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Health benefits from reducing indoor air pollution from household solid fuel use in China — Three abatement scenarios

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Abstract

According to the World Health Organization (WHO), indoor air pollution (IAP) from the use of solid fuels in households in the developing world is responsible for more than 1.6 million premature deaths each year, whereof 0.42 million occur in China alone. We argue that the methodology applied by WHO – the so-called fuel-based approach – underestimates the health effects, and suggest an alternative method. Combining exposure–response functions and current mortality and morbidity rates, we estimate the burden of disease of IAP in China and the impacts of three abatement scenarios. Using linear exposure–response functions, we find that 3.5 [0.8–14.7 95% CI] million people die prematurely due to IAP in China each year. The central estimate constitutes 47% of all deaths in China. We find that modest changes in the use of cooking fuels in rural households might have a large health impact, reducing annual mortality by 0.63 [0.1–3. 2 95% CI] million. If the indoor air quality (IAQ) standard set by the Chinese government (150 μg PM_{10}/m^3) was met in all households, we estimate that 0.9 [0.2–4.8] million premature deaths would be avoided in urban areas and 2.8 [0.7–12.4] million in rural areas. However, in urban areas this would require improvements to the outdoor air quality in addition to a complete fuel switch to clean fuels in households. We estimate that a fuel switch in urban China could prevent 0.7 [0.2–4.8] million premature deaths. The methodology for exposure assessment applied here is probably more realistic than the fuel-based approach; however, the use of linear exposure–response relationships most likely tends to overestimate the effects. The discrepancies between our results and the WHO estimates is probably also explained by our use of "all-cause mortality" which includes important causes of death like cardiovascular diseases, conditions known to be closely associated with exposure to particulate pollution, whereas the WHO estimate is limited to respiratory diseases.

Keywords: Indoor air pollution; Rural; Urban; Exposure; China; Solid fuels; Health

1. Introduction

Indoor air pollution (IAP) from solid fuels (biomass and coal) is known to pose a major health risk, leading to such serious illnesses as acute lower respiratory infections (ALRI) in small children, and chronic obstructive pulmonary disease (COPD) in adults. There is also evidence that lung cancer is associated with household coal combustion (Zhao et al., 2006). Other conditions like asthma, adverse pregnancy outcomes, loss of eye sight and cardiovascular diseases may also be associated with indoor air pollution, adding to population morbidity and mortality (Smith et al., 2005). The World Health Organization (WHO) estimates that IAP is responsible for more than 1.6 million premature deaths each year in the developing world (WHO, 2002). In China alone, WHO estimates that about 420,000 die each year from the effects of IAP (Zhang and Smith, 2005).

These estimates, however, were made using a method known as the fuel-based approach. The fuel-based approach uses the prevalence of fuel as an exposure surrogate and odds ratios of diseases combined with disease specific mortality and morbidity rates. This approach tends to underestimate the total disease burden due to both exposure misclassification and to limiting the estimates to selected diseases and population groups such as

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children under five and adults — the most susceptible population groups. Smith and Mehta (2003) argue that with the current data availability the fuel-based approach is the most reliable.

An alternative method is the pollutant-based approach where exposure assessment and exposure–response functions are used in conjunction with current rates of mortality and morbidity. The main criticism of pollutant-based approaches in general is that they tend to overestimate the health impact. Generally, the exposure–response functions originate in urban studies of developed countries. These functions are developed for populations with quite different socio-economic characteristics, pollutant mix and exposure levels than what is found in developing countries. There are indications that the slope of the exposure–response function is reduced at high concentrations. However, we do not know the true form of these functions, and adjusting the slope at high exposure levels is arbitrary. In order to estimate the burden of disease using this method, a lower exposure limit has to be defined where the pollutant concentration is assumed to no longer pose a health threat. In the case of particulates, no limit concentration has been identified (WHO, 2005), and thus setting a limit becomes subjective. In addition, we know little about the actual exposure experienced for large population groups subject to IAP from solid fuel burning. In earlier attempts to use the pollutant-based approach, simple exposure assessment has been used. In WHO (1997), the distribution of time spent by the world population in the eight most important environmental settings is combined with the mean particulate level in those settings to estimate population exposure. This results in a crude exposure assessment for developed and developing country populations divided in rural and urban areas.

