Hoonah Indian Association

Indoor Air Quality Study 2017
Particulate Matter 2.5 and Carbon Monoxide

Final Report

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Abstract

In the winter of 2017, Hoonah Indian Association undertook an indoor air quality study of particulate matter 2.5 (PM2.5) and carbon monoxide (CO). This study sought to quantify PM2.5 and CO in households, and to quantify or document underlying drivers of indoor air quality issues. Through the study we surveyed 65 homes, and a subset of those homes received a PM2.5 monitor and a CO monitor. Along with the survey homeowners were given a brochure on the intent of the study, and how they may improve their indoor air quality. Our results showed households with stoves greater than 20 years old had significantly higher emissions of PM2.5 than houses with stoves less than 20 years old. We also found a need for weatherization and ventilation upgrades.

Introduction

Indoor air quality is a concern of many Alaska Natives living in villages. There are a number of factors that contribute to Alaska Natives exposure to IAQ contaminants. Homes in Arctic environments are built with the goal of minimizing the amount of cold air inside the home. The tightness of construction does not allow for the exchange of fresh air, resulting in higher concentrations of IAQ contaminants. Long winter seasons result in more time spent indoors exposed to potentially poor IAQ. The sources of concern include cooking and heating appliances, stored chemicals, environmental tobacco smoke, allergens and sources of moisture.

Within the community of Hoonah, houses may use wood or diesel to heat their houses. Because many of the houses in Hoonah were built in the 1940s and stove upgrade rates are low due to the high cost and difficult logistics of getting a new stove (e.g., over water), many stoves may be out of date. Since wood is abundant and easy to harvest, it is used extensively as a primary heat source for many private residences in Hoonah. Although a convenient source of heat, burning wood releases particulate matter (PM) into the air and even short term exposure to PM 2.5 may have consequences to human health as it is can penetrate deep into the lungs. In their review article of research on the effects of wood smoke and PM2.5 on human health, Zelikoff et al. 2002 found evidence throughout the literature of the negative effects of wood smoke on human health. Of note, it may increase the need for asthma medication, lead to early mortality, decrease immune response, and lead to serious respiratory diseases.

The silent killer carbon monoxide (CO) is colorless odorless and tasteless; it accounts for hundreds of deaths and thousands of emergency room visits yearly nationwide. In and around the residence there are many producers of CO such as running a vehicle close to the home, wood stoves, and oil furnaces. Levels of CO can elevate to higher concentrations when chimney or ducting for the heat source becomes restricted or is assembled incorrectly; and the residence is not allowed to vent properly. The initial symptoms of low to moderate CO poisoning are similar to the flu (but without the fever). They include headache, fatigue, and shortness of breath, nausea, and dizziness. CO poisoning can be deadly and is preventable by keeping exhaust for heat sources clean and allowing the residence to vent properly.

Ventilation, whether it's naturally or mechanically, is a key component in improving in home air quality resulting in a healthier living environment. There are many sources of pollution in a residence such as wood stoves, oil stoves and even cooking to name a few. When a residence is not ventilated properly the pollution is allowed to build up in the residence resulting in poor in home air quality and unhealthy living conditions. Prolonged exposure to poor in home air quality can have serious health consequences including and not limited to cancer, heart disease, blood clots, and asthma. Allowing a residence to vent/ breath naturally or mechanically will lower the level of pollutants in the air and results in healthier cleaner in home air quality.

One component of indoor air quality is directly tied to the quality of wood being burned and is exacerbated in houses where wood is not dried to at least 20% moisture level. If this is the case, particulate matter 2.5 (PM2.5) levels may increase by 166% for every 10% of moisture in the wood (NESCAUM 2006). A comprehensive household assessment with an indoor air quality component would be well informed by the age and quantity of wood burned by a household each season.

A study of in home air quality has never been performed in Hoonah. Within our community, we know that many are using wood stoves and oil stoves as a primary source of heat and producers of PM 2.5, and CO in their homes. Many houses in Hoonah were built after the community burned in 1947. These older homes were not built for Alaska's climate, as the homes were built for tropical climates and are poorly equipped due to single pane windows, and no insulation under floors or in walls. The condition of these homes in Hoonah has caused people to adjust their homes by covering their windows and doorways as well as flooring. Some go as far as disabling ventilation systems and covering or plugging the vents to keep the heat in. Disabling the home's ventilation systems and covering the windows and door restricts the homes ability to vent the pollutants out and bring fresh air in.

Survey Methods

House Selection

The objective of the sampling design was to represent the population of buildings in the communities by sampling 75-100 homes in the community. We initially selected 100 houses randomly from the community by address. We also went door-to-door in order to meet our sampling size objective.

Oral Survey

We conducted our sampling via methods in an approved Quality Assurance Project Proposal (QAPP) to collect data focusing on CO, PM 2.5, and their correlates. We also asked questions adopted from the ANTHC "Healthy Home" survey. A full list of the questions asked during the survey are located in Appendix A of this document.

To conduct the survey we made an appointment with the owner, resident, or responsible person in advance, allowing sufficient time for the assessment. On the day of the survey, we obtained the written permission of the homeowner to conduct the assessment and only conducted the indoor air quality survey with assistance from the responsible resident. At each location we recorded the address, outdoor conditions and weather information. We also recorded the outdoor ambient air quality parameters (temperature, current weather). Each record was logged on the field data sheets as they were conducted.

