories:

1 Well-accepted, although not completely quantified: supporting evidence from studies of active smoking, passive smoking and outdoor air pollution; human exposure and animal studies; and more than a dozen good epidemiologic studies in developing-country biomass-using households.
2 Highly suggestive: some supporting evidence from other sources and at least three epidemiological studies in biomass-using households.
3 Speculative: strong evidence from tobacco and outdoor air pollution studies, but no relevant studies yet in biomass-using households.

The major diseases associated with biomass smoke and a summary of the evidence are shown in Table 5.1.

Table 5.1 Health effects of the use of solid household fuels in developing countries

Disease	*Population affected*	*Relative risk (95% confidence interval)*	*Strength of evidence*
Chronic obstructive pulmonary disease	Females >15 years Males >15 years	3.2 (2.3, 4.8)* 1.8 (1.0, 3.2)*	Strong Intermediate
Acute lower respiratory infections	Children <5 years	2.3 (1.9, 2.7)*	Strong
Lung cancer (coal smoke only)	Women >15 years Men >15 years	1.9 (1.1, 3.5)* 1.5 (1.0, 2.5)*	Strong Intermediate
Blindness (cataracts)	Females >15 years	1.3–1.6**	Intermediate
Tuberculosis	Females >15 years	1.5–3.0**	Intermediate

Notes: For illustration, a relative risk of 1.5 indicates that a population living in solid fuel-burning households have a rate of the disease in question 1.5 times that of people living in clean fuel burning households.

* Based on formal meta-analyses.

** Range of results in published studies.

Source: Based on review and meta-analysis of published epidemiologic studies; Smith et al, 2004

Well-accepted effects

Chronic obstructive pulmonary disease (COPD)

Apparently, the first people to identify woodsmoke exposures as a hazard for women cooks were local physicians concerned with a particular kind of heart disease commonly thought to be nearly entirely due to smoking. *Cor pulmonale*, which is often fatal, is an unbalanced and enlarged heart, usually secondary to chronic lung disease. Independently in the 1970s, a general practitioner in India and a cardiologist in Nepal noted high rates of this condition in relatively young non-smoking women and traced it to correspondingly high rates of COPD, such as chronic bronchitis, in rural non-smoking women cooking with biomass fuels. Subsequently, there have been several dozen published studies pinning down this relationship, not only in terms of diagnosed COPD, but also in lung function and other changes that precede the development of this disease. COPD is a highly disabling disease with no known cure and inadequate palliative treatments available for low-income populations. It is also one of the most important causes of premature death in the world, killing perhaps 2.7 million annually (WHO, 2004). Although much of the overall burden is due to smoking, it is now thought also to be an outcome of long-term exposure to biomass smoke in developing-country households, particularly for women cooks. Of the premature mortality identified in the WHO-managed comparative risk assessment studies, as summarized in the lost life-years shown in Figure 5.1, about one-third is due to COPD.

Acute lower respiratory infections (ALRI)

The largest single impact of biomass smoke exposures is thought to be ALRI in young children, who receive most of their exposure while being cared for by their cooking

mothers. As pneumonia, ALRI is the chief cause of death among the world's children, killing nearly 2 million per year. All children around the world experience the usually self-limiting and rarely fatal acute *upper* respiratory infections at similar rates, but the rate of child ALRI and pneumonia in developing countries is hundreds of times greater than in developed countries. Because it affects the youngest members of the population, globally it causes more lost life-years than any other disease (WHO, 2004).

For such an important disease, unfortunately, neither its microbiology nor its risk factors are well understood. In general, most fatal ALRI infections are thought to be due to organisms that are present all the time in the environments where poor children live, rather than being the result of epidemics. The main proximate causes, therefore, are those that affect the ability of children's immune systems to withstand infection and to limit the severity of infections when they occur. General malnutrition, along with specific micronutrient deficiencies, are thought to be the main problems. It is also known that children weakened by other diseases, including measles, diarrhoea and HIV, are more likely to contract ALRI. Insufficient parental education and access to emergency medical care are clear factors in ALRI mortality, which can occur within a day or two of a malnourished child becoming ill. Even including such suggested factors as crowding and chilling, however, established risk factors do not completely account for the worldwide incidence and mortality of this dangerous disease.

