Air Pollution and Human Health in Developing Countries

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Abstract

Indoor air pollutant levels in urban and rural areas of developing countries are much higher than ambient air pollutant levels in urban areas of developed and even of developing countries. Health effects due to indoor air pollution are, however, much less studied than in developed countries. Therefore, this paper summarizes the information available on indoor air pollutant levels in developing countries. The evidence on the health impacts is presented and discussed. Starting from ongoing work on the global disease burden from air pollution at the World Health Organization (WHO) estimates of particle pollution induced mortality and morbidity are reported.

Key words: indoor air, air pollution, human health

Introduction

Indoor spaces are important microenvironments when assessing risks from air pollution. For many air pollutants most of the daily exposure by inhalation occurs indoors because of the amount of time spent indoors or because of the pollutant concentration levels encountered. The air quality inside buildings is affected by many factors. In an effort to conserve energy, modern building design has favoured tighter structures with lower rates of ventilation. By contrast, in some areas of the world, natural ventilation only is used; in others, mechanical ventilation is common. In modern buildings most of the pollution problems arise from low ventilation rates and the presence of products and materials that emit a large variety of compounds, whereas the inhabitants of many less developed countries face problems related to pollutants generated by human activities, in particular by combustion processes.

Traditional fuels (wood, charcoal, agricultural residues, and animal excrements) are the dominant source of energy in the developing world. More than 2 billion people rely on them to meet the majority of their energy needs. It is estimated that traditional fuels account for about 20–35% of the total energy consumption in South America, Africa and South East Asia [1].

Based on recent publications [2], [3], [4], [5], [6], this paper summarizes indoor air pollution levels of particulate matter and the major health effects of exposure to these concentrations as observed in developing countries. It also briefly describes recent attempts to estimate the global burden of disease due to air pollution from suspended particulate matter [7], [8], [9], [10].

Levels of Indoor Air Pollution

The demand of the risk management efficiency requires the quantification of the exposure and its health impact. Studies have been and are being performed at WHO to estimate the global burden of disease and to assess the causes of this disease burden [11], [12]. These studies aim at providing a better understanding of the more important environmental factors that affect the health of the general population and of potentially vulnerable groups. The main issue is the identification of environmental causes of ill-health using the tools of risk assessment and to assess the global burden of diseases from air pollution.

While in developed countries the evaluation of the exposure and the assessment of its impact has been attempted (e.g. [13]) similar projects for developing countries have not yet been performed systematically. In urban areas of developing countries, human exposures to outdoor gaseous air pollutants often exceed WHO guideline values by factors of 5–10 [10]. Indoor air pollution in developing countries plays a much more important role due to the fact that ovens and braziers used for cooking and heating in households lead to much higher air pollutant concentrations indoors than those observed in urban areas of developed or developing countries [6]. The resulting
human exposures to carbon monoxide and nitrogen oxides often exceed WHO guideline values by factors of 10, 20, or even more [7]. For suspended particulate matter (PM), a similar statement can be made when PM concentrations are compared with WHO guideline values derived prior to 1987 [14], [15], since the new Guidelines for Air Quality [3] provide linear relationships between concentrations and health effects.

Table 1 summarizes the findings from indoor particle air pollution from biomass combustion in developing countries [3], [6]. As can be seen from this table concentrations for total particulate matter and inhalable particles can easily reach several thousands of micrograms per cubic meter, those for respirable particles several hundred micrograms per cubic meter. The table, however, very clearly shows the scarcity of data, the small number of households investigated, and the very different exposure conditions. Table 2 shows the results of outcomes from selected studies of concentrations in the individual breathing area of women and infants during cooking [6]. Concentrations reach several thousand micrograms per cubic meter.