Measurements With in Households

We collected four different numeric variables at each household that are known to be related to CO and PM2.5. For each measurement, the data was collected with an instrument that we went through thoroughly with quality control steps as described in the QAPP. We measured carbon monoxide using a Lascar EL-USB-CO monitor with a detection range from 0-1000 parts per million (PPM) (Table 1). We measured air temperature using a glass thermometer. We measured particulate matter 2.5 (PM2.5) using a DustTrak 8530 and DustTrak 8533. We selected two rooms within the building for sampling locations, with the objective to take measurements where people spend most of their time. We also ensured that one room contained the primary heating source for the house and the other room was a common living space such as a bedroom. The equipment was brought indoors and given at least five minutes to adjust to indoor conditions. We standardized the sampling of these instruments by placing them at least two feet from any wall, door, or window, and two to four feet from the floor. We also ensured they were at least 2 feet from a wood stove. We logged where each sensor was placed, and the exact date and time the sensors were placed. We deployed the PM 2.5 and CO monitors for 24 hours and collected data at 15 minute intervals resulting in 96 data points per room.

We sought to quantify the percent moisture of wood from storage areas, and also from logs to be burned in the near future to gain insight into how wood moisture content may attribute to PM2.5. We collected the percent moisture of wood using a Dr. Meter MD918. We sampled the percent moisture of ten logs from a stacked woodpile by selecting a log from the top row and four logs directly below the first one in the lower rows. We repeated this in a second location in the wood pile. If the wood was not stacked, we selected five logs from the outside of the pile and five logs that are covered by at least one other log resulting in 10 sampled logs.

Table 1: Summary of instrumentation and protocols used to sample PM2.5, CO, air temperature, and wood moisture during indoor air quality surveys.

Parameter	**Instrument Type**	**Instrument Manufacturer**	**Instrument Model**	**Location**
Carbon monoxide (ppm)	Standalone Data Logger	Lascar	EL-USB-CO	At least two feet from any wall, door, or window. Between two and four feet above the floor, and at least 2 feet from a wood stove.
Air temperature (° Celsius)	Glass Thermometer		Alcohol-based thermometer	At least two feet from any wall, door, or window. Between two and four feet above the floor, and at least 2 feet from a wood stove.
$PM_{2.5}$	Light-scattering laser photometer	TSI Inc.	DustTrak 8530 & DustTrak 8533	At least two feet from any wall, door, or window. Between two and four feet above the floor, and at least 2 feet from a wood stove.
% moisture (wood)	Inductive Pinless/ Electromagnetic Waves	Dr. Meter	MD918	Hold against the surface of the wood sample.

Dataset Preparation

All data were entered into a database and analyzed in Microsoft Excel. We followed strict quality control measures as described in the QAPP to ensure that all data were entered correctly. The entered data passed our inspections after reviewing 20% of the records. To ensure that all of the CO data were collected within the household, we truncated the dataset to all records recorded 15 minutes after deployment and 15 minutes before retrieval.

Data Analysis

General Questions

We grouped data that would help characterize the house. For each yes and no question we summarized the percentage of respondents that stated yes and no. For numeric responses related to the house we summarized the average, minimum, and maximum. We did not report a standard deviation as the data were not normally distributed.

Ventilation and Air Flow

We grouped data that would help characterize ventilation in the house. For each yes and no question we summarized the percentage of respondents that stated yes and no. For numeric responses related to the house we summarized the average, minimum, and maximum. We did not report a standard deviation as the data were not normally distributed.

Heating Sources

We grouped data that would help characterize the heating source in the house. For each yes and no question we summarized the percentage of respondents that stated yes and no. For numeric responses related to the house we summarized the average, minimum, and maximum. We did not report a standard deviation as the data were not normally distributed.

Storage

We grouped data that would help characterize storage of wood in the household and chemical storage. For each yes and no question we summarized the percentage of respondents that stated yes and no. For numeric responses related to the house we summarized the average, minimum, and maximum. We did not report a standard deviation as the data were not normally distributed. We compared the mean moisture of wood stored outside for houses that had a wood shed to those that did not using a Welch's T-test.

PM2.5

We summarized the data in three hour intervals starting at midnight to examine whether PM levels were different during periods of the day. For each time period we reported the average, standard deviation, and maximum.

We also sought to determine the drivers in PM2.5 levels within the house. We used a t-test in the R-Project to determine if there was a significant difference between two groups. For all comparisons, we log-transformed the 24hr mean readings from each household that had a detector (n = 36) and from individual detectors (n = 69) to normalize the data. For each individual household we determined if the house used a wood stove, the average moisture of the next three logs to be burned, if the age of the stove was less than or greater than 20 years, how often the chimney was cleaned, and if the owner closes their windows. For each detector we determined if the detector was in a living space (i.e. a room without a heating source), if the room had wood stove, or if the room had an oil burner. To further group the data we classified the room as simply a room with a wood stove or a room without a wood stove. We ran a t-test to determine if there was a difference in log-transformed mean PM2.5 levels in houses that had a wood stove and those that did not. We ran a t-test to determine if there was a significant difference in log transformed PM2.5 levels between rooms with a wood stove and rooms without a wood stove. We ran a t-test to determine if there was a significant difference between houses with stoves less than 20 years old and stoves greater than that age. We used a linear regression to determine if there was a significant relationship between percentage wood moisture and the PM2.5 levels in rooms with the wood stove. We used a linear regression to determine if there was a significant relationship between the amount of time since the chimney had been cleaned and the PM2.5 levels in the room with the wood stove.

