Measurable Outcomes of a Woodstove Changeout on the Nez Perce Reservation

Final Report

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by

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1.0 Executive Summary

During the winters of 2006/2007, 2007/2008, and 2008/2009, a woodstove changeout program was conducted in Kamiah and Lapwai, Idaho on the Nez Perce Reservation. In addition to the replacement of old stoves with EPA-certified stoves, air sampling was conducted within 16 homes to measure the improvement in air quality before and after the changeouts on a home-by-home basis. A second objective of this project was to educate participating households on the health effects of being exposed to smoke from wood burning stoves, and how to operate the new stoves most efficiently.

$PM_{2.5}$ samples were collected within the common area (rooms where the stoves were located) of 16 homes both before and after the installation of the cleaner burning EPA- certified stoves. During the sampling, indoor $PM_{2.5}$ mass, Organic Carbon (OC), Elemental Carbon (EC), and chemical markers of woodsmoke (vanillin, acetovanillone, guaiacol, 4-ethylguaiacol, levoglucosan, abietic acid, and dehydroabietic acid) were measured. For the first winter season (2006/2007), the study established baseline $PM_{2.5}$ concentrations within five homes in Lapwai/Kamiah. For the 2007/2008 winter, baseline (pre-changeout) $PM_{2.5}$ measurements were collected within 11 additional homes. The old woodstoves in these 16 homes were then removed and new EPA-certified woodstoves were installed. The majority of post changeout air quality measurements were conducted during the winter of 2008/2009.

For the 15 homes (note that Home 14 did not have a complete dataset), the median pre-changeout $PM_{2.5}$ mass (as measured by TSI DustTraks) was $39.2 \pm 45.7\ \mu g/m^3$, with a median post-changeout concentration of $19.0 \pm 47.5 \mu g/m^3$. This resulted in a 52% reduction in indoor $PM_{2.5}$ (including a 60% reduction in $PM_{2.5}$ spikes) when the old stoves were replaced with EPA-certified stoves. OC/EC results show that the $PM_{2.5}$ mass measured within the homes was heavily enriched with the OC fraction, with a minimal contribution from the EC fraction. Out of the seven chemical markers of woodsmoke tracked in this program, levoglucosan had the highest measured concentrations. Levoglucosan showed a 63% reduction following the changeout, confirming that woodsmoke – related $PM_{2.5}$ were reduced within the homes as a result of the woodstove changeout. It is also unlikely that ambient $PM_{2.5}$ contributed to indoor levels of $PM_{2.5}$ measured within the homes, as the indoor levels were much more elevated when compared to outdoor levels.

Another significant finding of the project was that targeted education and outreach is a critical component of the overall success of the program. Homeowners need to be provided with specific instructions on how to operate their new stove, and additional visits may need to be made to the home in an effort to ensure that the residents learn best burn practices for their new stoves. In summary, the results of the Nez Perce woodstove changeout program suggest that replacing old, polluting woodstoves with EPA-certified stoves can be used to improve the indoor air quality within woodstove homes.

2.0 Introduction

In several rural valley locations throughout the northern Rocky Mountains, the major source of wintertime ambient $PM_{2.5}$ has been identified as woodsmoke from residential woodstoves (Ward and Smith, 2005; Ward et al., 2006). In many of these valley communities, woodstoves also serve as the primary source of home heating throughout the cold winter months. The Consumer Product Safety Commission estimates that there are 8.9 million woodstoves in use in the U.S., and they are the most intensively used type of space heater with an average annual usage per heater of 2100 hours (Zamula, 1989; AQMWG, 2005).

One strategy of reducing ambient emissions of residential woodsmoke $PM_{2.5}$ is by changing out old woodstoves with new, cleaner-burning EPA-certified woodstoves. An EPA certified woodstove is defined as a stove that has been independently tested by an accredited laboratory, and meets a PM emissions limit of 7.5 g/hr for noncatalytic wood stoves and 4.1 g/hr for catalytic wood stoves. While older uncertified stoves and fireplaces release 40 to 60 grams of smoke per hour, new EPA-certified stoves typically produce only 2 to 5 grams of smoke per hour.

Even though old woodstoves are considered significant sources of ambient $PM_{2.5}$, they have also been shown to be significant sources of indoor $PM_{2.5}$. In a 20-home study conducted in Libby, Montana, indoor $PM_{2.5}$ samples were collected to evaluate the effectiveness of a woodstove changeout on the indoor environment. Results from this study showed that average $PM_{2.5}$ concentrations and maximum $PM_{2.5}$ concentrations were reduced by 71% and 76%, respectively (as measured by TSI DustTraks) when old stoves were replaced with EPA-certified stoves (Ward et al., 2008). The results from this study suggested that replacing an old stove with a new EPA-certified stove can be an effective tool in improving indoor residential air quality.

The goal of the Nez Perce project was to evaluate the effectiveness of a woodstove changeout on indoor air quality within 16 homes in Lapwai and Kamiah. In this report, we present the methodologies used throughout the project, results, and a summary of our findings.

3.0 Experimental Design

Indoor $PM_{2.5}$ samples were collected within 16 homes in Lapwai and Kamiah throughout the winters of 2006/2007, 2007/2008, and 2008/2009, respectively. Both of these communities have populations of approximately 1,100 inhabitants, and rely heavily on the use of woodstoves for residential home heating. To participate in the study, homes had to be non-smoking, occupied by a tribal member, have an asthmatic child, and use older model woodstoves as the primary source of heat. The Nez Perce Tribe's Environmental Restoration and Waste Management (ERWM) Air Quality Program promoted the project and recruited homes through a number of outreach methods. These include: articles and advertisements in the local and tribal newspapers, letters to tribal members with woodstoves, presentations to community groups, and informational booths at community events. Also, by working closely with Nimiipuu Health, short questionnaires were available at both clinics in Lapwai and Kamiah. Originally, the intent was to sample 8 homes in each community for a total of16 homes. However, due to recruitment challenges, 9 homes were sampled in Lapwai, with 7 homes in Kamiah.

3.1 Residential Air Sampling

Students from the Northwest Indian College (Distance Learning Center), as well as an intern from ERWM were trained by The University of Montana to collect air samples. ERWM staff also received training on sampler operation. Sixteen homes were measured for $PM_{2.5}$ mass, Organic Carbon (OC), Elemental Carbon (EC), and chemical markers of wood smoke both before and after the changeout.

In each home there were two samplers: a DustTrak (Model 8520) that continuously measured $PM_{2.5}$ mass averaged over 60-second intervals, and a SKC, Inc. Leland pump/Personal Environmental Monitor (PEM) sampler fitted with a 37-mm quartz filter for OC/EC and chemical marker of wood smoke analyses. The goal of the sampling program was to collect samples within each home at least twice during the winter period (November - March), with each sampling episode consisting of 24 to 48 hours. For each of the homes, indoor samples were collected within the same room of the residence that the woodstove was located, usually in the common area (living room). Both the DustTrak and Leland/PEM were co-located during the sampling event, and placed approximately 3-5 feet off of the ground.

From January through March 2007, indoor $PM_{2.5}$ samples were collected within 5 homes in Lapwai and Kamiah to establish a baseline for indoor $PM_{2.5}$ concentrations before a woodstove changeout. For the 2007/2008 winter, baseline (pre changeout) $PM_{2.5}$ measurements were collected within 11 additional homes. The majority of post changeout measures were conducted during the winter of 2008/2009.

A comprehensive Quality Assurance/Quality Control (QA/QC) program was employed throughout the sampling program. Using a Bios DryCal flow meter, the flow rate on the Leland pump/PEM was measured both before and after each sampling event. Quartz filter field blanks were collected for approximately every 10 samples (10%). Field personnel followed the recommended maintenance and cleaning schedules for the DustTrak and Leland/PEM as described in their respective manuals throughout the program. The DustTrak was zeroed prior to each sampling event, with results documented on datasheets.

3.2 Activity Logs

In order to accurately assess the air sampling results within each of the homes, it is important to consider the many variables that may contribute to $PM_{2.5}$ exposures. During each sampling event, the home owner was asked to record some of the activities that occurred in the home during the day of sampling. Data collected in these home activity logs included the recording of wood burning, cooking, any cigarette smoking, and cleaning activities.

3.3 Ambient Air Data

At both the Kamiah and Lapwai ambient monitoring sites, a tapered element oscillating microbalance (TEOM) continuously measures ambient $PM_{2.5}$. Ambient $PM_{2.5}$ data were provided by ERWM to The University of Montana to investigate the possibility of ambient $PM_{2.5}$ influences on the indoor environments.

3.4 $PM_{2.5}$ Analyses

Analyses conducted on the 37-mm prefired quartz filters provided information on how much of the indoor PM resulted specifically from wood combustion, and not from other types of combustion sources such as diesel exhaust. All quartz filter samples, field blanks, and trip blanks were delivered to The University of Montana's Center for Environmental Health Sciences (UM-CEHS) in Missoula, MT for processing. At UM-CEHS, the filters were split into two equal halves.

