2. Indoor air pollution (solid fuel use)

2.1 Introduction

Indoor sources of air pollution may be associated with a substantial burden of disease in childhood because they are likely to produce very high exposure levels (Ezzati & Kammen, 2001). Since children spend a great deal of their time indoors, they are likely to reach high levels of exposure even to pollutants at relatively low air concentrations, and exposure levels can be even higher under conditions of poor ventilation. On a global basis, solid fuel use (SFU) represents the largest source of indoor air pollution. Household combustion of coal or biomass for cooking and heating produces smoke that contains carbon monoxide, nitrogen oxides, sulphur oxides, benzene, formaldehyde, polyaromatic compounds, and suspended particulates (WHO, 1999).

Several diseases have been linked to the exposure to SFU, including acute lower respiratory infections (ALRI) in young children and asthma in school-aged children (Bruce et al., 2000; Ezzati & Kammen, 2001). The evidence for the association between indoor air pollution and ALRI in small children is strong: several studies suggest that indoor air pollution increases the risk, although there is variability in the relative risk estimates (Bruce, Perez-Padilla & Albalak, 2002). The evidence for the association between exposure to solid fuels and asthma is moderate (see Annex 2), with a number of studies finding no effect, and others suggesting that indoor air pollution may increase the risk (Bruce, Perez-Padilla & Albalak, 2002).

In this section, we provide estimates of the burden of selected diseases that is attributable to indoor smoke from household SFU, for children 0–14 years old.

2.2 Methods

We estimated the burden of disease for outcomes and age groups for which there is strong evidence of an association (Annex 2). For this reason, ALRI was the outcome analysed in the age group 0–4 years, whereas asthma was investigated in the age group 5–14 years. Asthma was not considered to be an outcome for children 0–4 years old because there are no reliable estimates of the association between exposure to SFU and disease for this age group. For the same reason, we did not calculate a burden of disease (ALRI and asthma) attributable to indoor air pollution for people 15–19 years of age.

We used estimates of child exposure to SFU reported by Smith, Mehta & Feuz (2003). Exposure to solid fuels in the population was estimated as the product of the proportion of households using solid fuels, and a ventilation factor that reflected both ventilation and stove characteristics. The exposure of children (0–14 years of age) to indoor smoke from solid fuels in the three European subregions is given in Table 2.1. See Annex 3 for a list of countries for which estimates of household SFU were available.
Table 2.1 Exposure of children (0–14 years old) to indoor smoke from solid fuels, European subregionsa

<table>
<thead>
<tr>
<th>Subregion</th>
<th>Household SFUb (%)</th>
<th>Ventilation factor</th>
<th>Adjusted prevalence of exposure (%)</th>
<th>95% CI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUR A</td>
<td>0.2</td>
<td>0.73</td>
<td>0.0</td>
<td>0.0–0.4</td>
</tr>
<tr>
<td>EUR B</td>
<td>41.5</td>
<td>0.51</td>
<td>20.5</td>
<td>16.2–24.5</td>
</tr>
<tr>
<td>EUR C</td>
<td>22.8</td>
<td>0.24</td>
<td>6.4</td>
<td>4.3–10.4</td>
</tr>
</tbody>
</table>

a Source: (Smith, Mehta & Feuz, 2003).
b Abbreviations: SFU = solid fuel use. CI = confidence interval.

The relative risk for the association between exposure to indoor smoke from SFU and ALRI in children 0–4 years of age was estimated to be 2.3 (95% CI: 1.9–2.7; Smith, Mehta & Feuz, 2003). For asthma in children 5–14 years of age, the approach for estimating the relative risks and confidence intervals was different because the association was moderate. In this case, the lower end of the relative risk was set at 1.0 (no effect) and the upper end at the geometric mean of the available relative risks from studies of households in developing countries. The central estimate was set at the geometric mean between the upper and lower ends of the nominal confidence interval. Using this approach, a relative risk of 1.6 (95% CI: 1.0–2.5) was estimated (Desai, Mehta & Smith, 2003).

