HEALTHY HOMES IN ALASKA

Final Report

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Two agencies that took on the huge task of finding the homes, testing the homes, determining a strategy of improvement for the homes, and then implementing that strategy, proved to be the real heroes of the project, overcoming the huge logistical barriers of working and traveling in rural Alaska. These agencies are Rural Alaska Community Action Program (RCAP) that worked in Hooper Bay and Interior Weatherization (IWX) that worked in Fairbanks. Lead staff members for RCAP include Ralph Lee, Marla Tomblinson, Mert Stromire, Victor Night and Robert Reekie. Critical staff for IWX include Jim Lee, Cathy Daunias, Kathy Nichols, Rod Bogush, Charles Davis, and Tony Mora.

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Special thanks to all of our clients from Hooper bay and Fairbanks who had to put up with multiple visits from assessors, testers, inspectors, and who complied when necessary to the medical testing requirements, which often necessitated extra trips to the doctor. Most of our clients were very gracious in accommodating the time consuming activities surrounding the rehab work, and most were quite vocal about the improvements that were seen in their children's health.

Thanks also to Dale Darrow for monitoring our project while in progress and for accompanying us to Hooper Bay and Fairbanks to meet the clients and see first hand the conditions which make implementing Healthy Homes in Alaska a particularly difficult challenge, while no where is it needed more.

HUD Government Technical Representative
Alan Daly

HUD Government Technical Monitor
Dale Darrow

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ABSTRACT

The Healthy Homes Project was designed to test whether improving the indoor environmental quality of homes for children with asthma might improve their health. Only children who lived in low-income homes were eligible, and the parent or guardian of the child was required to own the home. Another goal of this project was to increase the capacity of the Low-income Weatherization Program to remove possible respiratory hazards in the homes of low-income people who have children with asthma or other upper respiratory diseases. The Healthy Homes in Alaska project was conducted in two areas in the state. Fairbanks is Alaska's second largest city and is located in the Interior. Hooper Bay is a larger bush community of 1014 residents on the Bering Sea coastline. These communities were selected because they have residents with diagnosed asthma, an involved health provider in the region, and are generally representative of conditions and housing stock throughout the state. The project provided indoor air quality assessment, health screenings of affected children, and housing remediation to selected homes. We identified and studied a total of 36 homes: 10 eligible participants in the Fairbanks area, 9 participants in Hooper Bay, and 8 and 9 control homes in Fairbanks and Hooper Bay, respectively. The remediation in the control homes consisted of the standard weatherization items such as improving insulation, replacing windows and doors, sealing air leaks, as well as providing some safety items such as smoke and CO detectors. In the participants houses the weatherization protocol was augmented by items designed to remove possible asthma triggers such as moldy window sills, bedding, or furniture. Some changes in the home were made to prevent the moisture and temperature conditions that lead to the growth of mold such as adding cloths dryers, installing shelving and bed frames to improve air circulation by the walls and floors, and installing quiet bath and kitchen fans to remove moist air from the house. Qualitatively, the clients in the healthy homes reported improved comfort and health as well as reduced energy bills. While the quantitative results of this study were based on a small number of research subjects, and asthma is a disease with multiple causes, there are some interesting suggestive results: (1) It is possible that the homes of children with asthma have higher levels of indoor air pollution than the homes of similar people without asthma; and (2) The remediation may have helped to improve the pulmonary function tests and the IgE levels of asthmatic children, although the numbers were not sufficient to reach statistical significance.

EXECUTIVE SUMMARY

Introduction

The Healthy Homes Project was designed to test whether improving the indoor air quality of homes for children with asthma might improve their health. Only children who lived in low-income homes were eligible, and the parent or guardian of the child was required to own the home. The low-income standards were set to meet both the requirements of the Healthy Homes and the Low-income Weatherization programs.

Another goal of this project was to increase the capacity of the Low-income Weatherization Program to remove possible respiratory hazards in the homes of low-income people who have children (ages 5-17) with asthma or other upper respiratory diseases. This goal was accomplished by training the workers in the weatherization programs and subcontractors of the program in the techniques adopted to meet the goals of reducing the sources of poor indoor air quality.

The Healthy Homes in Alaska project was awarded to the Alaska Housing Finance Corporation with the Cold Climate Housing Research Center serving as the project manager. The main remediation work in the selected homes was carried out by two of the Weatherization contractors in Alaska: RurAL CAP for the work in Hooper Bay and Interior Weatherization, Inc for Fairbanks. The medical protocol and analysis was designed and carried out by Dr. Mary Ellen Gordian of the Institute for Circumpolar Health at the University of Alaska Anchorage and Dr. Tim Foote of the Tanana Valley Clinic in Fairbanks. The indoor air sampling protocol and analysis was designed and implemented by Dr. Ron Johnson and Jack Schmid of the Institute of Northern Engineering at the University of Alaska Fairbanks.

The Healthy Homes in Alaska project was conducted in two areas in the state. Fairbanks is Alaska's second largest city and is located in the Interior. Hooper Bay is a larger bush community of 1014 residents on the Bering Sea coastline. These communities were selected because they have residents with diagnosed asthma, an involved health provider in the region, and are generally representative of conditions and housing stock throughout the state. The project provided indoor air quality assessment, health screenings of affected children, and enhanced housing remediation to selected homes. We identified and studied a total of 36 homes: 10 eligible clients in the Fairbanks area, 9 clients in Hooper Bay, and 8 and 9 control homes in Fairbanks and Hooper Bay, respectively.

The remediation in the control homes consisted of the standard weatherization items such as improving insulation, replacing windows and doors, sealing air leaks, as well as providing some safety items such as smoke and CO detectors. In the client houses the weatherization protocol was augmented by items designed to remove possible asthma triggers such as moldy windowsills, bedding, or furniture. Some changes in the home were made to prevent the moisture and temperature conditions that lead to the growth of mold such as adding cloths dryers, installing shelving and bed frames to improve air circulation by the walls and floors, and installing quiet bath and kitchen fans to remove moist air from the house.

Methodology
The hypothesis tested in this study was that by enhancing the weatherization protocol to include items designed to remove asthma triggers in the home environment, the indoor air quality could be improved and as a result the health of children living in the homes could also be improved. We wanted to test this hypothesis in both a rural and urban area of Alaska; a state where there is a high rate of respiratory disease[1,2] and where long, very cold winters lead to both a high exposure to indoor air and to building conditions that are conducive to poor indoor air quality.

We selected Hooper Bay, a relatively large village on the West coast of Alaska and Fairbanks, Alaska's second largest city in which to conduct the studies. The clients were recruited door-to-door in Hooper by and by advertising in the newspaper and on radio in Fairbanks. The clients were screened for initial eligibility by the weatherization agency and then by medical personnel for the health criteria. This medical screening constituted the pre-remediation medical exam of the children (see the IRB and medical sections for more details on the medical protocol). In addition to the client homes, 9 and 7 control homes were identified in Hooper Bay and Fairbanks, respectively. These homes were part of the regular weatherization program and received the normal workup and remediation for that program, except that before and after indoor air quality (IAQ) monitoring was done on these houses so they could be compared to the client homes. Environmental clearance was obtained for each house from HUD.

Once all the eligibility criteria were met, the client homes were monitored for pre-remediation indoor air quality using the techniques described in the IAQ testing section below. The homes were tested for temperature, relative humidity, carbon monoxide and dioxide, benzene, toluene, formaldehyde, radon, total volatile organic compounds (TVOC), and airborne particulates. Also, dust and tape lift samples were taken for mycelia and spore count analyses. A walk-through was made to determine the problems to be addressed by the remediation both for the weatherization and the healthy homes goals. A detailed remediation plan was written up for each house and it was reviewed with the homeowners, weatherization workers and subcontractors so they understood the work to be done and its relation to the energy-conservation, safety, and health goals of the project.

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[1] Karron RA, RJ Singleton, L Bulkow, A Parkinson, D Kruse, I DeSmet, C Indorf, KM Petersen, D Leombruno, D Hurlburt, M Santosham, and LH Harrison; *Severe respiratory syncytial virus disease in Alaska native children*; J Infect Dis. 1999 Jul; 180(1) 41-49.

[2] Peck AJ, RC Holman, AT Curns, JR Lingappa, JE Cheek, RJ Singleton, K Carver, and LJ Anderson; *Lower respiratory tract infections among American Indian and Alaska Native children and the general population of U.S.*; Children Pediatr Infect Dis J. 2005 Apr; 24(4) 342-351.

After the remediation was done by the weatherization agencies, the homes were retested for indoor air quality and the children were reexamined for their respiratory health condition. The intervals between IAQ tests and medical exams were quite variable and depended upon complex logistic issues. All of the homeowners received a copy of the guide to a healthy home produced by Ginny Moore as well as the regular educational materials provided by the weatherization agencies. Each client was surveyed to determine his/her level of satisfaction with the project.

Results

IAQ testing (Ron Johnson, et al, University of Alaska Fairbanks)

Following are the main results from the IAQ testing:

1) There was a general reduction in CO_2 with remediation, although it was not statistically significant.
2) There were significantly higher levels of CO_2 and RH in Hooper Bay homes compared to Fairbanks homes both before and after remediation.
3) Before remediation, Hooper Bay client homes had statistically higher RH than the control homes and Fairbanks client homes had statistically higher benzene and toluene than the control homes. After remediation, there was no significant difference between client and control IAQ in Hooper Bay or Fairbanks.
4) None of the homes tested in Fairbanks or Hooper Bay had one-week average benzene or toluene levels more than the NIOSH Recommended Exposure Limit (REL) of 100 ppb.
5) While all of the homes had average CO levels that were very low, a few had maximum one-hour or eight-hour averages that were above the outdoor air standards of 35 and 9 ppm, respectively. Only one home (a control home in Hooper Bay) had post-remediation CO levels that might have set off a CO alarm, and it is not clear what caused this one four-hour spike.
6) Thirty-seven out of 46 tests indicated 8 or 24-hour formaldehyde levels over the NIOSH REL of 16 ppb (but not over the OSHA limit of 750 ppb). In other studies we have noticed an increase in formaldehyde after occupancy, which suggests that the increase was related to materials introduced into the house by the occupants, such as furniture.

All of these data are consistent with a generally greater improvement in IAQ in client homes that started out worse than the controls. After remediation there was no significant difference between the controls and the client homes. Hooper Bay IAQ measurements are consistent with higher occupant loads and smaller houses compared to those in Fairbanks.

Remediation Work at Hooper Bay (Ralph Lee, RurAL CAP)

The houses in the Healthy Homes Alaska (HHA) portion of the project were some of the smallest homes in the village and also had the most occupants. Houses in the HHA averaged 658 square feet floor area and 4,924 cubic feet volume. This compares to the control houses that had 1,000 square feet and almost 7,100 cubic feet. The occupancy of the HHA houses averaged 7.8 people, ranging from seven to ten people. The control houses averaged 5.3 people, ranging from two to thirteen. These are all typical houses in remote rural Alaska—small with occasionally high occupant loads.

The blower door diagnostics of houses in the two portions showed that the smaller client houses had less pre-remediation air leakage than the larger control houses, but actually had slightly higher average air changes per hour. Most of the HHA houses were below recommended ventilation rates based on the high occupant loads. In almost all houses the air leakage was reduced (some quite significantly). Every house received a 50-cfm low-sone (quiet) fan to help alleviate moisture and provide ventilation.

The families all indicated much more comfortable homes with improved indoor air quality. Moisture levels appeared to be less, even though the houses were typically tighter. The families were able to maintain adequate heat in the house while using less fuel. The installation of humidistats to control the "run-time" for the exhaust fan should alleviate relying on the homeowner to turn the exhaust fan on/off when required. The ventilation fan in conjunction with the clothes dryer to control a significant portion of the moisture that used to be released inside the houses seems to have improved the IAQ.

Further research is needed to find an alternative approach to ventilation. Design goals would include: minimal (no?) maintenance, minimal mechanical system, and low operational cost.

Remediation Work in Fairbanks (Jim Lee, Interior Weatherization, Inc.)
A total of 17 homes were involved in the program: 7 control homes that received typical weatherization work and 10 client homes that were both weatherized and had additional work to improve the indoor air quality of the home. The goal of the program was to develop and implement low cost approaches to address common health concerns seen in single-family residential structures in interior Alaska. The additional work dealt with moisture, ventilation, cleanable surfaces, and filtration.

The project was separated into 4 different stages:

1. Client recruitment and education - Recruiting of qualified clients who met the income, medical and age requirements turned out more difficult than anticipated. We met our requirements in 9 of the 10 projects (priority 1). The only project that did not meet all of the requirements was a household that qualified for weatherization and had a child age 2 (not in priority-1 range of 5-17) with asthma (priority 2).

Each client (including the control homes) attended a 2-hour workshop concerning weatherization and moisture topics. The workshop covers: health and safety; moisture, condensation and mold causes and prevention; air movement and blower door operations; home maintenance; and energy upgrades that make sense. In interior Alaska, one of the main sources of mold and rot in a home is water condensing on cold surfaces. One way to prevent this condensation from occurring is to monitor relative humidity and control it from getting too high; to this end, every client who attends the workshop receives a hygro-thermometer and training on its use.

2. Assessment and scope of work - The initial inspection included diagnostic testing and visual inspection (see Volume IV for samples of the standard diagnostic testing and visual inspection forms used). The inspection was guided by finding sources and pathways of pollutants that may trigger asthma. The homes varied in size from 700 square feet to over 3,000 square feet. 60% of the homes had attached garages and each garage could be accessed directly from the living space. 40% of the homes had basements, 30% crawlspaces and the remaining 30% were elevated off the ground by piers or blocking. General pollutant sources found in homes included: attached garages, moist crawlspaces, plumbing problems, pets, dirty carpets, cleaning chemicals, smokers, condensation related mold, and exposed fiberglass insulation.

Pressure envelope and air tightness testing was key to determining if ventilation was needed or where and how much air sealing was required; 60% of the client homes were under ventilated. Every HHA home had visual mold present on inspection. Below is a table comparing the initial inspection for the 7 control homes and the 10 healthy homes.

	Control homes (total of 7)	Healthy Homes (total of 10)
Visual mold	14% (1)	100% (10)
Under ventilated per blower door targets	43% (3)	60% (6)
Indoor pets	43% (3)	40% (4)
Smokers live in home	14% (1)	50% (5)
Carpet in household	86% (6)	90% (9)
Working mechanical vent'n	71% (5)	30% (3)
Dryer ducted	71% (5)	20% (2)
Plumbing problems	0%	60% (6)
Furnace heating	71% (5)	50% (5)
Attached garage	14% (1)	60% (6)
Lead present	14% (1)	10% (1)
Condensation occurring on windows and/or doors	29% (2)	90% (9)
Humidifiers in use	0%	30% (3)

The client homes (selected for children with asthma) showed higher occurrences of mold, smokers, non-existent or inoperable ventilation systems, un-vented dryers, plumbing problems, attached garages, condensation occurring on windows and doors, and use of humidifiers.

In general, the scope of work addressed moisture and mold issues, ventilation and filtration, mitigation of indoor air quality pollution sources and installation of cleanable floor surfaces. Moisture and mold issues were addressed by installing ground vapor barriers, correcting drainage around the house, preventing condensation on pipes and toilets, repairing plumbing problems, and controlling relative humidity by installing ventilation systems.

3. Crew education - Work was completed utilizing local weatherization crews and specialized subcontractors (electrical, heating, etc.). Prior to starting work, weatherization crews attended trainings dealing with mold, ventilation, insulation and pressure diagnostics. Mold training included mold sampling, effects of mold on a person, mold growth environment and mold identification. Ventilation training included proper technique of installing bath fans and range hoods, protocols on how to test actual airflow and proper sizing of equipment. Ventilation training also included installation and testing of heat recovery ventilators (HRV). In addition to the above training, assessors received specialized training in healthy home inspections, typical questions to ask clients, general sources and mitigation procedures for moisture and mold problems and how to educate clients in making small behavior changes to allow for a healthier home.

4. Client responses and conclusions - At the completion of work each client filled out a questionnaire to provide feedback on housing improvements, occupant health and comfort. The responses are summarized in the questionnaire attachment. In general:

- 80% of the respondents stated their children's health was better than before the work was accomplished
- 90% stated less condensation on the windows
- 100% stated they were more comfortable in their home
- 50% were very satisfied with the program and 40% stated satisfied

Client satisfaction and noticeable changes in both health and comfort were significant. In addition to client responses, the crew commented that this was the best project they had participated in. The crew felt great satisfaction in knowing that they had made improvements in people's housing that directly affected their health.

Many lessons were learned from the Healthy Homes in Alaska grant that could affect the way we provide the weatherization and HOME programs:

- By air sealing a home, pollutant and moisture problems could be made worse if not ventilated correctly.
- When there is an attached garage, you have to be concerned about air exchange with the house. Forced air furnaces should never be located in the garage because leaking ducts entrain polluted garage air and transfer it to the house.
- Filtration (HEPA and charcoal) is effective in lowering particle concentrations in air (as seen by forest fire smoke in summer of 2004[3])
- Every home needs working, mechanical ventilation
- Mechanical ventilation needs to be sized and installed correctly to be effective
- When installing mechanical ventilation, assessment of where make-up air comes from must be evaluated (attached garages, moldy – wet crawlspaces, etc…)
- Work crews are motivated to do a good job when they realize they are helping the client's health
- Moisture sources and pathways into the home should be assessed on all weatherization and HOME projects.
- Client and crew education are vital in the success of a project.

<u>Medical Testing (Mary Ellen Gordian, University of Alaska Anchorage</u>)
The client children were seen by a medical doctor before and after remediation. They had a physical examination and laboratory tests. The laboratory tests included pulmonary function tests, skin prick tests for allergy (or RAST testing in Hooper Bay children), Serum immunoglobulin E (IgE) level, and complete blood counts. Parents also provided a medical

[3] Reynolds W, C Cahill, and J Connor; *Remediation of Smoke Particles in Fairbanks Homes, June-August 2004*; unpublished CCHRC report, Oct. 2005

history on their child, with an emphasis on respiratory health. The physical exam, lab tests, and medical history questions were selected to allow a determination of the severity of the children's asthma.

A total of sixteen children were examined—for a variety of circumstantial, logistic and cultural reasons only three in Hooper Bay and thirteen in Fairbanks. The children's ages ranged from 2 to 15 years, with five females and eleven males. Four of the children were Alaska Native/American Indian, two were Asian, and nine were white. No race was indicated for one child.

Fourteen children had a diagnosis of asthma, one had encephalopathy, and another had no diagnosis (the medical history form was not available).

The three children from Hooper Bay were flown to Bethel for the examination. They were all under five years of age (outside of the priority-1 range of 5-17). The children were too young to have pulmonary function tests done, and examinations were unremarkable except for the severe encephalopathy in one child, which was not related to asthma. One child had elevated IgE. Therefore, no follow-up examinations were done in Hooper Bay because there was nothing to learn. Ten children from Fairbanks were seen in follow-up.

Control houses were significantly different from participant houses in Fairbanks. In control houses, carbon dioxide levels were 20% lower, carbon monoxide levels were 25% lower, and benzene levels were 70% lower. Average mycelia counts were an order of magnitude lower in control homes than participant houses; however, one home had exceedingly high levels which accounted for the large difference. Nevertheless, both average mycelia and spore counts from the tape lifts were 4 times lower in control houses compared to participant houses even after removing counts that exceeded about 4 standard deviations from the average. Assuming the control homes were occupied with similar familial groupings, these results suggest that the homes of asthmatic children had higher levels of indoor air pollutants.