For the OC/EC analyses, one half of the exposed $PM_{2.5}$ filters were shipped in coolers to Chester LabNet (Tigard, Oregon) for analysis by Thermal Optical Reflectance. Chester LabNet employs a comprehensive analytical laboratory QA/QC program. The other half of the quartz filter was analyzed for chemical markers of woodsmoke including vanillin, acetovanillone, guaiacol, 4-ethylguaiacol (all methoxyphenols), levoglucosan (a sugar anhydride), abietic acid, and dehydroabietic acid (resin acids) at The University of Montana following an analytical method refined by Bergauff et al. (Bergauff et al., 2008). This method was adapted from methods reported previously by Schauer et al. (2001) and Simpson et al. (2005) Briefly, half of each filter is spiked with deuterated recovery standards, placed in a vial, and extracted by ultrasonication using ethyl acetate containing 3.6 mM triethylamine. The extract is filtered, reduced in volume to approximately 500 µL and split into two equal fractions. One fraction is evaporated to dryness and derivatized with N-*O*-bis(trimethylsilyl)trifluoroacetamide, trimethylchlorosilane and trimethylsilylimidazole to convert the sugar anhydrides and the abietic acids to their trimethylsilyl derivatives. The second fraction is treated with a 2:3 mixture of acetic anhydride:triethyl amine to generate the acetate derivatives of the methoxyphenols. Both sample fractions were analyzed by GC/MS on a Hewlett-Packard GC/MSD (GC Model 6890, MSD Model 5973) using an HP-5ms capillary column or equivalent. A comprehensive QA/QC program was employed throughout the analytical program, including the analysis of blanks to address artifact contamination (both from sampling and analytical activities), and spikes to address analyte recovery.

We were especially interested in measuring the levels of levoglucosan in this study. Levoglucosan (1,6-anhydro-β-D-glucopyranose) is a pyrolysis product of cellulose (Simoneit et al., 1999; Nolte et al., 2001), and is generally a major organic component of biomass combustion-related particulate matter (Simoneit and Elias, 2001; Lee et al., 2005). It is frequently used as a tracer for biomass burning because it is produced at relatively high levels, and is stable in the atmosphere (Simoneit et al., 1999).

3.5 Purchase and Installation of EPA Woodstoves

The first five EPA-certified woodstoves were installed by Anderson's Masonry Hearth & Home (Missoula, Montana) on October 26, 2007. The second set (11) of EPA-certified stoves were installed in April 2008. It should be noted that the stoves were "burned off" (i.e. the first burn in the stove occurred outdoors for at least 8 hours) before installation within the homes. Also, the old stoves were recycled after they were removed. An external consultant (Mr. Jerry Marquez) was then used to ensure that the 16 installations were conducted according to code. Mr. Marquez originally traveled to Lapwai and Kamiah on November 10-11, 2007 to inspect the first five installations conducted by Anderson's. He traveled back to Lapwai and Kamiah in April 2008, following the second set of installations. During each visit, Mr. Marquez spoke to the homeowners about best operating practices for the new stoves. Mr. Marquez also submitted short reports summarizing his findings.

4.0 Results

The goal of the sampling program was to collect as many samples as possible within the 16 homes both before and after the stove changeout in an effort to evaluate the potential improvement in indoor air quality. Some homes had only one 24-hour sample collected pre- and post changeout, while other homes had up to five 24-hour samples collected. As the DustTrak was often set to run for 48-hours (while the Leland samplers ran for 24 hours), the DustTrak data had to be formatted in an effort to make the applicable comparisons. Therefore, during data analysis, the 48-hour DustTrak runs were separated out into individual 24-hour events so they could be directly compared with the 24-hour OC/EC and chemical markers of woodsmoke concentrations. When comparing the pre- and post- change in indoor concentrations within each of the homes, the average of the 24-hour pre- and post-changeout concentrations were used.

Before final concentrations were calculated for $PM_{2.5}$, OC/EC, and chemical markers of woodsmoke, each 24-hour sample run collected in each of the 16 houses was carefully scrutinized to ensure that the data was of the highest technical quality. Any sample run that did not have adequate collection times (24 or 48 hours) or sufficient flow rates (~10 L/min for the Leland/PEM) was discarded from the final dataset. Additional results were excluded from the final calculations when abnormal events occurred during the sampling events (pitch on stove or blocked chimney), when the new stove was not operated correctly during the sampling event, or when the woodstove was not used at all during the sampling event. Appendix A lists all of the DustTrak and Leland sample runs that were excluded from the final data calculations, while Appendix B lists all of the DustTrak and Leland sample run parameters collected throughout the program.

Though the goal of each sampling event was to collect both a DustTrak ($PM_{2.5}$ mass) and Leland/PEM (OC/EC and chemical markers of woodsmoke) sample, there were several occasions where only a successful DustTrak run was collected. Therefore, in this report, we present the final results in three ways: 1) only $PM_{2.5}$ mass (medians, maximums, and minimums) for all pre- and post-changeout sample runs (not including those sample runs that had poor QA/QC, and/or had some type of malfunction or abnormal event), 2) those sample days that had complete data sets (i.e. mass, OC/EC, and chemical markers of woodsmoke), and 3) those homes that had some type of additional education and outreach training within the home following the changeout. As there is a large standard deviation when looking at the pre- and post-changeout $PM_{2.5}$ results (because of high $PM_{2.5}$ levels in some of the sample runs), results are presented in median concentrations (instead of averages) when evaluating the impact of the woodstove changeout.

4.1 $PM_{2.5}$ Mass Results for all Pre- and Post-Changeout Sampling Episodes

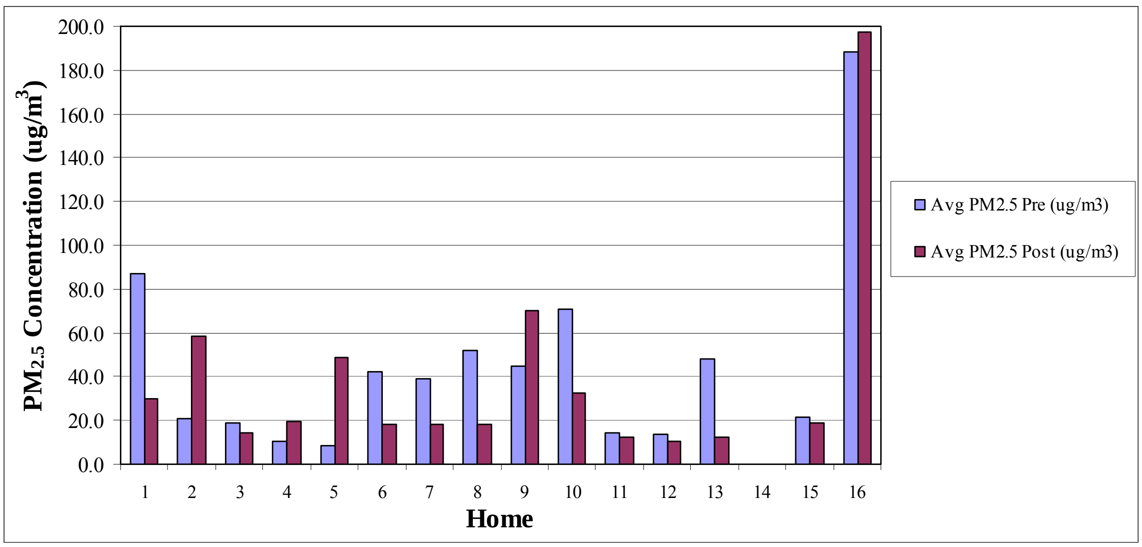
Table 1 presents the overall $PM_{2.5}$ sampling program results, including the pre- and post-changeout medians, minimum, and maximum mass concentrations. Figure 1 presents the pre- and post-changeout average $PM_{2.5}$ concentrations measured within each of the 16 homes in a graphical format, while Appendix C presents all of the $PM_{2.5}$ results measured within each of the homes. None of the results are blank corrected. Note that Tables 1 and Appendix C (and Figure

1) do not include those sample runs that had poor QA/QC, and/or had some type of malfunction or abnormal event.

Table 1: $PM_{2.5}$ Concentration ± Standard Deviation Sampling Results

	Median of the 24-hour $PM_{2.5}$ Concentrations ($\mu g/m^3$)	Minimum $PM_{2.5}$ ($\mu g/m^3$)	Maximum $PM_{2.5}$ ($\mu g/m^3$)
Pre Changeout Concentrations	39.2±45.7	4.5±6.2	437.5±572.4
Post Changeout Concentrations	19.0±47.5	3.5±11.6	175.5±354.0
Difference	**-52%**	**-22%**	**-60%**

Figure 1: Indoor Residential $PM_{2.5}$ Mass Comparisons ($\mu g/m^3$)



4.1.1 $PM_{2.5}$ Mass Results

When comparing the median pre- and post-changeout results, there was a 52% reduction in indoor $PM_{2.5}$, while maximum spike concentrations were reduced by 60%. Prior to the Nez Perce changeout, eight of the homes had 24-hour average $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ (EPA 24-hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) for comparison), with the maximum observed 24-hour average concentration of 188.0 $\mu g/m^3$ measured in Home 16. Following the changeouts, four homes still had 24-hour average concentrations above 35 $\mu g/m^3$. The maximum observed 24-hour average concentration in the post-measurements was 197.4 $\mu g/m^3$ (Home 16). Home 14 did not have a complete dataset to allow comparison.