Starting with early (although negative) studies in Papua New Guinea in the 1970s, continuing with a few studies in the 1980s, and occurring at an increasing rate in the 1990s and this decade, several dozen studies have been published in the international biomedical literature linking household biomass smoke exposures with signs and symptoms of child respiratory infections and pneumonia. A review of such studies as part of the WHO comparative risk assessment found that children living in households that burned solid fuel seemed to have about twice the disease rate of those living in households with cleaner fuels (Smith et al, 2004). If studies of those carried on the mother's back during cooking are included, children in smoky conditions had about 2.3 times more risk. These calculations are the basis of the results in Figure 5.1, which estimated about 1 million premature ALRI deaths annually from biomass smoke exposures in the world, with an uncertainty of ±40 per cent.

All studies to date have been 'observational' in that they carefully observe existing populations with no attempt to conduct experiments under controlled conditions. Although easier and less expensive, observational studies are not fully able to distinguish associations from causal relationships. For the most hard-nosed funders, randomized control trials, the gold standard of epidemiology, are required to make the strongest case, as is expected for vaccine and nutrition supplement trials. Randomized trials are not possible with long-term effects, such as COPD, but can be done with relatively common acute effects, such as ALRI. They are expensive and lengthy, however, and must be conducted under strict ethical criteria.

The first randomized air pollution trial ever done with any normal population has just finished in Guatemala, and its findings for ALRI and woodsmoke are just emerging from analyses of the data (Smith et al, 2006). We found that the introduction of a well-operating chimney woodstove caused the greatest reduction in the most serious kinds of ALRI – those

of bacterial origin – which are most likely to lead to death and thus lost life-years. Reduction in serious pneumonia was about 40 per cent, with a reduction of about 50 per cent in the smoke exposures of babies. The earlier observational studies probably have overstated the total effect on ALRI, perhaps because of the difficulty of distinguishing upper and lower acute respiratory infections in resource-constrained field studies, and residual confounding (confusing the effect of poverty with that of the smoke). With an intervention of improved fuels or low-emissions combustion of wood, however, the benefit would perhaps be larger.

Suggestive evidence

Evidence is mounting of several other health effects from biomass smoke exposures (Bruce et al, 2000; Smith, 2000; Smith et al, 2004). Here there is only space to briefly summarize what is known.

Tuberculosis (TB)

One type of biomass smoke exposure, that from tobacco in active smokers, is a clear risk factor for TB around the world, probably because it suppresses the body's immune systems, thereby increasing the chances that one will acquire the infection from others and that current latent infections will blossom into active TB (Lin et al, 2007; Bates et al, 2007). Woodsmoke exposures in households are much lower, of course, but evidence is growing of a similar if smaller effect. Two older studies, one in India and one in Mexico (Perez-Padilla et al, 2001), have found such an effect and more are underway. Although not likely to be a major cause of TB in itself, pinning down the effect of biomass smoke on TB would be useful because additional approaches to this ancient scourge are urgently needed. Current control measures, which are based solely on drug therapy, are inadequate in many poor countries, and TB is one of the few infectious diseases in the world that is on the increase because of its strong link with HIV and the emergence of drug-resistant strains.

Eye disease

Tobacco smoke is a risk factor for both cataracts and macular degeneration, debilitating and progressive conditions that can lead to blindness. Cataracts in particular are a problem in developing regions such as South Asia, where one-third of all cataracts occur. Known risk factors (age, sunlight, smoking) do not fully account for its prevalence. Several studies in South Asia have found a strong relationship with biomass smoke exposures, and cataracts have been triggered in rabbits by woodsmoke in laboratory studies (e.g., Pokhrel et al, 2005). Additional studies of biomass smoke and both cataracts and macular degeneration are underway in South Asia.