	Average Pre-remediation Values				Average Post-remediation Values			
	CO_2	CO	benzene	toluene	CO_2	CO	benzene	toluene
Units	(ppm)	(ppm)	(ppb)	(ppb)	(ppm)	(ppm)	(ppb)	(ppb)
Control Homes	816	1.5	2.9	13	964	1	9.1*	30.2
Num. of Homes	8	8	7	7	7	8	7	7
Participant homes	1070	2	10.2	49.7	911	1.3	8.8	37
Num. of Homes	10	8	9	9	8	7	6	6

*this value includes one home with 31 ppb benzene

There was improvement of all health related laboratory parameters from before remediation to after remediation, but none reached statistical significance. The first pair is before and after IgE (serum immunoglobin E). Since this in an indicator of asthma, a lower follow-up value would constitute improvement. The last three pairs are measures of pulmonary function (forced vital capacity, forced expiratory volume at one second, and forced expiratory flow between the 25th and 75th percentile) in which a higher number indicates better function.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	initial IgE	215.00	7	172.556	65.220
	follow-up IgE	172.71	7	134.888	50.983
Pair 2	initial FVC%predicted	103.83	6	8.886	3.628
	follow-up FVC%predicted	111.17	6	11.197	4.571
Pair 3	initial FEV1%predicted	90.33	6	14.208	5.800
	follow-up FEV1%predicted	96.33	6	15.756	6.433
Pair 4	initial FEF% predicted	75.67	6	29.811	12.170
	follow-up FEF% predicted	77.83	6	25.349	10.349

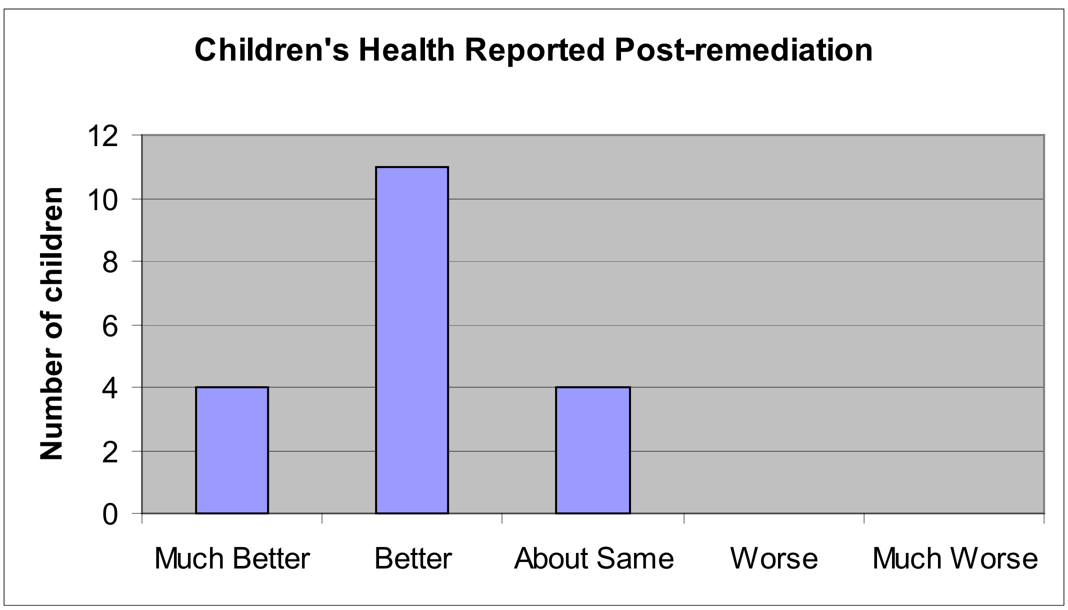
Paired T-test

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
initial IgE - follow-up IgE	42.29	54.04	20.42	-7.69	92.26	2.07	6.00	0.08
initial FVC%predicted - follow-up FVC%predicted	-7.33	7.84	3.20	-15.56	0.89	-2.29	5.00	0.07
initial FEV1%predicted - follow-up FEV1%predicted	-6.00	6.32	2.58	-12.64	0.64	-2.32	5.00	0.07
initial FEF% predicted - follow-up FEF% predicted	-2.17	15.52	6.34	-18.46	14.12	-0.34	5.00	0.75

While the medical results of this study are inconclusive due to the small number of research subjects and the multifactorial nature of asthma, there are, however, some interesting suggestive results:

- It is possible that the homes of children with asthma have higher levels of indoor air pollution than the homes of similar people without asthma.
- The remediation may have helped to improve the pulmonary function tests and the IgE levels of asthmatic children, although the numbers were not sufficient to reach statistical significance.

Satisfaction Questionnaire (Scott Waterman, Alaska Housing Finance Corporation)
Each client was surveyed to determine his/her level of satisfaction with the project. Perhaps the most significant question was number 3: “How has your children’s health been since the work was done?” The figure below shows the overall response to this question.



Of the 19 parents surveyed in both Hooper Bay and Fairbanks, 15 (79%) said their children’s health was “better” or “much better” following the remediation work in their home; four said it was the same, and none reported a decline in health. See Section 12 for the complete summary of the responses to the questionnaire.

Homeowner Guide (Ginny Moore, Alaska Building Science Network)
The Healthy Homes in Alaska project contracted with Ginny Moore of the Alaska Building Science Network to produce an educational booklet targeted at the clients of the weatherization program that would give them important information about maintaining a healthy home in simple language and using appropriate graphics. A copy of this booklet is included in the main

body of the report. Below is a copy of a poster that was developed with the booklet; it summarizes the advice in the booklet and shows the artistic style.

Conclusions
The Healthy Homes in Alaska project was a complex, difficult, and important study. It asked the two-part question: "Can we improve indoor air quality by augmenting the standard weatherization protocol and can that improved IAQ lead to better health for children with asthma who live in the homes that are remediated?" While there are many factors involved in both questions and the study was limited by funding to a small number of test cases and control houses, we can give a qualified "Yes" as the answer to both parts of the question. To understand the scope of the work done and the range of conclusions reached in each phase of this project it is necessary to read the details in each of the main sections of this report. However, there are some consistent threads that run through each sub-report.

The overall picture that emerges is that the houses in which the asthmatic children are living have generally worse IAQ than that found in the control houses where there were no asthmatic children present. The augmented protocol in the client houses and the standard protocol in the control houses resulted in homes with similar post-remediation IAQ. That is, the augmented protocol appears to have improved houses with much worse IAQ to an IAQ comparable to that reached in the control houses using the standard weatherization protocol.

The situation in Hooper Bay is different from that in Fairbanks. In Hooper Bay the main problem appears to have been a high moisture load driven by high occupancy and inadequate ventilation. The amount of mold seems to have been limited by the building materials. The strongest correlation in the IAQ data is a reduction in post-remediation RH compared to the pre-remediation levels. Both the occupants and the workers commented on the improvement in the moisture conditions in the homes. Many of the remediation items were focused on improving the ventilation and removing moisture sources from the client homes.

In Fairbanks, while there were similar moisture problems, there also appear to have been issues related to attached garages and improperly installed furnaces. The strongest correlation in the IAQ data is a reduction in benzene and toluene; these are often related to pollution from an attached garage. Again, while many of the remediation items were focused on improving the ventilation and removing moisture sources from the client homes they also focused on reducing pollution from the garage and furnaces and on filtering the indoor air.

There remain many questions as to the efficacy of each step of the remediation protocol developed for each house. The sample sizes are small and most of the correlations do not rise to the level of statistical significance. Nevertheless, it does appear from the IAQ data, the medical data, the observations of the weatherization workers, and those of the parents that the IAQ in the client homes and the health of the children both improved after the Healthy Homes remediation work was done.

Recommendations

<u>Programmatic lessons learned and recommendations</u>:

1. It is feasible to augment the standard weatherization protocol using the Healthy Homes strategies to improve occupant health by improving indoor air quality.
2. An important part of the protocol is training the workers and subcontractors in not only the techniques of the program, but also the goals for improving health. This seems to by an important motivator to do good work.
3. It is important to train the homeowner in the both the operational details of the equipment installed and the building science reasons for using the equipment properly.
4. For rural Alaska, especially, there is a need for a simple mechanical ventilation system that needs little maintenance or operator attention and is inexpensive to operate.

<u>Building science lessons learned and recommendations</u>:

1. By air sealing a home, pollutant and moisture problems could be made worse if not ventilated correctly.
2. When there is an attached garage, you have to be concerned about air exchange with the house. Forced air furnaces should never heat both the garage and house.
3. Every home in Alaska needs working, mechanical ventilation (as is now required by ASHRAE 62.2).
4. Mechanical ventilation needs to be sized, installed, and balanced correctly to be effective.
5. When installing mechanical ventilation, assessment of where supply air comes from must be done (attached garages, moldy – wet crawlspaces, etc…).
6. Moisture sources and pathways into the home should be assessed on all projects.
7. The design of interior systems such as wall surfaces, shelving, closets, and bed frames can be important to the ability to maintain a mold free environment.

INTRODUCTION

Summary of Proposed Work and Justification
The intent of this program is to increase the capacity of the weatherization program to remove possible respiratory hazards in the homes of low-income people who have children with asthma or other upper respiratory diseases. The weatherization program is a benefits program that assists low-income people by providing free weatherization including new windows, doors, insulation as well as smoke detectors, carbon monoxide detectors, ventilation fans, and other safety features. The program has an income eligibility test for recipients and is very popular in Alaska. It is funded by both state and federal funds and is administered in Alaska by the Alaska Housing Finance Corporation (AHFC).

The Healthy Homes Project added additional services to the weatherization protocol addressing the sources of moisture in the home and the removal and replacement of water-damaged materials and furnishings. There are many cross-sectional studies that have concluded that damp and moldy building environments adversely affect children's health. However, there are no published studies that have attempted to investigate changes in housing features such as water damaged residential building materials and furnishings and assess the effect of resultant changes in indoor air quality on the health of the residents. This is not a trivial question. Whether and how older housing can be successfully remediated, or whether housing funds should be prioritized to new housing is an important decision that AHFC and HUD have to make. This work can inform that decision.

General Background
Alaska's size, geography, and the severity of the climate are all factors that contribute to the unique situations presented in this proposal. Alaska is approximately one-fifth the size of the continental United States with a land area of 586,412 square miles. If placed over a map of the United States, Alaska would stretch from Georgia to Minnesota to Los Angeles.

According to the 2000 Census, Alaska has 626,932 residents. Approximately 60% of the population resides in Anchorage, Fairbanks and Juneau. The remaining population is spread throughout the state in an area referred to as "The Bush": smaller hub cities (3,000-5,000 residents) with outlying villages (typically 350 or more residents). Almost all of these communities are inaccessible by road. The primary mode of transportation is by air, with large shipments of supplies arriving by barge.

The severe climate means housing-based problems in Alaska happen much faster and are more pronounced than in the contiguous United States. In the northern half of the state, the first snow can fall in late August and remain until May. During the height of the winter solstice, Fairbanks, which is considered in the center of the state, has approximately 4 hours of daylight. Regions farther north experience even more darkness and severe conditions. The length and severity of winters in Alaska, coupled with little daylight in the dead of winter causes people to spend upwards of 95% of their time indoors, higher than people in more moderate climates. This is even a greater concern to low-income residents, because they're usually in overcrowded conditions and substandard housing.

Living in Alaska is very expensive and unforgiving to poor design and construction. As a result, many new homes in Alaska, particularly HUD subsidized homes in rural areas are very energy efficient and small (in the range of 1000 square feet) to keep construction and heating costs as low as possible. In these homes, the measured air tightness requires mechanical ventilation equipment to meet ASHRAE standards. Low income residents often neglect to operate and maintain ventilation systems due to the expense involved and lack of knowledge about the consequences of poor ventilation. The result is a small, overcrowded, low-volume home that is extremely tight with an atmospherically vented oil-fired heating system & woodstove, and no practical ventilation. Older owner-built homes in the villages are typically small cabins (300 – 500 square feet) and may house as many as 8 adults and children. They are seriously over crowded, lack running water, and generally have no ventilation, including operable windows. Many villages lack water and sewer systems. Water is hauled into the homes in 5 gallon buckets and stored in 30 gallon trash cans. It is heated on the stove, and dippered out of the can for drinking and washing. Water is inevitably splashed around the area and flooring and wall components often stay wet in the areas where the buckets are used. Sanitation consists of honey buckets (five gallon plastic buckets with a plastic trash bag liner) in a screened area, which are emptied into a sewage lagoon located within or near the village. Clothes are often hanging to dry in homes, adding significantly to already high moisture levels. Dryers are not installed in many homes, due in part to a lack of space, overcrowding and very small home design.

Many low-income residents in rural villages utilize their home for everything from living and socializing, to processing and drying meat or fish, or fixing a snowmobile. Often bare wood flooring is damaged by cutting and processing wild game.

These conditions and resultant problems are unfortunately an ideal testing ground and stand to provide measurable results that can be adapted throughout the country. The network of agencies that provides services to low-income people also provides an ideal source for historical data on house characteristics and their occupants. These agencies will be the sustainable network to carry on this program once the demonstration project is accomplished.

The statistics generated from previous studies paints a grim portrait of the circumstances facing Alaska's low-income and Native populations:

- Rates of smoking in Alaska are the highest in the country.
- Many homes also use fuel oil or wood stoves for home heating. These heating methods are sources of CO_2, CO, and particulate matter.
- Nationally, pediatric asthma rates rose by 86.8% between 1982 and 1995. No statistical data collection on asthma has ever been done in Alaska, but the American Lung Association of Alaska believes it may be even higher than the 88,156 Alaskan children estimated to be asthmatic by national prevalence levels in 1995.
- In a March of 1998 Housing Study commissioned by AHFC, over 18% of households reported an asthmatic residing in their residence. According to the State of Alaska Department of Health and Social Services, for every 10,000 hospitalizations for children under five, 200 (2%) are from asthma in the Medicaid eligible population alone.
- Incidence of Respiratory Syncital Virus (RSV), a viral cause of respiratory infections, "is the major cause of hospitalization for Alaska Native infants, with babies in the Yukon-

Kuskokwim Delta at highest risk. Hospitalization rates as high as 249 per 1000 have been reported among Y-K infants in contrast to 1 to 20 in the US."[4,5]

- Sanitation is lacking in many villages. Water and Sewer projects are projected to take 40 years to get piped water and sewer to most village homes. Hepatitis A, B, and C are found in the remote villages throughout the state and in many areas considered epidemic.
- Overcrowding of homes because of large family size or small dwelling size contributes to the spread of viral and bacterial infection, creates high moisture problems in the buildings (especially where no laundry facilities are present and clothes are dried on lines throughout the home), and exacerbates poor indoor air quality issues that exist in all the homes.

Project Description

The Healthy Homes in Alaska project was conducted in two areas in the state, each representing a unique type of community. Fairbanks is Alaska's second largest city and is located in the Interior. Hooper Bay is a larger bush community of 1014 residents on the Bering Sea coastline. These communities were selected because they represent opportunities to correct some of the most extreme hazards to children's health, have voiced an urgent community need, shown strong local commitment to solving their problems, have residents with diagnosed asthma and an involved health provider in the region, and are generally representative of conditions and housing stock throughout the state. The initiative focused on homes of low-income families with children (including a sample of mobile homes) and provided indoor air quality assessment, health screenings of affected children, and housing remediation to selected homes. The goal was to identify 10 eligible participants in the Fairbanks City and Borough Area, and 10 participants in Hooper Bay.

<u>Selection Criteria for Participants</u>**:** All homes selected met the Weatherization eligibility requirements which are (1) low-income occupants, (2) home can be improved, and (3) has not been weatherized within past 10 years. Only the First Priority homes had the medical screening of the children. The priority selection was based upon the following:

> **First priority** will be given to homes with a child between the ages of 5 and 17 with diagnosed asthma or chronic upper respiratory illness.
>
> **Second Priority** will be given to homes with a child of any age diagnosed with asthma or chronic upper respiratory illness
>
> **Third Priority** will be given to homes with children that are not diagnosed with asthma or chronic upper respiratory illness.
>
> **Fourth Priority** will be given to homes where sanitation, and other health safety issues are present.

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[4] Gordian, ME; *Proposal to study indoor air quality as a cause of respiratory disease in children and adults in rural Alaska*; submitted to the Center for Disease Control, 2000

[5] Karron RA, RJ Singleton, L Bulkow, A Parkinson, D Kruse, I DeSmet, C Indorf, KM Petersen, D Leombruno, D Hurlburt, M Santosham, and LH Harrison; *Severe respiratory syncytial virus disease in Alaska native children*; J Infect Dis. 1999 Jul; 180(1) 41-49.

Fairbanks City and Borough Area**:** Every effort was made to recruit sufficient First Priority participants from the Fairbanks City and Borough area. We had to recruit one second priority home in the Fairbanks area.

Climate and Health: Due to Alaska's severe climate and long winters (October through April), residents spend many hours inside their homes. Prolonged winter temperatures below -20ºF (with ranges of -40 to -50 often reported) are common in the Interior Region (Fairbanks) but has a total average precipitation of less than 11 inches per year. The dry climate combined with extreme cold, poses significant challenges to providing a safe, healthy environment within the house. Hooper Bay's climate is typical of the Western region, with a combination of cold temperatures, high winds and an annual precipitation of approximately 20 inches per year. Small, tight homes are often overcrowded, with 5 -10 people living in homes of 1000 square feet or less.

Poverty and Housing Condition: Many of the Fairbanks neighborhoods are within a locally designated HUD Revitalization Area. The median household income for the area is less than 60% median income for the rest of the borough. These neighborhoods have the highest levels of economic distress. In fact, of the 2,692 households located in the Revitalization Area, only 17% are owner-occupied. The average homeownership rate in the State of Alaska is 70.4%.

In addition to the harsh climate, the houses within the Fairbanks City and Borough area are among the oldest homes, with a median year built of all housing units of 1965. Thus, the deteriorating condition of the housing stock and low income of the residents makes improvements in the housing conditions unaffordable for most families (i.e. most families living within the downtown neighborhoods of Fairbanks live in substandard conditions). Houses were built long before good ventilation systems were available, and are currently unaffordable to low-income families. Outside of downtown Fairbanks it is not unusual for homes to have more primitive sanitation systems such as outhouses, and water holding tanks.

Life in rural Alaska has economic challenges. Many residents, primarily Native Alaskan, depend on wild foods for their sustenance due to the high cost of groceries. (For example, dairy products or produce are approximately three times the cost of purchasing these products in urban areas.) There is tremendous pressure to stretch the meager cash resources to their limit.

Hooper Bay has a household median income of approximately $26,670 per year. There is no water or sewer system. Of the 1014 residents in Hooper Bay, approximately 46% are out of the work force. Many of those within the existing work force are only employed seasonally. Tables One and Two, with representative statistics about both communities, are located in Appendix 1.

Although the average size of a home in Hooper Bay is under 1000 square feet (many are under 500 square feet) and the condition of the individual homes is very poor, these are the buildings that Hooper Bay residents have to call home. The average replacement cost for building a modest home in rural Alaska is around $250,000. We started weatherizing homes in rural Alaska with a much more basic program over twenty years ago. Most of those homes are still being lived in today. When an elder receives a new home, someone younger and just as low income moves into the home. Population explosions have led to overcrowding and the utilization of every standing structure in the villages as housing. When assessing each building for rehabilitation, we are careful not to impose urban standards of building viability in judging whether or not a building is worthy of our investment. We walk away from few structures, and we have revitalized thousands of homes that others might have walked away from. These homes are often the most sustainable in the state since they have been lived in since they were built and they will continue to be lived in by folks who value a modest shelter and who need our assistance in making the home warm and healthy.

Number of children at risk: There are 1440 children designated as low income living in the City of Fairbanks. Many of these are seen as patients at the Tanana Valley Clinic (TVC), with reported respiratory distress. According to the US Census, 49% of population in Hooper Bay is under 18 years of age and there are 227 households. Approximately 60% of the 227 households in Hooper Bay are low income (60% median income limit) and an estimated 243 children under the age of 18 are in low-income households. 10 children have been identified having upper respiratory illness and qualify for weatherization.

Unavailability of public and private funds used to address the problem: The housing-based hazards facing low-income residents and children are well known throughout the state and federal government. However, there is no current agency or program that can gather the technical expertise and resources necessary to address the problem in a comprehensive way. In particular HOME Funds are not available in Hooper Bay because of the lack of sewer and water systems. CBDG funds have not been used by AHFC in Alaska for programmatic reasons.

This project is consistent with the State of Alaska's FFY 2000-2005 Housing and Community Development Plan (HCD) and addresses several of the plan's priorities.

All potential safety and health hazards were targeted during the assessment and intervention activities. These include but are not limited to:

a. Heating – improperly combusting devices and inefficient heating systems create indoor accumulation of CO and CO_2 gases, which contributes to respiratory illness, especially among children.
b. Ventilation – poor or inadequate ventilation can exacerbate the effects of poor heating systems, create moisture problems in the home (which can lead to mold or severe mildew), and contributes to the increased incidence of asthma or other upper respiratory illnesses. Excess moisture can cause durability and structural problems.
c. Indoor Air Contaminants – assess and detect levels of all indoor environmental contaminants (biological and chemical).
d. Moisture reduction. High moisture levels in the home provide a breeding ground for mold and other contaminants.
e. Radon – radon progeny is a particular concern in the Fairbanks area. However, previous studies indicate there is much less risk of elevated levels in other areas of the State. Participating Fairbanks homes will be tested for radon; representative sampling will be conducted in remaining locations.
f. Lead – visual risk assessments will be performed in accordance with HUD Guidelines and further testing will follow if warranted. Over 75% of the housing

stock in the two targeted communities is between 20-30 years old and therefore, is considered a low-risk for lead based paint.

g. Asbestos – assessments will be performed to detect the presence of asbestos. Proper remediation will be recommended if necessary.

h. Sanitation – No plumbing is available in Hooper Bay. Honey Buckets and hauled water can create situations where proper sanitation is difficult. This lack of sanitation has lead to almost epidemic levels of Hepatitis throughout rural Alaska. Simple systems to store and dispense water may be installed.

GOALS and OBJECTIVES

The primary goal of this project was to develop and implement cost-effective approaches to identify and control housing based hazards to low-income children throughout Alaska, and build local capacity to sustain the program after the grant term. The hypothesis was that the home environment of low-income, typically overcrowded households significantly affects respiratory health. Research was conducted in the homes of children with respiratory sensitivities to identify the existence of home contaminants. Selected homes were mitigated to reduce levels of indoor air contaminants; and the resident children underwent pre- and post-mitigation medical screening to detect any change in respiratory health associated with the mitigation. (See the medical IRB in Section 7.) Children in cold climates spend upwards of 95% of their time indoors, with approximately 16 hours per day in their home environment. Another potential and likely contributor is schools, which should be evaluated as a follow-on project. The strategy brings a comprehensive and coordinated approach that leverages technical experience and previously completed research and efforts to further the understanding and awareness of indoor contaminants. AHFC, the lead applicant in this proposal, already coordinates projects with all of the housing related entities involved in this project. This work built upon those relationships and the results of existing efforts to meet a critical need in Alaskan communities.