Unlike the Libby woodstove changeout program where there were substantial reductions in average and maximum $PM_{2.5}$ within each of the study homes, not all of the Nez Perce homes showed clear reductions following the changeout. When looking at the final results, five of the 16 homes had higher $PM_{2.5}$ concentrations following the changeout. Some of these results can be explained by looking at the notes documented in the sample run datasheets, as well as in the activity logs for each of the homes. The datasheets and activity logs included the following notations:

- Home 2 (Post): This home had issues with pitch on top of the stove. A further discussion is provided on page 10.
- Home 5 (Post): On 2/10/09, the $PM_{2.5}$ concentrations rose between 18:00 and 18:30. The homeowner noted "frying" at 18:30. The homeowner also loaded their woodstove at 18:00, and stoked the woodstove at 18:30. The DustTrak recorded $PM_{2.5}$ spikes between ~19:20 and 19:45. The homeowner stoked the woodstove at 19:45.
- Home 9 (Post): The datasheet recorded that the wood was "wet, some dry" during the 2/23/09 and 2/24/09 sample dates.
  - On 2/23/09, $PM_{2.5}$ concentrations spiked between 11:00-11:30. This could be explained by the incense burning and smudging recorded on the home activity log.
  - At ~12:45, $PM_{2.5}$ concentrations spiked to ~4000 $\mu g/m^3$. As there was a notation in the datasheets that the windows were opened with the "door propped open", some unknown event occurred resulting in elevated levels of indoor $PM_{2.5}$.
  - At 15:55, $PM_{2.5}$ concentrations spiked during the boiling of kouse kouse.
  - On 2/24/09, the monitor spiked at around 01:23am. The homeowner recorded "stoked" at '023'. It is possible that this event caused the spike.
- Home 16: Both pre- and post-changeout concentrations were elevated within Home 16. During the post-sampling events, the homeowner said that everything in the home was normal, yet the indoor levels were still consistently high. It should be noted that the homeowner only operated the stove during the first 24 hours on 2/17/09, and the stove was not used at all on 2/18/09. Therefore, the 24-hour concentration (109.1 $\mu g/m^3$) for 2/18/09-2/19/09 was removed from the final calculations. The homeowner also described their burning as "light" compared to a "typical winter day". From the home activity log, "open windows-all day and night" was recorded. This suggests the likelihood of other indoor air quality issues in the home unrelated to woodstove usage. These might include:
  - (Pre): From home activity log: "A pot of orange peels, cloves, and cinnamon on the woodstove."
  - (Post): On 2/17/09, the DustTrak began running at 11:30. There was a spike of 838 $\mu g/m^3$ at that time. The home activity log indicated "frying" at 11:00. The levels remained above 600 $\mu g/m^3$ for the next two hours.
  - The presence of a dog within the residence.
- Participants such as Home 4 (10.2 $\mu g/m^3$) and Home 5 (8.2 $\mu g/m^3$) had low pre-changeout $PM_{2.5}$ concentrations, making it difficult to achieve an overall reduction when comparing with the post-changeout sampling events.

4.2 $PM_{2.5}$ Mass, OC/EC, and Woodsmoke Marker Results for Sample Days with Complete Datasets

Table 2 presents the $PM_{2.5}$ and OC/EC results for those homes (pre- and post-changeout) with complete data sets, while Table 3 presents the program medians for the chemical markers of woodsmoke. A complete dataset is defined as a successful DustTrak sample ($PM_{2.5}$ mass, maximum $PM_{2.5}$, and minimum $PM_{2.5}$) and quartz filter (OC/EC and chemical markers of woodsmoke) collected. None of the results are blank corrected. Note that the units in Table 2 are in $\mu g/m^3$, while the units in Table 3 are in ng/m^3. The $PM_{2.5}$ mass, OC/EC/TC for each of the homes with complete data sets are presented in Appendix D.

Table 2: Results for $PM_{2.5}$ and OC/EC/TC – Homes with Complete Datasets

	Median $PM_{2.5}$ ($\mu g/m^3$)	Minimum $PM_{2.5}$ ($\mu g/m^3$)	Maximum $PM_{2.5}$ ($\mu g/m^3$)	OC ($\mu g/m^3$)	EC ($\mu g/m^3$)	TC ($\mu g/m^3$)
Pre Changeout	21.6±57.5	5.0±6.6	254.0±731.1	16.9±15.3	0.3±0.4	17.2±15.5
Post Changeout	18.4±54.1	4.0±13.4	145.0±278.3	13.4±11.0	0.7±0.4	14.0±11.3
Difference	**-15%**	**-20%**	**-43%**	**-21%**	**+120%**	**-19%**

Table 3: Results for Chemical Markers of Woodsmoke – Homes with Complete Datasets

	Levoglucosan (ng/m^3)	Dehydroabietic acid (ng/m^3)	Abietic acid (ng/m^3)	Vanillin (ng/m^3)	Acetovanillone (ng/m^3)	Guaiacol (ng/m^3)	4-Ethylguaiacol (ng/m^3)
Pre Changeout	645.1±1315.3	113.0±147.7	11.3±118.7	0.5±2.3	0.3±9.2	0.9±256.0	0.8±0.8
Post Changeout	238.1±310.1	0.3±37.1	41.5±40.3	0.5±4.4	0.3±0.0	0.3±0.4	0.1±0.4
Difference	**-63%**	**-100%**	**+267.0%**	**No Change**	**No Change**	**-62%**	**-92%**

4.2.1 $PM_{2.5}$ Mass and OC/EC Results (Homes with Complete Datasets)

When looking at the $PM_{2.5}$ mass results in those homes with compete data sets, there was a 15% reduction in indoor $PM_{2.5}$, while maximum spike concentrations were reduced by 43%. OC/EC results show that the $PM_{2.5}$ mass measured within the homes is heavily enriched with the OC fraction, with a minimal contribution from the EC fraction. Even though there was an overall increase in EC following the changeout, levels were still extremely low when compared to OC. The 21% reduction in OC correlates with the 15% reduction in $PM_{2.5}$ mass, suggesting that the introduction of the EPA certified woodstoves directly impacts the OC fraction of $PM_{2.5}$.

4.2.2 Chemical Markers of Woodsmoke (Homes with Complete Datasets)

Out of the seven chemical markers of woodsmoke tracked in this program, levoglucosan was found in the highest concentrations. Levoglucosan showed a 63% reduction in concentrations following the changeout, with dehydroabietic acid showing nearly a 100% reduction. Abietic acid actually increased following the changeout, which is a trend we have observed in the Libby woodstove changeout program (Ward et al., 2008). Very low levels of methoxyphenols were measured in this program, likely due to low levels found in the particle phase within the homes. The levoglucosan results confirm that woodsmoke – related $PM_{2.5}$ were reduced within the homes as a result of the woodstove changeout.

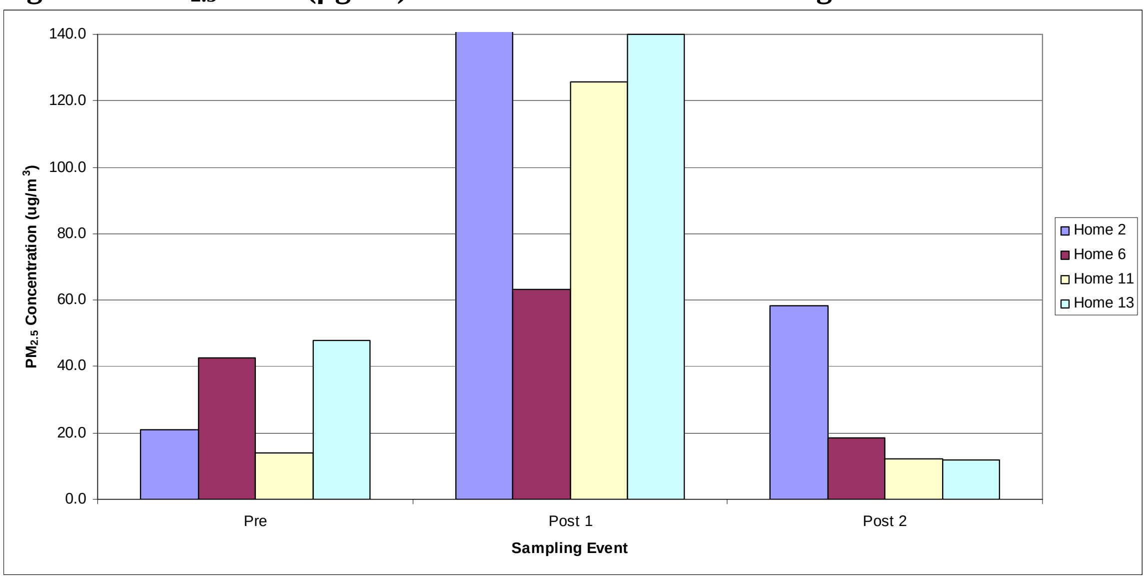
4.3 Impact of Education and Outreach Following the Changeout

Following the installation of EPA-certified woodstoves, some of the homes had higher $PM_{2.5}$ concentrations measured inside the homes after the changeout when compared to pre-changeout levels. After determining the causes of these elevated concentrations, ERWM staff worked with the home owners to deliver additional training. As a result of this education/outreach effort, $PM_{2.5}$ concentrations were lowered within four homes as demonstrated by followup sampling events. Both Table 4 and Figure 2 present the pre-changeout results, the initial post-changeout measurements (Post 1), and then those results measured within each of the four homes following the outreach/education provided to the homeowner (Post 2). A discussion of the issues within each of the four homes is presented below.