Cancer

Although a number of chemicals in woodsmoke are known to cause cancer in humans, there has not been definitive epidemiologic evidence yet of the risk of woodsmoke itself. It has thus recently been classified as a *probable* human carcinogen by the International

Agency for Research on Cancer (Straif et al, 2006). This is distinct from household coal smoke, which is well established as a cause of lung and other cancers from dozens of studies in China (Zhang and Smith, 2007) and classified as a *known* human carcinogen by this prestigious international agency. Tobacco smoke as well has been established as a carcinogen, not only in active smokers but also in passive smokers, who are exposed to smoke levels much lower than those in biomass-burning households. The 'probable' classification can be interpreted as indicating that woodsmoke is a weak carcinogen, and thus its effects are difficult to detect in the small epidemiologic studies that have been done to date. Given the many carcinogenic compounds in woodsmoke, as shown in Box 5.1, however, it seems likely that better and larger human studies will pin this effect down more firmly.

Adverse pregnancy outcomes

A small number of studies have shown an effect on the birth outcomes of women exposed to biomass smoke during pregnancy. Increased rates of stillbirth and low birth-weight have both been reported (WHO, 2007). Low birth-weight is a particularly prevalent and important problem in developing countries because it not only increases the chance of infant and child disease and mortality, but also seems to have a lifetime negative impact on cognitive development and health. Although several chemicals in woodsmoke are candidates for such an effect, carbon monoxide is likely to be the chief culprit because it interferes with the oxygen supply to the foetus. Given the importance of this condition, more studies are needed to pin down the effect of biomass smoke, although such studies are not easy because of confounding with nutrition, which is the major cause of low birth-weight. (Because they are poorer, biomass-using women tend to be more malnourished than those using other fuels.)

Speculative evidence

Cardiovascular disease

The chief health effect usually identified in active and passive tobacco use, as well as in outdoor air pollution studies, is cardiovascular disease. The increase from exposure may not be as great as for some other diseases, but because the background rate of heart disease is so high, the resulting public health impact is also high. No studies of cardiovascular disease seem yet to have been done in developing-country biomass-using households. Recently, however, a well-designed study in Guatemala found a definite effect on blood pressure among women cooks (McCracken et al, 2007). Although not a disease itself, of course, high blood pressure is an indicator of increased heart disease risk in all populations where it has been studied. Direct studies of woodsmoke and cardiovascular health would seem to be well warranted.

Asthma

Evidence is growing that asthma, particularly in children, is associated with outdoor air pollution in developed countries. A few studies have been done in developing-country

biomass-using households, but they have not had sophisticated designs and the results are hard to interpret. Although asthma rates have increased in recent years to alarming levels in some developed countries, perhaps counter-intuitively, they are not thought to be high in most developing countries, despite some evidence of increases. The evidence overall is confusing and inconsistent, but many observers believe that asthma may actually be precipitated by clean environments (the 'hygiene hypothesis'), in that the immune systems of children in developed countries may now not be sufficiently challenged in early life to properly develop. Research in developing-country households could help throw light on this perplexing disease of worldwide interest.

BENEFITS OF WOODSMOKE

Paradoxically, household woodsmoke may provide benefits from pest control in some parts of the world. Most commonly mentioned are the continual fumigation of thatched roofing materials and mosquito repellence from smoke indoors. No studies of the former benefits seem to have been done, although of course such fumigation could be arranged at times when the house is empty and achieve the same benefit without high health-related exposures. The few studies of household biomass smoke's impact on mosquitoes indicate a drop in biting frequency, depending on biomass type burned (Paru et al, 1995). A recent detailed review supports the early finding (Snow et al, 1987) that there is no measurable impact on malaria prevalence of indoor smoke and that there is no net health benefit to maintaining smoke in malarial areas (Biran et al, 2007). Increased comfort from less biting would have to be weighed against the health impacts of the smoke and the need to find other, more effective ways of mosquito control (see Chapter 9, this volume).