This project was structured into three Stages. Stage 1 identified low-income children with respiratory health issues (e.g. asthma) and the homes where they live. Targeted communities for this assessment were the Fairbanks City and Borough area and the village of Hooper Bay. An assessment of the indoor air quality within their homes and a medical screening of the child was completed in this stage. Stage 2 addressed prevention and elimination of the causes of house-based hazards. After mitigation, Stage 3 consisted of health and home post mitigation testing and monitoring to verify clearance of home-based hazards, and to assess the correlation between health and home environment. Homeowners were given a guide to keeping their homes healthy. "Lessons learned" from these stages were noted for later curriculum development that we hope to address, along with education and outreach, in a second Phase of the Healthy Home Initiative.

Objectives for "Healthy Homes in Alaska" Initiative included:

1. To identify low-income homes where children with chronic upper respiratory or asthma, and provide a baseline health and indoor air quality assessment of these homes.
2. To develop, demonstrate, and implement effective and affordable approaches to identify and control housing based hazards for low-income children, including sanitation issues.
3. To integrate indoor air quality screening into current nonprofit housing programs and statewide housing professionals to provide a sustainable long-term program.
4. To demonstrate that indoor air quality control intervention methods may improve the health, safety and quality of life of afflicted children.

5. To contribute to providing environmental equality to those low-income individuals who typically don't have an understanding of IAQ issues or the means to address them.
6. To mitigate environmental defects in housing that may adversely affect the health of the residents, within the budget of this project.

The project developed the standards and personnel for cost effective, affordable assessment and control, performed the mitigation, and monitored the results of control measures (environment and health improvements) to demonstrate the effectiveness of the strategies. This approach provided a logical, sequential and comprehensive methodology to address the health and safety hazards to low-income children in Alaska.

There have been previous studies conducted in other regions, such as Cuyahoga County, Ohio, which may deal with similar issues, but these studies are typically focused on local issues and housing stock. These studies provide valuable data, but cannot address problems in a collective manner that is standard in all settings and climates. This project comprehensively addressed house-based hazards in extreme cold climates, which will likely augment and benefit previous and ongoing research elsewhere. Key elements of this strategy included a strong coordination between the medical and building science disciplines, and integration of successful models from Canada and the US. This project provided a collaborative approach to one of Alaska's most predominant health issues.

The primary agencies for intervention were the Interior (Fairbanks City and Borough area) and RuralCAP (Hooper Bay) Weatherization Agencies, which are keenly aware of the air quality issues and had the capacity to implement and sustain the project. These areas were initially chosen because preliminary investigations or reports have indicated that there is a critical need for the services; and, they are generally representative of the circumstances and issues facing most rural Alaska communities. Though this project was targeted to rural and low-income residents, the information, programs, and education will benefit all Alaskans.

TASKS and TIMELINES

The following table outlines responsible entities, activities, and timeframes:

Project Team Key Personnel

Staff Name and Organization	Title/ Function	Per-cent of Time[6]	Role in Project	Salary Cost Covered By Grant
Primary Project Leaders				
Scott Waterman AHFC	**AHFC Program Manager**	3%	General Program Oversight, Reporting	In-Kind Match
Mimi Burbage AHFC	**AHFC Program Manager**	3%	General Program Oversight, Weatherization	In-Kind Match
Christie George AHFC	**AHFC Grant Administrator**	2%	Grant Administration, Financial Management	In-kind Match
Phil Kaluza, CCHRC	**Project Research Manager**	40%	Project management	$40,533
John Davies CCHRC	**Research Director**	20%	Project oversight	$20, 267
Community Partners				
Ralph Lee/Toy Owens RurAL CAP	**Weatherization Program Co-Directors**	6%	Oversight of Intervention and Testing Activities in Hooper Bay	Percentage of Salary Paid by Subcontract
James Lee, Interior Weatherization	**Executive Director**	5%	Oversight of Intervention and Testing Activities in Fairbanks	In-kind Match

[6] * Indicates percent of individuals time dedicated to this project

Medical Assessment Team				
Tim Foote, MD, Tanana Valley Clinic	Pediatric Physician (Pediatric Allergy & Immunology**)**	N/A	Medical director for Fairbanks area phase of project. Provide medical examinations and spirometry for selected participants.	$1,875 Grant $625 In-Kind Match $1,800 Exams, Spirometry
Mary Ellen Gordian, MD, MPH ICHS	Medical researcher on pediatric upper respiratory illnesses.	N/A	Consultation on health issues, testing protocols, interpretation of data and results.	Consultant fees paid through sub-contract

Training and Technical Assessment Team				
McGregor Pearce, Mold Analysis	IAQ consultant and trainer	N/A	Provide IAQ research testing and training/education.	Consultant fees paid through sub-contract
Alaska Building Science Network (ABSN)	Building Science technicians and trainers	N/A	Provide Homeowner Guide to Keeping their home healthy	Consultant fees paid through sub-contract.
Ron Johnson, Ph.D UAF	Dept. of Mechanical & Environmental Quality Engineering	7%	Particulate testing and IAQ protocols, testing and data evaluation.	Percentage of Salary Paid by Subcontract
Rich Siefert, PhD., UAF	Professor of Engineering Extension	3%	Provide training & education	Percentage of Salary Paid by Subcontract

Baseline Plan for Project Management

Stage 1 – IAQ Testing and Medical Assessments
Stage 2 – Mitigation
Stage 3 – Post Mitigation Testing & Monitoring (medical and IAQ) Data Analysis, and Report Writing

Major Task	Responsible Organization	Completion Date	Deliverable
STAGE 1			
HUD Grant allocation	HUD to AHFC	April 2002	Receive grant funds
Notice to Proceed	AHFC to CCHRC	April 2002	Begin Demonstration Project
New Healthy Homes Grantee Orientation	CCHRC	April 2002	Attend Orientation Meeting by Phil Kaluza
Project Coordination Meeting in Fairbanks (Other areas teleconference)	**CCHRC** AHFC UAF/UA Mac Pearce TVC IWI RurALCAP	July 2002	Phase 1 coordination and initiation, to include project schedule and action plan.
Refine medical assessment strategy and protocol	CCHRC TVC ICHS	July - October 2002	Develop protocol & submit to IRB at UAA
Quarterly Report to HUD FY 2002	AHFC CCHRC	July 15, 2002	Quarterly project & financial reports (SF Form 269)
Healthy Homes Project Coordination Meeting in Fairbanks	**CCHRC** AHFC UAA, UAF	September 2002	Follow-up coordination meeting with key players
House/Participant Recruitment & Selection Medical Screening	**CCHRC** AHFC TVC RuralCAP	September 2002 – ongoing	Finalize list and conduct notifications of eligible homes & participants in each area (Fairbanks, Hooper Bay)
UAF IAQ Monitoring IRB Approval	**UAF**	September 2002	Received IRB approval for IAQ monitoring
Quarterly Report to HUD FY 2002	AHFC CCHRC	Oct. 15, 2002	Quarterly project & financial reports (SF Form 269)
Home IAQ Investigations Training	**CCHRC** RurAL CAP IWI UAF Mac Pearce	November 2002	Weatherization & lead based paint inspections, identify homes for complex testing, prescreen for mitigation.
UAA Medical IRB Approval	**UAA**	December 2002	Received UAA IRB Approval for Medical portion of the project.

Yukon Delta Heath Board IRB Approval	**UAA**	December 2002	Received YKHB IRB Approval for Hooper Bay.
Quarterly Report to HUD FY 2003	**AHFC** CCHRC	January 15, 2003	Quarterly project & financial reports (SF 269)
IAQ Physical Assessment on homes in Hooper Bay	**CCHRC** UAF RuralCAP	April 2003	Obtain Pre IAQ testing data
Attend Healthy Homes Orientation Meeting	**CCHRC**	April 2003	Attend Orientation Meeting by John Davies
IAQ Physical Assessment on homes in Fairbanks	**CCHRC** UAF IWI	March 2002 – June 2004	Obtain Pre IAQ testing data
Quarterly Report to HUD FY 2003	**AHFC** CCHRC	April 15, 2003	Quarterly project & financial reports (SF 269)
Exterior Air Quality (Summer Fire Season) Dependent upon severity of fires. If no fires no assessment will be done.	**UAF** CCHRC	June-August 2003	Measure interior and exterior air quality/particulates to compare effects of forest fires on health of asthmatics.
Health Assessments (Summer Fire Season) Only if applicable.	**TVC** UAA-ICHS	June-October 2003	Medical assessments of participants in an area affected by forest fire smoke.
STAGE 2			
IAQ Data Analysis, & Mitigation Plan for Hooper Bay	**CCHRC** UAF RurALCAP	May - July 2003	Data analysis and & remediation plan
Pre Remediation Medical Exam for Hooper Bay Children	**CCHRC** UAA	July – August 2003	Perform pre remediation medical exams.
Stage 2 Meeting at AHFC in Anchorage	**AHFC** CCHRC	May 2003	Stage 2 coordination/update meeting, refine mitigation plan, budget review
IAQ Data Analysis & Mitigation Plan for Fairbanks	**CCHRC** UAF, IWI	March 2002 – January 2004	Data analysis and remediation plan

Pre Remediation Medical Exams on Fairbanks Children	**CCHRC** TVC	April 2002 – December 2002	Perform Pre Remediation Medical Exams on Fairbanks Children
Quarterly Report to HUD FY 2003	**AHFC** CCHRC	July 15, 2003	Quarterly project & financial reports (SF 269)
Initiate mitigation plans in selected homes in Hooper Bay	**RurAL CAP**	July 2003 – June 2004	Initiate remediation action on 10 selected homes in Hooper Bay
Quarterly Report to HUD FY 2003	**AHFC** CCHRC	October 15, 2003	Quarterly project & financial reports (SF 269)
Initiate mitigation plans in selected homes in Fairbanks	**IWI**	July 2003 - December 2004	Initiate remediation action on 10 selected homes in Fairbanks
Post Remediation Medical Exams on Fairbanks Children	**TVA** CCHRC	Aug 2004-Jan 2005	Perform post medical exams on children.
Post IAQ testing in Hooper Bay	**CCHRC** UAF RuralCAP	June 2004 – Dec 2004	Perform Post IAQ measurements
Post Remediation Medical Exams on Hooper Bay Children	**CCHRC** UAF	June 2004	Perform Post Medical Exams on Hooper Bay Children
Homeowner Healthy Homes Guide	**ABSN**	Dec. 2004	Complete Healthy Home Guide for distribution to participants
Quarterly Report to HUD FY 2004	**AHFC** CCHRC	Jan 15, 2004	Quarterly project & financial reports (SF 269)
Post IAQ Testing in Fairbanks	**CCHRC** UAF IWI	Jan – Dec 2004	Perform Post IAQ measurements
"Lessons Learned" Project Meeting at AHFC in Fairbanks	**AHFC** CCHRC IWI RuralCAP	November 2004	Conduct follow-up meeting to outline lessons learned in assessment and mitigation stages for inclusion in remaining tasks.

Quarterly Report to HUD FY 2004	**AHFC** CCHRC	April 15, 2004	Quarterly project & financial reports (SF 269)
STAGE 3			
Post Intervention Monitor and Screening (all participants- mitigated homes & control group)	TVC UAA ICHS	November 2003 – June 2004	Develop data correlating IAQ improvements and affects on health and quality of life.
Project Meeting at CCHRC in Fairbanks	**CCHRC** AHFC UAF	March 2004	Stage 3 project meeting. Review/refine schedule, testing, and budget review.
Develop Draft Project Report	**CCHRC** AHFC UAF, UAA	April – Dec 2004	Write draft of final report.
Review of Draft Report	**UAF** UA	Jan – March 2005	Peer Review & 30 day comment period
Quarterly Report to HUD FY 2004	**AHFC** CCHRC	July 15, 2004	Quarterly project & financial reports (SF 269)
Write Final Report	**CCHRC** UAF	March 2004	Incorporate comments on Draft Report
HUD Meeting	AHFC CCHRC	To Be Determined	Final Project Meeting at HUD HQ, Washington DC
Quarterly Report to HUD FY 2005	**AHFC** CCHRC	April 15, 2005	Quarterly project & financial reports (SF 269)

Implementation

CCHRC recruited volunteer participants in the Fairbanks City and Borough area. Recruitment in the Fairbanks area consisted of:

- Coordinate with Tanana Valley and other local Clinics for possible clients
- Contact local school nurses
- Radio and newspaper ads
- Interior Weatherization will screen all wait-listed and new clients for eligibility.

Of these options, the radio and newspaper ads were by far the most effective.

Hooper Bay recruitment:

- Work closely with local village Health Clinic and YK Regional Hospital to identify potential clients
- RuralCAP will query potential clients as they recruit for normal Weatherization

The latter was the most effective.

Potential participants were screened for age, medical and low-income Weatherization eligibility. Those children meeting the First Priority criteria were scheduled for a medical exam to document their pre-remediation medical condition. This examination included a history, physical examination, pulmonary function tests, blood tests for white cell counts and IgE, and skin or serum testing for allergies.

Because of the limited number of participants from Hooper Bay requiring medical exams, those children were flown to Bethel for medical exams at the regional hospital. Costs were covered by YKHC. This allowed for a more comprehensive exam at a comparable cost to bringing the medical staff and equipment to Hooper Bay. Participants from Fairbanks scheduled exams with Tanana Valley Clinic.

Ten participants in both Fairbanks and Hooper Bay were selected and their homes remediated. In addition to those 20 homes, 7 homes in the Fairbanks area and 8 in Hooper Bay received only the low-income weatherization. This control group provided insight into how typical weatherization measures affect the IAQ of the home. These homes were selected randomly from the homes scheduled for weatherization. The project targeted a total of approximately thirty-four homes in Fairbanks and Hooper Bay. Eligible participants were selected on a first-come first-serve basis until the quota has been met in both locations. First-time weatherized homes will be prioritized over homes that have been previously weatherized.

The Tanana Valley Clinic (TVC) and the Institute for Circumpolar Health Studies (ICHS) developed and refined a medical assessment protocol for determining the baseline data for the children at risk. (See IRB, Section 7 and Health Outcomes, Section 13.) This provided a consistent evaluation tool, which can be used in the target communities. All research activities involving the voluntary participants conformed to 45 CFR Part 46, Protection of Human Subjects, and will receive Institutional Review Board (IRB) approval prior to commencing the project.

The project will provided indoor air quality assessment and mitigation training for Interior Weatherization and RuralCAP weatherization technicians. One key building block for developing infrastructure to combat indoor environment problems in low-income homes/villages, was the development and implementation of standards, protocols, and training for various agency technicians.

Evaluation and Mitigation

Testing was conducted for the following potential health hazards:

- **Carbon Dioxide.** (CO_2) is produced by occupants and improperly vented combustion appliances. High levels of CO_2 can be a key indicator of poor indoor air quality. This is typically due to the lack of ventilation. The University of Alaska Fairbanks (UAF) will conduct testing. CO_2 will be monitored using data logger equipment for a period up to two weeks. Data will be downloaded and analyzed after each monitoring period. All equipment will be calibrated per manufacturers' specifications prior to deploying.

- **Carbon Monoxide.** CO is a poisonous gas most commonly a byproduct of incomplete combustion and/or improper venting of combustion appliances. There are exposure limits, however any level above zero indicates a potential health hazard and requires immediate identification and correction of the source. This is expected to be a key contributor to indoor environmental health hazards due to the use of oil and wood fired heating systems. Testing will be conducted by UAF. CO will be monitored using data logger equipment for a period up to two weeks. Data will be downloaded and analyzed after each monitoring period. CO loggers will be tested and calibrated per manufacturer specification.
- **Mold/Microbials.** The presence of airborne microbials will be sampled using dust samples collected at each home via vacuum and Aerotech dust collection filter and/or tape lifts. Ergosterol levels and cytotoxicity assays will be measured by UAF to correlate data of other tests in determining the level of mold and cytotoxins from mold or bacteria in the air.
- **Relative Humidity (RH) & Temperatures.** The presence of high levels of RH in the home is a common source of mold growth. Inadequate ventilation may be the cause. Low indoor temperatures may result in cooler exterior surfaces and potential condensation and mold. Temperature & RH will be monitored using data logger equipment for a period up to two weeks. Data will be downloaded and analyzed after each monitoring period. Monitoring equipment will be tested and calibrated per manufacturers' specifications.
- **Particulate Matter (PM)** – UAF will be the primary investigator for detecting PM2.5 and ultra fine PM in the participating homes. Measurements will consist of ambient air and indoor environment during the walk-thru assessment to determine what if any correlation exists between the two. Ultra fine Particulates are below the 3-micron level, which are in the size range known to be potentially the most damaging to the lungs. Ultra fine particulate levels can be traced within inches of the source, which provides invaluable assistance in locating potentially dangerous conditions without dismantling equipment. Ultra fine particles can be measured when there is no indication of elevated CO levels. This is a particular concern in areas where oil-fired heat and wood burning stoves are common. Exposure to particles less than 2.5 microns in indoor air would be measured during the walk-thru assessment utilizing a P-TRAC particle sampler and ultrafine particles will be measured utilizing a handheld Photo Ionization Detector (PID)
- **Volatile Organic Compounds** (VOC's) - The two primary VOC's to be tested are formaldehyde and benzene. Both of these have documented health risks, and can result in an increased risk for cancer. UAF will be the primary investigator for VOC's with the Institute for Circumpolar Health a key collaborator. VOC's will be measured using a passive absorbent badge. It is a small, unobtrusive, soundless, and very easy to transport to the laboratory for analysis. However, it does not pick up very low levels unless it is exposed a long time, therefore monitoring periods will be a minimum of 4 days and up to several weeks when possible
- **Lead-Based Paint** – Lead-Based testing will comply with the HUD guidelines for testing and remediation. All homes involved in the project will likely be post-1978 construction. However, in homes constructed prior to 1978, lead-based paint testing will be conducted using an XRF. Sunex Consulting in Fairbanks will be contracted to conduct any lead-based paint testing where applicable.
- **Radon** – This colorless, odorless gas may contribute to lung cancer. UAF and CCHRC have extensive experience with radon testing and mitigation, and have collected baseline radon data for hundreds of homes. Alpha track detectors and continuous radon monitors will be

deployed as needed to gather information for mitigation strategies. Only homes located in the Fairbanks area with known high radon areas will be tested.

- **Pressure Envelope and Air Tightness of Structure** – The air exchange rate of the structure is a key element in evaluating the cause and effect of indoor environmental contamination. Blower door testing and/or tracer gas decay testing will be performed to quantify air changes and identify sources of leakage. Pressure differential testing will also be conducted to determine pressure imbalances. Weatherization technicians will provide air tightness testing.
- **Thermal Imaging/Scanning** – This process will be conducted on participating homes in Fairbanks during normal winter operation. This will provide visual data to correlate building characteristics, performance, and incidence of condensation and other air quality or durability issues. UAF and CCHRC will conduct thermal imaging.

Rural CAP, IWI, CCHRC & UAF performed complex testing. UAF was in charge of Quality Assurance/Quality Control.

Environmental Assessment Protocols

The definition of the project scope incorporated previous work as published in the literature, and the indoor air quality experience of the investigators with respect to houses in the sub arctic climate.

Each subject house was assessed using an initial survey to document the number of residents, general house use patterns, indoor air pollutant sources, descriptions of systems in the house, sanitation conditions, and a physical description of the house. Contaminants measured were CO, particulates, and VOC's. Other parameters of interest were CO2, RH, indoor and outdoor temperatures, and other evidence of contamination stemming from a lack of plumbing and sanitation facilities.

<u>QA/QC For Data Collection And Analysis</u> The University of Alaska lab, or a certified lab specializing in the analysis performed all lab workp All analysis utilized industry standard analysis methods and will be described in the report.

Medical Assessments - See Sections 7 and 13

Mitigation

The results of the preliminary IAQ tests and visual assessment were reviewed and analyzed to develop a process for the development of work specifications and the management of cost effectiveness. The extent of the remediation efforts was determined by the extent of the needs within the home, the severity of the health issues present in young residents, and the budget funds available to complete the work. Homes in Hooper Bay had significantly higher costs than the homes in the Fairbanks area due to logistics.

Measures were implemented to reduce asthma triggers, within the scope of the budget. Each measure was documented thoroughly with photographs. Because this project had limited funding for implementing a full compliment of measures for each home, our goal was to maximize the benefit with selected measures on an individualized basis. Overall the principals behind any recommendation that we made were threefold: the first is that all measures were directly tied to the health of our clients; secondly, they were prioritized to maximize the impact within the available budget; and, third that they were deemed as maximizing cost effectiveness in the long term.