Table 4: $PM_{2.5}$ and OC/EC/TC Results Following Outreach/Education

	Pre-Changeout Average $PM_{2.5}$ (μg/m^3)	Post 1 Changeout Average $PM_{2.5}$ (μg/m^3)	Post 2 Changeout Average $PM_{2.5}$ (μg/m^3)
Home 2	20.8	322.7	58.2
Home 6	42.4	63.1	18.4
Home 11	14.0	125.9	12.1
Home 13	47.9	2412.0	12.0

Figure 2: $PM_{2.5}$ Mass (μg/m^3) Measured in Homes Following Outreach/Education



Note: The bars in Figure 2 for Post 1, Home 2 (322.7 μg/m^3) and Post 1, Home 13 (2412.0 μg/m^3) are modified to fit the graph.

Home 2. The homeowner was drying wood on top of their new stove, and a layer of pitch was deposited on the top of the stove. This resulted in elevated $PM_{2.5}$ concentrations measured during the Post 1 event. ERWM staff worked with the homeowner to get most of it removed. Following the removal of the pitch, $PM_{2.5}$ levels within the home were dramatically reduced (Post 2).

Home 6. The homeowners were not opening the draft completely when using their woodstove, therefore shutting down the fire too quickly. The glass door was dirty and creosote built up in their chimney. ERWM staff met with the homeowner to discuss proper burning techniques using their new stove. Following this additional training, the second post-sample (Post 2) showed a reduction when compared to the first post-sample event (Post 1).

Home 11. The homeowner was leaving the woodstove door cracked when using the new stove. ERWM staff met with the homeowner, and explained that the stove operated differently than the old stove. Following this additional training, a dramatic improvement in air quality was achieved as demonstrated by the Post 2 sample event.

Home 13. The homeowner had not recently cleaned the chimney, therefore smoke accumulated within the home while using the new woodstove. ERWM staff met with the homeowner and explained that the chimney needed to be cleaned. Following the cleaning, the $PM_{2.5}$ concentrations were reduced within the home.

The results from these four homes demonstrate that education and outreach strategies following the changeout can greatly improve the operation (and therefore reduce the levels of $PM_{2.5}$ within the homes) of the newly installed stoves.

4.4 Ambient $PM_{2.5}$ Impact on the Indoor Environment

Ambient $PM_{2.5}$ levels vary widely by season in Lapwai and Kamiah. Before the project began, we had intended to compare the ambient and indoor mass to determine if ambient $PM_{2.5}$ influenced indoor $PM_{2.5}$ concentrations. After reviewing both the indoor and ambient $PM_{2.5}$ data sets, it is likely that the ambient $PM_{2.5}$ had an insignificant influence on the indoor $PM_{2.5}$ measured in this study. As shown in Appendix C, the indoor levels are far more elevated when compared to the ambient levels during the same time periods. The results from this study suggest that indoor sources (i.e. cooking, cleaning, and woodstove use) dominate the indoor $PM_{2.5}$ levels within each of the 16 homes.

4.5 QA/QC Results

Quartz filter field blanks were analyzed for approximately every 10 samples (10%) collected in the field. Results of these analyses showed no artifact contamination in the blanks. Table 5 presents the blank results, as well as the minimum detection limits (MDLs) for each of the parameters measured throughout the program. For $PM_{2.5}$ mass, MDLs are reported in the DustTrak manual. MDLs for OC and EC were reported by the contracted laboratory in µg. To calculate the final MDLs, the values for OC and EC, respectively, were divided by the average volume collected with the Leland pump / PEM during each sample run (14 L/min).

Table 5: Minimum Detection Limits

Parameter	Blank Results	MDLs
$PM_{2.5}$	0.000 mg/m^3	0.001 mg/m^3
OC	0.5 µg/m^3	0.098 µg/m^3
EC	0.02 µg/m^3	0.007 µg/m^3
Levoglucosan	52.0 ng/m^3	7.7 ng/m^3
Dehydroabietic Acid	48.6 ng/m^3	0.6 ng/m^3
Abietic Acid	0.02 ng/m^3	0.5 ng/m^3
Vanillin	0.03 ng/m^3	0.9 ng/m^3
Acetovanillone	0.02 ng/m^3	0.5 ng/m^3
Guaiacol	0.8 ng/m^3	0.03 ng/m^3
4 Ethyl Guaiacol	0.4 ng/m^3	0.1 ng/m^3

5.0 Challenges Faced and Lessons Learned

In addition to the finding that indoor air quality was improved as a result of the woodstove changeout, another significant finding of the project was that targeted education and outreach is a critical component of the overall success of the program. Homeowners need to be given specific instructions on how to operate their new stove, and additional visits may need to be made to the home to ensure that the residents learn best burn practices for their new stoves.

For the Nez Perce woodstove changeout, initial outreach/education/training was conducted by Mr. Jerry Marquez shortly after each home received their new stove. In addition to inspecting the stove installations, he talked with the homeowners about their new stove and burning practices, and also provided them with a handout on best burn practices. In addition to this effort, ERWM staff provided the homeowners with a packet of information (DVD, wood smoke information, asthma information, materials for kids, and manual for the stove). Although important, this outreach and education strategy did not work for every home, and additional strategies were needed.

After some of the post-changeout measurements showed an increase in $PM_{2.5}$ levels, ERWM staff decided to provide a "new stove refresher" to the homes. They met with homeowners to show them an Environment Canada film on burning techniques, with each home receiving a specific, step-by-step protocol on how to use their new stove. It was also learned that directions need to be clearly spoken and written down, and that providing too much educational material can overwhelm the homeowner. The materials need to be concise, and should be reviewed in detail with the homeowner during the home visit.

Additional lessons were learned in this project, including the results from Home 13 that demonstrated that new stoves do not operate properly when the chimney has not been cleaned. In addition, Home 9's data indicated that burning wet wood can create high levels of smoke within the home. Finally, for future changeouts, it is recommended that when people sign up to participate in a stove changeout, they should go to a mandatory meeting where videos are shown on burning practices and wood storage, with handouts provided to the homeowner describing best burn practices. After the new stoves have been installed, it is recommended that additional in-home training be conducted to ensure that the homeowner is successfully using their new stove.

6.0 References

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Appendix A

DustTrak samples that were excluded from the overall dataset.

Home	Sample Date	Reason
11 – Pre Changeout	12/20/06	1-second averages instead of 1-minute.
11 - Pre Changeout	1/9/07	Only ran 533 minutes
11 – Pre Changeout	2/7/07	Only ran 29 minutes.
12 – Pre Changeout	1/16/08-1/17/08	Only ran 987 minutes.
12 – Pre Changeout	1/19/08	1-second averages instead of 1-minute – ran 516 minutes.
13 – Pre Changeout	12/5/07-12/6/07	Only ran 476 minutes
14 – Pre Changeout	1/29/08	Only ran 1 minute.
14 – Pre Changeout	2/29/08	Only ran 210 minutes.
16 – Pre Changeout	1/15/07	1-second averages instead of 1-minute – ran 533 minutes.
1 - Post Changeout	2/5/09-2/6/09	No fire built on 2/5/09
2 - Post Changeout	2/2/09–2/4/09	Pitch on stove was causing lots of smoke.
5 - Post Changeout	2/9/09	Only ran 619 minutes.
6 - Post Changeout	1/30/09–2/1/09	Homeowner was not using stove correctly.
11 - Post Changeout	3/17/08–3/19/08	Homeowner was not using stove correctly. Leaving the door open.
13 - Post Changeout	1/22/09-1/23/09	Homeowner had not yet cleaned the chimney.
14-Post Changeout	2/24/09-2/26/09	Did not use their woodstove.
14 – Post Changeout	3/5/2009	Only ran 257 minutes.
16 – Post Changeout	1/13/09-1/15/09	No data recorded.
16-Post Changeout	2/18/09-2/19/09	Woodstove not used on this sample day.

Quartz filter (Leland/PEM) samples that were excluded from the overall dataset.

