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Indoor Air Pollution in Cold Climates: The Cases of Mongolia and China

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This note provides a snapshot of indoor air pollution (IAP) interventions in two cold climate environments. It illustrates the different methodologies used for each of the cases and presents a comparative analysis of results and lessons learned.

There are to date more than 3.5 billion people, mostly in developing countries, who still rely on coal and biomass—such as wood, dung, and crop residues—as their main source of energy for both cooking and heating. Traditional sources of energy burned in simple stoves with no proper ventilation can be extremely polluting and cause serious environmental health problems (Smith, 2006). Women and children are at greater risk because of household responsibilities and increased exposure indoors (Dasgupta et al., 2004).[1]

Despite documented health risks (Ezzati et al., 2002),[2] indoor air pollution continues to be a global challenge. Cold climate countries face additional burdens due to prolonged periods of burning fuels for heating purposes. Poor combustion can incur additional fuel expenses and cause an increase in refueling periods, a process that emits a high amount of emissions. Additionally, bed stoves – traditionally known as *kangs* in China – used in households in cold environments can add to the level of emissions indoors if poorly insulated.

In earlier studies, interventions looked at indoor air pollution (IAP) by measuring pollutants and stove efficiency. More recent work has shown the importance of approaching it from a combined multi-sectoral angle. This note illustrates interventions in two cold climate environments, Mongolia and China, and draws an analysis based on the two projects.

MONGOLIA

Ulaanbaatar, Mongolia, is the coldest capital in the world. Most of the families live in *gers*, traditional Mongolian dwellings consisting of wooden frames beneath several layers of wool felt and with no partition separating kitchen from living/sleeping areas. Heating and cooking is typically conducted by metal stoves with chimneys and for many homes bed stoves are also popular sources of heat. The most widely used fuel in the *ger* district is coal, although wood is also used for some tasks (ESMAP, 2005).

New stove designs to improve fuel efficiency and help mitigate emissions in Mongolia—one of the highest per capita emission rates in the world—have been installed in the past years. In January 2004, a field study followed up on a 1997 project where improved stoves were distributed to 40 families, reportedly saving families 34% coal and 15% fuel wood. Over the years, the number of stove installations has increased considerably to 2,740 improved stoves by the end of 2003.

The pilot study highlighted in this brief is a collaborative effort by the World Bank and the Environmental Health Sciences Division of University of California, Berkeley. The study measures IAP levels in *ger* households that use one of three different types of popular stoves to create an understanding of how and to what degree improved stoves affect indoor air quality and fuel efficiency in *gers*. The study specifically focuses on carbon monoxide (CO) and particulate matter (PM).

Methodology

Baseline data show that the 24-hour average CO and PM concentrations in all homes exceeded Mongolian national standards. In the case of CO, the national standard is 2.6 parts per million (ppm) and the average in households is 9.5 ppm. For 24-hour average total suspended particles (TSP), the national standard is 150-200 µg/m3 (micrograms per cubic meter of air)[3] and the average 24-hour observed PM concentration is 700 $\mu g/m^3$ over all households.[4] The United States Environmental Protection Agency maximum national ambient air quality standard for $PM_{2.5}$ is 35 $\mu g/m^3$.[5]

Independent household and environmental factors considered included *ger* volume, average indoor temperature, average ambient temperature, age of stove, distance between the stove and the monitors, and the number of cigarettes smoked in the household during the monitoring period. Coal and wood were provided to residents at no cost, and quantity for each household was measured and distributed equitably. Households were requested not to modify their behavior for the study.

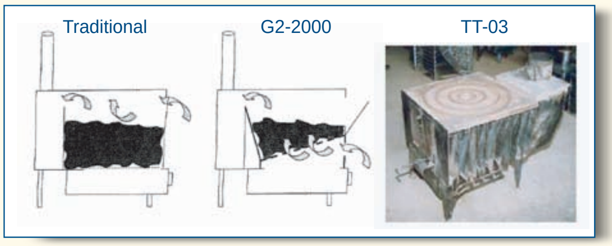
ESMAP promotes the role of energy in poverty reduction and economic growth with redistribution in an environmentally responsible manner.
Its work applies to low-income, emerging and transition economies and directly contributes to achieving the Millennium Development Goals.