The attributable fraction (AF) for the whole population was calculated as described in the Section 1, Outdoor air pollution, using the formula for only two exposure levels (Equation 1.3). The attributable burden (AB) was then calculated as:

\[
AB = AF \times \text{disease burden}
\]

The burdens for ALRI and asthma were obtained from Global Burden of Disease 2001 estimates (WHO, 2001). Uncertainty in the final burden of disease estimates attributable to indoor air pollution was expressed as the lower and upper estimates of the 95% CI values for the relative risks. For the outcomes included in the analysis, the width of the interval between lower and upper estimates expresses the uncertainty in the relative risk estimates, but not the exposure.

2.3 Results

2.3.1 The burden of ALRI for children 0–4 years of age (strong evidence, see Annex 2)

It has been estimated that, in 2001, 385 children 0–4 years of age died from ALRI in EUR A; 44 145 died in EUR B; and 7 234 died in EUR C (WHO, 2001). The morbidity burden of ALRI in the three subregions was estimated to be 14 630 DALYs, 1 527 799 DALYs and 251 724 DALYs, respectively. The corresponding burden of ALRI attributable to SFU is shown for the three EUR subregions in Tables 2.2–2.4. In EUR A, where virtually all households use cleaner cooking and heating systems, there was no attributable burden for ALRI due to indoor air pollution (Table
2.2). Proportionally, the greatest burden from ALRI attributable to household SFU was in EUR B (Table 2.3). In this subregion, over 9 000 deaths and 320 000 DALYs could be prevented every year if children were no longer exposed to indoor smoke from SFU. The burden of ALRI that is attributable to household SFU in the three EUR subregions is summarized in Table 2.5 for children 0–4 years of age.

2.3.2 The burden of asthma for children 5–14 years of age (moderate II evidence, see Annex 2)

It has been estimated that, in 2001, asthma caused 53 deaths and 191 656 DALYs among children 5–14 years of age in EUR A; 69 deaths and 92 795 DALYs in EUR B; and 27 deaths and 44 186 DALYs in EUR C (WHO, 2001). The corresponding burdens from asthma attributable to SFU are given in Tables 2.6–2.8. In EUR A, the burden of asthma attributable to SFU was zero (Table 2.6), while children in EUR B bore the heaviest burden (Table 2.7).

### Table 2.2
Acute lower respiratory infections in children 0–4 years of age attributable to household use of solid fuels, EUR A, year 2001

<table>
<thead>
<tr>
<th>Burden of disease attributable to SFU Central estimate (lower–upper)</th>
<th>% of total ALRI burden Central estimate (lower–upper)</th>
<th>ALRI per 10 000 children Central estimate (lower–upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths</td>
<td>0 (0–0)</td>
<td>0 (0–0)</td>
</tr>
<tr>
<td>DALYS</td>
<td>0 (0–0)</td>
<td>0 (0–0)</td>
</tr>
</tbody>
</table>

### Table 2.3
Acute lower respiratory infections in children 0–4 years of age attributable to household use of solid fuels, EUR B, year 2001

<table>
<thead>
<tr>
<th>Burden of disease attributable to SFU Central estimate (lower–upper)</th>
<th>% of total ALRI burden Central estimate (lower–upper)</th>
<th>ALRI per 10 000 children Central estimate (lower–upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths</td>
<td>9 289 (6 876–11 409)</td>
<td>21.0 (15.6–25.8)</td>
</tr>
<tr>
<td>DALYS</td>
<td>321 483 (237 973–394 837)</td>
<td>21.0 (15.6–25.8)</td>
</tr>
</tbody>
</table>

### Table 2.4
Acute lower respiratory infections in children 0–4 years of age attributable to household use of solid fuels, EUR C, year 2001

<table>
<thead>
<tr>
<th>Burden of disease attributable to SFU Central estimate (lower–upper)</th>
<th>% of total ALRI burden Central estimate (lower–upper)</th>
<th>ALRI per 10 000 children Central estimate (lower–upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths</td>
<td>556 (394–710)</td>
<td>7.7 (5.4–9.8)</td>
</tr>
<tr>
<td>DALYS</td>
<td>19 335 (13 710–24 700)</td>
<td>7.7 (5.4–9.8)</td>
</tr>
</tbody>
</table>
### Table 2.5
Summary of the burden of ALRI in children 0–4 years of age attributable to household solid fuel use in EUR, year 2001