Carbon Monoxide

We summarized the data using the average and maximum at 3 hour intervals throughout the day for the entire dataset.

Results

We broke the results of the survey down into natural groupings. For each numeric value we reported the minimum, average, and maximum value. Sampled houses (n=65) were evenly distributed around Hoonah (Figure 1).

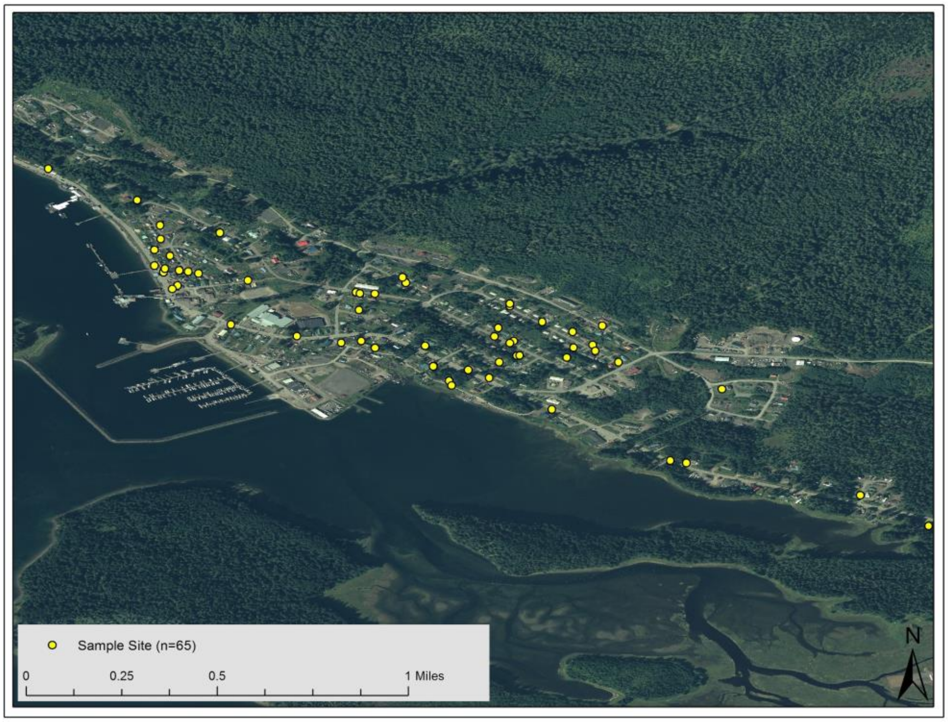

Figure 1 : IAQ survey sites throughout the community of Hoonah.

Homeowner and House Information

We characterized the households surveyed to help us place other results of the study in context of the household size and how long members had lived there, as well as ensure that we sampled across housing types. The amount of time that homeowners have lived in their residence had very high variance from 5-876 months. House age also ranged widely from 18-1044 months. Houses were between 1-3 floors, 2-12 rooms, and 650-3400 square feet. This suggests that most floors are about 1000 square feet.

Table 2: Summary of in-home characteristics. The units for each minimum, average, and maximum are inferred by the question asked.

General Questions	**Results**		
	Minimum	**Average**	**Maximum**
How many months have you lived there?	5.00	221.80	876.00
How many months old is the house?	18.00	448.94	1044.00
How many floors is your house?	1.0	1.40	3.0
How many rooms in your house?	2.00	5.40	12.00
How many square feet is your house?	650.00	1387.89	3400.00
How many residents live in the house year round?	1.00	2.80	9.0

General Questions	**Results**	
	% Yes	**% No**
Do you have any pets that stay indoors?	57	43
Have you seen mold in your house?	51	49

Ventilation and Air Flow

Table 3: Summary of IAQ questions related to ventilation. The table is broken into percent yes and percent no as well as the summary statistic if the result is numeric. For numeric responses we report the average, minimum, and maximum to look at the variation, as not all data were normally distributed and hence a standard deviation could not be calculated

Ventilation Questions	**Results**	
	% Yes	**% No**
Do you have a range vent?	80	20
Does range vent outside?	65	35
Do you have roof vents?	68	32
Do the windows leak?	55	45
Are windows covered?	37	63
Do you have window screens?	80	20
Are the outside doors covered?	23	77
Do the outside doors leak?	78	22
Do the outside doors latch?	83	17
Do you have a bathroom fan?	85	15
Does the bathroom fan function?	88	12

Ventilation Questions	**Results**		
	Minimum	**Average**	**Maximum**
How often do you clean range vent?(Month)	0.00	17.63	180.00
How many roof vents do you have?	0.00	2.00	8.00
How many windows do you have?	5.00	11.22	40.00
How many panes are the windows?	1.00	1.84	2.00

How many outside doors does the house have?	1.0	2.29	6..0
How many inside doors does the house have?	0.0	5.03	9.0
When was the bathroom fan last cleaned? (Month)	0.18	19.16	96.00

Heating Sources

Oil heating (86% of respondents) and wood heating (48% of respondents) were the primary sources of heating in the community. On average stoves were 13.25 years old, but 50% of respondents reporting having a stove that is greater than 20 years old.