Home	Sample Date	Reason
7 – Pre Changeout	2/19/08-2/20/08	From Datasheet: "Put two filters into the PEM"
8 – Pre Changeout	1/22/07	From Datasheet: "Battery died"
8 – Pre Changeout	1/23/07	From Datasheet: "Pump died"
11 – Pre Changeout	2/5/07-2/6/07	Initial and final flows too low.
11 – Pre Changeout	2/7/07-2/8/07	Initial and final flows too low.
16 – Pre Changeout	1/31/07-2/1/07	No final flow rate or Leland final flow rate recorded.
6 – Post Changeout	2/26/09-2/27/09	No final sample time recorded.
11 – Post Changeout	3/18/08-3/19/08	No final sample time recorded.
14 – Post Changeout	3/18/08-3/19/08	No final sample time recorded.

Appendix B

DustTrak Sampler Data: Pre Changeout Sample Runs

Home	Start Date	Start Time	End Date	End Time	Total sample time (min)	Logging Interval (sec)	Avg. PM 2.5 (mg/m3)	Min PM2.5 (mg/m3)	Date Min	Time Min	Max PM 2.5 (mg/m3)	Date Max	Time Max	DustTrak zeroed	Notes
1	11/27/2007	9:04	11/29/2007	9:04	2880	60	0.12	0.007	11/27/2007	11:15	1.844	11/27/2007	12:16	yes	Ok
	11/29/2007	9:37	11/30/2007	9:37	1440	60	0.022	0.008	11/29/2007	15:20	0.16	11/30/2007	4:25	yes	Ok
2	11/19/2007	9:34	11/21/2007	9:34	2880	60	0.021	0.005	11/19/2007	9:35	0.165	11/20/2007	17:33	yes	Ok
3	12/3/2007	9:44	12/6/2007	9:44	4320	60	0.019	0.004	12/5/2007	6:16	0.254	12/5/2007	9:52	yes	Ok
4	1/8/2008	19:09	1/10/2008	19:09	2880	60	0.01	0.001	1/9/2008	13:44	0.05	1/10/2008	11:08	yes	Ok
5	1/14/2008	13:45	1/16/2008	13:45	2880	60	0.008	0	1/14/2008	13:46	0.087	1/14/2008	13:47	yes	Ok
6	1/29/2007	14:09	1/31/2007	14:09	2880	60	0.05	0.011	1/31/2007	6:54	0.573	1/30/2007	14:29	yes	H3-1 and 2 Lapwai? – ok
	1/31/2007	14:50	2/2/2007	14:47	2877	60	0.035	0.007	2/2/2007	3:33	0.377	2/1/2007	16:10	yes	H3-3 and 4 Lapwai?, H3-C.Guzman_2[1] – ok
7	2/18/2008	9:45	2/20/2008	9:45	2880	60	0.043	0.004	2/19/2008	12:32	2.037	2/18/2008	17:08	yes	Ok
	3/18/2008	15:30	3/19/2008	15:30	1440	60	0.032	0.003	3/18/2008	15:30	0.318	3/18/2008	20:09	yes	Ok
8	1/22/2007	13:14	1/24/2007	13:14	2880	60	0.026	0.003	1/24/2007	6:42	0.602	1/23/2007	16:50	yes	H1, sample 1 and 2? – ok
	3/5/2007	15:44	3/7/2007	15:44	2880	60	0.079	0.005	3/5/2007	17:35	4.03	3/6/2007	20:02	yes	H1, sample 3 and 4? – ok
9	1/24/2007	14:35	1/26/2007	14:35	2880	60	0.045	0.003	1/25/2007	13:40	1.44	1/24/2007	16:45	yes	Ok
10	12/11/2007	16:29	12/14/2007	16:37	4328	60	0.071	0.016	12/12/2007	1:56	2.772	12/12/2007	17:20	yes	Ran for 3 days – ok
11	12/20/2006	14:07	12/20/2006	23:05	533	1									do not use - 1 second averages.
	1/8/2007	10:11	1/8/2007											yes	no data

	1/9/2007	12:40		12:50											no data
	1/10/2007	13:07													no data
	1/9/2007	12:56	1/9/2007	21:49	533	1	0.007	0.001	1/9/2007	21:02	0.564	1/9/2007	21:22	yes	
	,	13:07													Incomplete data set
	2/5/2007	9:40	2/7/2007	9:40	2880	60	0.016	0.004	2/6/2007	16:40	0.2	2/7/2007	9:38	yes	need to check file - can't find file, assume OK.
	2/7/2007	19:40	2/7/2007	20:09	29	60	0.015	0.012	2/7/2007	19:49	0.3	2/7/2007	20:09	yes	no datasheet - do not use - time is 29 min.
	2/8/2007	12:29	2/9/2007	12:29	1440	60	0.01	0.004	2/8/2007	15:54	0.064	2/9/2007	9:45	yes	no datasheet - can't find file - assume OK.
12	1/8/2008	10:00	1/9/2008	10:00											no datasheet
	1/16/2008	18:59	1/17/2008	11:26	987	60	0.023	0.016	1/16/2008	19:00	0.122	1/16/2008	20:47		no datasheet, only ran 987 minutes.
	1/19/2008	13:02	1/19/2008	21:38	516	1	0.029	0.016	1/19/2008	20:49	4.401	1/19/2008	15:12		no datasheet, don't use - 1 sec averages, ran for 516 minutes.
	1/28/2008	17:29	1/29/2008	17:29	1440	60	0.027	0.012	1/29/2008	15:32	0.29	1/28/2008	22:29	yes	Ok
	3/20/2008	19:59	3/22/2008	19:59	2880	60	0.007	0.002	3/22/2008	18:43	0.035	3/20/2008	20:20	yes	Ok
13	12/5/2007	16:29	12/6/2007	0:25	476	60	0.037	0.012	12/5/2007	23:58	0.104	12/5/2007	17:29	yes	
	12/11/2007	16:29	12/14/2007	16:37	4328	60	0.071	0.016	12/12/2007	1:56	2.772	12/12/2007	17:20	yes	
	2/26/2008	17:59	2/28/2008	17:59	2880	60	0.013	0.004	2/28/2008	15:51	0.038	2/27/2008	18:21	yes	Ok
14	1/29/2008	19:29	1/29/2008	19:30	1	60	0.012	0.012	1/29/2008	19:30	0.012	1/29/2008	19:30		no datasheet - don't use - only 1 minute sample.
	2/29/2008	11:34	2/29/2008	15:04	210	60	0.005	0.004	2/29/2008	12:13	0.007	2/29/2008	11:46		no datasheet - only ran 210 minutes - do not use.
	2/29/2008	18:59	3/2/2008	18:59	2880	60	0.036	0.006	3/1/2008	8:04	1.717	3/1/2008	17:48	yes	Ok
15	3/3/2008	16:59	3/5/2008	16:59	2880	60	0.022	0.002	3/4/2008	6:30	0.278	3/4/2008	16:26	yes	Ok
16	1/15/2007	12:33	1/15/2007	21:27	533	1	0.449	0.052	1/15/2007	15:31	3.434	1/15/2007	14:38	yes	no datasheet - 1 sec averages – do not use.
	1/16/2007	13:29	1/17/2007	13:29	1448	60	0.154	0.072	1/16/2007	21:29	0.585	1/16/2007	16:29	yes	no datasheet or file- assume OK.
	1/30/2007	9:10	2/1/2007	9:10	2880	60	0.192	0	1/30/2007	9:10	0.465	1/31/2007	15:53	yes	From datasheet: "She had a pot of orange peels, cloves, and cinnamon on the woodstove." - ok - no file.
	2/1/2007	10:20	2/3/2007	10:20	2880	60	0.201	0.017	2/2/2007	12:23	0.91	2/1/2007	18:24	yes	Ok

DustTrak Sampler Data: Post Changeout Sample Runs

Home	Start Date	Start Time	End Date	End Time	Total sample time (min)	Logging Interval (sec)	Avg. PM 2.5 (mg/m3)	Min PM2.5 (mg/m3)	Date Min	Time Min	Max PM 2.5 (mg/m3)	Date Max	Time Max	DustTrak zeroed	Notes
1	2/4/2009	10:55	2/6/2009	10:55	2880	60	0.033	0.007	2/5/2009	5:09	0.303	2/5/2009	12:29	yes	Ok
	3/11/2009	10:55	3/13/2009	10:55	2880	60	0.037	0.004	3/12/2009	17:39	1.716	3/11/2009	14:03	yes	Ok
2	2/2/2009	9:50	2/4/2009	9:50	2880	60	0.323	0.012	2/4/2009	9:35	3.808	2/2/2009	19:58	yes	From datasheet: "Pitch burnt on to top of stove." - not ok
	3/4/2009	9:14	3/6/2009	9:14	2880	60	0.058	0.002	3/5/2009	7:10	0.77	3/4/2009	20:55	yes	Ok
3	1/26/2009	13:40	1/28/2009	13:40	2880	60	0.014	0.003	1/28/2009	2:02	0.374	1/27/2009	9:38	yes	From datasheet: "Power outage early Tuesday (1/27/09)." – ok
4	12/19/2008	10:24	12/21/2008	10:24	2880	60	0.02	0.004	12/21/2008	4:23	0.228	12/21/2008	6:03	yes	Ok
5	2/9/2009	12:29	2/9/2009	22:48	619	60	0.034	0.005	2/9/2009	20:56	0.157	2/9/2009	13:04	yes	From datasheet: "Returned to house and found DustTrak turned off. Saved test and set back up." - run only 619 minutes.
	2/10/2009	12:50	2/11/2009	12:50	1440	60	0.049	0.002	2/11/2009	6:11	0.719	2/10/2009	19:19	yes	Ok
6	1/30/2008	13:59	2/1/2008	13:59	2880	60	0.063	0.003	2/1/2008	6:50	2.302	2/1/2008	13:37	yes	From datasheet: "Homeowner was having problems operating the stoves. Smoke spilling out into room." – ok
	2/26/2009	10:59	2/28/2009	2:30	2371	60	0.017	0.003	2/26/2009	16:11	0.242	2/27/2009	20:54	yes	From datasheet: "Homeowner said power was accidentally turned off early Saturday (2/28/09) morning." - almost a full 48 hours.
7	1/28/2009	14:39	1/30/2009	14:39	2880	60	0.018	0.002	1/30/2009	3:25	0.166	1/28/2009	20:13	yes	Ok
8	2/11/2008	13:24	2/13/2008	13:24	2880	60	0.018	0.003	2/13/2008	5:35	0.187	2/12/2008	21:36	yes	ok - says D. Henry on datasheet, but correct address.
9	12/29/2008	12:24	12/31/2008	12:24	2880	60	0.014	0	12/30/2008	3:05	0.538	12/29/2008	19:05	yes	Ok