Specific Interventions
The following is a list of some of the interventions considered to mitigate identified hazards:

1. Insure that all combustion appliances are drafting properly (repair and replace as necessary).
2. Repair and/or remove and replace any combustion appliances that are producing toxins.
3. Provide adequate ventilation in under-ventilated homes. Add fans and vents or HRV systems. Dryers may be added in some homes to reduce moisture from wet laundry. In some cases additional space may be constructed (approximately 32-60 square feet)
4. Provide adequate combustion and/or makeup air into the home.
5. Seal with a ground vapor barrier in the crawl space and provide adequate ventilation or power vent to rid excess moisture from the crawl space.
6. Air seal the building envelope to prevent migration of moisture into building components.
7. Where appropriate institute lead hazard reduction measures.
8. Where appropriate institute asbestos remediation methods.
9. Where necessary institute recommended mold mitigation measures (cleanup, removal of materials and elimination of source moisture) including mattress and sofa replacement where mold and other microbial contamination is extreme. Mattresses will be lifted off of floors with simple bed frames to eliminate condensation on the undersides.
10. Contaminated bedding materials will be cleaned when possible, or replaced as necessary. Covers will be provided to prevent future contamination.
11. Change carpet (and/or replace with other flooring component) and other sources of indoor air pollutants if necessary. Add shelving and organization to get clothing and household materials off floors.
12. Cover and seal all insulation exposed to the indoor living space.
13. Add insulation to wall components where icing is a problem (leading to degradation of building materials).
14. Air and bypass seal the attic space and provide proper ventilation.
15. Replacement of interior wall and flooring materials where necessary if off gassing of specific products is an asthma trigger with the occupants.
16. Electrical repairs where necessary to eliminate fire hazards or to support installation of an electric appliance (such as a fan or a stove).
17. Isolate the garage with bypass and airsealing methods from the living area.
18. Relocate exhaust flues that may short circuit into outdoor air intake vents.
19. Seal ducts and air distribution systems to improve efficiency and air quality.
20. Add hand washing station and grey water disposal to reduce moisture loads and improve sanitation. (In some cases additional space may be constructed (approximately 32-60 square feet.)

In addition to identifying environmental contaminants and their cause, we also identified other home-based hazards. These included serious Building Code or safety violations; use of ozone generators, physical needs assessments, lead-based paint, etc.
If serious hazards, such as potential fire, structural failure, or other dangerous condition were encountered, the occupant, landlord, or housing agency was notified immediately.

Remediation strategies corresponded to the type and level of contaminants and other home based hazards. The intervention strategies began with identification of the contaminant source or the catalyst. Sources of moisture or contamination were repaired or mitigated prior to any further remediation work. Some of the possible intervention strategies included: wet vacuum, damp wipe (biocides if warranted), HEPA vacuum, and material removal/disposal. Training for all investigators and remediation technicians included guidelines and use of personal and occupant protection equipment. Interior Weatherization and RuralCAP conducted all remediation activities. One or two persons from each organization were designated the Worker Safety Representative, and received further training in coordinating and implementing safety programs and monitoring. Personal protective equipment was provided to workers.

A guide to keeping your home healthy was developed for each participant (see Section 11). The guide includes necessary maintenance on ventilation and other mechanical equipment installed as part of the remediation efforts. Other general topics include controlling moisture and dust in your home and other healthy home recommendations

RESULTS & DELIVERABLES
A. Coordination and Training Meetings
John Davies (Cold Climate Housing Research Center)

Meetings were held on the following dates for the indicated purposes:

Date	Location	Purpose
July 10, 2002	Fairbanks	Planning and Coordination
Nov. 25, 2002	Fairbanks	Training and coordination
Dec. 18, 2002	Fairbanks	Update on IRB and planning
June 30, 2003	Teleconf.	HUD conf. call Re: Online report system
Aug. 11, 2003	Teleconf.	Dale Darrow on revised statement of work
Feb. 24, 2004	Fairbanks	Coordination and update
Nov. 3, 2004	Fairbanks	Wrap-up and report planning

Minutes of the Nov. 25, 2002 training meeting, for example, follow on the next page.

HUD HEALTHY HOMES

COORDINATION MEETING

Fairbanks, Alaska

On November 25 & 26, 2002, training was conducted for the Healthy Homes program.Phil Kaluza, Project Manager conducted the meeting.

The following individuals participated in the meeting:

Jack Hébert, President/CEO, John Davies, Research Director, Phil Kaluza, Project Manager, Gail Koepf, Office Manager, Robert Maxwell, Project Manager, all of the Cold Climate Housing Research Center (CCHRC):

Ron Johnson & Jack Schmid of the University of Alaska, Fairbanks, Institute of Northern Engineering, Mimi Burbage & Scott Waterman of Alaska Housing Finance Corporation (AHFC), Paul Woodman of Interior Weatherization, Ralph Lee & Toy Owen of Rural Cap, and McGregor Pearce, microbiologist and mold specialist

The purpose of the training was to familiarize the Weatherization Assessors on utilizing the IAQ assessment forms and monitoring equipment.

- Phil Kaluza did an introduction to the Healthy Homes Project to include the goals, objectives, and expected deliverables.
- Paul Woodman stated the budget for Interior Weatherization is $3,500 – the general cost for weatherization and $8,000 for remediation, remove carpeting and mitigation of mold.
- Ralph Lee of Rural Cap stated they have a $15,000 limit for the general cost of weatherization in rural areas.
- Ron Johnson and Jack Schmidt discussed the need for and the use of monitoring, assessment and Equipment for the following suspected pollutants
    1. HCHO – Formaldehyde
    2. SVOC – Semi-VOC
    3. PM – Particulate
    4. ETS – Environmental Tobacco Smoke
    5. CO, CO2, H20, NO, NO2, SO2, HCHO, HCs
    6. NO2 – can cause respiratory
    7. PAH – Polycyclic Aromatic Hydrocarbons (eg. Mothballs)
    8. Fungi – 25% of world's biomass
    9. P Trak – measures fine particles
    10. Dust Trak – measures lager particles
    11. Q Trak –
    12. Passive Badges – benzene (long term risk of leukemia)
    13. Bioaerosols – pollen, spores, dust mites, bacteria, mold, animal dander
    14. ALA estimate 30% of US population are allergic to cats
    15. HEPA – high efficiency particle

16. Measurement times needed for good indoor air quality evaluation –
    Particulate – 8 hours
    Hobo data loggers – 2 weeks
    Badge – 1 week
    Mold - ?
    Building use pattern

Ron and Jack explained how they would create a testing box with that equipment. From this meeting these test boxes were created with temperature, relative humidity, carbon monoxide and carbon dioxide data loggers. Benzene and formaldehyde badges were also included. These boxes were then deployed in the project homes and the control homes for pre and post remediation testing.

Further discussion was held to talk about:

- The need to submit modified strategy to HUD.
- The need to identify towns – Fairbanks & Hooper Bay or Emonak.
- Phil will contact Dr. Mary Ellen Gordian and finalize town choice.
- Any publicity that goes out has to have income guidelines included.
- School nurses will distribute flyers.
- Interior Weatherization has a waiting list of rentals.
- Weatherization – heating system – repair/replacement
  Ventilation
  Themal – Attic, floors
  Air sealing
  Health & safety – electrical, CO detectors, smoke alarms
  Replace cookstove, kitchen hoods
  Possible replacement of mattress, carpet etc.

Various equipment on hand was brought in, and each weatherization person, and project manager had the opportunity to go over the use of each type of tester. An assessment protocol was developed, and from this meeting the assessment form evolved. Mac Pearce did a lecture/demonstration on various types of mold testing protocols. Since this was preliminary and prior to selection of the homes that would be worked on, no one protocol was selected for mold testing.

RESULTS & DELIVERABLES
IRB Proposals
Mary Ellen Gordian (University of Alaska Anchorage)

I. TITLE: Healthy Homes in Alaska

II. DESCRIPTION

A. Overview

The **Healthy Homes** project is the result of a grant received by Alaska Housing Finance Corporation (AHFC) from the U.S. Department of Housing and Urban Development. AHFC contracted with Cold Climate Housing Research Center in Fairbanks to oversee the program. The original intent of the program was to increase the capacity of the weatherization program, a program supported by AHFC, to remove possible respiratory hazards in the homes of low-income people who have children with asthma. A copy of the original proposal is attached. The extent of the repairs that were targeted by this proposal is listed on page 16 of the proposal. CCHRC has contracted with the Institute for Circumpolar Health Studies to help define and implement the health component of the project.

The weatherization program is implementing the Alaskan Healthy Homes project, which is different from other Healthy Homes projects, which were implemented by universities and public health institutions. The weatherization program is a benefits program that assists low-income people by providing free weatherization including new windows, doors, insulation as well as smoke detectors, carbon monoxide detectors, ventilation fans, and other safety features. The program has an income eligibility test for recipients and is very popular in Alaska. The **Healthy Homes** project will add additional services including removal and replacement of water-damaged material and carpeting to the weatherization protocol.

The **Healthy Homes** project in other areas has focused on eliminating cockroaches or environmental tobacco smoke in inner cities apartments in New York City (Kinney et al 2002, Crain et al 2002), reducing dust mites in low-income homes of children with asthma in Seattle (Krieger et al 2002). The Seattle study noted "mold was visible in 26.8% of homes, water damage was present in 18.6% of homes, and damp conditions occurred in 64.8% of households." and "The project was limited in resolving structural housing quality issues that contributed to exposure to indoor triggers." There are many cross-sectional studies that have concluded that damp and moldy buildings adversely affect children's health (Platt et el 1989, Brunekreef et al 1989, Dekker et al 1991, Etzel & Rylander, 1999). A recent review of the non-industrial indoor environment in relation to asthma is presented in Chapter 8 of the book *Environmental Asthma* edited by Robert K. Bush. However, there are <u>no</u> published studies that have attempted to investigate changes in structural housing features such as water damaged residential building materials and assess the effect of changes in building integrity on the health of the residents. This is not a trivial question. Whether older housing can be successfully remediated, or whether housing funds should be prioritize to new housing is an important decision that HUD has to make. This work has the potential to inform that decision.

B. Background and Significance

Respiratory conditions, both acute and chronic, are common in Alaska children. Acute pediatric respiratory infections occur more commonly among Alaska Natives than in many other populations. Respiratory syncytial virus (RSV) infection is the most common viral cause of lower respiratory infections (LRIs) in infants. In the Yukon Kuskokwim (YK) Delta region of Alaska, the annual hospitalization rates of infants infected with RSV average 150 per 1000 population (range: 50 to 250/1000) and are the highest ever reported anywhere. *Streptococcus pneumoniae*, the most common cause of bacterial pneumonia in children, is a common cause of infection in the YK Delta as well. The incidence of invasive *S. pneumoniae* infection in infants <2 years of age in this region (1200/100,000) is among the highest in the world.

Chronic respiratory disease is also common in Alaska Native children. Asthma is the most common chronic disease in Alaska Native children just as it is in other populations. The prevalence of asthma has been increasing, especially among minority populations including Alaska Natives. In spite of improved living conditions and improved availability of medical care, asthma is one of the few medical conditions that is not improving for the Alaska Natives. In a 1997 survey of 465 Alaska Native children in grades 6-9 in the YK Delta, 24% had asthma or asthma-like symptoms, another 37% were sputum producers, and only 39% were normal.

Bronchiectasis, another chronic respiratory condition that is rare in other U.S. populations, is relatively common in Alaska Natives, especially in the YK Delta. The high prevalence of bronchiectasis in this population of Alaska Native children has continued for the last several decades, despite control of tuberculosis, pertussis, and measles. In a recent review of 46 cases of bronchiectasis we found that the most common predisposing factor was early and recurrent pneumonias and other LRIs, presumably viral in etiology. The most common co-morbid conditions were asthma (74%), chronic otitis media (30%), and abuse/neglect (22%); medical non-compliance was also common (33%).

It is not known why asthma and other chronic respiratory diseases in the Alaska Native population is so prominent nor why bronchiectasis continues to remain such a problem for Alaska Natives living in the YK Delta. In this study we will explore the hypothesis that environmental conditions in homes may promote respiratory infections such as pneumonia and bronchiolitis in infants and young children and initiate processes which culminate in the chronic respiratory conditions of asthma and bronchiectasis.

The majority of asthma in children over five years through young adults is thought to be allergic or extrinsic asthma characterized by increased responsiveness to common allergens. In intrinsic asthma chronic inflammation and bronchial hyper-responsiveness occurs without specific IgE elevation or positive allergy skin tests. Intrinsic asthma is frequently seen in occupational exposures in adults, but it can also be found in children. An evaluation of allergy status and IgE will help to characterize the type of asthma found in Alaskan low-income children.

In chamber studies a mixture of volatile organic compounds known as VOC's was shown to increase lower respiratory symptoms-chest tightness, shortness of breath, and cough in a dose response manner both immediately and two hours after exposure. (Pappas et al 2000) There have been case reports of new onset of asthma after exposure to hydrocarbon fumes. (Todd &Buick, 2000) The fumes of environmental tobacco smoke are a common source of benzene and other VOCs indoors (Wallace 1989) and mold that produces distinctive VOCs is suspected to be associated with chronic respiratory symptoms (Rylander and Etzel, 1998).

The Leipzig Allergy Risk Children Study (LARS) found that children at risk for atopy exposed to VOC's indoors had an increased risk of allergic sensitization to food allergens. The VOC levels were measured over four weeks in children's homes. Children living in homes in the highest quartile had increased allergic sensitization based on RAST testing as compared to all other children. A sub-sample of children showed a trend toward higher numbers Type 2 cells producing IL-4 with increasing exposure to VOCs (Lehmann et al 2001).

In Anchorage, 25% of the housing stock was found to have elevated VOC levels (Air Quality Program, DHHS, 1998). Urinary biomarker, trans,trans muconic acid ttMA was found to be positively correlated with indoor benzene levels in adults during this study (personal communication, Virginia Weaver). Because of the expense and intrusiveness of indoor air monitoring, using urinary biomarkers to assess exposure to pollutants is very promising, but needs to be studied in many different situations to determine the reliability of this non-invasive measure of exposure.

C. Research Hypothesis

Hypothesis1) Weatherization crews can improve the indoor air quality and reduce exposure to indoor pollutants in children with chronic respiratory disease.

Hypothesis 2) Children with chronic respiratory disease will show improvement in objective measures of disease after pollutant sources are removed from their homes.

Hypothesis 3) Biomarkers of exposure will be reduced in children with chronic respiratory disease after removal of source pollutants from their homes.

Because of the high cost of remediation the number of subjects in this study is small. This is an observational study designed to assess the feasibility of improving the health of low-income children with chronic respiratory disease in Fairbanks and in Hooper Bay by removing water damaged building materials and other sources of indoor air pollutants in their homes. Low-income children have less access to physicians for evaluation of respiratory symptoms and this project will pay for two visits to a healthcare provider for a complete respiratory health evaluation. The initial visit will determine whether a chronic condition exists. The second visit would occur after the renovations have been done and the house is restored to order, to determine whether there is a change in symptoms, signs or biomarkers.

D. Objectives

1. Describe the respiratory status of
   - a group of low-income children living in Hooper Bay
   - a group of low-income children living in Fairbanks
2. Explore possible associations between environmental factors and chronic respiratory signs and symptoms
3. Examine the relationship of specific urinary biomarkers and indoor measurements of VOCs and particulate matter.

E. Power Calculation

Power was calculated for a range of correlation coefficients between measured benzene and measured urinary ttMA, which is the only biomarker that we have experience with in Alaska.

	Power for correlation coefficient of				
N	*.3*	*.4*	*.5*	*.6*	*.7*
10	*.22*	*.32*	*.46*	*.62*	*.79*
20	*.37*	*.56*	*.76*	*.90*	*.98*
30	*.50*	*.73*	*.90*	*.98*	*.99*
40	*.60*	*.83*	*.96*	*.99*	*.99*

Thus given 20 subjects enrolled, there is an approximate 90% power to detect a significant ($p < 0.05$) correlation coefficient of 0.6 and 76% power to detect a correlation of 0.5. The correlation coefficient for adult ttMA and indoor benzene was 0.63.

III. METHODS AND MATERIALS

A. Study Design

This is an observational study with prospective follow-up.

B. Sample Size and Selection

The subjects for this study will be recruited by advertising, word of mouth, and letters from local providers to families with children with chronic respiratory illness. The first criteria for selection will be income eligibility for weatherization, the second will be home ownership, and the third will be having a child with chronic respiratory disease. The subjects are low-income children with chronic respiratory disease. The program has resources to examine up to 20 children in each location and to renovate the homes of 10 families. If more than 20 families apply for the program, the healthcare provider will be asked to review the medical records for the children and select 20 who have evidence of chronic respiratory disease by their medical history. If there are still more than 20 eligible, the healthcare provider will select 20 names from that group by lottery. After the children have been examined for chronic respiratory disease, the healthcare provider will rank them in order of severity of disease using the criteria outlined below. Enhanced weatherization will be given to the ten families with children who have severe or moderate to severe asthma unless their home is unfixable. If there are more than ten children in this category than the participants will be chosen by lottery. The families of children who are examined but not selected can still have their indoor air quality monitored, if they chose, and they are still eligible to receive regular weatherization. Ten families will receive enhanced weatherization in Fairbanks and ten in Hooper Bay. If there are not ten who meet the criteria in Hooper Bay, the same steps will be taken in Emmonak until ten houses are found. Only children whose parents agree to have the child examined for respiratory illness will be examined, some of who may not have significant respiratory illness. A child is eligible for inclusion in the Healthy Homes in Alaska study only if they are found to have signs or symptoms of chronic respiratory disease. The families of children who are examined but are not found to have signs or symptoms of chronic respiratory disease are still eligible to receive weatherization.

For the study, in Hooper Bay, CCHRC will contract with a healthcare provider from YK Healthcare Corporation who will contact the parents of potential participants by phone to explain the study, obtain preliminary assent to participate, and to set up a village visit date. Informed consent and assent from participants 6+ years old will be obtained at the time of the village visit. Subjects will be at least six years old at the time of the exam, the minimum age when cooperation with pulmonary function testing is anticipated. In Fairbanks, a healthcare provider from Dr. Timothy Foote’s office will contact parents and set up an appointment with Dr. Foote. Informed consent and assent from participants 6+ years old will be obtained at that time.

C. Clinical and Laboratory Evaluations

After informed consent, the subject’s medical history (including family history of asthma, allergies or chronic respiratory disease) will be obtained from the parent or guardian. A review of medication use relating to respiratory symptoms (bronchodilators, adrenocortical steroids, antibiotics) will be obtained by asking the parents and/or reviewing the village clinic record and the computerized pharmacy records from YK Delta Regional Hospital and ANMC, or any other medical facility if needed.

Subjects will be evaluated in their home communities. The evaluation will include a physical examination, including height and weight determination and vital signs on each subject, paying special attention to ENT and respiratory findings. Pulmonary function testing (spirometry and oximetry, if available) and chest auscultation will be performed on each subject to document signs of respiratory disease including bronchial hyper-reactivity. Skin testing will be done on all children, if possible. Blood (≤15 ml) will be collected on each subject for total IgE antibody levels to document evidence of atopy, a CBC will be done on the Fairbanks children, a slide for white cell differential will be done on the village children. Urine specimens will be collected by subjects in their homes and brought to the visit.

Additional evaluations or referral to the regional hospital for chest radiographs will be made if needed. Transportation and x-ray costs will be not be paid by the research study. All families will be given information about Denali KidCare as a resource for follow-up care.

Diagnostic criteria: (the presence of any sign or symptom will allow participation if substantiated by medical examination.)

A. Symptoms of chronic respiratory disease
   1. Recurrent ($\geq$4 times in 12 months) of lower respiratory tract illness, or
   2. Chronic (daily or every other day) occurrence of
      a. Shortness of breath (hard time breathing)
      b. Productive cough or non-productive cough
      c. Wheezing
      d. Nocturnal awakening with shortness of breath or cough

B. Signs of chronic respiratory disease
   1. Hyperinflation (increased A-P chest diameter)
   2. Abnormal breath sounds, wheeze, rales, rhonchi, or decreased sounds
   3. Tachypnea
   4. Spontaneous productive cough

C. Pulmonary Function Testing Abnormalities
   1. FVC, FEV1, FEV1/FVC or $FEF_{(25-75)}$ less than 80% of predicted value.

D. Data and Specimen Collection

The consent form will include a request and authorization for interview, exam, and release of information from the village health center, YK Delta Regional Hospital, ANMC, or any other medical facility, if needed. Standardized forms will be available for the recording of information from medical records, medical history, physical examination, and pulmonary function testing. The physical examinations will be done by Dr. Foote in Fairbanks, or a nurse-practitioner employed by YK Healthcare Corporation. A respiratory therapist utilizing a maximum expiratory flow volume loop with a portable spirometer will perform the spirometry. A blood specimen ($\leq$15 mL) will be obtained by venipuncture. Serum specimens will be spun down in the village. A single drop of blood will be smeared on a slide for white blood cell differential.