Table 4: Summary of general heating questions. The table is broken into percent yes and percent no as well as the summary statistic if the result is numeric. For numeric responses we report the average, minimum, and maximum to look at the variation, as not all data were normally distributed and hence a standard deviation could not be calculated

Heat questions	**Results**		
	Minimum	**Average**	**Maximum**
How many months ago was oil heat last maintenance?	0.00	12.97	144.00
How often do you clean the fireplace or wood stove? (Month)	0.25	2.19	12.00
How long since the chimney was cleaned (months)?	0.04	6.72	36.00
What is the age of wood stove (months)?	12.00	253.38	564.00
When was wood stove last maintenance (months)?	0.04	40.52	300.00
How many cords of wood do you burn a year?	0.00	5.55	16.00
What is the age of fuel stove (months)?	2.00	159.67	576.00
When was electric heat system last maintenance (months)	0.00	1.50	3.00

Results		
	% Yes	**% No**
Do you use a wood stove?	48	52
Do you use oil heat?	86	14
Do you use electric heat?	15	85

Storage Questions

There was not a significant difference in wood moisture between houses with and without a woodshed. The mean wood moisture of wood stored outside in a wood shed was 20% while the wood stored in other methods (under a tarp or no cover) had a average moisture of 25%. For those with wood stoves, their wood was seasoned for 5.8 months on average. The average percent moisture of 10 logs stored outside was 21% and then next three to be burned was 12%. Almost all wood-burners stored wood, however, many of the respondents (>50%) reported not having a wood shed or tarp to cover their wood with.

Table 5: Summary of IAQ questions related to wood storage and chemical storage. The table is broken into percent yes and percent no as well as the summary statistic if the result is numeric. For numeric responses we report the average, minimum, and maximum to look at the variation, as not all data were normally distributed and hence a standard deviation could not be calculated.

Storage questions	**Results**		
	Minimum	**Average**	**Maximum**
How many months do you season your wood?	0.50	5.84	14.00
% of moisture of outside wood to be burned this season?	7.50	21.87	32.40
% moisture of the next 3 logs to be burned?	1.16	12.18	32.16

	Results	
Storage questions	**% Yes**	**% No**
Do you store wood?	43	57
Do you store wood in the house?	34	66
Do you have a wood shed?	23	77
Do you cover wood with a tarp?	23	77
Do you store cleaning supplies	98	2

in the house?		

PM 2.5 Data

We monitored PM2.5 in 36 houses and generated 6,627 data points from those houses. We found that 2638 (22%) of records exceeded the recommended threshold of 0.035 mg/m^3 PM2.5 for indoor air quality. The maximum average 24hr mean was 0.865 mg/m^3.

We found that heating sources and household practices could significantly change the levels of PM2.5 in the household. We compared 24-hour mean levels between all rooms with and without a woodstove in our study. Based on our results (Table 6), there was a significant difference (Table 6) between 24-hour mean levels of PM2.5 in rooms with a wood stove (0.039 mg/m^3) compared to those without woodstoves (0.027 mg/m^3). We also found that there was a significant difference (Table 6) in the mean PM2.5 levels in houses with stoves older than 20 years (0.054 mg/m^3) compared to stoves that were younger than 20 years (0.014 mg/m^3). We did not find a significant difference in the 24 hour mean of the household if it had a wood stove (0.031 mg/m^3) compared to those without (0.035 mg/m^3). We found a significant difference (Table 6) in the 24-hour mean levels of PM2.5 for the household if residents covered their windows (0.06 mg/m^3) compared to those that did not (0.02 mg/m^3).

We also examined relationships between PM2.5 numeric variables. We found a positive but non-significant relationship between 24-hour mean PM2.5 and wood moisture (Figure 1), and 24-hour mean PM2.5 levels compared to the amount of time since chimney cleaning (Figure 2).

Table 6: Results of statistical tests. Tests were conducted on the log-transformed 24 hour means of household or detectors depending on the question being asked. Results with significantly different values are noted with **.

Question	test	p-value**	Degrees of freedom	r-squared
Is there is a significant difference in the means of PM2.5 in houses without a woodstove and with one?	Welch's T-Test	0.25	32.9	N/A
In our entire study, is there a significant difference between means of PM 2.5 in rooms with wood stoves and those without?	Welch's T-Test	0.02**	27.7	N/A
Is there a significant difference between PM2.5 levels in houses with stoves older than 20 years compared to houses with stoves younger than that?	Welch's T-Test	0.02**	9.9	N/A
Is there a significant difference between PM2.5 levels in houses that cover their windows compared to those that do not?	Welch's T-Test	0.01**	19.4	N/A
Is there is a significant relationship between moisture of wood to be burned and PM2.5 levels?	Linear Regression	0.17	8	0.115
Is there a significant relationship between how long it has been since the chimney has been cleaned and PM2.5 level?	Linear Regression	0.13	8	0.166