### Health Effects of Indoor Air Pollution

The potential hazards of the major air pollutants (particulate matter, environmental tobacco smoke, nitrogen dioxide, carbon monoxide, volatile organic compounds, radon and others) in indoor environments of developed countries is well known. Epidemiology and toxicology has provided us with information on a multitude of chemicals and other substances producing adverse health effects. This research has allowed to identify the hazards and to propose the actions reducing the probability of population exposure to high indoor air pollutant concentrations and preventing the most obvious adverse health effects of the exposure.

In contrast, relatively few studies have been conducted to determine the health effects of indoor exposures to air pollutants in developing countries. Enough data has become available in recent years, however, to obtain some preliminary information on the type and very approximate magnitude of effects [16].

The following defines some major categories of effects where there is reasonable evidence from smoking studies, urban air studies, and multiple studies of

<table>
<thead>
<tr>
<th>Country</th>
<th>Year of publication</th>
<th>Description of sample (n=number of measurements)</th>
<th>Mean concentration [g/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>1992</td>
<td>n=11, 2-3 h, trad/impr</td>
<td>1100/90 (I)</td>
</tr>
<tr>
<td>China</td>
<td>1986, 1987</td>
<td>n=64, n=4, 8 h</td>
<td>2570, 10,900 (I)</td>
</tr>
<tr>
<td></td>
<td>1988</td>
<td>n=9, 2 houses, 12 h</td>
<td>2900</td>
</tr>
<tr>
<td></td>
<td>1988</td>
<td>n=12, 4 houses, dung</td>
<td>3000 (I)</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>15 houses, dung, winter/summer</td>
<td>1670/830 (I)</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>straw, avg summer-winter kitchen/living room/dung</td>
<td>1650/610/1570 (I)</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>1-story/2-story houses</td>
<td>80/170</td>
</tr>
<tr>
<td></td>
<td>1993</td>
<td>4 kitchens</td>
<td>1080 (I)</td>
</tr>
<tr>
<td></td>
<td>1993</td>
<td>n=36, 24 h, dry/wet season</td>
<td>2000/2100 (I)</td>
</tr>
<tr>
<td>Guatemala</td>
<td>1993</td>
<td>n=44, 24 h, trad/impr</td>
<td>1200/530 (I)</td>
</tr>
<tr>
<td></td>
<td>1996</td>
<td>n=18, 24 h, trad/impr</td>
<td>720/190 (I), 520/90 (R)</td>
</tr>
<tr>
<td></td>
<td>1996</td>
<td>n=43, 24 h, trad/impr</td>
<td>870/150 (R)</td>
</tr>
<tr>
<td>India</td>
<td>1982</td>
<td>n=64, 30 min, wood/dung/charcoal</td>
<td>15,800/18,300/5500</td>
</tr>
<tr>
<td></td>
<td>1988</td>
<td>n=390, cooking, 0.7m/ceiling</td>
<td>4000/21,000</td>
</tr>
<tr>
<td></td>
<td>1992</td>
<td>n=145, cooking/non-cooking/living</td>
<td>5600/820/630</td>
</tr>
<tr>
<td></td>
<td>1994</td>
<td>n=61, 24 h, ag-resid/wood</td>
<td>2800/2000 (I)</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>n=50, breakfast/lunch/dinner</td>
<td>850/1250/1460 (I)</td>
</tr>
<tr>
<td></td>
<td>1996</td>
<td>n=136, urban, cooking/sleeping</td>
<td>2860/880 (I)</td>
</tr>
<tr>
<td>Kenya</td>
<td>1971/2</td>
<td>n=8, overnight, highlands/lowlands</td>
<td>4000/800</td>
</tr>
<tr>
<td></td>
<td>1988</td>
<td>n=64, 24 h, thatched/iron roof</td>
<td>1300/1500 (R)</td>
</tr>
<tr>
<td>Mexico</td>
<td>1995</td>
<td>n=31, 9 h</td>
<td>335 (R)/439 (I)</td>
</tr>
<tr>
<td>Nepal</td>
<td>1986</td>
<td>n=17, 2 h</td>
<td>4400 (I)</td>
</tr>
<tr>
<td>South Africa</td>
<td>1993</td>
<td>n=20, 12 h, kitchen/bedroom</td>
<td>1720/1020</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>1990</td>
<td>n=40, 2 h</td>
<td>1300 (I)</td>
</tr>
</tbody>
</table>