[1] Indoor air pollution, caused from incomplete combustion, produces a complex of small and large particulates. Studies show that acute and chronic exposure to high levels of particulate matter, especially fine particulates (PM_{10}), is associated with respiratory illness and death.
[2] In the year 2000, nearly 3% of the total global burden of disease measured as Disability Adjusted Life Year (DALY) was attributable to IAP from solid fuel use.
[3] A microgram is a millionth of a gram. Microgram per cubic meter of air measures the weight of particulates suspended in the air.
[4] The monitor used to measure the particulate levels in this study captured particulate sizes corresponding roughly to $PM_{2.5}$.
[5] To attain this standard, the 3-year average of the 98th percentile of 24 concentrations must not exceed 35 $\mu g/m^3$.

Stove Characteristics

An important characteristic in Mongolian stoves, regardless of type, is the chimney. Although the design of improved stoves is different from the traditional version, both improved and traditional stoves have chimneys extending to the outside. As shown in Figure 1, the G2-2000 type has smaller combustion chambers than the traditional stoves and a grate and air inlet that together force air upward through the burning coal from underneath. The TT-03 is designed with metal flanges on each of the sides to improve heat radiation in the room, clay lining to hold heat and a chimney valve to help control the burn rate.

Figure 1: Traditional and Improved Stoves in Mongolia



Only *ger* households with stoves in use for six months or longer were considered, taking into account time needed for stove familiarity. Kitchen layouts in households were not disturbed and household members were not introduced to or trained in improved kitchen practices.

Results

Independent household characteristics and environmental factors considered did not vary significantly across households, regardless which stove types were used. The study did show that for improved stoves there was a reduction in CO levels, but results for PM data were mixed. Such results are likely due to significant levels of outdoor pollution, caused by chimneys from both traditional and improved stoves venting emissions.

Table 1: Reduction of Fuel Consumption

Areas Stove Type	Decrease of fuel consumption（%）
MONGOLIA[1]	
G2-2000 – Ulaanbaatar	
Wood Use	N/A
Coal Use	22%
TT-03 – Ulaanbaatar	
Wood Use	12%
Coal Use	21%
CHINA[2]	
Guizhou: Coal stove	30%
Gansu: Biomass stove	51%
Shaanxi: Coal underground stove	41%
Inner Mongolia: Biomass stove - bed device	N/A

[1] Data has been calculated from Table 3.2 (Cowlin, et al. 2005).
[2] Data has been calculated from Table 4.8 (Baris and Ezzati, 2006)

Gers using traditional stoves sampled in the study had a combined mean of 24-hour CO concentration of 11.6 ppm, while homes with improved stoves had a 24-hour mean value of 8.9 ppm for the TT-03 stoves and 7.9 ppm for G2-2000 stoves – a CO reduction of 23% and 32% respectively.

Stove Improvement Project Receives Blessing from Supreme Lama of Mongolia

Buddhist traditions run deep among the residents of the *ger* district. The popular belief concerning *golomt*—the hearth/fire spirit—received particular attention during preparation of the Stove Improvement Project.

The stove, traditionally constructed in the center of the *ger*, symbolizes the family's ties with ancestors. Desecration or disrespect of the stove space is a sin and insult to the master of the house.

The *golomt* dwells within the stove. It is the highest being in the household, bringing peace and good luck to those within the *ger* or house. The fire spirit is passed from parent to "best" child—at the parents' discretion—and a decision to alter the stove requires a consideration of the *golomt*. When a new stove is installed, a *lama* or priest takes ash from the old one to place in the new one and prays that the *golomt* will reside in the new stove and bring blessings on the family as before. Because a buyer would not know about the *golomt* of the previous owner, there is a limited market for second-hand stoves.