All data collection forms and specimens will be labeled with birth year, current date, and identification number. All blood specimens except for CBCs will be transported to the Arctic Investigations Program (AIP/CDC) in Anchorage for further testing. CBCs and slides will be sent to Laboratory Corporation of America. Urine specimens will be sent to the chemistry laboratory at the University of Alaska Anchorage.

E. Laboratory Analysis

Dr. Timothy Foote, pediatric pulmonologist will analyze the results of the pulmonary function testing. Serum IgE will be performed at AIP/CDC using commercial kits. Blood eosinophil counts and CBCs will be performed by Laboratory Corporation of America laboratory. The chemistry department of the University of Alaska Anchorage will analyze the urinary biomarkers.

F. Data Analysis

1. Primary outcome measures are the abnormal objective respiratory findings with increased bronchial hyper reactivity:

a. Abnormal chest physical exam: hyperinflation, abnormal breath sounds, and tachypnea
b. Abnormal spirometry: FEV_1/FVC or FEV1 <80% predicted;
c. Abnormal oxygen saturation: oximetry O_2 <94%

2. Secondary outcome measures
   a. History of chronic cough: daily or every other day cough for 3 months
   b. Urinary biomarkers of exposure
   c. IgE levels
   d. Eosinophilia
   e. Skin allergy testing

Data will be entered in Cardiff software for computerized data entry and analysis will be performed at Institute for Circumpolar Health Studies. Associations between the outcomes of disease and measures of exposures will be examined.

G. Reporting of Results

1. At the time of the initial assessment of the child, the parent will be informed of the health care provider's initial impression of the child's condition and whether follow up care will be recommended.
2. A written report of the child's individual evaluation and the house evaluation will be sent to the parents within four months of the encounter.
3. The results of the individual subjects' physical examinations, pulmonary function testing, and blood IgE will be kept at the village clinic, and/or the YK Delta Regional Hospital medical records for YK Delta participants. Fairbanks's children results will be kept with Dr. Foote.
4. The summary results of the entire study will be reported to the Office of the YK Health Corporation Medical Director and to the parents upon completion of the study and prior to publication of results.
6. After completion of the study, the investigators will submit a complete analysis of the study for publication in a medical journal. The location of the research will not be identified in detail to preserve confidentiality.

IV. STUDY POPULATION

The study population includes boys and girls between six and seventeen years old residing in Hooper Bay of the YK Delta and in Fairbanks. There will be a total of twenty homes receiving enhanced weatherization through Healthy Homes. Each home must have at least one child with chronic respiratory illness with a reversible component.

V. RISK/BENEFIT INFORMATION

There are minimal risks to participating in this study. There will be mild discomfort while obtaining a blood specimen by venipuncture and a chance of mild bruising at the site where the blood is withdrawn. There should be no risk associated with pulmonary function testing. The examination including skin allergy testing is not painful.

The examination is a standard medical assessment that has been agreed upon by local pediatric asthma specialists (Dr. Jeffery Demain and Dr. Timothy Foote) as a standard of medical practice. The benefit for the participant includes knowledge about the presence of chronic respiratory disease and its extent. This may lead to further medical interventions to improve the subject's long-term outcome. Records of the physical examination, pulmonary function testing, and blood tests will become part of the permanent medical record of the subject.

Learning to what allergens the child is allergic will benefit the child and his/her parents in avoiding these allergens thereby preventing exacerbations of illness. Similarly, learning that the child is not allergic to particular allergens increases the child's autonomy.

There is potential benefit to the Alaskan population in terms of increased understanding of the effect of indoor exposures on chronic respiratory disease of Alaskan children and the potential that interventions can be designed to prevent harm.

Home improvements are a benefit for families.

VI. INFORMED CONSENT PROCEDURES

Written informed consent will be obtained from each parent/guardian after a thorough explanation of the research accompanied by an opportunity to ask questions. Assent will also be obtained from all children after explaining the examination to the child. No child will be forced to do any part of the examination to which he/she does not assent.

VII. RECORDS MANAGEMENT

The principal investigator at the ICHS will maintain the signed protocol, necessary approvals, and institutional review board correspondence. The original consent form will be maintained in a secured file at ICHS. The blood tests results will be maintained in a secure computer file at AIP/CDC. Information from the history and physical examination will be kept in the medical facility and secured as any medical records. The pulmonary function data will be kept in the medical facility. All results that leave the medical facility will be coded with no personal identifiers on them. Keys to coded information will be kept in a locked safe at ICHS.

VIII. ASSURANCES OF CONFIDENTIALITY

Individuals providing information requested by our questionnaires and giving permission will be informed of the reasons for collecting the information and how the information will be used. All data will be kept confidential. Names of individual subjects or individual towns will not appear on any publication.

IX. FUNDING

The funding for this study is from the Cold Climate Housing Research Center in Fairbanks. Special in-kind services will be provided by Centers for Disease Control and Prevention/Arctic Investigations Program for analysis of IgE.

X. INVESTIGATORS/COLLABORATORS

A. Principal Investigator: ICHS
Mary Ellen Gordian, MD

B. Co-Investigators: CCHRC
Timothy Foote, MD

C. Project Manager
Phil Kaluza, Anchorage

XI. REFERENCES

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XII. CONSENT FORM

INFORMED CONSENT FORM

The Healthy Homes in Alaska project

INTRODUCTION:
Alaska Housing Finance Corporation, the University of Alaska, and the Cold Climate Housing Research Center are studying the effects of housing factors on the health of children with chronic respiratory illness. The intent of the program is to remove possible respiratory hazards in the homes of low-income people who have children with asthma. We would like to know whether removing respiratory hazards and improving air quality in the home will help children have fewer symptoms. You are invited to participate in this study because you are the parent or guardian of a child who may have asthma or other chronic respiratory problems. You must also meet an income requirement and you must be the owners of your own home to participate. <u>Only ten houses and ten families</u> can be enrolled in the enhanced weatherization, all other houses will receive regular weatherization. If more than 10 families are qualified, the decision as to who receives enhanced weatherization will be based on the results of the examination. We can examine up to 20 children to determine eligibility. If there are more than 20 applicants we will ask that you present past medical records to substantiate that the child has asthma to have the child examined. Anytime there are more children potentially eligible than we are able to accommodate, children with equal eligibility will be selected by lottery. Only healthcare providers working for the project will review any medical records.

PURPOSE OF THIS RESEARCH:
Many children suffer from wheezing and cough. Often, things in the air, like dust, fumes, mold or smoke, can make breathing problems worse. We would like to see if there are high levels of dust, smoke, mold, or gas fumes in the air in people's houses. Then we would like to know if we can reduce these pollutants by eliminating sources or increasing

ventilation. Finally, we want to know if removing the sources of indoor air pollution in a child's home results in improvements in respiratory health.

WHAT THE RESEARCH INVOLVES:
If you agree to take part in the study you will be asked to have your child examined by our local health care provider, Dr. Foote in Fairbanks, and a healthcare provider credentialed by the Yukon-Kuskokwim Health Care Corporation in Hooper Bay, who will do a standard medical examination for respiratory problems.

- Ask you and your child questions about child's medical history & symptoms.
- Do a routine physical examination for respiratory problems, looking at ears, nose, throat, listening to lungs and heart, measuring weight height and vital signs..
- Do a breathing test for lung function, where the child will be asked to breathe quickly into a machine.
- Do allergy skin prick tests to determine whether the child has allergies to common things like mold or animals.
- Draw a sample of blood (about one tablespoon) to test for allergy and infection.
- Collect your child's urine to look for biomarkers of exposure to fumes and particles.
- Suggest follow-up treatment, if necessary

If the healthcare provider finds that your child does not have a chronic respiratory condition you are still eligible for regular weatherization, which will be done as quickly as is possible without any penalty.

If your child has had a medical examination for respiratory problems by a physician in the last six months and these records are available, you can submit these records to the healthcare provider in place of all or part of the examination. Urine specimens would still be requested because these are the only part that are not standard in medical examinations.

The weatherization team will also ask you questions about your home and inspect for mold, carpeting, heating, ventilation, safety concerns, and size of the house. They will place put a small monitor in your house for about a month that reads temperature, humidity, carbon dioxide and carbon monoxide. The will also put a small container in your house that measures some fumes in the air from things like gasoline or propane and put a small instrument in your house for 24-48 hours with a small fan that draws in air to measure particles of dust and smoke. Dust samples to test for allergens will be vacuumed from an area in the living room and from your child's bed.

After these tests are completed weatherization crews will develop a work plan with you and your family. They may add insulation, replace deteriorating windows or doors that leak, and they will test for ventilation. All houses will receive standard weatherization and safety improvements. Removing water-damaged materials and sources of allergens will be included in the work plan if you agree.

After the work is completed we will monitor the air quality again in the same way, and we will ask you to have your child re-examined by the same local healthcare provider. The health care provider who sees your child will also be able to arrange for treatment of any respiratory illness that is discovered during either examination. Treatment and referrals will not be paid for by the research grant, however, healthcare personnel will assist you in applying for Denali KidCare, which provides health insurance to low-income children without cost to the family.

All medical specimens will be destroyed in the appropriate manner when the research is completed.

RISKS AND DISCOMFORTS:
There may be additional dust created in the home during the home improvement phase of the project. The air monitoring instruments are small, less than the size of a shoebox, and they will be placed out of the way, and unnoticeable with the exception of the dust monitor that sounds like an aquarium pump**.**

Obtaining a urine sample only requires that your child pee in a container and that will be done in the privacy of your home. The blood tests are standard medical procedures and will be done by the staff skilled in the procedure. There is slight pain when the needle is put into the skin and a bruise might appear at the site. Skin prick tests are standard medical treatment and are not painful, if positive they may produce a small welt on the skin, but no adverse effects have been documented from them.

BENEFITS OF THIS STUDY:
There is no cost to you to take part in this study, including the medical tests and the home improvements.

The medical examination and tests have been designed by respiratory specialists to provide sufficient information to diagnose and treat respiratory illness except for a chest x-ray, which has not been included. The medical exam will give you reliable information about your child's respiratory problems. Your child will also be able to find out about allergies from the exam. If the provider thinks that additional tests are needed, they will discuss this with you and arrange for the tests to be done. However, additional tests will not be paid for by the research project.

You will be advised if air quality problems are found in your home. You will learn about the sources of air pollution in your home and ventilation will be improved, if necessary. You will receive replacement windows or doors, if needed. You will receive additional insulation as needed. You will receive safety devices such as smoke detectors and carbon monoxide monitors. You may receive additional improvements, if needed. The air quality in your home should improve, and your home may become safer for your child. The problems in your home will be repaired on a priority system within the limits of our budget for each home. You will be provided with a full report.

CONFIDENTIALITY:
All information will be kept confidential to the extent legally possible. Neither your home nor your child will be identified in any report or publication resulting from this study. The medical records and test results will be available to you from the clinic. Research information will be coded in a way that does not allow identification of individuals before they are released to the University for analysis. No personal identification will be sent outside of the medical office.

RESULTS:
We will send you the results of the testing on your house and a summary of the results of the medical examination with explanations of abnormal findings. You can take the results to your health care provider for follow-up.

VOLUNTARY AGREEMENT:
Taking part in this research is your choice. You may refuse to participate at any time. You may receive standard weatherization services without participating in the medical examination. Participation in this study will not affect any other medical benefits to which you or your child may be entitled.

PERSONS TO CONTACT:
If you have questions about the medical aspects of the study, please call Dr. Mary Ellen Gordian at the University of Alaska Anchorage 907-786-6569.
If you have questions about the monitoring of the air quality, please call Prof. Ron Johnson at University of Alaska Fairbanks 1-800-478-8324.
If you have questions about the conduct of the research project in Hooper Bay , you can contact the medical director of Yukon-Kuskokwim Health Care Corporation, Dr. Joseph Klekja at 907-543-6028.
If you have questions about the conduct of the research in Fairbanks, you can call the project manager, John Davies at Cold Climate Housing Research Center 907-457-3454.
If you have questions about the home improvements, please call Phil Kaluza at 907-348-6695.
If you have questions about eligibility to participate, please call Mimi Burbage at Alaska Housing Finance Corporation 907-330-8192.
If you think that you have not been treated fairly, or have been hurt by joining the study; or if you have questions about your rights in this study, contact Dr. Kim Peterson, Associate Vice-Provost for Research at University of Alaska Anchorage 907-786-4833

APPROVAL: I have read or have been told about this research study, and all of my questions have been answered to my satisfaction. I have been given a copy of the consent and I agree to take part in this study.

Please initial:

( ) I have received, read, and understand this information and consent to take part, *OR*,

(   ) I am non-English speaking but the details of this project have been clearly translated to me in my native language, and I consent to take part.
Interpreter's signature: ________________________

Name of Child/Participant:____________________________ **C#:**

Date of birth:________________

Signature of Parent: ____________________________ Date:_____________

Signature of Witness: ____________________________ Date:______________

Child's Assent

I understand that I will have a medical examination to check for lung problems. The examination may help me to find out more about my body. My parents or guardians and the researchers have explained to me what will happen during the examination and I understand that I will not be hurt by the examination. All of my questions are answered. I agree to do it.

Child's signature _____________________

YK Health Corporation IRB Application

1) Name of the Study **Healthy Homes in Alaska**

2) Names of the Researchers and their Affiliations
The medical aspects of the study, Mary Ellen Gordian, MD, MPH, The Institute for Circumpolar Health Studies, University of Alaska Anchorage.
Air quality monitoring, Rich Seifert, PhD. University of Alaska Fairbanks 1-800-478-8324.
Home remediation Phil Kaluza Cold Climate Housing Research Center .
Eligibility to participate Mimi Burbage Alaska Housing Finance Corporation 907-330-8192.

3) A contact address, phone number, and email.

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Mr. Phil Kaluza
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4) Funding Source and length of funding
Department of Housing and Urban Development funded Alaska Housing Finance Corporation who have contracted with Cold Climate Housing Research Center in Fairbanks to implement the grant. CCHRC has contracted with the Institute for Circumpolar Health Studies to design the health assessment part of this 3 year study with 2.5 years remaining.

5) Anticipated Dates of study
In Hooper Bay and possibly Emmonak January 2003, through June, 2005

6) Goals of the Study (Why do study)
The goal of the study is to determine whether removing environmental pollutants from the home environment might benefit children with chronic respiratory disease. This will be done in conjunction with the regular weatherization program which is available to all low-income people.

7) Population to be studied
Children between 6 and 17 years with chronic respiratory disease including asthma in low-income families who are eligible for weatherizarion and own their own home.

8) Synopsis of the Protocol

A medical examination will be offered to children 6 to 17 years with chronic respiratory disease from low-income families who are eligible for weatherizarion and own their own home. This examination will include a history, physical examination, pulmonary function tests, blood tests for white cell counts and IgE, and skin testing for allergies. They will also be asked to bring in urine specimens collected at home. Their homes will be monitored for particles, fumes, and carbon monoxide for as long as a month with passive badges that do not require electricity. Dust samples will be taken to look for mold and other respiratory irritants. Based on the results of the examination and with input from the local health provider, the homes of the ten most severely ill children will be chosen to have additional improvements such as removing water-damaged building materials and other sources of pollutants especially in the child's area. All homes will receive regular weatherization which includes improved ventilation, even the homes of low-income people without children. Ten homes will received "enhanced weatherization". Seven additional homes can receive the monitoring but not additional renovations. Those children whose homes are renovated will receive a second examination similar to the first except for allergy testing. The air pollutants in the home will also be monitored again after the renovations are completed.

If there are more than 10 children severely ill and the selection cannot be made based on severity of illness than the 10 homes will be selected by random drawing from this pool of severely ill children. If the home cannot be fixed because of structural problems, than another home will be selected. Homes that cannot receive "enhanced weatherization" may still receive some regular weatherization as needed.

9) Risks of the Study

There are minimal risks to participating in this study. There will be mild discomfort while obtaining a blood specimen by venipuncture and a chance of mild bruising at the site where the blood is withdrawn. There should be no risk associated with pulmonary function testing. The examination including skin allergy testing is not painful.

10) Benefits of the Study

The examination is a standard medical assessment that has been agreed upon by pediatric asthma specialists as a standard of medical practice. The benefit for the participant includes knowledge about the presence of chronic respiratory disease and its extent. This may lead to further medical interventions to improve the subject's long term health. Records of the physical examination, pulmonary function testing, and blood tests will become part of the permanent medical record of the subject.

Learning to what allergens the child is allergic will benefit the child and his/her parents in avoiding these allergens thereby preventing exacerbations of illness. Similarly, learning that the child is not allergic to particular allergens increases the child's autonomy.

There is potential benefit to the Alaskan population in terms of increased understanding of the effect of indoor exposures on chronic respiratory disease of Alaskan children and the potential that interventions can be designed to prevent harm.

Home improvements are a benefit for families. All improvements are at no cost to the home-owner.

11) Has this study received IRB approval and by whom, and when
This study is being reviewed the UAA IRB on Dec 13, 2002. It has been approved by the IRB at the University of Alaska Fairbanks for in- home air monitoring.

12) Data Management (Storage, Access, Protection, When will it be destroyed)
All medical data will be kept at the local medical office, only coded data without personal identifiers will be sent to the University of Alaska Anchorage. The key to the code will be kept in a safe at the Institute for Circumpolar Health Studies. ICHS has data confidentiality and storage capability.

RESULTS & DISCUSSION
C. Indoor Air Quality Assessment –

Ron Johnson, Satish Dinakaran, and Jack Schmid
(University of Alaska Fairbanks)

1. Introduction

Thirty-six homes were chosen in Hooper Bay and Fairbanks as client or control homes for the Healthy Homes project in Alaska. The main role of our team (UAF) in the project was to establish a baseline for indoor air quality [IAQ] prior to remediation to be compared with post-remediation data. We also wanted to see if there were obvious problem areas that could help focus remediation efforts. We wanted to compare the baseline readings with National Ambient Air Quality Standards [NAAQS] as well as with IAQ data obtained elsewhere and look for correlations between levels of pollutants and key variables such as remediation activities and summer vs. winter. This project is also an opportunity to compare indoor environments between rural and urban homes and between homes in Alaska and elsewhere. Others on our team dealt with influences of intervention in building characteristics on children's health. Such intervention could have an effect on the IAQ.

Indoor air quality is influenced by many factors including indoor sources of pollutants, outdoor air quality, ventilation rates, and building use patterns. There are no overall national standards for IAQ in homes, including those used for business activities. Allowable levels of critical constituents in the outdoor ambient air are quantified by the National Ambient Air Quality Standards (NAAQS). The six NAAQS constituents are sulfur dioxide, ozone, nitrous oxides, carbon monoxide, fine particulate matter (PM), and lead. Allowable levels are typically around a hundred parts per billion (ppb), except for CO at 9 parts per million (ppm) over 8 hours, and lead at a few ppb (Johnson et al., 2002). The 24-hour allowable level for $PM_{2.5}$ is 65 $\mu g/m^3$. Major indoor pollutants include radon, formaldehyde, combustion products, biological contaminants, tobacco smoke, organic gases, lead, pesticides, and asbestos. Researchers established for the first time in the mid-1960s that air pollutants generated indoors might be responsible for adverse health effects originally attributed to outdoor air (Namiesnik et al., 1992).

The criteria for choosing a client home was that it would have at least one child with asthma related symptoms. In Fairbanks, ten homes were chosen as clients and eight were chosen as control homes while Hooper Bay had nine of each.

The air quality indicators that were monitored are CO, CO_2, $PM_{2.5}$, PM_1, RH, Temperature, Formaldehyde, benzene, toluene, radon and Total Volatile Organic Compounds (TVOC). Here, $PM_{2.5}$ refers to the mass concentration of particles less than 2.5 μ in diameter while PM_1 refers to the number concentration of particles less than 1 μ in diameter. In addition, dust and tape lift samples were taken for subsequent microbiological analysis. CO, CO_2, RH and Temperature were recorded by instruments in an IAQ package deployed for about 14 days. A walk through was conducted in many houses to measure $PM_{2.5}$, PM_1, and TVOCs (as units of Isobutylene) using a Dust trak, P-trak and PID respectively. The walkthrough lasted for 20 minutes to 1 hour in each house and notes were taken about activities in the home during testing. Passive badges, deployed for formaldehyde, benzene, toluene and radon, were later sent to an outside lab for analysis. A more detailed explanation of the testing and instrumentation is discussed in the methods section.

The nine Hooper Bay client homes were tested prior to the remediation process in spring 2003 and the results of this test are summarized under "HB-Pre". Another test, conducted in March 2004 while the remediation process was still underway, is summarized under "HB-Post-1". After the remediation process was complete, the client homes were tested in November 2004 (HB-Post-2). The Hooper Bay control homes were pre-tested in March 2004 and post-tested in November 2004.
The Fairbanks homes, unlike the Hooper Bay client or control homes, were not tested simultaneously. The pre and post testing, of both, the client and control homes, were conducted between March 2003 and January 2005.

2. Methods

Instruments:

The Healthy Homes project relied on a variety of instruments and methods to collect IAQ information about the subject homes. Data logging instruments recorded temperature, relative humidity, CO_2 concentrations, and CO concentrations over multi-day sampling periods. Other logging instruments recorded aerosol and VOC concentrations over sampling periods that were on the order of minutes or hours. Passive badges provided overall average VOC and formaldehyde concentrations. Tape lifts and vacuum cartridges were used to collect samples of surface dust and bedding debris for analysis.