(Woodfuel, rural, and TSP unless otherwise stated; I = inhalable (cutoff at approx. 10μm); R = respirable (cutoff at 5μm or smaller); Trad/impr = traditional open stove/improved stove with flue)
solid-fuel use in developing countries. Also listed, where known, are the apparent odds ratios comparing the risk of these diseases between people living in houses using unvented biomass fuel and similar households not using such fuels. All the odds ratios (OR) reported here are statistically significant results, mostly of multivariate analyses in which a number of potentially confounding variables were included:

### Acute respiratory infections in children
This is the chief cause of ill-health in the world and strongly associated with indoor use of solid fuels for cooking in a number of studies in Asia and Africa (OR = 2–6) (e.g. [17], [18], [19], [20]).

### Chronic obstructive pulmonary disease (COPD)
This has been shown to be strongly associated with use of solid fuels in non-smoking women often along with cor pulmonale in studies from Latin America, South Asia and Saudi Arabia (OR = 3.4–15) (e.g. [21], [22], [23], [24], [25]).

### Lung cancer
Lung cancer has been shown in many Chinese studies to be statistically associated with use of coal for cooking and heating, but not biomass fuels (OR = 3–9) [26], [27].

There is some evidence from studies of solid-fuel use in developing countries indicating a relationship between adverse pregnancy outcomes, the third most important category of ill-health in the world, and smoke exposure. After multivariate analyses, stillbirth has been associated with biomass fuel use by pregnant women in one Indian study (OR = 1.5) [28] and with low birth-weight in Guatemala [29]. After multivariate analyses, tuberculosis and blindness (cataracts) have been shown to be related to use of biomass fuels in two national and two local studies in India [30], [31], [32], [33]. Unfortunately all these studies relied on the type of stove or fuel as the indicator of pollution. More studies are needed that measure concentrations and exposures to indoor air pollutants so that exposure-response relationships can be more firmly determined.

### Global Estimates of Mortality and Morbidity Resulting from Indoor Air Pollution through Respirable Suspended Particulate Matter

The information necessary to estimate the health impact of a pollutant on a population includes the indoor air pollutant concentrations affecting a population, the number of people at risk i.e. the number of people exposed to levels at which excess mortality or and incidence and prevalence of morbidity can be expected, the time spent indoors, and the increase of mortality or morbidity with a unit increase of a certain pollutant. This information differs from the general knowledge that a substance is harmful; a quantitative estimation of the effects in the general population at certain exposure levels is necessary. Often, additional information on the presence of sensitive subjects in the target population may be needed to assess the magnitude of an impact. For very few indoor air pollutants all this data is available for a valid health impact assessment.

Based on the methodology used in the estimates of the global disease burden, [7], [12] one can attempt to estimate mortality and morbidity caused by the impact of air pollution. In this presentation excess mortality and respiratory morbidity from indoor air pollution in developed and developing countries is considered. Published data for indoor air pollutant concentrations are used for the indoor air concentrations in urban and rural areas in order to roughly estimate
excess mortality and prevalence/incidence of respiratory diseases caused by suspended particulate matter. Estimates are performed for different economic groupings according to different regions of the world. Eight economy categories were defined according to [34]: Latin America (AL), China, Established Market Economies (EME), Eastern Europe (EE), India, Sub-Saharan Africa, and South East Asia/Western Pacific (SEAWP). Concentration data of the Air Management Information System AMIS [35] and data collected by Smith [6] were used to estimate population exposure to indoor (and ambient) particulate matter pollution.