Our approach deviates from those applied in previous pollutant-based studies in several ways. We have earlier developed a Monte Carlo based method to estimate detailed exposure patterns for a large population based on indoor and outdoor air pollution and time activity tables (Mestl et al., 2007). Our approach divides the population in age, sex and whether people live in urban or rural settlements, and the pollution levels are estimated for several indoor and outdoor environments based on fuel use and geographic location. This approach makes large-scale exposure assessment possible revealing the finer patterns of exposure in the population. It also makes it possible to estimate exposure for people using 'clean fuels' such as gas and electricity, and to apply this as the lower limit, representing no exposure due to solid fuels. We argue that with the better exposure assessment this approach can be useful, at least for the Chinese population where several exposure–response studies have been conducted.

The question we address here is thus, what is the burden of disease in China if we use a pollutant-based approach instead of a fuel-based approach? Because this approach enables estimation of continuous risk reduction, it allows for a more detailed impact assessment of possible interventions than what would be possible from the fuel-based approach. We look at how IAP affects different population groups and argue that the burden of disease in China may be even more substantial than previous estimates indicate. We then consider what exposure reduction and subsequent health improvement can be expected as a result of some manageable interventions with respect to fuel-switching in Chinese households. We consider two different scenarios in this respect: clean fuels in all urban households and partial use of clean fuels in rural households. We also look at a scenario of meeting China's existing national indoor air quality (IAQ) standards, and ask whether these standards provide a useful goal, and if so, how they might be met. By looking at the exposure reduction from these scenarios in relation to the baseline mortality and morbidity, we estimate the potential health impact of the scenarios. Based on the findings we construct a fourth scenario to allow a more direct comparison with WHO estimates. The fourth scenario is a combination of the original three, and represents the 'impact of solid fuels' in China. We find that the WHO estimates may greatly underestimate the health risks associated with solid fuel use. We conclude that large health improvements can be achieved in China through manageable interventions in the households, and that through better exposure assessment the pollutant-based approach may be a useful supplement to the fuel-based approach in estimating burden of disease in developing countries.

2. Materials and methods

The method used in this study is described in detail in a previously published exposure assessment methodology paper (Mestl et al., 2007). Here, we use the method to estimate exposure reduction for the three different scenarios described below. More specifically, for each scenario, the reduction in population weighted exposure (ΔPWE) is combined with dose–response functions and disease specific incidence rates for China to estimate change in burden of disease for each of the scenarios compared to current exposure levels.

2.1. Estimating exposure reduction

The method described by Mestl et al. (2007) is based on published indoor air pollution (IAP) data and population time activity tables. The estimates are made using two-dimensional Monte Carlo simulations (2D-MC) to account for variability in large populations and uncertainties associated with the measured values.

In our study, a total of 45 publications on IAP reporting measurements in China of particulate levels in kitchens, bedrooms, living rooms and workplaces were selected. The measurements were classified according to fuel used in the study households, the time of year for measurement, and geographic location (urban/rural and province). Urban outdoor particulate levels were based on monitoring in 45 Chinese cities in 2002 (Sinton et al., 2004a). The rural outdoor particulate levels were estimated based on local emissions and background levels (Mestl et al., 2007).

The time activity patterns were based on two Chinese surveys, one from Chongqing (Wang et al., submitted of publication), and one from Hong Kong (Chau et al., 2002). The Chongqing survey includes both urban and rural populations. However, the survey was made in winter and did not include small children, an important group when estimating health impact. For the urban population we included small children by also using the Hong Kong study. For the rural population we had to turn to a study from Bangladesh (Dasgupta et al., 2004). There are, of course, cultural differences between China and Bangladesh, leading to different time use. However, the Chongqing and the Bangladesh time activity results show similar age and gender patterns. Where the patterns differed, we modified the Bangladesh study according to the Chongqing survey. For instance, the Bangladesh study lacks school attendance for children, and we therefore added the time that children attend school from the Chongqing study, and subtracted those hours partly from the time they spent indoors at home, and partly from the time spent outdoors in the Bangladesh survey. In the Bangladesh study we found that the time activity patterns for small children (both sexes) and for the elderly women were quite similar. The small children group (0–5 years) is missing in the Chongqing study, and we added a time activity for this age