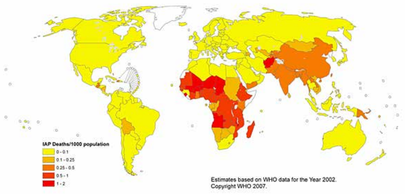
Innovations in Ventilation for Kitchens in the Developing World: An Interdisciplinary Study of Indoor Air Pollution

Dylan M. Friedgen-Veitch'16, Shane McDevitt'15, Amber E. Schrum'16, Maria Theresa Mejia[G], Kellyn M. McCarthy[G], Ilch Yiliqi[G]

Introduction

Three billion people use solid fuels, such as wood and coal, for domestic energy needs. Women often are in charge of household cooking in unventilated kitchen structures separate from the home. This exposes women and children to pollutants such as particulate matter and carbon monoxide, ultimately leading to health issues.

While many programs focus on bringing improved cook stoves to developing communities, there has been little research into improved ventilation. Unfortunately, the addition of cook stoves to a home is too expensive without subsidization, requires different cooking practices, and without improved ventilation actually is less efficient than originally used three stone fires. We ultimately wanted to find a ventilation modification for the typical Ugandan kitchen that was low technology, cost effective, practical and culturally sensitive. We did so with a team of environmental engineers, environmental policy researchers, and social scientists.



Methods

We researched stoves used in the area, potential ventilation modifications, and cultural norms to decide which testing parameters to use. We concluded to use a three stone fire and tried to replicate the conditions of the structure. We constructed an eight foot by six foot timber framed building with a corrugated steel roof. Using Ugandan construction techniques we filled in the walls with a cement-like mud mixture.

Our projected solution to the problem entails creating small vents in the wall near the base of the structure and on an adjacent wall near the roof. This is not culturally invasive and using the positioning of the vents to control air flow through the building. The benefit of multiple smaller holes instead of one window is that they can be screened with discarded materials, such as mosquito netting or screens with unripped portions.

Results

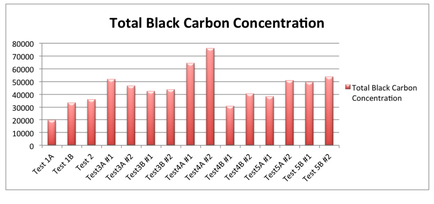
Air Monitoring

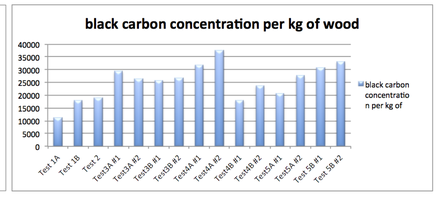
Quality of air in a small structure changes dramatically when there is an open fire. The highest amount of smoke and air pollution is found directly above the fire, although the whole volume of the strucutre is filled with lower concentrations. We positioned one monitor to take readings over the fire in order to simulate where a woman would stand to cook. The other air monitor was placed in the center of the room to record a more average reading for the structure.

The concentrations of indoor air pollution exceeded the limits the monitors used could accurately detect. With the vents open, we could visibly see smoke moving through and out of the structure, so with better equipment it is likely that we would collect data that the vents increase the quality of air. Smoke is produced variably throughout the cooking test; most noticeably as the fire is lit. Even without totally conclusive data, we can advise that people should not occupy the structure immediately after a fire is lit.

Monitoring results suggest:

- Total black carbon concentrations are lower in the middle of the structure than above the fire. Thus, standing two steps away from the stove while cooking will help reduce exposure.
- Higher wind speed reduces the black carbon concentrations when the door is open and all holes are closed.
- When the wood is more wet, the total black carbon concentration is higher, though the black carbon produced per kg of wood burned remains similar because more wood is burned in total during the test.
- Piled up ashes in the structure may cause higher total black carbon concentrations. Having half of the holes open which are closer to the fire with the door open may have higher black carbon concentrations than all holes closed due to turbulent air flow.
- Most effective configuration is top holes open with door open. This is more effective in reducing black carbon concentrations than all holes open.





Indoor Air Pollution and Socio-Economic Problems

Women's Empowerment

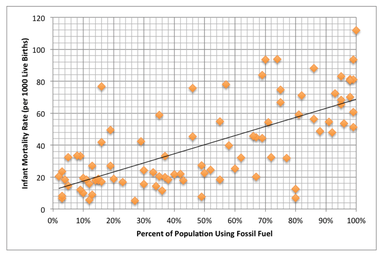
Since women are responsible for household duties, including gathering and managing fuels, they are more susceptible to indoor air pollution created by the burning of biofuels. We utilize a gendered approach in understanding the key predictors that lead populations to burn solid fuels. It is hypothesized that gender inequalities contribute to patterns in solid fuel burning. Increased socio-health standing of women may positively influence their energy use choices, and therefore, the indoor air pollution burden by reducing vulnerabilities for women and the children they care for.

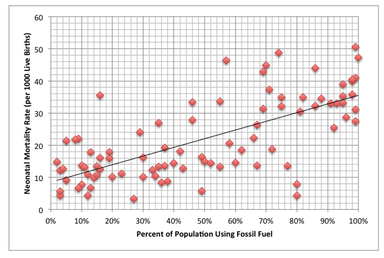
International Monetary Fund Structural Adjustment Policies

Our study strives to identify the key predictors that lead populations to burn solid fuels. Our analysis focuses on macro-level organizations, such as the International Monetary Fund (IMF), and the role they play in determining which countries burn wood and why the countries are forced to do so. Through analysis of data regarding solid fuel burning, specifically wood burning in less-developed nations, a relationship was found between countries where wood burning in rural areas is prevalent and the countries that receive structural adjustment loans from the IMF.

Through cross-national analyses involving 69 nations and multiple OLS regression models, we find that IMF structural adjustment policies have a significant impact on the decision to burn wood in rural areas in less-developed nations. This is supported since the IMF structural adjustment variable is statistically significant in every model of our analysis. By understanding the important and devastating effects that structural adjustment policies have on developing nations, and the ramifications for those who are least able to deal with these effects, we can better understand the circumstances at the root of solid fuel burning and indoor air pollution. We hope to raise awareness about the severity of indoor air pollution and connect macro-level agencies like the International Monetary Fund to indoor air pollution in order to address the true causes of wood burning, and the diseases and fatalities that result from it.

Neonatal and Infant Mortality





We conducted research on the indoor air pollution and Neonatal and Infant mortality rate and found a strong positive relationship while controlling for other socio-economic variables.

Future Work

Our results suggest that there is a need to redesign methods for natural ventilation in strucutres. We must determine the ideal location, number and size of holes in the walls of the strucutre and which walls require holes. Our data was restricted due to a large number of unpredictable and uncontrollable variables. In the future, an effort to isolate the multitude of variables must be taken into account. For example, more conclusive results may be obtained if tests were conducted during different weather patterns, with different wetness of wood, and different diameter of wood.

This procedure can easily be applied to different types of biofuels, such as crop residues and dung.

When the ideal modifications have been determined these improvements must be diffused within developing communities.

Acknowledgements

Special thanks to Dr. Kelly Austin and Dr. Breena Holland for their guidance and continued encouragement. We appreciate the generous funding from Mountaintop Experiential Grants for this project, George Yasko for his assistance throughout the project, and University Facilities.