	2/23/2009	10:29	2/25/2009	10:29	2880	60	0.127	0.002	2/24/2009	17:35	4.141	2/23/2009	12:49	yes	Ok
10	1/28/2009	18:40	1/30/2009	18:40	2880	60	0.033	0.004	1/29/2009	15:39	0.365	1/30/2009	10:03	yes	Ok
11	3/17/2008	18:59	3/19/2008	18:59	2880	60	0.126	0.004	3/17/2008	19:02	2.781	3/19/2008	12:26	yes	From datasheet: "May 7' 08: Johna Boulafentis: Kayla told me that Julie keeps her door cracked throughout most of the day. When she loads in the morning she keeps the door cracked and during the afternoon because the kids say that it's too hot inside." – ok
	1/26/2009	10:40	1/28/2009	10:40	2880	60	0.012	0.002	1/27/2009	7:38	0.114	1/27/2009	8:09	yes	Ok
12	2/19/2009	14:29	2/21/2009	14:29	2880	60	0.01	0.003	2/20/2009	16:01	0.052	2/21/2009	7:49	yes	Ok
13	1/22/2009	16:30	1/23/2009	16:14	1425	60	2.412	0.027	1/23/2009	16:08	7.819	1/22/2009	17:04	yes	From datasheet: "I don't know why it only ran for 23:45 because when I checked it was running fine." - ran for only one day.
	2/12/2009	17:59	2/14/2009	17:59	2880	60	0.012	0.001	2/14/2009	17:43	0.175	2/13/2009	16:32		no datasheet, but there is a DustTrak file - ok.
14	2/24/2009	10:59	2/26/2009	9:43	2804	60	0.065	0.006	2/26/2009	5:53	0.407	2/25/2009	13:39		no datasheet, but there is a DustTrak file - ok. - did run 76 minutes short.
	3/5/2009	12:29	3/5/2009	16:46	257	60	0.11	0.002	3/5/2009	12:30	0.204	3/5/2009	13:17		no datasheet, but there is a DustTrak file - ran for only 257 minutes - not good.
15	2/10/2009	12:58	2/12/2009	12:58	2880	60	0.019	0.002	2/10/2009	17:24	0.074	2/12/2009	10:50	yes	Ok
16	1/13/2009	11:10	1/15/2009	11:10											From datasheet: "Yes, the batteries were going out, but it was running fine until I unplugged it. Also, there was no data on the Dk."
	2/17/2009	11:29	2/19/2009	11:29	2880	60	0.153	0.032	2/19/2009	8:17	0.838	2/17/2009	11:32		no datasheet, but there is a DustTrak file - ok.

Leland/PEM Sampler Data: Pre Changeout Sample Runs

Home	Start Date	Start Time	End Date	End Time	Initial Measured Flow Rate (LPM)	Final Measured Flow Rate (LPM)	Avg Calc Measured Flow Rate (LPM)	Avg Flow Rate From Leland (LPM)	Total Time from Leland (min)	Total Calc Measured Volume (m^3)	Total Volume, from Leland (L)	Notes
1	11/27/2007	9:05	11/28/2007	9:05	9.929	9.785	9.857	10	1440	14.19	14400	Ok
	11/28/2007	9:25	11/29/2007	9:25	9.905	9.884	9.895	10	1440	14.25	14400	Ok
	11/29/2007	9:20	11/30/2007	9:20	10.03	9.989	10.010	10	1440	14.41	14400	Ok
2	11/19/2007	9:35	11/20/2007	9:35	9.99	9.531	9.761	10	1440	14.06	14400	Ok
	11/20/2007	9:40	11/21/2007	9:40	9.83	10.13	9.980	10	1440	14.37	14400	Ok
3	12/3/2007	9:50	12/4/2007	9:50	9.99	9.53	9.760	10	1440	14.06	14400	Ok
	12/4/2007	10:15	12/5/2007	10:15	10.04	9.98	10.010	10	1440	14.41	14400	Ok
	12/5/2007	10:35	12/6/2007	10:35	9.745	9.42	9.583	10	1440	13.80	14400	Ok
4	1/8/2008	19:15	1/9/2008	19:15	9.738	9.33	9.534	10	1440	13.73	14400	Ok
	1/9/2008	19:30	1/10/2008	19:30	9.53	9.989	9.760	10	1440	14.05	14400	Ok
5	1/14/2008	13:45	1/15/2008	13:45	10.01	9.89	9.950	10	1440	14.33	14400	Ok
	1/15/2008	14:00	1/16/2008	14:00	9.956	10.68	10.318	10	1440	14.86	14400	Ok
6	1/29/2007		1/30/2007									No sample collected
	1/30/2007		1/31/2007									No sample collected
	1/31/2007	14:10	2/1/2007	14:10	9.515	9.197	9.356	11.5	1440	13.47	16560	H3-S1 or H3_3?
	2/1/2007	14:25	2/2/2007	14:25	9.197	9.021	9.109	11.5	1440	13.12	16560	H3-S2 or H3_4?
7	2/18/2008	9:45	2/19/2008	9:45	10.008	9.982	9.995	10	1440	14.39	14400	Ok
	2/19/2008	9:55	2/20/2008		9.863	8.649	9.256	10	823	7.62	6161	Put 2 filters into the PEM- bad sample – not OK.
	3/18/2008	14:20	3/19/2008	14:20	10.035	9.971	10.003	10	1440	14.40	14400	Ok
8	1/22/2007	13:15	1/23/2007		10.04		10.040	9.5			12883	Battery died - bad sample - not OK.
	1/23/2007		1/24/2007									Pump died - bad sample - not OK.

	3/5/2007	15:30	3/6/2007	15:30	8.41	8.371	8.391	12	1440	12.08	17014	From datasheet, may be H1-4 or H1-3. – ok
	3/6/2007		3/7/2007									No sample collected
9	1/24/2007		1/25/2007									No sample collected
	1/25/2007		1/26/2007									No sample collected
10	12/12/2007	15:16	12/13/2007	15:16	10.02	9.873	9.947	10	1440	14.32	14400	No total sample time, or final time. Can't tell if ran 1440. Assume OK.
	12/13/2007	17:18	12/14/2007	17:18	10.01	9.556	9.783	10	1440	14.09	14400	Ok
11	12/20/2006	14:07	12/21/2006	14:07	10.02	9.463	9.742	10.7	1440	14.03	15408	Ok
	1/8/2007	10:00	1/9/2007	10:00	11.5	9.44	10.470	11.5	1440	15.08		Ok
	1/9/2007	12:50	1/10/2007	12:50					1440			Bad sample - not OK.
	1/10/2007	13:06	1/11/2007	13:06					1440			Bad sample - not OK.
	2/5/2007	9:15	2/6/2007	9:15	8.684	6.854	7.769	11.6	1440	11.19	16704	Flow too low - not OK.
	2/6/2007	9:22	2/7/2007	9:22	9.684	8.761	9.223	11.1	1440	13.28	15984	Ok
	2/7/2007	9:44	2/8/2007	9:44	7.083	9.717	8.400	11.1	1440	12.10	15984	Flow too low - not OK.
	2/8/2007	10:11	2/9/2007	10:11	9.992	9.901	9.947	11.1	1440	14.32	15984	Ok
12	1/8/2008	16:35	1/9/2008	16:35	10.01	9.436	9.723	10	1440	14.00	14400	Ok
	1/28/2008	17:30	1/29/2008	17:30	10.03	9.481	9.756	10	1440	14.05	14400	Ok
13	2/26/2008	17:50	2/27/2008	17:51	10.01	9.6	9.805	10	1441	14.13	14410	Ok
	2/27/2008	18:40	2/28/2008	18:19	9.99	9.68	9.835	10	1419	13.96	14194	Ok
14	2/29/2008	18:05	3/1/2008	18:05	9.991	9	9.496	10	1440	13.67	14400	Ok
	3/1/2008	18:10	3/2/2008	18:10	10.02	8.92	9.470	10	1440	13.64	14400	Ok
15	3/3/2008	16:30	3/4/2008	16:30	10	8.67	9.335	10	1440	13.44	14400	Ok
	3/4/2008	17:23	3/5/2008	17:23	9.99	8.93	9.460	10	1440	13.62	14400	Ok
16	1/15/2007	12:31	1/16/2007	12:31	10.01	10.01	10.010	10.7	1440	14.41		Ok
	1/16/2007											No datasheet