The primary field data collection device was a small inexpensive plastic toolbox with a volume of approximately 4 liters. The box system was designed to be transportable and easily placed out of the reach of children to reduce tampering. Nine of the boxes were assembled for the project. Each box contained a Biosystems ToxiUltra CO logger, a Telaire 7001 CO_2 transmitter, a hobo temp/RH logger, and a 6-volt dry cell lantern battery. The passive samplers relied on convection and diffusion of air through an array of 13mm holes in the sides and tops of the boxes to provide ambient air to the respective sensors. The 6-volt dry cell could supply power to the Telaire CO_2 transmitter for a period in excess of 30 days, much longer than the anticipated sampling deployment.

At the time of deployment of the field instrument box, a passive VOC monitoring badge was exposed for the duration of the sampling period and a passive formaldehyde badge was deployed for 8 hours to one day. Limiting the exposure of the formaldehyde badge to the short period of deployment required typically relied on the subject occupant sealing the badge in a plastic bag and placing it in a freezer after an agreed upon time. When practical, a VOC badge was placed outdoors to expose it to ambient VOC concentrations.

In addition to the primary field instrument box, the following instruments or enclosures were used to provide auxiliary data when practical.
TSI Dust Trak; $PM_{2.5}$ and PM_{10} aerosol concentrations
TSI P-Trak; Aerosol counts for aerosols in the submicron range
TSI Q-Trak; temperature, relative humidity, CO, and CO_2, to provide a comparison with the instrument box
PpbRae; VOC concentrations via PID detector
MetOne 9012 particle counter; particle counts for aerosols smaller than 10um.
Hobo temperature loggers for outdoor temperature
Temperature regulated environmental enclosure (fabricated January 2004)
RSSI alpha track radon monitor

In order to reduce bias in collecting field data, the UAF field researchers did not seek out or record information about the status of homes in terms of being control or sample homes. All homes in both Hooper Bay and the Fairbanks area were instrumented in as similar of a manner as practical.

<u>Fairbanks area deployments:</u>
The proximity of the Fairbanks area homes to UAF made it feasible to use more of the available tools on each site visit. Research personnel from UAF accompanied local weatherization crews on site visits to each Fairbanks area home prior to the fall of 2004 to deploy equipment, visually assess the subject house, and perform short-term measurements. During the fall of 2004, Interior Weatherization personnel deployed the field instrument boxes, passive badges and took vacuum and tape lift samples.
In the UAF lab, prior to each deployment, the calibration of the CO_2 transmitters was checked using zero gas and 1000 ppm span calibration gas. The CO loggers were calibrated using zero gas and 35 ppm span calibration gas. A zero check was performed on the aerosol monitors.

During a typical instrument deployment and site visit in the Fairbanks area, outdoor $PM_{2.5}$ concentrations and ultrafine particle counts were monitored with the Dust Trak and P-Trak operating on internal batteries and left covered in an automobile, with the sampling probes led out of the window to sample outdoor air. The covering was to reduce temperature gradients affecting instrument operation. In January of 2004, an insulated and heated enclosure was fabricated to provide a stable thermal environment for the outdoor sampling equipment. An outdoor VOC sample using the PID detector was taken. The house was entered and a $PM_{2.5}$ Dust Trak monitor was placed in a common area and logging initiated. A walkthrough was performed with the TVOC PID detector and times were manually noted to correlate VOC concentrations with various locations in the house. Unusual concentrations and possible causes were noted. After the TVOC PID walkthrough, the instrument was shut off and a walkthrough was performed with the ultrafine particle counter. Since the ultrafine particle counter employs alcohol (a VOC), this required separate walkthroughs with the two instruments. Both the TVOC PID monitor and the ultrafine counter were used to investigate suspected trouble spots and anomalies were pursued, so the values and averages recorded by these instruments cannot be construed as representative of the air in the house.

The box was prepared by checking that the enclosed Hobo data logger was logging, that the CO_2 transmitter was operating and that the CO logger was operating. The researcher then explained to the occupant the instrument box and the function of the recording instruments, as well as what might constitute an optimal location. With the agreement of the occupant, the box was placed in its logging location. Typically, this was a location about 4 to 6 feet above the floor in a common area. The height of the box was to minimize interference from children and pets. A common area, such as an area near a kitchen and active living/dining space, was chosen to represent the indoor air. Because of the variety of house configurations, using this kind of common area was a best attempt at collecting data in zones that are most comparable between houses and where occupants spend a large fraction of their time. The indoor VOC badge and formaldehyde badge were clipped to the box closure. If an alpha track radon detector were to be deployed, it would be deployed at this time adjacent to the instrument box.

A vacuum dust sample was taken from a bed, preferably from the bed of a child with adverse respiratory symptoms. Dust tape lifts were taken from surfaces near the sampled bed. Typical surfaces would be shelves, bureau tops, and windowsills.

An outdoor VOC badge was deployed and, if outdoor temperature were to be logged, the logging device would be placed outdoors at this time. The auxiliary instrumentation would then be shut off and removed from the house. The events of the walkthrough were recorded on chronologically in a field notebook.

The duration of the site visit was typically about 2 hours. The instrument box, badges and outdoor temperature logger were picked up after approximately two weeks by the UAF researcher or Interior Weatherization, Inc personnel and returned to the UAF lab.

Fall 2004 deployments;

In the fall of 2004, Interior Weatherization personnel deployed the instrument boxes and badges, and took tape lift and dust samples. Prior to deployment, the CO_2 monitor and CO logger were calibrated in the UAF lab and this activity was recorded in the researcher's field notebook. The data loggers in the instrument boxes were started in the UAF lab prior to weatherization personnel picking up the equipment. They were also provided field worksheets, VOC and formaldehyde badges, tape lift supplies, and bedding dust sample supplies.

Hooper Bay deployments:

A UAF researcher conducted a site visit and instrument deployment in April of 2003 and March of 2004. UAF prepared the instrument boxes for deployment by others in April of 2004. Preparation included calibration checks of the CO_2 transmitter, calibration of the CO logger and replacement of batteries. A CCHRC contractor used his own instruments for deployment in November of 2004.

A typical site visit and instrument deployment began with doing an outdoor sampling with the TVOC PID monitor then entering the house and deploying an indoor $PM_{2.5}$ Dust Trak monitor. A walkthrough was conducted with the TVOC PID monitor, after this, a walkthrough was done with the ultrafine particle counter. The purpose of the instrument box was explained to the client and it was then placed in an appropriate location. Some of the houses were a single room and a typical location was either hanging from the ceiling on a shelf about six to 7 feet above the floor in the common area. The VOC and formaldehyde badges were affixed to the box. The occupant was given instruction about limiting the exposure of the formaldehyde badge by bagging and freezing it until picked up at the end of the sampling period.

A vacuum dust sample and tape lifts were taken in the same manner as in the Fairbanks area homes. Outdoor $PM_{2.5}$ concentrations and ultrafine particle counts were measured as time permitted.

At the end of the sampling period of approximately two weeks, the instrument box and badges were collected by a local village worker and shipped to Fairbanks for analysis.

A deployment of the UAF instrument boxes was made in April 2004 by shipping them to Hooper Bay for deployment by a CCHRC representative. After this deployment, the boxes were shipped back to UAF for analysis. Details of the UAF equipment and grab sample devices used are presented in Tables (1) and (2). An IAQ survey form (Table (3)) was used, in many instances by the person conducting the house visit, to document necessary details.

3. Results:

3.1. HB Client Pre-remediation tests:

Pre-remediation testing of the client homes in Hooper Bay was conducted in April-May 2003. The mean ambient temperature at Hooper Bay during the pre-testing was 28 to 37 ^{o}F.

The ventilation rates in two houses were 0.3 to 0.21 ACH (Air Changes per Hour), calculated from the steady decay of CO_2 during unoccupied periods. Ventilation rates were not calculated for the other 6 houses from CO_2 decay because the occupancy was such that decay, with no sources present, only occurred for short periods of time.

One and 8-hr CO averages appear in Figures (1) & (2). One can see that all homes but one satisfied the NAAQS for maximum 1 hr levels and all but two for 8-hr maxima. The high values for house HB-4006 were due to a spike in the CO concentration [reaching a maximum of 109 ppm] and lasting 1.5 hours as shown on Figure (3). Since this spike occurred about the same time as a peak in CO_2 and a drop in interior T, we can speculate that the peaks were caused by a 4-wheeler operating outside with the door open.

$PM_{2.5}$ ranged from 17 to 57 ug/m^3, relative humidity (RH) from 33 to 47 %, and T from 65 to 76 ^oF with the first an average of one 20-minute batch sample and the latter two averaged over two weeks. A summary of all data appears in table (4).

Average 14-day carbon dioxide levels ranged from 879 ppm at HB-4008 to 2189 ppm at HB-4002. HB-4008 also had the lowest maximum of 1591 ppm while the other eight homes had maximum levels greater than 2000 ppm.

Indoor PM_1 levels ranged from 175k pt/cc to 1k pt/cc with spikes in concentration coinciding with the time when a four-wheeler was passing by. Ambient levels were significantly different from those in HB-4009 (P-value=0), which might suggest indoor activities as the main source of PM 1. A caveat here is that the ambient data were collected for a period immediately after the indoor data were collected [only one sensor available].

The Total Volatile Organic Compounds [TVOCs] ranged from 294 ppb in HB-4004 and 2422 ppb in HB-4005. The highest level of 15 k ppb was due to a resident cleaning a firearm using solvents when the walk through was being conducted at HB-4005.

Benzene and toluene levels, from the analysis of passive organic vapor monitors deployed for about 2 weeks, ranged from 4.4 to 33.7 ppb and 11.7 to 103.8 ppb respectively.

Formaldehyde levels, also from passive badges deployed for 8 to 24 hours, ranged from 10 to 30 ppb.

3.2. HB Client Post-1 tests:

The second testing of the client homes in Hooper Bay was done in March'04 when the remediation process was almost complete with only the installation of ventilation controls left to be done in some homes. The mean ambient temperature at Hooper bay during post testing in March 2004 was 13 ^oF.

The CO_2 levels averaged over the duration (12 days) of the test ranged from 973 ppm to 2121 ppm as shown in Table (5). This average is affected by the fact that the CO_2 logger can record a maximum of 2485 ppm and for periods when the CO_2 concentration is recorded as 2485 ppm, the actual concentration could be much higher.

The percentage of the testing duration for which CO_2 levels were recorded as 2485 ppm ranged from 0.7 % to 43% during the pre- test and 0% to 65% during the post-1 test.

Carbon Monoxide, averaged over the 12 day testing period ranged from 1 to 3 ppm; the maximum 1 hr CO average ranged from 3.2 ppm to 11.8 ppm and the maximum 8 hr CO average ranged from 2.6 to 5.7 ppm as shown in figures (1) and (2).

The 12-day average RH ranged from 24 to 36 % and indoor temperature, from 69 ^oF to 78 ^oF.

From the walkthrough testing of about 15-minutes, the average TVOC concentration was lowest in HB-4002 at 370 ppb and highest in HB-4006 at 6420 ppb. Average $PM_{2.5}$ was measured for 8 to 15 minutes in each home and ranged from 13 to 342 ug/m^3 and PM_1 for the same periods ranged from 12 K to 50 K pt/cc.

The ventilation rate calculated from the decay of CO_2 was highest in HB-4003 at 0.35 ACH during the post-1 test and lowest in HB-4004 at 0.11 ACH.
Data from organic vapor monitors, deployed for the duration of the test in each home resulted in benzene ranging from 3.5 to 15.8 ppb and toluene ranging from 12.3 to 56 ppb.

3.3. HB Client Post 2 tests:
The final post-remediation testing was carried out in November'04 after some ventilation controls were installed in the client homes. Sensors were deployed to record levels of CO_2, CO, RH and Temperature but data were lost for HB-4006 due to equipment malfunction. The mean ambient temperature at Hooper Bay during the testing period in November 2004 was about 24 ^oF.

Carbon dioxide, averaged over the testing period of 12 days, ranged from 619 ppm to 1525 ppm. Carbon monoxide for the same period ranged from 0 to 1 ppm. The maximum 1 hr average was highest in HB-4007 at 33.2 ppm and lowest in HB-4009 at 1.7 ppm. The maximum 8 hr CO average ranged from 8.6 ppm at HB-4004 and 1.3 ppm at HB-4009. The summary data averages appear in Table (6). The 12-day average RH was approximately 30% in 5 homes and about 40% in the other 2 homes. Indoor temperature ranged from 71 to 80 ^oF.

3.4. HB Control pre tests:
The pre-remediation testing of nine control homes was conducted in April 2004 to monitor CO, CO_2, RH and Temperature. The mean ambient temperature at Hooper Bay in April 2004 was about 30 ^oF. Unlike the prior tests, batch sampling of PM 2.5, PM_1, and TVOC was not done nor were dust samples taken for subsequent microbiological analysis.

Carbon monoxide, averaged over the testing period of 10 days ranged from 1 to 2 ppm as shown in summary Table (7).
One hour and eight hour CO averages were below the respective 35 ppm and 9 ppm NAAQS in all but one home (HB-4064) where the corresponding maximum 1 hr and 8 hr levels were 41 and 18 ppm. On figure (4), appears the 1 hr maximum CO and, on Figure (5), the maximum 8 hr CO. The CO levels were greater than 10 ppm for a period of 5.5 hours in this home. During this time, they correlated with the CO_2 levels with an r-value of 0.80 while the r-value for all the CO and CO_2 data for this home was 0.12.

The average CO_2 levels over the 10-day testing period ranged from 944 ppm to 2183 ppm with two homes having CO_2 levels reach the upper range of the HOBO logger, which is 2485 ppm. HB-4071 had CO_2 levels at 2485 ppm 50 % of the testing time while HB-4068 had 2485 ppm CO_2 for 8% of the time.
Average indoor RH ranged from 33% to 41% while average temperature ranged from 69 ^oF to 74 ^oF in the nine homes.

3.5. HB Control Post tests:
Post-remediation testing of the nine control homes was done in November 2004 when the mean outdoor temperature in Hooper Bay was approximately 24 ^oF.

The test consisted of monitoring CO, CO_2, RH and Temperature for 11 days in each home; the data summary appears in Table (8).
Average 11 day CO_2 ranged from 607 ppm to 1838 ppm and CO ranged from 0 to 3 ppm. The maximum 1 hour average CO ranged from less than 1 ppm in HB-4063 and HB-4070 to 123 ppm in HB-4064. The home, HB-4064 also had the highest 8-hour maximum average, among the nine homes, of 29 ppm. No noticeable, change in temperature or relative humidity, or correlation with CO_2 occurred during the four-hour period of high CO concentration of more than 10 ppm, averaging 57 ppm at HB 4064. HB-4063 and HB-4070 had the lowest 8-hour maximum average of less than 1 ppm among the nine homes. The maximum 1 hr and 8 hr CO are illustrated in figures (4) and (5).

HB-4045 had maximum 1 hr CO below the NAAQS of 35 ppm but had maximum 8 hr CO above the NAAQS of 9 ppm by 2 ppm. This home had consistently high CO levels, when compared with the other test homes, which correlated well with the indoor CO_2 as shown in figure (6). The r-value for the period 11/16 04 13:00 to 11/20/04 14:36 was 0.877 and for the whole test period was 0.55. The indoor temperature seemed to track CO_2 during this period as shown in figure (7). Indoor temperature, CO, and CO_2 typically correlate well when indoor combustion of fossil fuels are sources of CO and CO_2.

RH and indoor Temperature averaged from 20 to 43 % and 65 to 81 ^oF respectively during the 11-day testing period.

3.6. Fairbanks Client pre-remediation tests:
The pre remediation test data statistics appear in Table (9) and, because Fairbanks homes were each tested at different dates, a summary of the test dates with the outdoor temperature for Fairbanks appears in Table (14).

The client homes had 14 day average CO_2 levels ranging from 533 ppm at Fbks-de to 1623 ppm at Fbks-mc with four out of the ten client homes having average CO_2 less than 1000 ppm.

Average CO ranged from 0 ppm at Fbks-na to 5.2 ppm at Fbks-fa. One and 8-hr CO averages appear in Figure (8) and fig (9) respectively. The highest 1 hr average occurred at Fbks-de due to high CO concentrations, (peak at 43 ppm) lasting 30 minutes, which affected the maximum 8-hour CO, which was 11 ppm. There was no significant change in CO_2 and Temperature during that period to relate the high concentration to any outdoor activity. The average CO level for that home was 1.7 ppm. Fbks-fa had the highest 8 hour average CO of 18 ppm and CO levels correlated well with CO_2 levels in this home as shown in figure (10) suggesting a possible indoor source when there was an increase in indoor temperature with CO_2 shown in figure (11)

Walkthrough monitoring of $PM_{2.5}$, PM_1 and TVOCs was conducted at five homes; Fbks-de, Fbks-kn, Fbks-co, Fbks-na and Fbks-si. Average 20 minute $PM_{2.5}$ ranged from 11 ug/m^3 to 44 ug/m^3. Indoor PM $_{2.5}$ concentrations in Fbks-na increased from 13 µg/m^3 in the living area to 182 µg/m^3 in the garage and went up to 352 µg/m^3 in the vicinity of two smokers in the garage.

Average 20 minute PM 1 values ranged from 3 K pt/cc at Fbks-de to 121 K pt/cc at Fbks-kn. At Fbks-kn, PM_1 levels at the bathroom, where candles were lit, was close to 200K pt/cc and the maximum-recorded level of 350 Kpt/cc occurred at the washer and dryer area. The washer and dryer were operating for the duration of the visit and there was odor and indications of dryer exhaust leak.

Average TVOC levels ranged from 263 to 127K ppb with levels in Fbks-si causing the PID to reach its maximum limit of 200 K ppb. This was attributed to the dryer being vented indoors. The average Living area TVOC levels at Fbks-si were greater than 3 K ppb and were minimum at the Kitchen (about 1000 ppb). The levels near the dryer caused the PID to reach its maximum and dropped to 7 K ppb when the dryer was turned off.

Benzene and Toluene, analyzed from passive badges, ranged from 4.1 to 25 ppb and 12.6 to 101.7 ppb respectively. Formaldehyde levels from badges deployed in three homes appear in Table (9).
Alpha track radon monitors deployed in two of the client homes gave 14 day average levels as 1.2 and 3.4 pCi/l

3.7. Fairbanks Client post remediation tests:
The average 14 day CO_2 ranged from 688 ppm to 1440 ppm and 14 day average CO ranged from 1 to 2 ppm as tabulated in Table (10). The highest average was at Fbks-de where the remediation crew was still working and contributed to the CO_2 level.
Figures (8) and (9) show the maximum1 hr and 8 hr CO respectively; none of the homes had 1 hr or 8 hr CO over the NAAQS of 35 ppm and 9 ppm respectively.

Walkthrough sampling of $PM_{2.5}$, PM_1 and TVOC was conducted only in Fbks-na. In this home, 20 minute average indoor $PM_{2.5}$ was at 30 ug/m^3 when outdoor $PM_{2.5}$ was 16 ug/m^3. Also, outdoor PM_1 (43 K pt/cc) was more than indoor PM_1 (17K pt/cc) during the 20-minute walkthrough. TVOC level was 682 ppb, averaged over the 20 minute test.

Average 14-day temperature and RH ranged from 64 to 74 ^{o}F and 23 to 27 % respectively.

Results from organic vapor monitors showed benzene and toluene ranged from 5.9 and 10.5 ppb and 23.7 and 73 ppb respectively.

A Met One particle counter along with a Qtrak was deployed at Fbks-stillv (Post) for about 18 hours. The average levels over the 18 hours were 21659 counts/liter of PM $_{0.3}$, 2102 counts/liter of PM_1, 431 counts/liter of PM_2, 180 counts/liter of PM_3, 218 counts/liter of PM_4 and 4 counts/liter of PM_5. The actual data representing 1 minute averages are shown in Figure (12).

The particulate levels along with CO, CO_2 each increased around 10 PM and then the particulate number density decayed. The CO and CO_2 data appear in Figure (13). There were noticeable particulate peaks at 8:30 PM, 10:00 PM and 10:30 PM and CO_2 peaks around 8:40 PM, 9:30 PM, and 10:30 PM. These may also suggest some activity in the vicinity of the instruments by the occupants that was intermittent and of short duration. The instruments were near the kitchen/living area and the occupants were one adult and school age children. These events coincide with a drop in outdoor temperature (from –7 ºF to –26 ºF in 3 hours) as shown in Figure (14) suggesting that a heating source could have been used in the home that caused the particle levels to go up. This was a post weatherization test, so the house had been made more habitable by reducing air leakage and improving insulation. The indoor temperature remained relatively constant with an average of 69 ^oF and standard deviation of 1 ^oF for the logging period.