WHAT CAN BE DONE?

Alleviating the health impacts of woodsmoke is not impossible. Although the ultimate cause of ill-health from woodsmoke is poverty, which prevents people from obtaining clean fuels and purchasing safe stoves, it does not necessarily follow that the best solution is poverty alleviation. The art and science of public health is finding ways of making people healthy before they are wealthy, through such 'magic bullets' as vaccines, targeted technologies such as clean water and sanitation, or women's education. Simple improvements in income, while eventually improving health, are usually extremely slow by comparison and much more expensive (inefficient) in achieving health goals. In addition, of course, economic goals will be more easily achieved with healthy and educated populations.

Four technological fixes are feasible:

1 improved ventilation of households and direct venting of stoves (chimneys);
2 improved stoves that reduce the production of pollution through better combustion of wood;

3 acceleration of the natural transition to clean fossil fuels, particularly liquefied petroleum gas (LPG); and
4 development of alternative gaseous and liquid fuels from biomass or coal that can be burned cleanly.

Efforts have been made in all four areas, but only the first and third in the list above have had significant sustained support by implementing agencies, and with only mixed success.

Improving general household ventilation by opening the eaves and related methods can somewhat reduce indoor pollution levels, but not nearly as much as the approaches above. There are also often limitations on the degree of change possible because of considerations of security, privacy and construction materials. Although it is generally true that the indoor air pollution problem is inversely related to income, however, the poorest populations often live in poor and open housing (and cook less), and thus may have somewhat lower exposures to the smoke than populations living in more substantial houses.

Perhaps the most successful effort was the National Improved Stove Programme in China, which introduced some 180 million improved stoves with chimneys over 15 years – probably one of the largest household-level development efforts in history (Sinton et al, 2004). The programme enjoyed good technical input, long-term (16 years) government support and a significant allocation of resources (although still less than a 15 per cent subsidy on average). Such characteristics have not been found in any other programme in the world.

Although focused on fuel efficiency, the Chinese programme nevertheless seems to have achieved a consistent reduction in smoke exposure in many households. Nevertheless, as has been found in smaller stove programmes, the reduction was not sufficient to bring exposure levels down to what would be considered healthy by WHO and national health-based standards (Edwards et al, 2007). The primary reason is that the stoves do not actually reduce emissions, but merely vent most of them immediately outdoors, where they can still expose people in the household environment.

Subsidizing LPG and kerosene for the poor has been a policy in many developing countries, although largely for political and equity reasons as well as a desire to reduce the impacts on natural ecosystems of fuel harvesting. Such direct subsidies, however, have generally been quite inefficient in achieving their stated goals, often operating in such a way that they do not adequately reach the poor, and at huge expense in some countries. India and Indonesia, for example, have spent more annually on such subsidies than they spend on all primary education (Smith et al, 2005). The programmes have thus become quite unpopular among development agencies and the international financial institutions.

Nevertheless, there would be significant benefits in finding smarter ways to promote these fuels among populations that are close to affording them on their own, particularly LPG, which is so clean, easy to use and efficient. The small degree to which cooking by the poor would add to the demand for petroleum by the rich, and thus exacerbate climate change and international energy supply problems, is minuscule compared with the potential benefits (Smith, 2002).

The global scale of the health impacts of woodsmoke is becoming better understood and accepted by scientists, governments and donor agencies, yet substantial scepticism about the cost-effectiveness of the available interventions remains, partly because of the mixed success of programmes to date. Several points can be made in response, however.

First, because it was done without foreign funding, technical input or coordination, the success of the Chinese stove programme is little known. China's experience can provide important lessons that could be adapted and applied today in many countries (Sinton et al, 2004).