	1/31/2007	9:03	2/1/2007	9:03	9.408		9.408	11.4	1440	13.55		No final flow rate - cannot use.
	2/1/2007	10:12	2/2/2007	10:12	9.389		9.389	11.6	1440	13.52	14365	No final flow rate, but Leland total volume looks OK.
	2/2/2007	12:12	2/3/2007	12:12	8.164	9.339	8.752	11.6	1440	12.60	16704	Initial flow very low - still use? – OK
15	3/3/2008	16:30	3/4/2008	16:30	10	8.67	9.335	10	1440	13.44	14400	Ok
	3/4/2008	17:23	3/5/2008	17:23	9.99	8.93	9.460	10	1440	13.62	14400	Ok
16	1/15/2007	12:31	1/16/2007	12:31	10.01	10.01	10.010	10.7	1440	14.41		Ok
	1/16/2007											No datasheet

Leland/PEM Sampler Data: Post Changeout Sample Runs

Home	Start Date	Start Time	End Date	End Time	Initial Measured Flow Rate (LPM)	Final Measured Flow Rate (LPM)	Avg Calc Measured Flow Rate (LPM)	Avg Flow Rate From Leland (LPM)	Total Time from Leland (min)	Total Calc Measured Volume (m^3)	Total Volume, from Leland (L)	Notes
1	2/4/2009	10:50	2/5/2009	10:50	10.022	10.076	10.049	10	1440	14.47	14400	Ok
	2/5/2009	11:16	2/6/2009	11:16	10.068	9.648	9.858	10	1440	14.20	14400	Ok
2	2/2/2009	9:43	2/3/2009	9:43	10.047	10.149	10.098	10	1440	14.54	14400	From datasheet: "Pitch burnt on to stove". - will need to take out for final calcs.
	2/3/2009	9:57	2/4/2009	9:57	9.986	10.208	10.097	10	1440	14.54	14400	From datasheet: "Pitch burnt on to stove". - will need to take out for final calcs.
	3/4/2009	9:15	3/5/2009	9:15	10.013		10.013	10	1440	14.42	14400	No final flow, but Leland volume looks OK.- assume OK.
	3/5/2009	9:30	3/6/2009	9:30	9.768	9.51	9.639	10	1440	13.88	14400	Ok
3	1/26/2009	13:30	1/27/2009	13:30	10.024	9.646	9.835	10	1440	14.16	14400	From datasheet: "Power outage early Tuesday (1/27/09) morning". - OK
	1/27/2009	13:50	1/28/2009	13:50	10.013	9.883	9.948	10	1440	14.33	14400	Ok
4	12/19/2008	10:24	12/20/2008	10:24	10.105	9.185	9.645	10	1440	13.89	14400	From datasheet: "Had problems getting final flow rate. Only sampled w/ Leland for 24 hours."
5	2/9/2009	12:10	2/10/2009	12:10	10.072	9.77	9.921	10	1440	14.29	14400	Ok
	2/10/2009	12:45	2/11/2009	12:45	9.927	9.88	9.904	10	1440	14.26	14400	Ok

6	1/30/2008	13:50	1/31/2008	13:50	9.952	9.721	9.837	10	1440	14.16	14400	From datasheet: "Homeowner said stove was spitting smoke back into room."
	1/31/2008	14:05	2/1/2008	14:05	9.998	10.153	10.076	10	1440	14.51	14400	Ok
	2/26/2009	11:00			10.089	10.182	10.136	10	1440			Tui named this sample Post 1 - no final sample time info - cannot use - not OK
	2/27/2009	11:10	2/28/2009	11:10	10.011	9.579	9.795	10	1440	14.10	14400	Tui named this sample Post – OK
7	1/28/2009	14:30	1/29/2009	14:30	10.013	9.907	9.960	10	1440	14.34	14400	Ok
	1/29/2009	14:48	1/30/2009	14:48	9.969	9.754	9.862	10	1440	14.20	14400	Ok
8	2/11/2008	13:15			10.002	9.679	9.841	10	1440	14.17	14400	No final flow, but Leland volume looks OK.- assume OK.
	2/12/2008	13:20	2/13/2008	13:20	9.917	10.81	10.364	10	1440	14.92	14400	Ok
9	12/29/2008	12:20	12/30/2008	12:20	10.005	10.35	10.178	10	1440	14.66	14400	Ok
	12/30/2008	12:50	12/31/2008	12:50	10.061	9.926	9.994	10	1440	14.39	14400	Ok
	2/23/2009	10:20	2/24/2009	10:20	10.01	9.756	9.883	10	1440	14.23	14400	Tui named this sample Post 2 - OK.
10	1/28/2009	19:05	1/29/2009	19:05	9.949	9.403	9.676	10	1440	13.93	14400	Ok
	1/29/2009	19:25	1/30/2009	19:25	9.99	9.651	9.821	10	1440	14.14	14400	Kayla named this sample Post 1 - ok.
11	3/17/2008	18:03	3/18/2008	18:03	9.99	9.87	9.930	10	1440	14.30	14400	Ok
	3/18/2008		3/19/2008		10.01		10.010	10			14400	no final flow or final time info - do not use.
	1/26/2009	10:40	1/27/2009	10:40	10	9.509	9.755	10	1440	14.05	14400	Kayla named this sample Post 2 / She keeps her woodstove door cracked - ok.
	1/27/2009	11:03	1/28/2009	11:03	9.902	9.301	9.602	10	1440	13.83	14400	Kayla named this sample Post 2 / She keeps her woodstove door cracked - ok.
12	2/19/2009	13:30	2/20/2009	13:30	9.93	9.35	9.640	10	1440	13.88	14400	Ok
	2/20/2009	18:00	2/21/2009	18:00	10	9.653	9.827	10	1440	14.15	14400	Ok
13	1/22/2009	16:20	1/23/2009	16:20	10	9.53	9.765	10	1440	14.06	14400	Ok
	1/23/2009	16:45	1/24/2009	16:45	9.966	9.912	9.939	10	1440	14.31	14400	Kayla named this sample Post 1 - ok
14	2/24/2009	10:35	2/25/2009	10:35	10.01	9.65	9.830	10	1440	14.16	14400	Ok
	2/25/2009		2/26/2009		10.02		10.020	10	1440	14.43	14400	No start / stop time, and no final flow - can't use.

15	2/10/2009	13:30	2/11/2009	13:30	9.9	9.51	9.705	10	1440	13.98	14400	Ok
	2/11/2009	13:50	2/12/2009	13:50	9.95	9.568	9.759	10	1440	14.05	14400	Kayla named this sample Post 1 – ok
16	1/13/2009	11:10	1/14/2009	11:10	9.9	9.565	9.733	10	1440	14.01	14400	Ok
	1/14/2009	11:20	1/15/2009	11:20	9.9	9.5	9.700	10	1440	13.97	14400	Kayla named this sample Post 1 – ok
	2/17/2009	11:12	2/18/2009	11:12	9.945	9.306	9.626	10	1440	13.86	14400	Kayla named this sample Post 2 – ok
	2/18/2009	11:24	2/19/2009	11:24	9.96	9.5	9.730	10	1440	14.01	14400	Kayla named this sample Post 2 – ok