3.8. Fairbanks Control pre remediation tests:
Average 12 to 14 day CO_2 as shown in Table (11) ranged from 571 at Fbks-br to 1104 ppm at Fbks-and which was the only one of the eight control homes to have average CO_2 more than 1000 ppm. Carbon monoxide, averaged over the test period ranged from 1 ppm to 3 ppm; while 1 hr and 8 hr maximum CO, appearing in figures (15) and (16), were below the NAAQS.

Twenty minute walkthrough $PM_{2.5}$ average ranged from 4.4 ug/m^3 to 196.3 ug/m^3; Fbks-wi had the highest average level of 196 $\mu g/m^3$ which could be attributed to ETS as the bathroom was being used as a smoking area. The outdoor levels were 38 $\mu g/m^3$ during that time. Fbks –lo had the highest level of $PM_{2.5}$ (49 $\mu g/m^3$) that was not influenced by ETS but was close to the outdoor level (46 $\mu g/m^3$). The 24-hr NAAQS for $PM_{2.5}$ is 65 $\mu g/m^3$. The maximum, minimum, average and standard deviation of $PM_{2.5}$ is shown in Table (11).

PM_1 levels over the 20-minute walkthrough ranged from 4.6 K pt/cc to 69 K pt/cc and were affected by activities such as cooking or smoking. The levels in Fbks-lo went from 26 K pt/cc to 171 K pt/cc when the occupant started cooking over an electric range. A walk through sample of PM_1 at Fbks-wi showed a jump to 254 K pt/cc, when recorded in the vicinity of a smoker, from an average level of 42 K pt/cc in the house.
The highest average PM_1 of 69K pt/cc was at Fbks-br where the occupant was cooking over the electric range and the oven was turned on; the maximum-recorded reading in this house was 181K pt/cc.

RH ranged from 23 to 32 % and indoor temperature, from 68 to 75 ^oF (Table (11)).
Results from passive badges are also tabulated in Table (11). Benzene and toluene ranged from 1.2 to 5.7 ppb and 9.6 and 20 ppb respectively; Formaldehyde and radon ranged from 0.02 to 0.06 ppb and 1.4 and 7.4 pci/l respectively.

3.9. Fairbanks Control Post remediation tests:
The average 12 to 14 day CO_2 ranged from 496 ppm to 1083 ppm as shown in Table (12). The lowest average of 496 ppm was at Fbks-br, which was unoccupied for eight of the twelve days of testing.
Figure (15) and (16) shows all the homes were below the NAAQS for maximum 1 hr and 8 hr CO. The average CO over the test period was 1 to 2 ppm in the control homes.

$PM_{2.5}$ ranged from 2.3 to 27 ug/m^3 and PM_1 ranged from 3.4K pt/cc to 62K pt/cc averaged over the 20 minutes of the walkthrough. A monitor stove was operating in Fbks-kl, which had the highest PM_1 average of 62 Kpt/cc but also the lowest $PM_{2.5}$ average of 2.3 ug/m^3.

TVOC levels, averaged over the period of the walkthrough, ranged from 130 to 481 ppb.
Twelve to 14 day average RH and temperature ranged from 23 to 29 % and 61 to 75 ^oF respectively.
Benzene levels ranged from 2.5 to 31.3 ppb and toluene from 5.4 to 107.8 ppb. Radon from alpha tracks deployed in four homes ranged from less than 1.7 to 2.9 pci/l. Formaldehyde was maximum at Fbks-lo (0.04 ppb) and minimum at Fbks-kl (0.01 ppb) during the post-test of the control homes.

3.10. Tape-lift results
Tape lift samples were taken at 17 Fairbanks homes prior to remediation and at 9, after remediation; the results are summarized in Table (13).

Three pre-test samples had total fungal spores (TFS) greater than 1000 per cm^2 and a total of seven samples had greater than 100/ cm^2. The total fungal spores per cm^2 is shown in Figures (17) and (18) from pre and post samples respectively. Fbks-KN, Fbks-DE, Fbks-KL and Fbks-NA had greater than 100/cm^2 Aspergillus/Penicillium-like spores, with Fbks-NA having greater than 400/ cm^2 Chaetomium. Fbks-WA and Fbks-AND samples had pollen observed in them. In the post-test samples, Fbks-WA had greater than 3000 Stachybotrys/cm^2 and more than 4000 Chaetomium. No other houses had detectable Stachybotrys or greater than 15 Chaetomium [detection limit]. Other spores identified over 15 count/cm^2 were Ascospores, Basidiospores, Cladosporium, Smuts/Myxomycetes/Periconia and Torula.

There was occasionally poor correlation between results from duplicate samples taken from the same vicinity. For example, Fbks-and (post) had 139 TFS/ cm^2 in one sample and 31 TFS/ cm^2 in another duplicate sample. The higher of the two is taken, as the concentration in that home, in this report. The type of spores found in duplicate samples was also occasionally different; Fbks-stillv (post) had Aspergillus/penicillum-like and Cladosporium in one sample and none of the two in the other sample.

4. Discussion of results:
A comparison of the measured concentrations with data from other studies and recommended levels and between the two communities (Fairbanks and Hooper Bay), is done in this section. We also discuss events during which any of the measured constituent concentrations exceeded recommended levels.

4.1. Hooper Bay

4.1a Hooper Bay Client homes:
Carbon dioxide, in itself is not considered harmful in moderate quantities [500 to 3000 ppm (Taylor, 1995)] but acts as a surrogate for other pollutants and ventilation. Although the two week average CO_2 levels from the pre-testing data of the client homes were over the ASHRAE* standard of 1000 ppm in most homes, they were below the OSHA** PEL (Permissible Exposure limit) and ACGIH** * TLV (Threshold Limit Values) of 5000 ppm. The OSHA standards govern the workplace where people are typically exposed for up to 8 hrs/day. The ASHRAE standards provide guidance to those operating public and commercial buildings to help insure adequate ventilation. After post-1 remediation, no significant reduction in CO_2 was found except in two homes HB-4002 and HB-4003 where average CO_2 was reduced by about 40 %. Post-2 remediation further reduced average CO_2 levels from the pre-test levels by 20 to 70 % in five homes.

Average carbon monoxide levels were reduced from 1 to 4 ppm to either close to 0 or close to 1 ppm in all homes after the post-2 remediation process. In a study by Howell et al (1997), about 10% of the homes in 5 villages in Alaska had elevated CO levels for which the most common cause was improperly ventilated hot water heaters.

ASHRAE Standard 55-1981 (revised Dec –2004) suggests an optimal relative humidity for a corresponding summer or winter indoor temperature as shown in Table (16). However, some have suggested that the lower limits in Alaskan homes during the winter should be less than (about 10% less than) those in Table (16) partially because of our very dry ambient air in Interior Alaska. During the pre-test, which was conducted in April and May of '03, the indoor temperatures ranged form 65 to 76 ^oF and the outdoor temperature 32 ^oF. Hence, RH comfort level for winter indoor temperatures can apply. During the pre-test, the RH for all nine homes was 33 to 47 %, which is over the lower limit, of 30%, of the ASHRAE acceptable range. Problems from mold generally occur at RH more than 60 % at which microbial growth is promoted.

* American Society of Heating Refrigeration and Air Conditioning Engineers
** Occupational Safety and Health Administration
*** American Conference of Governmental Industrial Hygienists

During the post-1 test in March'04 when the remediation process was underway, for indoor temperatures of 69 to 78 ^oF, the RH was below the 30% minimum level in six of the nine homes. After the post-2 process, the RH was below 30 % for only three homes in spite of the indoor temperature being, 71 to 80 ^oF while the outdoor temperature averaged 24 ^oF. This suggests that the remediated homes are better at retaining humidity, after the second remediation process.

In Hooper Bay, the pre-test $PM_{2.5}$ levels were below 40 ug/m^3 for 8 of 9 homes and post-1 results showed levels less than 40 ug/m^3 in 6 of 9 homes. While it cannot be concluded that any homes were above or below the NAAQS for $PM_{2.5}$ using only data from the 20-minute walkthrough, it can be used to see if there are any sources dispersing large amounts of $PM_{2.5}$ indoors during or prior to the walkthroughs. For HB-4004, during the post-1 test, 15 minute $PM_{2.5}$ averaged 342 ug/m^3 and the PM_1 was 42K pt/cc. The other homes had much lower $PM_{2.5}$ (less than 90 ug/m^3) with sometimes-higher PM_1 levels. The current NAAQS for 24 hr $PM_{2.5}$ is 65 ug/m^3. PM_1 and $PM_{2.5}$ correlate well in the presence of tobacco smoke (Simoni et al, 2002). Johnson et al (2005) found a good correlation between ambient $PM_{2.5}$ and numbers of particles smaller than 2 µm during periods of elevated particulate levels due to forest fires as shown in Fig. (19).

TVOC levels during the pre-test were above the State of Washington Building Standard of 500 ug/m^3 or 215 ppb for all 9 homes. Normal indoor air has a TVOC level of 100 to 400 ppb isobutylene units (RAE Systems 2002). Wallace (2001) found about half of 750 homes sampled in the United States had TVOC levels greater than 1,000 ug/m^3 or 431 ppb. Building materials and consumer products such as air fresheners are major VOC sources in nonsmoking homes.

4.1b Hooper Bay Control homes:

We found the 10-day average CO levels lower after remediation in all homes except HB-4045. The maximum 1 hr and 8 hr average CO for this home was 13 and 11 ppm. For this house, CO and CO_2 correlated well for the first four days (r-value= 0.87) but neither correlated with RH as might happen when cooking using a gas-fired stove. If the source of combustion air for a furnace is interior air [which ultimately comes from the outside], then CO_2 levels decrease when the furnace fires as outside air is drawn in to supply for combustion. The CO level was over the 8 hr maximum NAAQS for only one instance during the 12 day test with levels over 10 ppm for six hours.

Relative humidity was below the minimum 30 % ASHRAE standard for two homes for a corresponding indoor temperature range of 65 to 81 ^oF.

Appin associates (1991) found winter RH in 60 Canadian homes averaging 25%. They also found 23 out of 30 homes falling above the Health and Welfare Canada (HWC) Acceptable Long-Term Exposure Range (ALTER) of 40 ug/m^3 for $PM_{2.5}$ measured over a seven day period using gravimetric techniques. $PM_{2.5}$ was not measured in any of the Hooper Bay control homes.

4.2 Fairbanks homes:

A direct comparison of pre and post CO_2 shows lower levels after remediation in six of the eight client homes for which we had data. For the control homes, post CO_2 was lower than pre levels in only three of the seven homes with data. One client house [Fbks-de] had high CO2 concentrations in the post test partly because of the crew still working on the house, but the benzene and toluene were much lower post. This house had an attached garage with leakage into the living spaces and the weatherization efforts were intended to minimize this. The benzene and toluene data support this.

Seven of the eighteen Fairbanks homes had pre RH close to the ASHRAE recommended level of 30%. Post RH in all the Fairbanks homes were below the ASHRAE recommended 30% except for Fbks-wi. However, we must consider that for Alaskan homes, some have suggested an optimum RH of 25 to 30 % and all homes were within this range after remediation. Some of the differences between pre-and post could be due to operation of bathroom ventilation fans installed as part of the remediation efforts.

TVOC levels at Fbks-si were greater than 3 K ppb and were minimum at the Kitchen (about 1000 ppb). The levels near the dryer cause the PID to reach its maximum (200 K ppb maximum, 100 K ppb average) and dropped to 7 K ppb when the dryer was turned off. This correlation of TVOC levels with the operation of the dryer is due to the venting of the dryer indoors. In a study done by Kulmala et al (2000), high TVOC concentrations in the washroom was attributed to an aliphatic hydrocarbon solvent that was a component of the detergent used.

The United States Environmental Protection Agency (U.S.EPA, 1997) recommends a maximum indoor level of 200 $\mu g/m^3$ (approximately 86 ppb). TVOC levels at Fbks-br were higher (350 ppb) in the bedroom than in the living room (300 ppb). At Fbks-de, TVOC levels were higher in the living area (500 ppb) than in the garage (129 ppb). Similarly for Fbks-lo, TVOC levels were higher in the upper levels (240 ppb), especially in the nursery (283 ppb) than in the basement (217 ppb). This higher concentration of TVOCs in places where occupants spend their time most, suggests an anthropogenic source like air fresheners, sanitary products etc… In a study by El-hougeiri et al (2002) of IAQ in 28 non-residential buildings in urban Beirut, TVOC levels ranged from 700 ppb (without combustion sources present) to 1200 ppb (with ETS sources present). The measurements were taken for 30 to 60 minutes three to four times a week. At the locations without combustion sources present, the outdoor levels were close to or a little higher than the indoor levels. At locations where TVOCs were measured with ETS sources present, outdoor levels were about 50 % of the indoor concentrations.
In our study, the two homes known to have indoor ETS sources, Fbks-wi and Fbks-na, had 20 minute TVOCs 180 to 263 ppb before remediation and 682 ppb at Fbks-na after remediation.

4.3 A comparison between the two communities (Fairbanks and Hooper Bay):

One of the most obvious differences between Fairbanks and Hooper Bay homes is the average CO_2 levels. In HB after remediation, the loggers were at the maximum recordable level of 2500 ppm for 2 to 66 % of the test duration in six of 9 client homes and 8 to 51 % in 2 of 9 control homes. None of the Fbks homes had CO_2 levels reaching 2500 ppm except Fbks-de (post-remediation), which had about 2 hours of maximum recordable CO_2 of the total 14-day test period. The amount of time the samplers were reading the maximum levels is expressed as a percentage of the total testing duration in Table (15).

In a study done by Appin associates (1991) on IAQ in Canadian homes, the highest average seven-day level of CO_2 was 2000 ppm, with 25 out of the 54 homes tested having levels above the ASHRAE 62-89 guide line of 1000 ppm. The house floor areas were much larger than those in Hooper Bay and there were fewer occupants. Johnson et al (2002a) collected data from eight homes in Fairbanks of which six had average CO_2 levels less than 1000 ppm over a one to two week period. The floor area ranged from 400 to 3000 ft^2 with 2 to 4 occupants whereas the Hooper Bay homes had about 300 to 700 ft^2 of floor area with 2 to 8 occupants. The difference in indoor CO_2 concentrations between Hooper bay and Fairbanks could be ascribed to building use patterns, per capita house floor area, ventilation rate and heating system used.

The Hooper Bay client Post-2 14-day CO_2 averages were lower than the Post-1 data except for HB-4010. The second remediation process consisted of retrofitting ventilation controls, which could have contributed to the reduced CO_2 averages.

A recent Canadian study (Parent et al, 1996) involved the measurement of CO_2 levels in 30 homes heated by electric baseboards during the heating season. The houses were chosen to have a similar distribution of air leakage as a random sample of several thousand homes in Québec. The air changes per hour (ACH) during blower door tests ranged from 1.25 to 11.75 with a peak around 4.25 (all at 50 Pa ΔP). The average indoor air contaminant levels (total VOCs, formaldehyde, radon, CO_2 and water vapor) were measured during a one-week period between December and March. From the data presented, one can infer that the gain in CO_2 above ambient ranged from 264 to 1271 ppm with an average of 569 ppm. The average occupancy rate was 73 person hours per day, the average air exchange rate and house volume 27.6 l/s and 449 m^3 respectively. Dividing 27.6 l/s by the house volume results in an average of 0.22 ACH. In a study in a Swedish urban community, Norback et al (1995) found the average CO_2 concentration was above 1000 ppm in 24 percent of the 50 randomly selected dwellings.

The NAAQS for PM 2.5 over a 24-hour period of 65 ug/m^3 was exceeded by three Hooper Bay client homes after remediation. Again, as mentioned in previous section, $PM_{2.5}$ was measured over a period of 20 minutes and the 24-hour concentration could be different. Walkthrough testing was not conducted in the Hooper Bay control homes.
The average pre-remediation $PM_{2.5}$ levels in the two homes (Fbks-wi and Fbks-na) with ETS sources, were 44 and 196 $\mu g/m^3$ during the walkthrough sampling. The post-remediation 20 min average $PM_{2.5}$ level at Fbks-na was 30 ug/m^3. A similar study (Simoni et al, 2002) showed $PM_{2.5}$ levels were significantly higher in the presence of tobacco smoke.

Although there are no NAAQS for benzene, toluene, or formaldehyde, it may be useful to compare the levels we found with standards used in the workplace. To that end, we have tabulated the OSHA and NIOSH maximum allowable daily averages for the workplace below. The former, called a Permissible Exposure Limit (PEL), represents an 8 hour time weighted average [TWA] and the latter, called a Recommended Exposure Limit (REL), a 10 hour average [NIOSH, 2005]. TWA is the employee's average airborne exposure in any 8 or 10 -hour shift of a 40-hour work week. Here OSHA indicates the Occupational Safety and Health Administration and NIOSH the National Institute for Occupational Safety and Health.

TWA maximum average values for three chemicals

	Benzene [ppb]	Toluene [ppm]	Formaldehyde [ppb]
NIOSH [REL]	100	100	16
OSHA [PEL]	1000	200	750

None of the homes tested for benzene in Fairbanks or Hooper Bay had one-week average benzene levels more than 34 ppb. Only two homes had toluene over 100 ppb [just barely] with one being a remediated home. This home also has indoor tobacco smoke sources. Although none of the homes had 24 hour formaldehyde levels over 750 ppb, 37 out of 46 tests indicated levels over 16 ppb. Some of the tests were on the same dwelling after remediation.

The ACGIH Threshold Limit Value (TLV) is 500 ppb for benzene, 300 ppb for formaldehyde, and 50 ppm for toluene.

Adgate et al (2002) found 6 day benzene and toluene in 284 homes averaged 5 and 25 ug/m^3 (1.6 and 7 ppb) respectively. They also found homes with smokers or attached garages had significantly higher benzene levels than others.

Most of these exposure standards were established for a work place and the duration of exposure includes only working hours, which typically is eight hours per day. Exposure standards for a home are lower as the duration of exposure could be 24 hours a day.

When comparing results, we must consider that the pre and post testing were conducted at different ambient conditions. The outdoor temperature during the test will likely influence ventilation rates. A summary of the outdoor temperature during testing in each home appears in Table (14). The ventilation rates are typically higher during warmer months due to infiltration of outdoor air through open windows. Due to the higher ventilation rates, we might find pollutant concentration lower than would be in the colder months.

Radon was measured in nine Fairbanks homes and was found ranging from 1.2 to 3.5 pci/l, which is below the maximum recommended levels of 4 pci/l.

In a study (Grimsrud et al (1987)) of the effects of house weatherization on IAQ in forty Pacific Northwest homes, no significant affect was noticed in the indoor pollutant levels. There was, in some cases, reduction in radon levels due to installation of crawl space ventilation. Formaldehyde levels in the same study were 0.03 ppm to 0.05 ppm from pre and post testing respectively. The weatherization process caused about 50 % increase in tightness and about 58% increase in formaldehyde levels was noticed.

In our study, radon was monitored by passive badges in nine Fairbanks homes before remediation and four homes after remediation. Before remediation, values ranged from 1.2 to 3.5 pCi/l, which is below the maximum recommended levels of 4 pCi/l. There was a reduction from 3.3 to <1.7 pCi/l in one home but the other three had a difference, between pre and post levels, of less than 1 pCi/l.

We included one or two field or laboratory blank samples when VOC and formaldehyde badges were sent to an outside laboratory for analysis. Benzene levels were close to 0 ppb from the three blank VOC badges (pre-test samples). Toluene levels from the same batch of blank samples ranged from 0.3 to 0.5 ppb. The field samples ranged from 0.6 to 33.7 ppb and 3.7 to 103.8 ppb in benzene and toluene concentrations respectively.

Formaldehyde, in the laboratory blank sent with the Fairbanks-pre samples, was 0.126 ppm while the field samples had levels ranging from 0.02 to 0.06 ppm. This high difference between the blank and field samples may be an anomaly.
Two field blanks were sent along with the Hooper Bay pre samples and formaldehyde was <0.007 ppm in both. The house samples had formaldehyde levels ranging from 0.01 to 0.03 ppm. From the Hooper Bay post samples, the laboratory blanks had 0.06 and 0.02 ppm formaldehyde and the field measurements were from 0.01 to 0.05 ppm
Fourteen samples, collected in Nov'04 from Fairbanks pre and post testing, had two lab blanks which had <0.014 and <0.00035 ppm formaldehyde while the field measurements ranged between 0.00113 and 0.26 ppm. The OSHA 8 hour exposure limit is 0.3 ppm.

4.3a t-tests:
To compare results from "before" remediation with "after" remediation, we used Excel to perform paired t-tests. The results for Hooper Bay and Fairbanks are tabulated in Tables (17) and (18) respectively. For a paired t-test, we excluded subjects (house or measured constituent) with missing data (either pre, post or both) from the analysis. For the CO data, we noticed that the difference in means was less than the accuracy of the instrument (±1 ppm) and thus conclude no significant difference in CO means between any of the groups tested.

Comparing the means of IAQ constituents from the HB client pre data with HB client post-1 (remediation still underway) data led to only RH being significantly different ($p < 0.05$) with the post being lower. When the pre means were compared with the post-2 (remediation complete) means RH was again significantly different with the post now being higher. CO_2 and RH means were significantly different when the post-1 data was compared with the post-2 data for the HB client homes with the post-2 being lower for CO_2 and higher for RH. There was no significant difference in means between the pre and post data of the HB control homes.

