ABSTRACT

Household use of solid fuels such as biomass, charcoal and coal is now recognized as an important risk factor for disease burden in populations, especially in developing countries. Use of these fuels in open or un-vented stoves results in emissions of a range of toxic pollutants resulting from incomplete combustion. These emissions expose household members, in particular women and children to concentrations that are often several fold in excess of available health based guideline values. It is now estimated that indoor air pollution that results from the use of such solid fuels may be responsible for nearly 1.6 million excess deaths, about 3% of the global burden of disease annually, making it the second leading environmental risk factor after poor water quality and sanitation.

Much of this epidemiological evidence is however based on the increased risk of health effects observed in households using solid fuels relative to those that do not use these fuels. In India over the last two decades, although a few dozen studies concerning indoor air pollution levels/exposures associated with biomass combustion have been carried out, they have had small sample sizes and were not statistically representative of the population. Routinely collected information in national surveys often lack precision for estimating household-level exposures. The influence of multiple household level variables such as the type of fuel, type and location of kitchen and type of stove, on actual exposures is poorly understood. Further, compared to the north and west, relatively few studies have been carried out in southern India.

Based on this background, the present study was designed to monitor household pollution concentrations in a statistically representative rural sample in southern India and to record time/activity and other information at the household-level, in order to estimate the exposures of different household members. This study was designed as a cross sectional exposure assessment exercise that was carried out in 1162 rural households spread across 55 villages of 10 districts in three states of southern India. Short-term (2-4 hrs) and long-term (24 hour)
concentrations of respirable particulate matter (PM) were measured in all households (that included households using gas or other clean fuels). Concentrations of carbon monoxide and polycyclic aromatic hydrocarbons were measured in a small subset of households from this sample. Time activity recall collected from 1934 individuals in these households allowed the reconstruction of daily average exposures of household members to particulate matter, while in a subset of households peak personal exposure assessments were carried for the cooks during the cooking period by placing the filters at breathing zone. An exposure assessment questionnaire was collected at the end of a 24 hour monitoring period from the chief cook or head of the household to assess the contribution of multiple household level determinants for area concentrations and/or exposures. Taking advantage of an on-going market based program in the study area to distribute improved cook stoves that reduce fuel use by increasing combustion efficiency and heat transfer, measurements were conducted in subset of around 60 households that had access to improved stoves to assess reductions in area concentrations that were being achieved. All data were analyzed using ‘SPSS’ version 13.0 and ‘R’ version 2.5.1.

The 24 hour average PM concentrations in kitchen, living and near outdoor areas in these households ranged from 55 to 668 µg/m³, 50 to 413 µg/m³ and 80 to 113 µg/m³ respectively. The highest average concentrations were observed in households using dung, wood chips or miscellaneous agricultural produce (540 µg/m³), followed by households using wood (463 µg/m³), kerosene (130 µg/m³) and LPG (73 µg/m³) respectively. In addition to fuel type, kitchen configuration was also found to be an important determinant of concentrations in solid-fuel but not gas-using households. Kitchen area concentrations were significantly higher in enclosed kitchens as compared to outdoor kitchens. Among solid fuel users, both kitchen and living area concentrations were correlated with fuel quantity, while only living area concentrations were correlated with the number of rooms and windows. Neither kitchen nor living room concentrations were significantly correlated with kitchen volume, cooking duration, or the number of people being cooked for.
Concentrations were highest in Andhra Pradesh state (AM 500 µg/m³, GM 310 µg/m³), followed by Karnataka (AM 353 µg/m³, GM 217 µg/m³), and Tamil Nadu (AM 386 µg/m³, GM 206 µg/m³). The difference in PM concentrations are attributed to the types of fuel used, housing and ventilation characteristics of study households.

Mean 24-hour average exposure concentrations in solid fuel and gas using households ranged from 573 µg/m³ (GM= 402 µg/m³) to 79 µg/m³ (GM= 75 µg/m³). Among solid fuel users, mean 24-hour average exposure were highest for women cooks (442 µg/m³; GM= 318 µg/m³) and were significantly different from exposures for men (mean= 204 µg/m³; GM= 146 µg/m³) and children (mean= 291 µg/m³; GM= 170 µg/m³).

The average concentrations in households using improved stoves were significantly lower than levels recorded in the same households with traditional stoves. Levels for PM were nearly 60% lower (219 µg/m³ with improved stoves as compared to 549 µg/m³ with traditional stoves) and levels of CO were around 25% lower (5.4 ppm with improved stoves as compared to 7.45 ppm with traditional stoves). Although fuel saving enhanced by nearly 28%, improved stove use was not consistent on a daily basis. Reasons cited include inadequate design in relation to cooking demand and psychological adaptation.

The 24 hour average kitchen area concentration of sum of 17 polycyclic aromatic hydrocarbons in wood, crop residue, kerosene and LPG using households were found to be 8.49, 1.72, 1.51 and 0.95 µg/m³ with one LPG household measuring only 0.34 µg/m³. The 24 hours average kitchen area concentration of Benzo(a) pyrene (B[a]P) in wood, crop residue, kerosene and LPG using households were found to be in range between 8-22, 2-165, 3 and 3-7 ng/m³ respectively.

The study has provided measurements for 24-hour concentrations and exposure estimates for a wide cross-section of rural homes using a variety of
household fuels under a variety of exposure conditions. The study has been instrumental in providing standard operation procedures for large scale indoor air pollution assessment related to solid fuel combustion for use at either regional or national level. The strengths and weaknesses of range of monitoring equipments and procedures have also been documented which could be used to judge the relative appropriateness of the method based on resource availability.

Given that health benefits from interventions would take a much longer time (often several years) to establish, region-specific quantitative exposure information from this study could be useful for developing metrics to assess the potential of the available interventions for exposure reduction. Results of the quantitative assessment have, for example, provided additional evidence of the benefits of looking at interventions other than fuel switching. Ventilation and behavioral initiatives may offer a potential for substantial exposure reduction, and given that these are likely to be the short-term alternatives for a great majority of rural populations, the results could be used to aid the design of such efforts. Additional research needs for exposure assessment studies have also been identified from this study.

Health risks from indoor air pollution in rural household settings have complex inter-linkages, and a holistic understanding of these linkages is crucial for the design of strategies to minimize negative impacts especially for the most vulnerable sections of the population such as women and children. It is hoped that the information presented here represents a small but significant incremental step towards better understanding the issue of indoor air pollution exposure in homes of rural India, and that it has improved the evidence base for implementing and integrating environmental management initiatives in the household, energy, and health sectors.