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Urban and rural exposure to indoor air pollution from domestic biomass and coal burning across China

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Abstract

Although indoor air pollution (IAP) from solid fuel use in the households of the developing countries is estimated to be one of the main health risks worldwide, there is little knowledge of the actual exposure experienced by large populations. We have developed a method to estimate exposure to PM_{10} from IAP for large populations, applied to different demographic groups in China. On a national basis we find that 80%–90% of exposure in the rural population results from IAP. For the urban population the contribution is somewhat lower, about 50%–60%. Average exposure is estimated at 340 $\mu g/m^3$ (SD 55) in southern cities, and 440 $\mu g/m^3$ (SD 40) in northern cities. For the rural population we find average exposure to be 750 $\mu g/m^3$ (SD 100) and 680 $\mu g/m^3$ (SD 65) in the south and north respectively. Quite surprisingly our results indicate that the heavily polluted northern provinces, largely dependent on coal and believed to have the population with the largest exposure burden, turn out to have medium exposure when IAP is included. We find that the largest exposure burden is in counties relying heavily on biomass, and that there are only small gender differences in exposure.

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

1. Introduction

Indoor air pollution (IAP) from solid fuel use in developing countries is estimated by the World Health Organization (WHO, 2002a) to be the eighth leading health risk worldwide. Although there is general consensus that IAP is a major risk factor, there is very little knowledge of actual exposure experienced by the population subject to indoor air pollution.

The WHO estimates of disease burden from IAP are based on binary measures of exposure: exposed or not exposed. The WHO chose this approach because the bulk of epidemiological research looking at the impact of solid fuels on population health is given in that form, and because of the current paucity of reliable exposure data. While useful for providing a general overview of exposure, binary exposure estimates are not suitable for answering more complex questions, such as who is at risk, how large the exposure is, and how efficient interventions are. Answering questions of this complexity requires estimating more detailed exposure patterns.

In this paper we demonstrate a method for making detailed estimates of exposure for multiple demographic

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groups in a large population. The method is an extension of a formerly published exposure assessment for the Shanxi population in China (Mestl et al., 2006). The exposure estimates are Monte Carlo based and make use of previously published IAP data in conjunction with time activity patterns for different population groups, and demographic data for the population being studied.

We apply this method to investigate exposure patterns in the Chinese population.

The Chinese government is one of the first in the world to define a national health based indoor air quality (IAQ) standard for residences (Edwards et al., in press). The standard is set at 150 μg PM_{10}/m^3, a level which still represents substantial health risks. China has also undertaken several large-scale programs to promote improved household stoves, primarily improved efficiency in biomass stoves in response to a biomass shortage in the 1980s. A total of 786 counties took part in the first program, and most households in these counties had improved stoves installed, i.e. stoves with a chimney and grate. Coal-using households were not targeted in this effort, and some of the 'improved' coal stoves cannot be considered as improved at all because they lack a chimney. In a recent study assessing the effect of the programs, the indoor air did not meet the Chinese standard for IAQ, even after installing improved stoves (Sinton et al., 2004a; Edwards et al., in press). The exposure estimates presented here provide a far more detailed picture of who is at risk, where they live, the fuel they use, and the level of particulates to which they are exposed, and thus provide a basis for more precise targeting of intervention policies.

2. Materials and methods

The exposure assessment method described below makes use of published IAP data and time activity patterns. The exposure estimates are made for demographic groups based on age, sex, household fuel, and geographic location based on climate zone and urban or rural classification. The IAP data are grouped according to geographical location, and the time activity patterns are estimated for all demographic groups.

2.1. Population data for China

Comprehensive demographic data from the China census in 2000 is assembled by All China Marketing Research Co. Ltd. (ACMR, 2004). We use data for the population, disaggregated for age and sex, and the reported household cooking fuel. For the exposure modeling, we split the population into several groups. The classification is based on the assumption that different population groups are subject to different levels of exposure, as discussed below. The classification criteria are related to geographic location (north/south and urban/rural), age and sex, and the reported household cooking fuel.

2.1.1. North and south

China can be divided into five climate zones: (1) severe cold; (2) cold; (3) warm summer, cold winter; (4) hot summer, warm winter, and (5) warm (Ogawa et al., 2005). Traditionally, heating in winter was required by law in the two coldest zones with average temperatures in the coldest month around and below −10 °C. In zones 4 and 5, no heating in winter is required by law. These are all provinces south of the Yangze River. Zone 3 comprises the provinces surrounding the Yangze River. Here, heating may be necessary in many areas. We divide the population into north and south along the Yangze River, with a 'heating zone' in the north, and the 'non-heating zone' in the south. Thus zones 1 and 2, and parts of zone 3 fall into the 'heating zone'. The remaining part of zone 3, and zones 4 and 5 fall into the 'non-heating zone'. Some counties south of the Yangze River have a relatively cold climate in winter, but many people cannot afford heating, and we assume that heating in winter occurs predominantly in the north. We also assume that the stoves used within each of the two zones are of similar quality and technology. Most households use more than one stove, typically three to four, of varying design and quality. The assumption of similar technology across various stoves and regions within each zone is a very crude approximation with potentially large effects on the exposure estimates.

2.1.2. Urban and rural populations

China is divided into several administrative levels. Below the state level, there are 23 provinces, five autonomous regions, and four centrally administered municipalities (corresponding to province level). These entities are typically divided into prefectures, containing a core urban area surrounded by counties. The counties are either rural (which includes townships and villages), or so-called county level cities, which are administrative units with an urban centre and rural surrounding. The China Census 2000 (ACMR, 2004) includes data for 2871 counties and districts in mainland China. Of these, 793 are urban districts of prefecture level cities, and 26% of the Chinese population lives in these urban areas. There are 401 county level cities, home to 21% of the Chinese population, where the population is defined as partially urban and partially rural. Fifty-three percent of the