During project preparation stage, the project team designed a social marketing component sensitive to the the significance of the *golomt*. The project benefited from extensive consultation with the head of a Buddhist temple in Ulaanbaatar and the Supreme Lama of Mongolia. In traditional style, a fire offering ceremony took place to bless the Stove Improvement Project and initiate its launch.

One of the most important emerging benefits of using improved stoves is the reduction of coal consumption. Table 1 shows that coal consumption for the households studied decreases for improved stoves. This is significant considering the strong correlation between fuel usage and PM/CO. Despite the fact the PM results were mixed, the reduction in fuel consumption can ultimately lead to lower PM levels in the long run and improve indoor air quality.

The study shows that improved stoves and ventilated layouts reduce indoor pollution substantially; however, the impact of outdoor pollutants on indoor concentrations remains a question. Future work calls for more in depth research of ambient (or surrounding) conditions on indoor sources.

CHINA

More than 70% of households in China rely on solid fuels (biomass and coal) for domestic energy use. China is particularly interesting to study due to its wide topography, regional climactic variation, varied fuel use and availability, and its socio-cultural demography. IAP in China is the fifth most important health risk factor and an energy transition to cleaner fuels continues to be slow (Baris and Ezzati, 2006).

The World Bank in collaboration with the China Center for Disease Control and Prevention and the Foreign Loan Office at the Ministry of Health carried out one of the first community-based trials to assess the linkages between technology, user knowledge and behavior. The project built on a field study that started in 2002 in the four provinces of Gansu, Guizhou, Shaanxi, and Inner Mongolia to: (1) better determine the scope and severity of IAP in these areas; (2) pilot a combination of solutions from a multi-sectoral perspective; and (3) evaluate cultural, socio-economic and organizational feasibility of these solutions.

For the purpose of this note, we will focus on methodology, stove characteristics, and IAP results based on heating season exposure.

Methodology

The study took place during a 2-year period to monitor pollutants (PM and CO) in multiple locations and better understand the role of cooking, heating, and food drying exposure. In China, most households interchange biomass and coal in multi-purpose stoves for both cooking and heating (Yinlong et al. , 2005[a]).

Baseline data indicate that IAP is a serious issue in all four provinces. Carbon monoxide levels exceeded WHO guidelines of 10 ppm in Shaanxi and Gansu during the peak-heating season in December. On average, levels of PM exceeded the national standard by almost 100% in Inner Mongolia and by about 70% in Gansu, Shaanxi, and Guizhou. Levels of CO exceeded the national standard by almost 50% in Inner Mongolia, and by 45% and 33% in Shaanxi and Gansu, respectively (Baris and Ezzati, 2006).

During implementation of the intervention, sampled households were divided into 1) stove plus behavioral intervention, 2) behavioral intervention, and 3) control groups. For the stove plus behavioral intervention group, 2,500 households were provided new stoves with improved ventilation systems on a subsidized basis. In addition, some 200 households from the behavioral intervention group decided to install new stoves at full cost.

Also considered in the study were the housing characteristics of the study population. For example, in all provinces most houses have a kitchen separated from the living/sleeping area. In Gansu and Inner Mongolia, there is no separate bedroom whereas in the other two provinces there is a third room. Interestingly, in Guizhou, much of the cooking actually took place in the living room and in Inner Mongolia people tended to go between the use of kitchen and bedroom for cooking. On average, 75% of the kitchens across the provinces (some provinces were higher in number than others) had windows, but ventilation fans were not widespread, with less than 1% in Guizhou province.

In addition, pollutant levels from a small number of old and new stoves were measured under controlled stove use conditions equal to ideal stove use behavior. Technical experts were available on site to assist with the operation of new stoves.

Stove Characteristics

The technology intervention in China involved improvement of entire kitchen layouts and ventilation systems, which were then customized for the different provinces. The types of stoves selected and improved are described here:

In ***Guizhou***, residents primarily use **a coal or air circular stove**, which is made of steel or high cast iron and composed of the basement, stove body, stove core, fire holding setting and covers. Important features are upper and lower outlets and a connected chimney. The closing of the upper outlet determines the smoke/heat flow through chimney tract that increases utilization for heating, and the lower inlet controls the smoke/heat flows for cooking.

