Development and Implementation of Sustainable Air Ventilation Systems for Rural Nicaragua

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RESEARCH QUESTIONS

1. Is it possible to build, install, and maintain an air ventilation system in rural Nicaragua?
2. Will such a system be accepted by and utilized by participant households?
3. Will indoor air quality be improved after installation of the ventilation units?
4. Will the overall health of the families be improved due to improved air quality?

BACKGROUND

More than 3 billion people worldwide use indoor fires fueled by kerosene or biomass on a daily basis[1]. These fires are inefficient and emit high levels of household air pollution including carbon monoxide and particulate matter, sometimes in excess of 40 times the recommended exposure levels[2]. Exposure to smoke is particularly high in women and children due to traditional roles of fire preparation and child rearing. Exposure to harmful pollutants produced by wood fires has been linked with negative health impact ranging from respiratory problems to cardiovascular issues, headaches and more.

METHODS

Our goal was to implement a low-cost ventilation system in a small cohort of homes across rural Nicaragua with the goal of improving respiratory health outcomes in the subject population.

A solar air ventilation system was designed by the Texas Christian University Department of Engineering for $60/unit and installed in 17 homes in rural Nicaragua. Environmental air quality was assessed using a novel field measurement approach and wellness of participants was measured using a survey and physical examination of vitals and exhaled carbon monoxide (ECO). Upon early recognition of low use/compliance with the solar-powered system, a hood and chimney system was designed and installed. Data were obtained at baseline and 8+ months post-installation of the hood and chimney ventilation system. Qualitative health outcomes were measured using a 5-point Likert score (0=no symptoms, 5=constant symptoms).

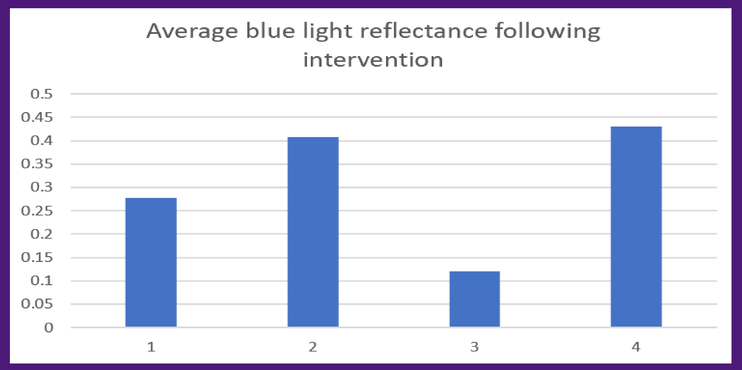
Low-cost hood ventilation systems achieve superior compliance vs. solar-powered systems and effectively reduce household air pollution while improving physical health and wellbeing when installed in rural communities in Central America.

KEY HEALTH RESULTS

	Mean Difference (8 months)	Significance
ECO	-4.03 ppm	p<0.001
Coughing	-0.8	p=0.001
Dry eyes, women	-0.9	p=0.030
Chest tightness, women	-0.8	p=0.02
Vision problems, men	-1.8	p=0.02
Headaches, men	-1.0	p=0.04
Fatigue, men	-1.0	p=0.04

Blood pressure, pulse oximetry, pulse, breathing difficulty, congestion were not significantly impacted by intervention. Chest tightness and dry, itchy eyes were not significantly impacted by intervention among males. Fatigue, vision problems, headache were not significantly impacted among women. Mean difference for qualitative health measures based on 5-point Likert scale. Negative mean difference (MD) correlates to improvement in symptoms.

ENVIRONMENTAL RESULTS



	T=0	T=1	T=2	T=3
Mean	0.278	0.408	0.120	0.431
Standard Deviation	0.189	0.151	0.081	0.062
Mean difference vs. baseline	N/A	0.131	-0.158	0.153
T Test	N/A	0.000	0.002	0.002

To approximate efficacy of the systems, filter paper was placed in households at 4 distinct time points and the reflectance of blue light spectrum was measured using the Albedo® application. Lower reflectance was correlated with higher levels of particulate matter accumulation.

T0=baseline
T1=Installation of solar
T2=4 months after installation of solar
T3=Installation of hood

RESULTS

It was possible to install an effective ventilation system at a cost of less than $60/unit. Hood and chimney systems were preferable to solar-powered systems due to low acceptance/compliance of the solar vent and desire of households to use solar power for purposes other than air filtration. Hood and chimney systems grossly improved household air quality as approximated by analysis of blue light reflectance on filter-paper samples gathered in subject households.

After a minimum of 8 months of hood use, ECO was significantly improved among both males and females (females P<0.001, males p<0.011).

Other health parameters were significantly improved including coughing among both males and females (MD -0.8, p<0.001). Among females (n=13), there was strong evidence for a reduction in chest tightness (p=0.021), and itchy, dry eyes (p=0.030). Among males (n=7), there was strong evidence for a reduction in vision problems (p=0.023), and moderate evidence for a reduction in headaches (p=0.043) and fatigue (p=0.043).

FUTURE DIRECTIONS

Our experiment represented a proof of concept among a small group of households over an 8 month timespan. There is an opportunity to continue to study health impact of the chimneys on a larger population and across a longer period of time. There is also an opportunity to correlate the field survey tool with quantified particulate matter levels. Additionally, there is an opportunity to continue to develop and investigate a sustainable business model to encourage long-term adoption of the ventilation systems with a focus on unpowered (vent-type) systems.

REFERENCES

1. Special Report: Energy Access Outlook, International Energy Agency, Published 2017. Accessed September 2021. WEO-2017. https://webstore.iea.org/weo-2017-special-report-energy-access-outlook

2. Balmes JR. Household air pollution from domestic combustion of solid fuels and health. *J Allergy Clin Immunol*. 2019;143(6):1979-1987. doi:10.1016/j.jaci.2019.04.016.

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