Second, to date, the major programmes, either for improved stoves or for clean fuel promotion, have had not health as an objective, but rather control of deforestation, improved energy efficiency or fuel subsidy for the poor. Thus, it is probably not surprising that it has been hard to show health benefits for any of them.

Third, the total amount of money spent on designing, testing and implementing improved technology to reduce household smoke exposures is tiny by international comparisons: far less than the incremental cost of air pollution control on just one of the 100 coal-fired power plants being built in 2007, for example. It is not at all commensurate with the scale of the problem, which is probably greater in health terms than from all coal-fired plants put together. In addition, only sporadic and limited programmes have ever been attempted in the second and fourth technological areas noted above. Thus, perhaps it is not surprising that neither the technology nor the dissemination methods are well developed.

Finally, in common with other important environmental health interventions – for example, clean water and sanitation – the cost-effectiveness of clean fuels and stove technology is marginal for achieving health benefits alone, thus limiting the degree to which the health sector, with its many resource constraints and severe problems to address, is able to respond. Unlike vaccines and other highly targeted health interventions, however, in many populations improved household fuel technology has non-health benefits as well, including: time savings in fuel harvesting; lower pressure on natural ecosystems; improved kitchen safety, hygiene and ergonomics; the enhanced status of women; and even reduced greenhouse emissions (Smith, 1995; 2006).

The last point indicates that we need a way to evaluate and combine multiple benefits into a cogent overall package and find an agency or group of agencies willing to undertake the research and development for, and implementation of, needed interventions, even if they do not achieve any one objective in a highly effective manner but do quite well for the suite of benefits.

In the modern climate of evidence-based health and development programmes, we must verify the benefits of a stove programme or other widespread intervention designed to lower air pollution exposures and improve health. This is not an easy task for a programme that should involve millions of households spread across vast rural areas with poor infrastructure and communications. Progress is being made, however, in developing standard monitoring and evaluation methods that can be reliably applied in these settings (Smith et al, 2007).

CONCLUSION

With oil prices rising and fuel subsidies dropping in developing countries, it is likely that the health problems due to household smoke have actually increased recently; more households have been forced back down the 'energy ladder' to biomass fuels, such as wood. Even without these recent trends, analysis shows that the number of biomass households is expected to remain about constant, although their proportion of the world's population will slowly fall as population grows and simple economic growth moves more people up the energy ladder (Smith et al, 2004). Thus the scale of exposure will remain large.

Current estimates for child pneumonia, thought to be the largest health impact of household fuel use, will probably be revised downwards because of the latest research results, but new studies are being published monthly showing a range of other kinds of effects, the quantification of which will add to the health burden. Although by no means completely understood, the health impacts of such exposures are substantial.

Finding the most effective way to deal with this problem will require new technology, new social understanding and new organizational approaches, as well as clearer understanding of the multiple benefits that are possible. What is less clear is whether and how the international and local health and development communities will respond and apply the resources needed to address this ancient and significant source of human ill-health.

REFERENCES

Bates, M., Khalakdina, A., Pai, M., Chang, L., Lessa, F. and Smith, K.R. (2007) 'The risk of tuberculosis from exposure to tobacco smoke: A systematic review and meta-analysis', *Archives of Internal Medicine* 167: 335–342

Binswanger, H.C. and Smith, K.R. (2000) 'Paracelsus and Goethe: Founding fathers of environmental health', *Bulletin of the World Health Organization* 78(9): 1162–1164

Biran, A., Smith, L., Lines, J., Ensink, J. and Cameron, M. (2007) 'Smoke and malaria: Are interventions to reduce exposure to indoor air pollution likely to increase exposure to mosquitoes?', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 101: 1065–1071

Bruce, N., Perez-Padilla, R. and Albalak, R. (2000) 'Indoor air pollution in developing countries: A major environmental and public health challenge', *Bulletin of the World Health Organization* 78(9): 1078–1092

