Air Quality Implications of Heating with Wood Stoves

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SUMMARY
This is an intermediate update for a continuing project on IAQ and climate impacts related to wood burning space heating stoves in a remote Alaskan village. At fifteen sites various data was collected relating to the flue gas composition, and indoor air quality. Following data collection, the stoves were replaced with modern EPA certified models, and the tests repeated to quantify improvements. This paper covers the baseline data collected with the original stoves in operation. The results show that occupants follow a variety of usage patterns but that clear trends exist within many homes. It also shows that some homes have indoor air concentrations that exceed published standards and guidelines for PM2.5 and CO.

PRACTICAL IMPLICATIONS
This research will help quantify the global impact of small distributed biomass combustion, and localized implications on indoor air quality. This will facilitate informed decisions and potential justifications on upgrades and alternatives.

KEYWORDS
Biomass Combustion, Wood Stove, PM2.5, Carbon Monoxide, Space Heating

1 INTRODUCTION
Small scale biomass combustion is a common practice in developing countries and remote areas. Timber, agricultural waste, and animal dung are frequently used as fuels for both cooking and space heating needs where availability and prohibitive costs make alternative fuel choices unpractical. There are numerous studies on cooking stove emissions around the world, however very little data exist related to heating stoves. As one component of an international EPA project, an investigation is currently underway to quantify the amount of particulate matter (PM2.5) and other contaminants that are being generated by wood burning heating stoves, and how much enters the living space where it can directly impact residents’ health. Following data collection, the stoves are being replaced with improved EPA-certified models, and data collection will be repeated to quantify improvements. This paper presents results from the baseline testing of existing heating stoves.

2 MATERIALS/METHODS
Fifteen homes in rural Alaska with wood burning stoves as the primary heating source were selected as field sites. A custom built instrument (Fumitron) which analyzes flue gas composition in real time for CO, CO2, PM2.5, temperature, and relative humidity was deployed at each site for a minimum of 6 hours, making sure to capture one complete fuel cycle. Concurrent with Fumitron testing, multiple IAQ sensors were deployed including a light scattering laser photometer aerosol monitor recording PM2.5 levels which sampled for 4 days, and passive data loggers monitoring indoor CO, temperature, relative humidity, and
stove usage patterns which sampled for 3 months. During, and for several days following the Fumitron testing, fuel consumption was monitored by weighing wood reserves at ~24 hour intervals. The various data were combined and analyzed for trends and correlations. The PM2.5 data from the aerosol monitor was adjusted using a correction factor calculated for each deployment from the mass of PM2.5 collected on the sampler’s gravimetric filter.

3 RESULTS
During the ~90-day period of indoor CO monitoring, the 1-hour OSHA permissible exposure limit of 35ppm was never exceeded, however the National Ambient Air Quality Standard of 9ppm over 8 hours was exceeded at 6 of the sites at an average of 2.4% of the time, and was above that level 6.1% of the time at the site with the highest average levels. During that same period, the average temperature in a house was 17.6°C above the outdoor temperature as reported by the nearest weather station. The coldest and warmest sites were maintained at an average of 12.6°C and 21.2°C above the outdoor temperatures. The average indoor dew point for the sites was 9.7°C, which was on average 7°C above the outdoor dew point.

During the ~4-day aerosol monitoring period, the 24-hour average PM2.5 concentration exceeded the EPA standard of 35 µg/m³ at 5 of 12 sites that had data available, and was above that level at those sites ~40% of the time; the site with the highest average concentration never dropped below that level. From the entire site sample, the instantaneous PM2.5 levels exceeded 35 µg/m³ an average of 11% of the time, and exceeded 90 µg/m³ nearly 4% of the time.

4 DISCUSSION
These heating stoves operate nearly continuously during the heating season, as opposed to the intermittent operation of the more extensively studied cooking stoves. The rare occasion that a stove goes unused usually corresponds with a period of house vacancy, but can be a result of low wood reserves, or when wood loading is unpractical; during these periods the indoor temperature either drops or is maintained by a secondary heating system, typically fueled by heating oil.

Several CO loggers showed evidence of drift during their deployment, and may have underestimated the severity of CO concentration at some sites.

The sites consumed on average 25 kilograms of wood per day, with the highest consumption site going through an average of 87 kg/day. Preliminary anecdotal reports from users of the upgraded stoves indicates that the wood consumption decreased by approximately half, resulting in decreased door opening events, which are events believed to escalate contaminant entry into the living space.

5 CONCLUSIONS
Although wood is an extremely practical fuel for heating in some applications, it is not without risks. An improperly installed or deteriorated stove can expose occupants to contaminants at levels in excess of safety standards.

ACKNOWLEDGEMENT
The authors would like to thank the Environmental Protection Agency for funding this project, and the Tlingit-Haida Regional Housing Authority for providing significant support on multiple aspects. Additional thanks to the homeowners who participated in the project.