** Results of the test were significant

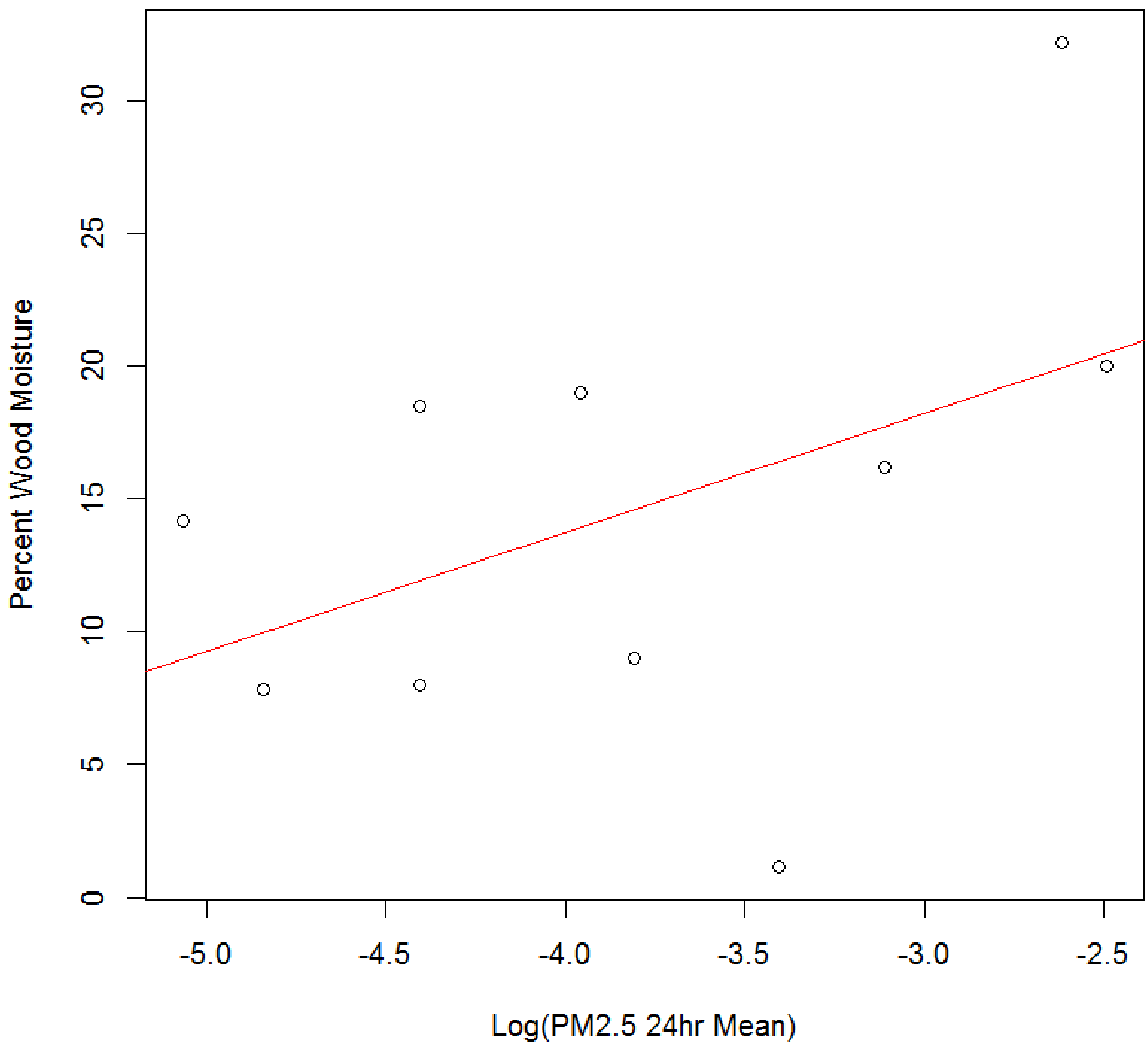

Figure 1: Linear regression results between wood moisture and log transformed PM2.5 levels in rooms with wood stoves (n=10). There was a non-significant positive relationship between the two variables.