Cohen, A.J., Anderson, H.R., Ostro, B., Pandey, K.D., Krzyzanowski, M., Kuenzli, N., Gutschmidt, K., Pope, C.A., Romieu, I., Samet, J.M., Smith, K.R. (2004) 'Mortality impacts of urban air pollution', in M. Ezzati, A.D. Rodgers, A.D. Lopez and C.J.L. Murray (eds) *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors*, World Health Organization, Geneva, pp1353–1433

Edwards, R., Liu, Y., He, G., Yin, Z., Sinton, J., Peabody, J. and Smith, K.R. (2007) 'Household CO and PM measured as part of the review of China's National Improved Stove Program', *Indoor Air* 17(3): 189–203

Ezzati, M., Lopez, A.D., Rodgers, A., Vander Hoorn, S. and Murray, C.J.L. (2002) 'Selected major risk factors and global and regional burden of disease', *Lancet* 360(9343): 1347–1360

ISOC (International Scientific Oversight Committee) (2004) *Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review*, Special Report 15, Health Effects Institute, Boston, MA

Last, J. (1992) 'Epidemiological considerations', in K.R. Smith (ed) *Epidemiological, Social, and Technical Aspects of Indoor Air Pollution from Biomass Fuel*, World Health Organization, Geneva, Switzerland

Lin, H., Ezzati, M. and Murray, M. (2007) 'Tobacco smoke, indoor air pollution and tuberculosis: A systematic review and meta-analysis', *Plos Medicine* 7(4): 1–17

McCracken, J.P., Smith, K.R., Mittleman, M., Diaz, A. and Schwartz, J. (2007) 'Chimney stove intervention to reduce long-term air pollution exposure lowers blood pressure among Guatemalan women', *Environmental Health Perspectives* 115(7): 996–1001

Naeher, L.P., Brauer, M., Lipsett, M., Zelikoff, J.T., Simpson, C., Koenig, J.Q. and Smith, K.R. (2007) 'Woodsmoke health effects: A review', *Journal of Inhalation Toxicology* 19(1): 1–47

PAHO (2005) *An Assessment of Health Effects of Ambient Air Pollution in Latin America and the Caribbean*, Pan American Health Organization, Washington, DC

Paru, R., Hill, J., Lewis, D. and Alpers, M.P. (1995) 'Relative repellency of woodsmoke and topical applications of plant products against mosquitoes', *Papua New Guinea Medical Journal* 38(3): 215–221

Perez-Padilla, R., Perez-Guzman, C., Baez-Saldana, R. and Torres-Cruz, A. (2001) 'Cooking with biomass stoves and tuberculosis: A case control study', *International Journal of Tuberculosis and Lung Disease* 5(5): 441–447

Pokhrel, A.K., Smith, K.R., Khalakdina, A., Deuja, A. and Bates, M.N. (2005) 'Case-control study of indoor cooking smoke exposure and cataract in Nepal and India', *International Journal of Epidemiology* 34: 702–708

Samet, J.M. and Brauer, M. (2006) 'Particulate matter', in *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogren Dioxide, and Sulfur Dioxide: Background Materials for the Global Update 2005,* A.S. Committee, Regional Office for Europe of the World Health Organization, Copenhagen, Denmark, pp217–306

Sinton, J.E., Smith, K.R., Peabody, J.W., Liu, Y., Zhang, X., Edwards, R. and Gan, Q. (2004) 'An assessment of programs to promote improved household stoves in China', *Energy for Sustainable Development* 8(3): 33–52

Smith, K.R. (1987) *Biofuels, Air Pollution, and Health: A Global Review*, Plenum, New York, NY

Smith, K.R. (1995) 'Health, energy, and greenhouse-gas impacts of biomass combustion', *Energy for Sustainable Development* 1(4): 23–29