<table>
<thead>
<tr>
<th>Subregion</th>
<th>Deaths</th>
<th>% of all-cause deaths</th>
<th>Deaths per 10 000 children</th>
<th>DALYs</th>
<th>% of all-cause DALYs</th>
<th>DALYs per 10 000 children</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUR A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>EUR B</td>
<td>9 289</td>
<td>6.6</td>
<td>5.2</td>
<td>321 483</td>
<td>5.0</td>
<td>178.9</td>
</tr>
<tr>
<td>EUR C</td>
<td>556</td>
<td>1.1</td>
<td>0.5</td>
<td>19 335</td>
<td>0.7</td>
<td>17.0</td>
</tr>
<tr>
<td>Total EUR</td>
<td>9 845</td>
<td>4.6</td>
<td>1.9</td>
<td>340 818</td>
<td>3.1</td>
<td>66.1</td>
</tr>
</tbody>
</table>

### Table 2.6
Asthma in children 5–14 years of age attributable to household use of solid fuels, EUR A, year 2001

<table>
<thead>
<tr>
<th>Burden of disease</th>
<th>% of total asthma burden</th>
<th>Asthma per 10 000 children</th>
</tr>
</thead>
<tbody>
<tr>
<td>attributable to SFU</td>
<td>Central estimate (lower-upper)</td>
<td>Central estimate (lower-upper)</td>
</tr>
<tr>
<td>Deaths</td>
<td>0 (0–0)</td>
<td>0 (0–0)</td>
</tr>
<tr>
<td>DALYs</td>
<td>0 (0–0)</td>
<td>0 (0–0)</td>
</tr>
</tbody>
</table>

### Table 2.7
Asthma in children 5–14 years of age attributable to household use of solid fuels, EUR B, year 2001

<table>
<thead>
<tr>
<th>Burden of disease</th>
<th>% of total asthma burden</th>
<th>Asthma per 10 000 children</th>
</tr>
</thead>
<tbody>
<tr>
<td>attributable to SFU</td>
<td>Central estimate (lower-upper)</td>
<td>Central estimate (lower-upper)</td>
</tr>
<tr>
<td>Deaths</td>
<td>8 (0–16)</td>
<td>11.5 (0–23.5)</td>
</tr>
<tr>
<td>DALYs</td>
<td>10 164 (0–21 824)</td>
<td>11.5 (0–23.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;0.1 (0–&lt;0.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.6 (0–5.7)</td>
</tr>
</tbody>
</table>

### Table 2.8
Asthma in children 5–14 years of age attributable to household use of solid fuels, EUR C, year 2001

<table>
<thead>
<tr>
<th>Burden of disease</th>
<th>% of total asthma burden</th>
<th>Asthma per 10 000 children</th>
</tr>
</thead>
<tbody>
<tr>
<td>attributable to SFU</td>
<td>Central estimate (lower-upper)</td>
<td>Central estimate (lower-upper)</td>
</tr>
<tr>
<td>Deaths</td>
<td>1 (0–2)</td>
<td>3.7 (0–8.8)</td>
</tr>
<tr>
<td>DALYs</td>
<td>1 634 (0–3 870)</td>
<td>3.7 (0–8.8)</td>
</tr>
</tbody>
</table>

### 2.4 Discussion

The results indicate that household SFU does not cause a substantial burden of ALRI among young children living in EUR A, where such fuel use, and hence exposure, is rare. In contrast, domestic combustion of solid fuels is still common in EUR B and EUR C (e.g. it is estimated that approximately two fifths of households in EUR B use solid fuels) (Smith, Mehta & Feuz, 2003). To some degree, the effects of SFU in these two subregions have been mitigated because a history of household SFU has led to the development of efficient techniques for lowering or eliminating indoor air quality.
Indoor air pollution emissions. Despite this, indoor air pollution from SFU causes significant ALRI mortality and morbidity among young children in these two subregions. In EUR B alone, it is estimated that almost 10,000 children 0–4 years of age died from ALRI attributable to household SFU in the year 2001. This is more than one fifth of all-cause deaths in the age group. Clearly, it would be greatly beneficial for the children if households in EUR B and EUR C countries could climb the “energy ladder” and shift from solid fuels to cleaner liquid or gaseous fuels.