In ***Shaanxi***, **coal range and underground stoves** are popular. Local people typically use brick-made range and underground stoves, however many are designed improperly and have no or poorly made chimneys. Improved stoves add chimneys and an improved tract system for better heat/smoke flow. The heating in the underground stove is favorable and results are best when the floor is properly treated after construction with no less 2.5m^2 cement sealing. Ceramic tile is sometimes used around stove mouth for decoration.

Figure 2: Biomass range stove intervention in Gansu Province

In ***Gansu***, **coal/biomass two-fuel range stoves** are used (see picture). A growing number of locals are using coal because of the shortage in wood/crop residues due to forest protection policies. Typically the kitchens are separate, but without a door. The intervention includes improved chimneys and smoke tracts for heated beds.

In ***Inner Mongolia***, **biomass bed stoves** are popular. Typically, the cave-like houses consist of stove beds without any chimney or separation between the actual stove and bed. Ventilation occurs usually through a small window or door only. Improved stoves introduced a partition to separate the bed from the stove, and also include an exhaustion fan and chimney.

Results

This study demonstrates that multiple uses of energy, such as cooking, heating, and food drying, result in multiple routes of exposure to IAP, varying substantially from one province to the other (Yinlong et al., 2005[b]). It also demonstrates that heating is an important source of exposure to indoor air pollutants, especially in the northern China. Both Gansu and Inner Mongolia had the highest PM concentrations, reflecting the impact of colder temperatures and longer heating hours on pollutant levels indoors.

A Family Affair: The Significance of the *Kang* in Chinese Culture

The *kang* is a heating platform made of bricks or fired clay. The interior cavity channels exhaust from an attached stove through a flue (pipe) or smoke tract connecting the two structures together. With great capacity to retain heat if insulated correctly, the *kang* provides warmth during cold winter nights and can be very efficient in utilizing smoke emitted by the connected stove.

Typically used for sleeping, the *kang* is also a place for congregation and family gatherings, where stories are shared between generations. Improved *kangs* in the China IAP project have a partition wall separating the stove from the platform.

The full intervention group was characterized by larger reductions of PM and CO in all of the provinces, with mixed significance between the sites. This is due to variation in stove use and different housing characteristics. Pollutant concentration levels and composition greatly depend on whether a stove is used for cooking or heating, and is a significant consideration especially when designing interventions for cold climate countries.

Overall, measurements under household conditions reveal that the new stove/ventilation technologies had much higher efficiency and lower emissions than the old stoves. The measurements taken under the controlled conditions show an even more substantial reduction in concentrations of PM and CO (13-15%). This can be explained by the fact that those operating the stoves in controlled conditions were of a higher skill or expertise.

Similar to the Mongolia case, Table 1 shows that new stoves decreased fuel consumption significantly and even more so in the China case with a 30-50% reduction rate. This is more likely a result of the new stoves improved combustion and ventilation systems. This study found no IAP reduction benefits from health education and behavioral interventions alone, despite the relatively extensive program.

Conclusion

The Mongolia program tackled IAP by carrying out a targeted fuel efficiency intervention. A major benefit of the intervention is the reduction of fuel consumption. However, the study also reveals that an important source of IAP in the *ger* district is ambient outdoor air pollution—a likely reason for the high concentration of pollutants indoors despite the introduction of improved stoves.

Outdoor pollution was not analyzed in the China study, which focused on user behavior and health education in combination with technology. However, similar to the Mongolia case, an important emerging benefit is the reduction in fuel use. In addition, there were significant reductions in PM and CO with varied results across the different provinces. Interestingly, there is little evidence that the health education programs improved risk behavior of users.

Both studies demonstrate the complexity of addressing indoor air pollution. In Mongolia, a look at ambient pollution is necessary to better understand the results of indoor pollutants in the *gers.* In China, where the intervention encompassed a multi-sectoral approach, unexpected considerations continue to emerge, in particular the different ways that cooking and heating impact health and pollution in cold climate environments. Future studies are necessary to better address these important and increasingly relevant issues.

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