Impact of Improved Stoves on Indoor Air Quality in Ulaanbaatar, Mongolia

Results of Pilot Study and Recommendations for Full-Scale Investigation

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November 2005

Executive Summary

Ulaanbaatar, Mongolia, is the coldest capital city in the world, with average winter low temperatures of –20° Celsius. Many families there live in *gers*, traditional Mongolian dwellings consisting of a wooden frame beneath several layers of wool felt. In the *ger* districts of Ulaanbaatar, cooking and heating energy is provided through indoor coal combustion in metal stoves with chimneys, and in wintertime, such stoves may be in use both day and night. Over the last several years, new stove designs with improved fuel efficiencies have been introduced into many homes with the primary objectives of reducing coal consumption, urban air pollutant concentrations, and greenhouse gas emissions.

To test the potential impact of the improved stoves on indoor air quality, 24-hour monitoring of particulate matter (PM) and carbon monoxide (CO) was done in 65 Mongolian *gers* during a pilot study in January 2004. The primary analyses focused on 58 households, 20 with original (or traditional-type) stoves, 18 with the improved stove type TT-03, and 20 with the improved stove type G2-2000. In addition to indoor pollutant concentrations, information on other relevant factors was collected, which included home sizes, indoor and outdoor temperatures, age of stove in use, amount of fuel used and number of refuelings, position of monitors relative to chimneys, and number of cigarettes smoked in the home. Analysis of variance showed that these factors did not differ significantly by stove type except that traditional stoves tended to be older than improved stoves. Multivariate regression methods were used to test for statistically significantly different indoor PM and CO concentrations between homes with different stove types while controlling for selected characteristics.

In homes with all stove types, the average level of indoor concentrations of PM and CO exceeded Mongolian national standards for 24-hour concentrations, and in the case of PM, the excess concentration was large. The Mongolian national standard for 24-hour CO is 2.6 parts per million (ppm), and the average of 24-hour CO concentrations over all households was 9.5 ppm. The Mongolian national standard for 24-hour average total suspended particles is 150–200 micrograms per cubic meter ($\mu g/m^3$), and the average 24-hour observed PM concentration was 730 $\mu g/m^3$ over all households. The indoor pollutant levels also exceeded air quality guidelines set by the World Health Organization and standards set by the U.S. Environmental Protection Agency. For both PM and CO, the statistical power of the pilot study design was insufficient to detect significant decreases in homes with improved stoves for 24-hour average concentrations, 15-minute maximum concentrations, or 2-hour averages during the morning refueling period. However, there was a nonsignificant trend toward lower CO levels with improved stoves.

Although the number of refuelings during the day did not vary by stove type, coal consumption was significantly lower in households with G2-2000 and TT-03 stoves than in households with unimproved stoves, with an average of 5 kilograms per day lower consumption in homes with improved stoves. Amount of fuel use, in turn, was found to be positively correlated with PM and CO concentrations. For coal use and all measures of CO, these correlations were statistically significant. For wood use, only the correlation with CO during the two-hour morning refueling period was statistically significant. Calculations based on the fuel use findings suggest that improved stoves could decrease indoor 24-hour average CO concentrations by 11 percent. However, reductions of this size were not statistically verifiable, given the sample size of this study.

A follow-up crossover study is suggested, which would involve sampling CO and PM in 55 homes before and after installation of an improved stove. This type of paired sampling study increases the statistical power to detect differences with smaller sample sizes than are necessary for a stratified study, the study design used in the pilot study. In addition to 24-hour sampling before and after stove installation, simultaneous sampling of indoor and outdoor concentrations in the absence of indoor sources should be conducted to determine the influence of outdoor conditions on indoor pollution levels. Personal exposures should also be estimated by matching measured concentrations with participant-reported time-activity data. This information will help clarify where protective measures are likely to be most helpful in reducing exposure and improving health.

In Mongolia, respiratory diseases are the primary cause of morbidity and mortality among children and the fifth leading cause of death for the overall population. Given the high burden of respiratory disease in Mongolia, and the well-known connection between air quality and respiratory health, efforts to accurately determine dominant exposure routes and reduce air pollution levels should receive high priority.