The burden of disease estimates presented here are subject to some limitations, especially that concerning the assessment of exposure to indoor air pollution. To date, there are few studies assessing household use of solid fuels, therefore a statistical model had to be developed to predict national SFU from a number of country-specific development parameters (Smith, Mehta & Feuz, 2003). This points out the need to collect better data from national surveys, such as those proposed by WHO in the World Health Survey initiative (WHO, 2004). In addition, burden of disease analyses consider exposure to solid fuels to be a binary variable (exposed or not exposed). This is consistent with the epidemiological literature (Smith, Mehta & Feuz, 2003), but in reality many different levels of exposure to indoor air pollution may occur, depending on the type and quality of the fuel and stove, cooking and heating methods, activity patterns, and the season.

The present work does not consider indoor pollutants (e.g. environmental tobacco smoke) other than smoke generated by SFU. Considering the important effects of environmental tobacco smoke on perinatal and child health (Courage, 2002), the actual burden of disease attributable to indoor air pollution is probably greater than that estimated here. Other diseases believed to be associated with SFU are also not included in the burden of disease analysis because the evidence on causality is either indirect or insufficient. Perinatal conditions are probably the most important of such excluded effects.

Asthma is included as an outcome for children 5–14 years of age, although the evidence on the cause–effect relationship is only moderate. Therefore, the results regarding this outcome should be interpreted conservatively.

2.5 Conclusions

Children 0–4 years old in countries of the EUR B and EUR C subregions bear all of the burden of disease from ALRI that is attributable to indoor air pollution. Economic growth and modernization are the factors most likely to contribute to a reduction in the use of solid fuels in the home and lead to a significant improvement in the health of children.
3. Water, sanitation and hygiene

3.1 Introduction

One sixth of the world's population, approximately 1.1 billion people, do not have
access to safe water and 2.4 billion lack basic sanitation. Six thousand children die
every day from diarrhoeal diseases alone and a large proportion of diarrhoeal disease
in the developing world is due to poor water, sanitation and hygiene (UNICEF, 2003).
In Europe, the health effects of poor water, sanitation and hygiene have been
underemphasized because it is assumed that industrialized nations do not have
problems in this area. Indeed, it is estimated that over 90% of the population of
Europe is covered by an improved water supply (Duke et al., 1996; Hildebrand et al.,
1996; Merrick, Davidson & Fox, 1996). However, outbreaks of water-related disease
occur even in these areas, due to temporary breaks in microbiological water quality, or
to the use of intermittent, small water supplies (Duke et al., 1996; Hildebrand et al.,
1996; Merrick, Davidson & Fox, 1996). In many of the new countries of Europe,
such as those of the former Soviet Union, the water and sanitation infrastructure is
underdeveloped, or has been disrupted due to lack of maintenance during the last two
decades. The water, sanitation and hygiene situation may thus not be very different
from that found in the developing world. Therefore, a true estimate of the burden of
disease in these countries is warranted.

In this section, we estimate the burden of diarrhoeal disease in children in the
European subregions that is due to unsafe water, sanitation and hygiene. It is one of
the first such estimates to be based on a combination of exposure and evidence-based
risk assessment.

3.2 Methods

We estimated the burden of diarrhoeal disease in children due to poor water,
sanitation and hygiene, using two age groups: 0–4 years and 5–14 years. We used
United Nations year 2000 population estimates (2002 revision) in the calculations
(UNPD, 2002). The European Member States included in the analyses were classified
according to the WHO subregions, based on levels of child and adult mortality (see
Annex 1).

Exposure analysis formed the basis of our estimates for the burden of disease due to
water sanitation and hygiene. Exposure at the household or individual level was based
on an approach developed at WHO (Prüss et al., 2002). This “scenario based”
approach assumes typical exposure scenarios of a population, based on combinations
of risk factors and policy. Levels of faecal—oral pathogen loads in the environment
characterize the major differences between the scenarios (Prüss et al., 2002). For
example, of the six exposure scenarios, scenario I represents the ideal situation where
there is no transmission of diarrhoeal disease through poor water, sanitation and
hygiene. Successively higher levels represent an increasing risk of transmission of
diarrhoeal disease. A breakdown of these scenarios is found in Annex 4. The relative
risk of developing diarrhoeal disease for each of these scenarios was calculated using