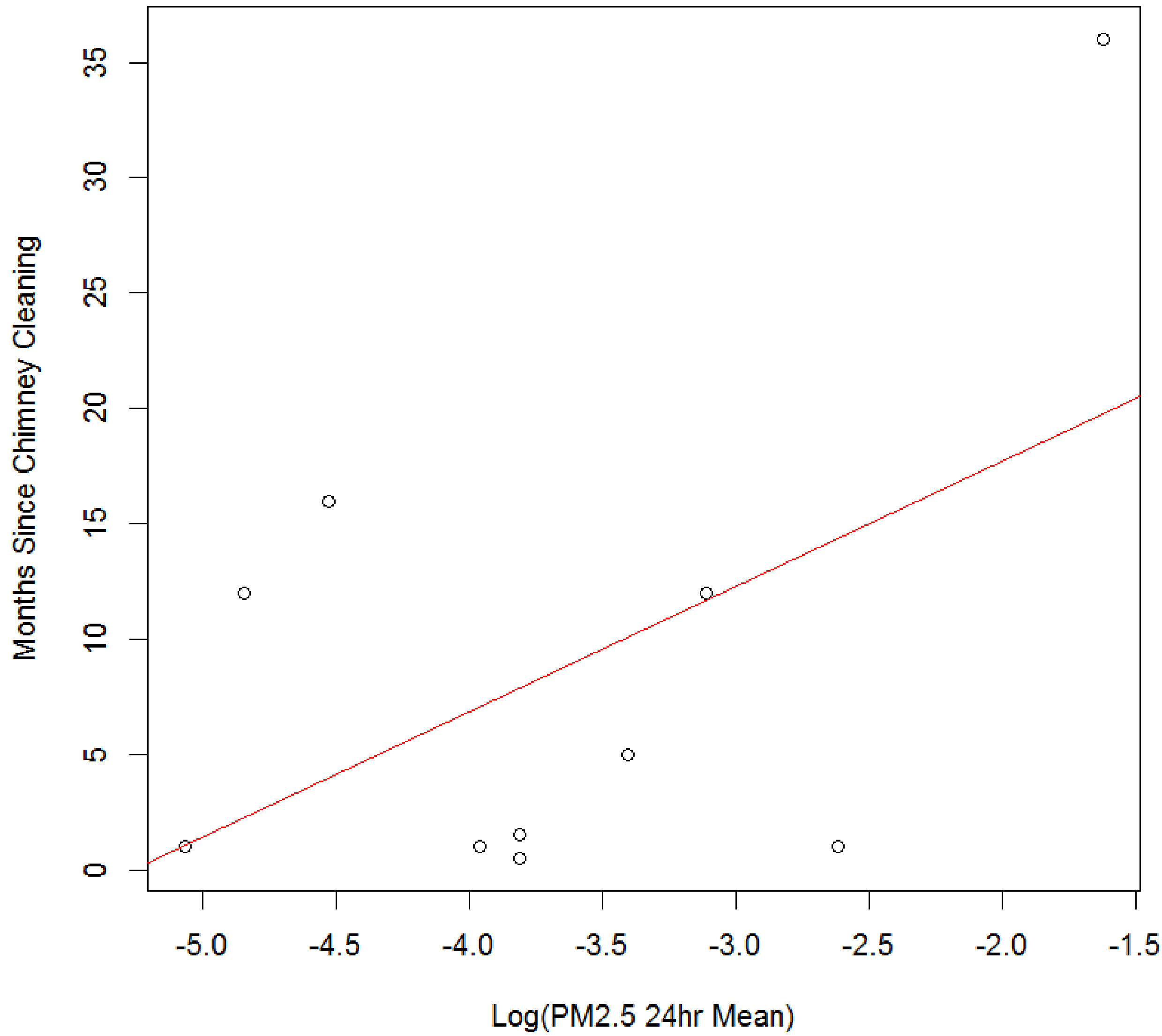

Figure 2: Linear regression results between time from chimney cleaning and log transformed PM2.5 levels in rooms with wood stoves (n=10). There was a non-significant positive relationship between the two variables.

Table 7: A summary of the PM2.5 monitors broken down by time of day. That was done to see if any temporal trends were exposed based on likely timing of events (e.g., stocking the wood stove in the morning). We all report the overall mean of the dataset with the standard deviation and maximum. It is assumed the minimum value is 0 for all time periods. We also report the percentage of houses with their highest average PM2.5 levels during that time.

Time Period	Average PM2.5 Levels	Standard Deviation of PM2.5 Levels	Maximum PM 2.5 Levels	Percent of Household with Highest Average during Time Period
All Data	**0.03**	**0.105**	**2.43**	**---**
Midnight to 3AM	0.016	0.038	0.486	5%
3AM to 6AM	0.008	0.016	0.353	0%
6AM to 9AM	0.024	0.098	1.48	19%
9AM to Noon	0.03	0.089	1.4	5%
Noon to 3PM	0.061	0.184	1.6	22%
3PM to 6PM	0.045	0.142	2.43	19%
6PM to 9PM	0.036	0.064	0.602	16%
9PM to Midnight	0.028	0.0932	1.16	11%

Carbon Monoxide

Average carbon monoxide levels did not fluctuate much throughout the day and the maximum value measured was 18 PPM.

Table 8: A summary of the CO levels in all monitored homes broken down by time of day. That was done to see if any temporal trends were exposed based on likely timing of events (e.g., stocking the wood stove in the morning). We all report the overall mean of the dataset with the maximum value. It is assumed the minimum value is 0 for all time periods. The data were strongly skewed to the left and hence we do not report the standard deviation.

Row Labels	Average	Maximum
All Data	0.541	18
Midnight to 3AM	0.566	7
3AM to 6AM	0.446	8
6AM to 9AM	0.470	18
9AM to Noon	0.533	11
Noon to 3PM	0.565	12
3PM to 6PM	0.490	12
6PM to 9PM	0.625	10
9PM to Midnight	0.639	10

Discussion

A key part of this study was determining if households were above recommendations of PM2.5 for indoor air quality. We will compare the results of our study to the EPA threshold of 0.035 mg/m^3, but it should be noted that the World Health Organization's (WHO) has a more stringent recommendation of 0.025 mg/m^3. 22% (n = 8) of survey houses had a 24 hours mean PM 2.5 greater than the EPA threshold. In those households, we suspect that the PM2.5 levels were due to a combination of poor ventilation, PM from wood stoves, and PM from smoking indoors. We suggest working individually with those households to reduce their PM levels.

Although long-term (i.e, 24 hour) exposure may have the greatest detriment to health, one household's PM2.5 levels that were 68 times greater (2.4 mg/m^3) than the EPA recommended threshold. High exposure may lead to immediate health issues. Some of the highest maximums occurred in households without a wood stove. In corroboration with this, 4 of 20 of the houses that did not have a wood stove in them had an average reading greater than the EPA recommendation. In those houses, we suspect the average was influenced by indoor smoking. Although we did not ask a question about whether or not the homeowner smokes inside, we know through personal relationships that some do smoke inside. We strongly recommend that any future studies ask whether the homeowner smokes indoors to help tease out this factor.

