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ORIGINAL RESEARCH

Household Air Pollution Exposures of Pregnant Women Receiving Advanced Combustion Cookstoves in India: Implications for Intervention

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Abstract

BACKGROUND Household air pollution (HAP) resulting from the use of solid cooking fuels is a leading contributor to the burden of disease in India. Advanced combustion cookstoves that reduce emissions from biomass fuels have been considered potential interventions to reduce this burden. Relatively little effort has been directed, however, to assessing the concentration and exposure changes associated with the introduction of such devices in households.

OBJECTIVES The aim of this study was to describe HAP exposure patterns in pregnant women receiving a forced-draft advanced combustion cookstove (Philips model HD 4012) in the SOMAARTH Demographic Development & Environmental Surveillance Site (DDESS) Palwal District, Haryana, India. The monitoring was performed as part of a feasibility study to inform a potential large-scale HAP intervention (Newborn Stove trial) directed at pregnant women and newborns.

METHODS This was a paired comparison exercise study with measurements of 24-hour personal exposures and kitchen area concentrations of carbon monoxide (CO) and particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$), before and after the cookstove intervention. Women (N = 65) were recruited from 4 villages of SOMAARTH DDESS. Measurements were performed between December 2011 and March 2013. Ambient measurements of $PM_{2.5}$ were also performed throughout the study period.

FINDINGS Measurements showed modest improvements in 24-hour average concentrations and exposures for $PM_{2.5}$ and CO (ranging from 16% to 57%) with the use of the new stoves. Only those for CO showed statistically significant reductions.

CONCLUSION Results from the present study did not support the widespread use of this type of stove in this population as a means to reliably provide health-relevant reductions in HAP exposures for pregnant women compared with open biomass cookstoves. The feasibility assessment identified multiple factors related to user requirements and scale of adoption within communities that affect the field efficacy of advanced combustion cookstoves as well as their potential performance in HAP intervention studies.

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INTRODUCTION

Household air pollution (HAP) resulting from the use of solid cooking fuels is a leading contributor to the burden of disease in India, accounting for about 1 million premature deaths and approximately 31 million disability-adjusted life years annually, approximately 6% of the national burden of disease.[1,2] Nearly 74% of India's population continues to rely on solid fuels (such as biomass, dung, and coal) for their everyday household energy needs[3], experiencing HAP exposures greatly in excess of the current World Health Organization air quality guideline (WHO-AQG) values.[4,5] Additional environmental effects from biomass fuel use include black carbon emissions,[6,7] unsustainable harvesting of fuelwood,[8] and regional air pollution.[9] The emissions, exposures, and disease burden estimates together argue for strenuous and targeted intervention efforts to address HAP in India.

The launch of the National Biomass Cookstove Initiative by the Ministry of New and Renewable Energy, Government of India represents an important step in this direction.[10,11] The initiative has catalyzed the availability of a newer generation of "advanced combustion" biomass cookstoves (ACS) that meet the more stringent cookstove emission standards developed in 2013 by the Bureau of Indian Standards. Results from laboratory emissions testing for the newer ACS have been reported and have shown reductions ranging from 50% to 90% in emissions of particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) and carbon monoxide (CO).[12-15] More recent studies also are beginning to provide an understanding of the determinants of community-level uptake and adoption of ACS.[16-18]

However, relatively little effort has been directed at assessing the concentration and exposure changes associated with the introduction of a new ACS. Results from field measurements in households using commercially available ACS models recently were reported from the states of Uttar Pradesh, Tamil Nadu, and Maharashtra.[19,20] Reported reductions in 24-hour kitchen concentrations of $PM_{2.5}$ and CO ranged from 2% to 71% and 10% to 66%, respectively compared with traditional cookstoves. Even with these reductions, however, resulting exposures and concentrations exceeded values recommended by the WHO-AQGs. Continued use of traditional stoves, infiltration of ambient air pollution, and perhaps other factors, appear to attenuate the reductions that are achieved by the ACSs within households, even when they perform as measured in the laboratory.

Laboratory testing of the Philips (Model HD 4012) forced-draft gasifier stoves consistently shows them to be among the best from an emissions standpoint.[21] User acceptance and sustained adoption, however, has been less consistent.[19,20,22-24] Additional field evaluations of the Philips stove, including personal and ambient monitoring are needed. Evidence from these evaluations could both improve the design of community-based intervention trials as well as inform the potential for intervention effectiveness in programs deploying ACS.

In this study, we describe the results of personal exposure and household and ambient monitoring after the dissemination of Philips ACS within the International Clinical Epidemiological Network (INCLEN) SOMAARTH Demographic Development & Environmental Surveillance Site (DDESS) located in Palwal, Haryana. These HAP monitoring results are part of a feasibility study to inform a potential large-scale HAP intervention (the NBS [National Newborn Stove] trial) directed at pregnant women and newborns. The details of the feasibility study and results from stove-use monitoring were published previously.[23,24] We also discuss the broader implications of study results for intervention effectiveness in the context of national and global initiatives to address HAP.

The study described here was jointly undertaken by teams from Sri Ramachandra University (SRU), Chennai, the INCLEN Trust International, University of California, Berkeley, and Columbia University.

METHODS

Study protocols were jointly developed by investigators from collaborating institutions and approved by