Smith, K.R. (2000) 'National burden of disease in India from indoor air pollution', *Proceedings of the National Academy of Sciences of the United States of America* 97(24): 13286–13293

Smith, K.R. (2002) 'In praise of petroleum?', *Science* 298(5600): 1847

Smith, K.R. (2006) 'Women's work: The kitchen kills more than the sword', in J.S. Jaquette and G. Summerfield (eds) *Women and Gender Equity in Development Theory and Practice,* Duke University Press, Durham, NC, pp202–215

Smith, K.R., Bruce, N. and Arana, B. (2006) 'RESPIRE: The Guatemala Randomized Trial', *Epidemiology* 17(6): S44–46

Smith, K.R., Dutta, K., Chengappa, C., Gusain, P.P.S., Masera, O., Berrueta, V., Edwards, E., Shields, K.N. and Bailis, R. (2007) 'Monitoring and evaluation of improved biomass cookstove programs for indoor air quality and stove performance: Conclusions from the Household Energy and Health Project', *Energy for Sustainable Development,* 15(2): 5–18

Smith, K.R., Mehta, S. and Maeusezahl-Feuz, M. (2004) 'Indoor smoke from household solid fuels', in M. Ezzati, A.D. Rodgers, A.D. Lopez and C.J.L. Murray (eds) *Comparative*

Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors, World Health Organization, Geneva, Switzerland, pp1435–1493

Smith, K.R., Rogers, J. and Cowlin, S.C. (2005) *Household Fuels and Ill-Health in Developing Countries: What Improvements can Be Brought by LP Gas?*, World LP Gas Association and Intermediate Technology, Paris, France

Smith, K.R., Zhang, J., Uma, R., Kishore, V.V.N., Joshi, V. and Khalil, M.A.K. (2000) 'Greenhouse implications of household fuels: An analysis for India', *Annual Review of Energy and Environment* 25: 741–763

Snow, R.W., Bradley, A.K., Hayes, R., Byass, P. and Greenwood, B.M. (1987) 'Does woodsmoke protect against malaria?', *Annals of Tropical Medicine and Parasitology* 81: 449–451

Straif, K., Baan, R., Grosse, Y., Secretan, B., El Ghissassi, F. and Cogliano, V. (2006) 'Carcinogenicity of household solid-fuel use and high-temperature frying', *Lancet-Oncology* 7: 977–978

WHO (2002) *World Health Report 2002: Reducing Risks, Promoting Healthy Life*, World Health Organization, Geneva, Switzerland

WHO (2004) *World Health Report 2004: Changing History*, World Health Organization, Geneva, Switzerland

WHO (2005) *WHO Air Quality Guidelines: Global Update for 2005*, Regional Office for Europe of the World Health Organization, Copenhagen, Denmark

WHO (2006a) *World Health Report 2006: Working Together for Health*, World Health Organization, Geneva, Switzerland

WHO (2006b) *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide: Background Materials for the Global Update 2005*, Regional Office for Europe of the World Health Organization, Copenhagen, Denmark

WHO (2007) *Indoor Air Pollution from Solid Fuels and Risk of Low Birth Weight and Stillbirth*, World Health Organization, Geneva, Switzerland

Wilkinson, P., Smith, K.R., Joffe, M. and Haines, A. (2007) 'A global perspective on energy: Health effects and injustices', Series on Energy and Health no. 1, *Lancet* 370: 5–18

Zhang, J. and Smith, K.R., (2007) 'Household air pollution from coal and biomass fuels in China: Measurements, health impacts, and interventions', *Environmental Health Perspectives*, 115(6): 848–855

Zhang, J., Smith, K.R., Ma, Y., Jiang, F., Qi, W., Liu, P., Khalil, M.A.K., Rasmussen, R.A. and Thornelow, S.A. (2000) 'Greenhouse gases and other airborne pollutants from household stoves in China: A database for emission factors', *Atmospheric Environment* 34(26): 4537–4549

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