Appendix C

Individual Home and Ambient $PM_{2.5}$ Results ($\mu g/m^3$) – Mass Only

Home	Ambient $PM_{2.5}$ (24-hr Average)	Indoor Average $PM_{2.5}$	Indoor Minimum $PM_{2.5}$	Indoor Maximum $PM_{2.5}$		Home	Ambient $PM_{2.5}$ (24-hr Average)	Indoor Average $PM_{2.5}$	Indoor Minimum $PM_{2.5}$	Indoor Maximum $PM_{2.5}$
1 –Pre	4.1	87.0	8.3	1205.3		**9 –Pre**	3.3	44.8	3.0	803.5
1 –Post	2.3	30.1	6.3	607.7		**9 –Post**	1.4	70.3	2.0	1235.8
Difference	**NA**	**-65%**	**-24%**	**-50%**		**Difference**	**NA**	**+57%**	**-33%**	**+54%**
2 –Pre	6.3	20.8	6.5	108.5		**10 –Pre**	14.5	70.7	20.3	1246.7
2 –Post	1.1	58.2	2.5	535.0		**10 –Post**	8.1	32.5	4.0	233.5
Difference	**NA**	**+180%**	**-62%**	**+393%**		**Difference**	**NA**	**-54%**	**-80%**	**-81%**
3 –Pre	2.5	19.0	4.0	254.0		**11 –Pre**	6.4	14.0	4.0	154.7
3 –Post	4.0	14.3	3.5	218.0		**11 –Post**	7.6	12.1	4.0	95.0
Difference	**NA**	**-25%**	**-13%**	**-14%**		**Difference**	**NA**	**-14%**	**No Change**	**-39%**
4 –Pre	1.9	10.2	2.0	36.0		**12 –Pre**	3.3	13.8	6.3	110.7
4 –Post	5.6	19.8	5.0	175.5		**12 –Post**	5.1	10.1	3.5	43.5
Difference	**NA**	**+95%**	**+150%**	**+388%**		**Difference**	**NA**	**-27%**	**-45%**	**-61%**
5 –Pre	1.8	8.2	1.5	68.5		**13 –Pre**	9.9	47.9	11.6	1676.4
5 –Post	2.0	49.0	2.0	719.0		**13 –Post**	7.0	12.0	1.5	110.0
Difference	**NA**	**+494%**	**+33%**	**+950%**		**Difference**	**NA**	**-75%**	**-87%**	**-93%**
6 –Pre	2.7	42.4	10.3	437.5		**14 –Pre**	3.6	35.7	7.5	964.0
6 –Post	1.9	18.4	3.5	157.5		**14 –Post**	No Data	No Data	No Data	No Data
Difference	**NA**	**-57%**	**-66%**	**-64%**		**Difference**	**NA**	**NA**	**NA**	**NA**
7 –Pre	3.3	39.2	4.0	1350.0		**15 –Pre**	3.9	21.6	3.0	186.0
7 –Post	2.5	18.3	3.0	102.0		**15 –Post**	5.5	19.0	2.0	74.0
Difference	**NA**	**-53%**	**-25%**	**-92%**		**Difference**	**NA**	**-12%**	**-33%**	**-60%**
8 –Pre	3.0	52.1	4.5	1278.8		**16 –Pre**	7.6	188.0	21.2	667.0
8 –Post	1.2	18.4	4.0	145.0		**16 –Post**	5.1	197.4	48.0	838.0
Difference	**NA**	**-65%**	**-11%**	**-89%**		**Difference**	**NA**	**+5%**	**+126%**	**+26%**

Appendix D

Individual Home $PM_{2.5}$ and OC/EC/TC Results (µg/m³) - Homes with Complete Datasets

Home	Average $PM_{2.5}$ (µg/m³)	Minimum $PM_{2.5}$ (µg/m³)	Maximum $PM_{2.5}$ (µg/m³)	OC (µg/m³)	EC (µg/m³)	TC (µg/m³)
1 –Pre	87.0	8.3	1205.3	26.7	1.0	27.6
1 –Post	16.5	7.0	60.0	12.4	0.4	12.8
Difference	**-81%**	**-16%**	**-95%**	**-53%**	**-59%**	**-54%**
2 –Pre	20.8	6.5	108.5	9.8	0.3	10.2
2 –Post	58.2	2.5	535.0	31.4	0.7	32.1
Difference	**+180%**	**-62%**	**+393%**	**+219%**	**+98%**	**+216%**
3 –Pre	19.0	4.0	254.0	11.7	0.2	11.9
3 –Post	14.3	3.5	218.0	14.9	1.3	16.2
Difference	**-25%**	**-13%**	**-14%**	**+27%**	**+565%**	**+36%**
4 –Pre	10.2	2.0	36.0	16.9	0.3	17.2
4 –Post	15.0	6.0	123.0	13.4	0.6	14.0
Difference	**+48%**	**+200%**	**+242%**	**-21%**	**+107%**	**-19%**
5 –Pre	8.2	1.5	68.5	10.1	0.02	10.1
5 –Post	49.0	2.0	719.0	23.1	0.7	23.8
Difference	**+494%**	**+33%**	**+950%**	**+129%**	**+4282%**	**+136%**
7 –Pre	52.4	5.0	2037.0	17.0	1.3	18.3
7 –Post	18.3	3.0	102.0	12.3	1.0	13.3
Difference	**-65%**	**-40%**	**-95%**	**-28%**	**-24%**	**-27%**
8 –Pre	47.7	5.0	440.0	34.1	0.2	34.3
8 –Post	18.4	4.0	145.0	10.5	0.1	10.6
Difference	**-61%**	**-20%**	**-67%**	**-69%**	**-55%**	**-69%**
10 –Pre	92.9	22.5	1841.5	28.7	0.5	29.2
10 –Post	32.5	4.0	233.5	8.6	0.8	9.4
Difference	**-65%**	**-82%**	**-87%**	**-70%**	**+77%**	**-68%**

11 –Pre	16.0	4.0	200.0	8.8	0.4	9.1
11 –Post	12.1	4.0	95.0	10.4	0.8	11.1
Difference	**-25%**	**No Change**	**-53%**	**+18%**	**+100%**	**+22%**
15 –Pre	21.6	3.0	186.0	13.9	0.04	13.9
15 –Post	19.0	2.0	74.0	16.9	0.4	17.3
Difference	**-12%**	**-33%**	**-60%**	**+22%**	**+1134%**	**+25%**
16 –Pre	201.0	17.0	910.0	60.2	0.9	61.1
16 –Post	197.4	48.0	838.0	44.7	1.7	46.3
Difference	**-2%**	**+182%**	**-8%**	**-26%**	**+77%**	**-24%**

Note that the following homes did not have matched pairs: 6, 9, 12, 13, and 14.

Individual Home Chemical Markers of Woodsmoke Results (ng/m^3) - Homes with Complete Datasets

Home	Levoglucosan	Dehydroabietic acid	Abietic acid	Vanillin	Acetovanillone	Guaiacol	4-Ethylguaiacol
1 –Pre	4707.1	0.3	162.8	0.5	0.3	0.9	1.2
1 –Post	294.7	0.3	0.3	0.5	0.3	0.02	0.1
Difference	**-94%**	**No Change**	**-100%**	**No Change**	**No Change**	**-98%**	**-96%**
2 –Pre	963.5	334.6	84.9	0.5	0.3	0.7	1.4
2 –Post	344.0	0.3	18.0	14.9	0.3	0.3	0.1
Difference	**-64%**	**-100%**	**-79%**	**+3212%**	**No Change**	**-60%**	**-97%**
3 –Pre	585.6	113.0	66.9	5.3	21.6	293.7	0.4
3 –Post	136.2	0.3	41.5	0.5	0.3	0.2	0.3
Difference	**-77%**	**-100%**	**-38%**	**-92%**	**-99%**	**-100%**	**-19%**
4 –Pre	876.7	162.0	4.1	2.8	22.8	559.7	0.1
4 –Post	3.9	0.3	0.3	0.5	0.3	0.1	0.1
Difference	**-100%**	**-100%**	**-94%**	**-84%**	**-99%**	**-100%**	**-39%**
5 –Pre	647.8	158.2	5.9	6.9	13.2	555.6	0.2
5 –Post	176.2	0.3	41.6	0.5	0.3	1.2	0.1
Difference	**-73%**	**-100%**	**+607%**	**-94%**	**-98%**	**-100%**	**-76%**
7 –Pre	1609.3	532.0	395.5	0.5	0.3	0.9	2.0

7 –Post	310.9	16.8	55.3	0.5	0.3	0.8	0.2
Difference	**-81%**	**-97%**	**-86%**	**No Change**	**No Change**	**-13%**	**-90%**
8 –Pre	3.9	88.6	4.7	0.5	0.3	No Data	No Data
8 –Post	3.9	16.8	0.3	0.5	0.3	0.6	1.4
Difference	**No Change**	**-81%**	**-95%**	**No Change**	**No Change**	**-------**	**-------**
10 –Pre	382.0	100.2	112.7	0.5	0.3	0.7	0.5
10 –Post	807.5	33.5	46.8	0.5	0.3	0.02	0.1
Difference	**111%**	**-67%**	**-58%**	**No Change**	**No Change**	**-98%**	**-86%**
11 –Pre	379.5	133.6	11.3	0.5	0.3	No Data	No Data
11 –Post	125.7	98.1	123.8	0.5	0.3	0.8	0.4
Difference	**-67%**	**-27%**	**+994%**	**No Change**	**No Change**	**-------**	**-------**
15 –Pre	3.9	63.5	0.3	0.5	0.3	0.02	1.8
15 –Post	238.1	92.4	86.9	0.5	0.3	1.0	0.2
Difference	**+6084%**	**+45%**	**+34670%**	**No Change**	**No Change**	**+6435%**	**-89%**
16 –Pre	645.1	105.0	7.9	0.5	0.3	No Data	No Data
16 –Post	971.9	0.3	0.3	0.5	0.3	0.3	0.1
Difference	**+51%**	**-100%**	**-97%**	**No Change**	**No Change**	**-------**	**-------**

Note that the following homes did not have matched pairs: 6, 9, 12, 13, and 14.