In Hoonah, wood stove age is a significant contributor to PM2.5 levels (Table 6). We found that houses with stoves older than 20 years had PM2.5 levels 1.5 times greater than the EPA recommended threshold. We recommend that homeowners upgrade their stoves to higher efficiency and lower-emission EPA rated stoves. Higher average levels of PM2.5 exposure were observed during the day (Table 7). These results are not unexpected as most activity and wood stove stocking occurs during the daylight hours. Since PM2.5 levels are highest during the day, homeowners with controllable ventilation systems may consider increasing ventilation during daylight hours to filter out PM2.5 and thus increase their IAQ.

We found that houses that covered windows and doors had significantly higher PM2.5 levels than houses that did not. We cannot deduce exactly why that is, but window covering may trap particles and keep the house from breathing properly. Covering the doors may compartmentalize the house and maintain higher concentrations of smoke and PM2.5 in a single room. Since we cannot account for indoor smoking, another explanation may be that in our sample, windows with covered houses had a higher percentage of indoor smokers.

High wood moisture is known to contribute to PM2.5. The EPA BurnWise program recommends that wood should be burned if it contains 20% or less moisture. A 2006 report (NESCAUM 2006) found a 166% increase in PM2.5 levels for every 10% of moisture above 20% (i.e., a 30% moisture log will output 166% more PM than a 20% log). The average wood moisture in Hoonah was 21.7%. There was a not a significant difference in moisture of wood stored under a wood shed versus wood that was not, however, our sample size of homes storing wood (n = 12) was small and had high variation. The sample size limited our ability to compare wood stored without a tarp or woodshed (n =2) to wood stored under cover (n = 10), but with a larger sample we would have run that analysis. Likewise, we were not able to detect a statistically significant relationship between wood moisture or the amount of time since chimney cleaning and PM2.5, but this may be due to a small sample size as there was a positive trend in the data.

In contrast to PM2.5, the health effects (e.g., headaches, nausea) of carbon monoxide may be felt immediately if exposure is high. The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air (55 milligrams per cubic meter (mg/m(3))) as an 8-hour time-weighted average (TWA) concentration (EPA 2017). During our study, the maximum of our readings never exceeded 18ppm, and hence the

8-hour weighted average would be below 50ppm. In short, we did not find carbon monoxide levels to approach a threshold that would negatively impact human health.

Ventilation and airflow is key to alleviating indoor air quality issues, and there is room for improvement in nearly all of the areas surveyed. For instance, 12% of residents had bathroom fans that did not work (Table 3), 55% of residents had windows that leaked, and 78% of residents had outside doors that leak. As a result, 37% of residents covered their windows with blankets or some other insulator and 23% of residents covered their outside doors. By simultaneously weatherizing the house and improving ventilation, residents could trap heat while alleviating potential issues such as mold. Mold is a key concern due to the wet climate of Southeast Alaska, and 51% of residents report seeing mold in their houses. A future assessment may more comprehensively look at indoor mold to begin to address that issue.

During work we drafted a list of ideas that may have improved this type of study in the future. We found it was important to know whether the household owner is an indoor smoker as this directly impacts PM2.5 levels. We may have further standardized our placement of the meters by measuring the distance of the detector from the heat source and ensuring consistent placement of the machine by building a stand for the detector to be placed on. An adequate sample size is critical for the statistical analysis. We do not feel we could have achieved more surveys, but feel that if we had more samples of wood moisture storage types that we would gain insight into how indoor air quality is affected by wood storage methods.

The results of this study are the first to quantify indoor PM2.5 and CO in Hoonah households. One of the key findings is the relationship between stove age and PM2.5 levels in Hoonah households and that 50% of residents report having high-emitting stoves over 20 years old. Indoor air quality improvement programs could target stove replacements as a way to decrease the risk of PM2.5 in households. These replacements should be done strategically, and the households monitored to document the gains in indoor air quality. Another air quality issue that was barely touched during this study is indoor mold. Future studies should comprehensively look at indoor mold as 51% of respondents report seeing mold in their house (Table 2) and work one-on-one with homeowners to address issues found.

Future Actions

There are many opportunities to improve the indoor air quality of residents in Hoonah. Below we have highlighted key statistics which may be addressed through in-home remediation. By “improving” these statistics, we may better human health in Hoonah, and decrease illness related to indoor air quality.

Key Statistics

-- 50% of respondents had stoves greater than 20 years old. Consider a stove replacement program to mitigate these stoves.
--20% homes don't have a range vent
--35% of the homes that have a range vent say it doesn't vent outside. Consider range installation/ inspection program
-- 55% homes report windows leaking
--33% cover windows, consider weatherization program/ inspection
--77% homes don't have screens on their windows
--15% don't have a bathroom fan
-- 12% with bathroom fans have bathroom fans do not work, consider vent inspection/ fixing program.
--21.87% average moisture on wood to be burned this season
--57% don't store wood
--77% do not have a wood shed consider a wood distribution program, or wood shed building program
--51% of respondents report seeing mold indoors

Outreach and education

-- There was misconception about where bathroom fans vent to. Outreach could target homeowners in helping them understand how their ventilation is handling moisture

Literature Cited

NESCAUM. 2006. Assessment of Outdoor Wood-fired Boilers.