Using the exposure-response relationships available for the increase in respiratory morbidity and total mortality with unit increase in pollution levels by 10 μg/m³ of suspended particulate matter SPM (PM_{10}, particles of aerodynamic diameter less than 10 μm) as reported in the Guidelines for Air Quality [3], it is possible to estimate the incidence of respiratory diseases and the number of premature deaths due to exposure to SPM in indoor urban and rural envi-

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**Fig. 1.** Premature mortality due to ambient and indoor particulate matter (EME=established market economies; EE=Eastern Europe; SEAWP=South East Asia Western Pacific regions; AL=Latin America; SSA=Subsaharan Africa).

**Fig. 2.** Percentage of mortality due to various causes.
ronments for the different economy categories, following a model published by Schwela [7]. Fig. 1 shows the results of this estimation of the number of excess deaths due to SPM in urban ambient, urban indoor, and rural indoor areas. Fig. 2 shows a breakdown of mortality causes. From Fig. 1 it can be estimated that between 4 and 8% of the total mortality per year is due to air pollution (suspended particulate matter). From these very rough estimates most premature deaths from SPM are to be expected in urban indoor areas of India, Sub-Saharan Africa, and China followed by the South East Asia/Western Pacific region. A similar, only in details slightly different picture emerges for the incidence/prevalence of respiratory diseases. Fig. 3 gives percentage of respiratory diseases and shows that between 20 and 30 per cent of respiratory diseases may be due to suspended particulate matter.

Discussion

The comparison in Fig. 1 of the health impacts of outdoor and indoor air pollution strikingly shows that rural indoor air pollution in developing countries and countries in transition is a major contributor to premature death due to particulate matter exposure. This is particularly evident for India, Sub-Saharan Africa (SSA), China, and the South East Asian/Western Pacific (SEAWP) regions. The range estimates given here are conservative ones and are not necessarily to be considered the worst case. Indoor air pollution by suspended particulate matter in rural areas of developing countries, therefore, turns out to be a most serious problem with consequences for human health, which can hardly be overestimated.

Air pollution in general and indoor air pollution in particular have been associated in many people’s minds with industrialization and urbanization and thus with the cities in developed countries where most of the measurements of ambient and indoor air pollution have been made. Although most studies of indoor air quality have been carried out in developed-country buildings, the greatest indoor concentrations are found in both rural and urban households of developing countries. Therefore, the total human exposure to many pollutants is much more substantial in the homes of the poor in developing countries than in the outdoor air of cities in the developed as well developing world, because of the high concentrations, the large number of people exposed, and the time spent indoors. However, it is the outdoor problem that has received the most attention in the form of air pollution research and control efforts.

Conclusions

The main issue of the study on the global disease burden due to air pollution presently being performed by WHO is the identification of environmental causes of disease using the tools of risk assessment. WHO, in its World Health Report for 2002 plans to estimate more reliably the number of premature deaths and increase in the prevalence and incidence of diseases due to enhanced levels of suspended particulate matter and other pollutants in different regions of the world. Although these estimates are only educated guesses for reasons of insufficient data and the need to make many assumptions, they can be used to provide strong incentives for decision-makers to take necessary action.

These estimated health consequences are of such importance that, in the interests of equity and solidarity, they are considered worthy of the urgent attention of all UN Member States. Urgent action in reducing...
indoor air pollution in developing countries is required.

A better understanding and assessment of the problem of indoor air pollution in developing countries can be achieved by [36]:
- International agency assistance to sponsor and/or fund programs to inform policy makers;
- Regional expert meetings in developing countries, sponsored by international agencies, to create awareness;
- Cooperative programs to develop information turntables referring to remedial actions, taking local influential parameters into account;
- Case studies for assessing the magnitude of the problem quantitatively, in particular to provide information on the relation between sources of indoor air pollution and health effects; and
- Education programs in schools through regional networks at a local level, in both rural and urban areas.

The indoor air project of the World Bank in India [37] and WHO’s programme on Children’s Environmental Health [38], [39] can help to make these recommendations operational.

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