Zelikoff J.T., Chen L.C., Choen M.D., Schlesinger R.B. 2002. The Toxicology of Inhaled Woodsmoke. Journal of Toxicology and Environmental Health. 5: 269 – 282

https://www3.epa.gov/region1/airquality/pm-aq-standards.html

http://burnwise.alaska.gov/moisture.htm

EPA.2017.https://www.epa.gov/indoor-air-quality-iaq/carbon-monoxides-impact-indoor-air-quality. Last Update March 13, 2017. Accessed August 14th, 2017.

Appendix A - Survey Questions

Parameter	Description
How long have you lived here?	Number of years the resident has lived in the house
How old is the house?	Year that the house was built
How many stories is your house?	Number of stories in the house
How many rooms are in your house?	Record the number of rooms in the house
How many square feet is your house?	Have the homeowner estimate the number of square feet. If the total is unknown estimate the size of each room and total.
How many residents live in this house year around?	The number of residents in the house.
Do you have a pet that stays indoors?	Check Yes if owner answers yes. Only include pets which pose an allergen risk (e.g., do not include fish)
Have you seen mold in your house?	Check yes if house owner answers yes.
Do you have a range vent?	Check yes if owner has a range vent above their stove or in their kitchen, regardless if it is working or not.
What is the condition of the range vent?	Note on condition of range vent. Things to look at: are the intakes clogged? Does it turn on?
How often do you clean the range vent?	How often (in years) does the homeowner clean the vent?
Does the range vent to the outside?	Check yes if you can see that the vent goes to the outside.
Do you have roof vents?	Check yes if the owner says they have roof vents. You can also check the roof.
How many roof vents do you have?	Record the number of roof vents.
What is the condition of the roof vents?	Note on condition of roof vents. Do they look like they are sealed properly? Are there any cracks in them? Are they blocked?
How many windows do you have?	Total number of windows on outside walls. Do not count the number of panes. Count the number of frames.
Do the windows leak?	Feel around the windows for drafts
Are the windows covered?	Check yes if the house owner is covering the windows on outside walls with blankets, plastic, or another material.
What is the condition of the windows?	Check around the windows and the frame. Are the frames in good shape? Are there any holes in the windows? Is there moisture or mold on or around the windows?
Do you have window screens?	Check yes if the owner has screens in the windows
How many outside doors does the house have?	Number of outside doors in the house
How many doors in the house total?	Number of doors to all the rooms in the house, including the number of outside doors from the above question.
Do the doors leak?	Check around bottom and sides of the door. Check yes if significant gaps can be seen

	or if drafts can be felt
Do the doors latch?	Pull on the door handle while shut to mimic a gust of wind. If the door comes open, check no.
Do you have a bathroom fan?	Check yes if there is a vent in the bathroom
Does the bathroom fan function?	Try the bathroom fan, if the fan turns on check yes.
Where does the bathroom fan vent to?	Check where the bathroom vents to. List as either outside or inside.
When was the bathroom fan/vent cleaned?	How long ago was the bathroom fan cleaned in years?
Do you use a fireplace or wood stove?	Check yes if the owner uses a fireplace or wood stove to heat their house.
What is the serial number of the stove?	Find the serial number of the stove and record it here.
What is the age of the stove?	Ask the homeowner how old the stove is
How many cords of wood do you burn per season on average?	Record the number of cords the owner burns each season.
How often do you clean the fireplace or wood stove?	How often does the homeowner clean the stove (in years?)
How long since chimney was cleaned?	Number of days since the chimney was cleaned
Do you use diesel or other fuel oil for heat?	Check yes if the owner used a Toyo or other stove to burn diesel or fuel oil
When was last maintenance?	List the date of the last maintenance
What is the age of your fuel stove?	Ask the owner how old the stove is and list it.
Do you use electric heat?	Check yes if the owner uses electric heat in their house.
Do you store wood?	Check yes if the owner has a wood pile
How long is it seasoned for?	Ask owner the amount of time that the wood they are currently burning has been seasoned (# months)
% moisture of outside wood to be burned this season.	Sample 10 of the logs (see Section 3.2.3.3 on sampling procedure from the woodpile that will be burned this season. Use the MD810 meter to determine moisture.
Do you store wood in the house and if so how long do you store it inside before being burned?	Check yes if wood is stored indoors before it is burned. If yes, then include the number of days the wood is stored inside before burning.
% moisture of next 3 logs to be burned in the fireplace	Ask the homeowner which three logs they will burn next. Take the %moisture of those logs.
Do you have a wood shed?	Check yes if the owner stores their wood in a wood shed
Do you cover your wood with a tarp?	Check yes if the owner stores their wood under a tarp
Do you store cleaning supplies in your house?	Check yes if the owner stores cleaning products in their house. Examples include toilet cleaner, bleach, and drain cleaner. In the comments include if the homeowner is using any green cleaning supplies such as vinegar
What green cleaning supplies (if any) do you use?	A list of green cleaning supplies such as vinegar, baking soda, or chlorine free bleach.

Where do you store cleaning supplies?	List the location of the stored chemicals. Example “In a cabinet under the sink”
Do you store liquid fuel in the house?	Does the homeowner store fuel supplies in the house? Fuel includes diesel tanks or gas cans, but does not include sealed canisters of propane.
Where do you store liquid fuel?	List the location of the stored fuel. Example “In the spare room on the floor”
What type of container is the liquid fuel in?	List the type of container. Example “A plastic gas can”
Do you store paint in the house?	Check yes if the owner has cans of paint stored in the house.
Where in the house is paint stored?	List the location of the stored paint. Example “On a shelf in the garage”