From the t-test results for Fairbanks homes (Table-18), we can see that pre-RH was significantly different [higher] from post-RH in the client homes and pre-$PM_{2.5}$ was significantly different [higher] from post- $PM_{2.5}$ in the control homes ($p<0.05$ for both). However, as mentioned in the methods and results sections, $PM_{2.5}$ was measured during a walkthrough of about 20 minutes and, in a previous study by Johnson et al (2005) in a Fairbanks home, the levels were found to vary by as much as 293 ug/m^3 within a period of 24 hours. Shown in figure (19) is a plot from this study illustrating the variation of ambient $PM_{2.5}$ and Black Carbon (BC) over a period of 20 hours. The latter is an indicator of the presence of incomplete combustion products on the particles.

A t-test assuming unequal variances was performed to compare means of IAQ constituents between two different groups; like, client and control, Fairbanks and Hooper Bay, etc. The results or the p-values are tabulated in Table (19) for the t-test performed where $p < 0.05$ implies that the means from group-1 was significantly different from the means from group-2. Only the t-tests for which there was significant difference noted [nine cases] are shown in Table (19).

In a study (Frisk et al, 2002), the difference between asthmatics and non-asthmatics controls was statistically significant only in the variables of internal moisture supply and relative humidity. Hooper Bay client homes had RH significantly different [higher] from that in the HB control homes prior to remediation. However, for Fairbanks homes (pre), the average RH in the client homes was not significantly different from that in the control homes but benzene and toluene were significantly different [higher in client].

A comparison between Hooper Bay and Fairbanks homes [Table 19] showed that CO_2 and RH were significantly different in the client and control homes prior to remediation [higher in Hooper Bay]. After remediation, RH was significantly different when HB client homes were compared with Fairbanks client homes and between HB and Fairbanks control homes [again higher in Hooper Bay].

In another study of IAQ in houses with asthmatic (88 cases) and non asthmatic (104 controls) children in Australia (Rumchev et al. 2002), a higher level of pollutants were found in the case homes in summer but there was no significant difference in winter. Formaldehyde levels during summer were 37.8 and 23.5 ug/m^3 (30 and 19 ppb) in the case and control homes respectively. TVOCs were 100.7 and 37.1 ug/m^3 (44 and 16 ppb) in the case and control homes respectively during the same period.

The means of the pollutant levels were higher in Hooper Bay homes than in Fairbanks homes except for TVOCs, benzene, toluene and sometimes CO. A higher level of pollutants in rural homes would not necessarily show more IAQ related health disorders. In a study (Simoni et al, 2002), acute respiratory symptoms were more prevalent in urban homes in spite of lower pollutant levels as compared to rural areas. This was attributed to the contribution of exposure to ambient levels, which were higher in the urban areas.

Some other studies on IAQ before and after remediation concluded minimal difference in pollutant levels. One example is Berk et al (1981) where seven houses were retrofitted using standard weatherization methods that included installation of moisture barrier, ceiling, floor and duct insulation, storm doors and weatherstripping. Some of the IAQ parameters measured were CO_2, CO, NO_2, NO, O_3, formaldehyde, Radon and RH.There was no significant difference in the parameters measured before and after the retrofitting process.

5. Conclusions:

7) There has been a reduction in CO_2 with remediation [Tables 17 and 18] although a statistically significant difference was found only between HB client post-1 and post-2 averages.

8) There was a significant difference in CO_2 and RH between Hooper Bay and Fairbanks homes before and after remediation. Hooper Bay homes had higher pre and post CO_2 and RH means than Fairbanks homes [Table (19)].

9) Before remediation, Hooper Bay client and control homes differed with statistical significance in RH [higher client] and Fairbanks client and control homes, in benzene and toluene [higher client]. After remediation, there was no significant difference between client and control IAQ in Hooper Bay or Fairbanks.

10) None of the homes tested for benzene in Fairbanks or Hooper Bay had one-week average levels more than 34 ppb. This is less than the NIOSH Recommended Exposure Limit of 100 ppb. None of the homes had toluene levels greater than the NIOSH REL of 100 ppm. In fact, the highest level was just over 100 ppb. Thirty-seven out of 46 tests indicated 8 or 24-hour formaldehyde levels over 16 ppb [the NIOSH REL]. Some of the tests were on the same dwelling after remediation. So, for these three parameters, only formaldehyde was found to exceed workplace standards."

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List of Tables

Table1: UAF Field Equipment Specifications

	function	accuracy	range	resolution	sampling time
Biosytem Toxiultra	CO	greater of ± 1% or ± 5%	0-999 ppm	1 ppm	1 sec
Telaire model 7001	CO_2	greater of ± 50 ppm or 5% of reading	0-4000ppm	1 ppm	1 sec
Hobo H08-003-02	Temperature	±0.7° at 21°C (±1.27° at 70°F)	-20° to 70°C (-4° to 158°F)		
	Relative humidity	±5% RH	25% to 95% RH		
	voltage (for recording CO_2 transmitter output)		0-2.5V	0.01V	
Q-Trak 8551	Temperature	± 0.6°C (1°F)	0° to 50°C (32° at 122°F)		1 sec
	Relative humidity	± 3% RH			
	CO	greater of ± 3% or 3ppm	0-500 ppm		
	CO_2	± 50 ppm ± 3%	0-6000 ppm		
Dust Trak 8520	PM 2.5		0.001 - 100 mg/m^3	greater of 0.1% or 1 mg/m^3	1 sec
MetOne 9012	particle count		0.3 um - >5 um		1 sec
P-Trak	ultrafine particle count		0.02 - > 1um		1 sec
ppbRae	VOC (reported as isobutelyne)		1 ppb - 2000 ppm	1ppb	1 sec

Table 2: Grab Sample details

	function	Sampling mechanism	Analysis
vacuum sample	bedding debris	0.8 um Aerotech DustChek vacuum cartridge used with Red Devil Ultra hand vacuum	Ragnar Rylander
tape lift	settled surface dust	Scotch brand clear tape	Aerotech Labs
3M 3500 VOC badge	VOC	Diffusion to Sorbant carbon wafer	UAA
3M 3720 Formaldehyde badge	formaldehyde >0.65 ug	Diffusion to Bisulfite impregnated filter	B.I.C. Chemistry dept Mpls, Minnesota
RSSI Alpha Track detector	Indoor Radon concentration > 1 pCi/l	Diffusion to etchable polycarbonate substrate	RSSI, Inc Morton Grove, Illinois

Table 3: Healthy Homes IAQ Survey Form

HEALTHY HOMES IAQ SURVEY

House Identifier ____________________
____
____

Box #__________________
Date __________________

Instrument box [for CO, CO_2, RH, T]
Relative location of red instrument box in home
____
____

Tape lift [for fungal spore count]
Relative location of tape lift in home
____
____

Vacuum sample [for beta-glucans and endotoxin assessment]
Location of vacuum sample (preferably child's bedding, about a thimbleful in filter is sufficient) ____

Badges

VOC monitor badge (Brown badge in single can) [used for benzene and toluene analysis]
Secure VOC badge to red box
Badge # _________________
begin exposure date/time _________________
end exposure date/time _________________

Formaldehyde badge (purple badge in double can)parts that remain in the can have a serial number that needs to go with this badge when it is picked up
This is the one that needs to be picked up the next day or ask the client to bag it and place it in the freezer

Secure Formaldehyde badge to red box and expose for approximately 8-24 hours
Badge # _________________
begin exposure date/time _________________
end exposure date/time _________________

Radon alpha trak detector may be deployed for 3 months

OUTDOOR SAMPLES
VOC monitor badge (single can)
Badge # _________________
begin exposure date/time _________________
end exposure date/time _________________

Table 4: Hooper Bay Client Homes Pre-remediation (April-May 2003) IAQ Summary

Hooper Bay Client Homes Pre-remediation (April-May 2003) IAQ Summary table

	HB-4002	HB-4003	HB-4004	HB-4005	HB-4006	HB-4007	HB-4008	HB-4009	HB-4010	
CO2 (ppm)		**Duration of test: 14 days**				**Logging Interval:10 mins**				
Max	2485	2485	2485	2485	2372	2547	1591	2485	2000	
Min	845	669	425	610	421	575	458	425	526	
Avg	2189	1750	1243	1885	1194	1939	878	1481	1092	
SD	391	470	439	527	310	525	199	513	245	
CO (ppm)		**Duration of test:14 days**				**Logging Interval:30 mins**				
Max	4	7	6	14	109	6	3	10	4	
Min	0	1	0	0	0	0	0	0	0	
Avg	2	4	3	3	1	2	1	2	1	
SD	1	1	1	1	6	1	0	1	1	
RH (%)		**Duration of test: 14 days**				**Logging Interval:10 mins**				
Max	55	54	56	56	58	56	50	56	54	
Min	34	29	27	29	24	23	27	35	24	
Avg	47	42	42	44	38	41	33	46	41	
SD	4	5	7	5	6	4	4	4	8	
PM 2.5 (micro g/m^3)		**Duration of test: 20 mins**				**Logging Interval:1 min**				**Ambient**
Max	37	28	28	38	37	20	26	24	92	72
Min	30	23	19	23	19	16	14	13	33	8
Avg	34	26	21	27	25	18	17	20	57	13
SD	2	2	2	4	4	1	4	3	16	9
PM 1 (pt/cc)		**Duration of test: 20 mins**				**Logging Interval:1 sec**				**Ambient**
Max	118000	77700	34700	54500	31800		13200	175000	112000	289000
Min	63300	35400	4190	42800	1090		7130	8310	36300	161
Avg	87769	51417	15621	45434	8581		8945	119412	61518	6306
SD	14198	11614	6794	2390	3681		851	32371	14122	13291
TVOC (ppb)		**Duration of test: 20 mins**				**Logging Interval:1 min**				**Ambient**
Max	1737	2030	404	15078	1394	1669	731	1424	563	140
Min	796	865	294	2422	883	879	539	842	377	31
Avg	955	1408	328	4776	1238	1342	609	1160	444	74
SD	198	377	29	3410	143	221	56	184	50	26
Temperature (*F)		**Duration of test: 14 days**				**Logging Interval:10 mins**				
Max	77	84	81	95	84	78	75	77	104	
Min	49	68	53	48	50	53	66	45	52	
Avg	67	76	65	76	72	72	72	69	69	
SD	6	2	5	7	3	3	2	6	9	
Formaldehyde (ppm)						**Duration of test: 8 to 24 hours**				
	0.03	0.03	0.02	0.02	0.01	0.03	0.01	0.01	0.02	
Benzene (ppb)						**Duration of test: 1 week**				
	23.3	23.6	9.3	13.8	4.4	11.0	4.9	4.4	33.7	0.6
Toluene (ppb)						**Duration of test: 1 week**				
	103.8	68.1	15.4	46.6	11.7	58.1	14.0	12.3	46.0	3.7

Table 5: Hooper Bay Client Homes Post-1 remediation (March 2004) IAQ summary

Hooper Bay Client Homes Post 1-remediation (March 2004) IAQ Summary table

	HB-4002	HB-4003	HB-4004	HB-4005	HB-4006	HB-4007	HB-4008	HB-4009	HB-4010	Ambient
CO2 (ppm)	Duration of test: 11.7days					Logging Interval:10 mins				
Max	2485	2485	2485	2485	2485	2485	2485	2485	2485	
Min	464	454	581	562	513	522	444	454	396	
Avg	1271	1052	1613	1904	1502	2121	1205	1293	973	
SD	478	392	415	529	467	508	425	339	266	
CO (ppm)	Duration of test:11.68 days					Logging Interval:30 mins				
Max	3	21	6	8	6	7	6	5	5	
Min	0	0	0	0	0	0	0	0	0	
Avg	1	2	2	2	2	3	1	2	3	
SD	1	1	1	1	1	1	1	1	1	
RH (%)	Duration of test: 11.7days					Logging Interval:10 mins				
Max	47	41	48	53	52	56	42	44	53	
Min	23	23	23	23	23	23	23	23	23	
Avg	28	24	28	32	33	36	26	29	28	
SD	3	2	5	6	6	8	4	4	5	
PM 2.5 (µg/m^3)	Duration of test: 8-15 mins					Logging Interval:1 min				
Max	38		678	31	362	106	77	38	23	
Min	24		294	26	13	58	18	16	10	
Avg	30		342	29	67	89	38	20	13	
SD	4		84	2	112	13	20	5	3	
PM 1 (pt/cc)			Duration of test: 5-12 mins ambient: 5.43 hrs				Logging Interval:1 sec			
Max	87600	43500	57900	132000	440000	70500	29700	129000	25000	329000
Min	38800	29000	24300	12500	3490	34100	19500	13000	12400	322
Avg	50492	32602	42316	21690	12233	48184	25560	38094	20352	28081
SD	10183	1999	8315	11836	22787	5714	1637	8177	2225	27171
TVOC (ppb)	Duration of test: 10-15 mins					Logging Interval:1 min				
Max	391	792	613	1579	25421	3815	805	831	615	
Min	280	746	95	777	606	1127	587	806	546	
Avg	370	768	517	1199	6420	1913	621	823	582	
SD	28	17	154	264	6390	976	66	7	21	
Temperature (°F)	Duration of test: 11.7days					Logging Interval:10 mins				
Max	75	84	84	91	82	89	81	80	89	
Min	64	61	60	62	42	39	32	33	42	
Avg	70	78	75	77	74	69	76	73	73	
SD	2	4	6	3	3	8	3	5	5	
Ventilation rate (hr^-1)										
	0.19	0.35	0.11		0.16	0.23	0.14	0.27	0.17	
Formaldehyde (ppm)						Duration of test: 24 hrs				
	0.0219	0.0474	0.0354	0.0295	0.0264	0.022	0.0284	0.0141	0.0137	
Benzene (ppb)						Duration of test: 1 week				
	3.54	15.84	7.65	6.97	3.56	6.64	14.76	8.40	9.76	
Toluene (ppb)						Duration of test: 1 week				
	12.30	47.68	30.16	40.63	31.52	35.45	55.36	22.86	56.03	

Table 6: Hooper Bay Client Homes Post-2 remediation (Nov 2004) IAQ Summary

Hooper Bay Client Homes Post 2-remediation (Nov 2004) IAQ Summary table

	HB-4002	HB-4003	HB-4004	HB-4005	HB-4006	HB-4007	HB-4008	HB-4009	HB-4010
CO2 (ppm)	**Logging Interval:10 mins**				**Duration of test: 12 days**				
Max	1513		2166	1992		2100	1828	2053	1991
Min	370		370	389		370	498	370	517
Avg	619		1171	1080		1525	962	968	1291
SD	118		389	402		501	248	295	418
CO (ppm)	**Logging Interval:10 mins**				**Duration of test: 12 days**				
Max	8		38	20		44	5	8	3
Min	0		0	0		0	0	0	0
Avg	1		1	0		1	1	1	1
SD	1		2	1		3	1	0	1
RH (%)	**Logging Interval:10 mins**				**Duration of test: 12 days**				
Max	37		49	55		84	47	48	54
Min	22		16	30		33	19	24	17
Avg	27		27	40		45	27	33	33
SD	3		7	3		6	4	4	7
Temperature (°F)	**Logging Interval:10 mins**				**Duration of test: 12 days**				
Max	75		90	75		86	83	81	95
Min	64		48	60		57	69	61	70
Avg	71		78	71		71	76	73	80
SD	2		8	2		4	2	3	4

Table 7: Hooper Bay Control Homes Pre-remediation (April 2004) IAQ Summary

Hooper Bay Control Homes Pre-remediation (April 2004) IAQ Summary table

	HB-4064	HB-4066	HB-4062	HB-4063	HB-4070	HB-4045	HB-4071	HB-4048	HB-4068
CO_2 (ppm)			**Logging Interval:10 mins**				**Duration of test: 10 days**		
Max	1860	2485	1528		2104	1538	2485	2104	2485
Min	415	415	601		796	454	620	854	435
Avg	965	1121	1097		1323	944	2183	1434	1727
SD	261	407	181		263	218	462	258	469
CO (ppm)			**Logging Interval:30 mins**				**Duration of test: 10 days**		
Max	41	5	5	2	6	2	3	3	6
Min	0	0	0	0	0	0	0	0	0
Avg	2	1	1	1	2	1	1	1	2
SD	4	1	1	0	1	0	0	0	1
RH (%)			**Logging Interval:10 mins**				**Duration of test: 10 days**		
Max	62	69	60		53	62	60	61	60
Min	24	24	24		24	24	24	24	24
Avg	33	35	41		35	37	40	33	38
SD	8	8	10		7	7	10	7	9
Temperature (*F)			**Logging Interval:10 mins**				**Duration of test: 10 days**		
Max	91	94	88		78	74	89	82	79
Min	57	53	58		59	53	51	48	56
Avg	74	71	72		72	69	73	72	71
SD	6	4	5		4	2	5	4	3

Table 8: Hooper Bay Control Homes Post-remediation (Nov 2004) IAQ Summary

Hooper Bay Control Homes Post-remediation (Nov 2004) IAQ Summary table

	HB-4064	HB-4066	HB-4062	HB-4063	HB-4070	HB-4045	HB-4071	HB-4048	HB-4068
CO_2 (ppm)		**Logging Interval:10 mins**				**Duration of test: 11 days**			
Max	2011	1219		1159		2106	2011	1985	1993
Min	645	370		370		370	766	613	716
Avg	1440	619		607		899	1838	1305	1541
SD	461	139		151		322	303	406	345
CO (ppm)		**Logging Interval:10 mins**				**Duration of test: 11 days**			
Max	124	14	5	0	0	13	2	1	4
Min	0	0	0	0	0	0	0	0	0
Avg	2	0	1	0	0	3	0	0	0
SD	9	1	1	0	0	3	0	0	0
RH (%)		**Logging Interval:10 mins**				**Duration of test: 11 days**			
Max	65	60		82		95	79	52	84
Min	20	21		11		29	25	24	26
Avg	34	28		20		43	42	33	42
SD	8	3		4		7	9	4	6
Temperature (°F)		**Logging Interval:10 mins**				**Duration of test: 11 days**			
Max	95	86		98		76	94	89	89
Min	70	52		69		50	68	72	65
Avg	81	73		81		65	80	78	72
SD	4	5		5		5	4	3	3

Table 9: Fairbanks client Homes Pre-remediation IAQ Summary

Fairbanks Client Homes Pre-remediation IAQ Summary table

	DE	WIL	KN	CO	NA	SI	STILLV	FA	KH	MC
CO2 (ppm)		**Logging Interval:10 mins**			**Duration of test: 14 days**					
Max	1694	1782	1616	2349	2320	1909	1050	1479	2212	2368
Min	386	425	747	542	613	483	464	474	591	396
Avg	533	933	1061	1210	1161	1051	638	832	1089	1623
SD	96	186	172	370	338	222	122	210	307	355
CO (ppm)		**Logging Interval:30 mins**			**Duration of test:14 days**					
Max	44	16			3	4	13	27	17	13
Min	0	0			0	0	0	0	0	0
Avg	2	1			0	1	1	5	1	1
SD	4	1			0	1	2	10	5	1
RH (%)		**Logging Interval:10 mins**			**Duration of test: 14 days**					
Max	55	47	34	37	47	61	42	43	58	37
Min	23	23	23	23	24	23	23	23	24	0
Avg	25	30	24	26	31	30	27	32	45	25
SD	3	5	1	3	4	5	2	3	11	2
PM 2.5 (µg/m^3)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Max	24		61	14	352	40				
Min	2		21	8	7	11				
Avg	14		42	11	44	22				
SD	6		6	1	69	10				
Outdoor PM 2.5 (µg/m^3)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Max	388		16	10		9				
Min	0		3	5		5				
Avg	22		7	7		6				
SD	89		3	1		1				
PM 1 (pt/cc)		**Logging Interval:1 sec**			**Duration of test: 20 mins**					
Max	5400		350000	39500	235000	227000				
Min	489		1470	888	439	10500				
Avg	3225		121371	8625	17834	26254				
SD	1219		41912	4338	27472	22748				
Outdoor PM 1 (pt/cc)		**Logging Interval:1 sec**			**Duration of test: 20 mins**					
Max	280000		51300	24600	59400	55600				
Min	594		6290	10000	439	13900				
Avg	2115		14780	11454	6046	32533				
SD	7726		4699	1864	8930	10656				
TVOC (ppb)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Max	554		1288	330	595	MAX				
Min	108		32	83	36	777				
Avg	427		706	249	263	12727				
SD			245	83						
Outdoor TVOC (ppb)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Avg						49				
Temperature (°F)		**Logging Interval:10 mins**			**Duration of test: 14 days**					
Max	82	81	75	95	78	84	75	77	79	83
Min	49	60	66	50	32	39	59	61	48	38
Avg	71	69	72	73	70	73	70	71	65	70
SD	3	2	1	11	4	4	2	2	6	2
Formaldehyde (ppm)					**Duration of test: 8 to 24 hours**					
	0.02				0.04	0.03	0.13	0		
Benzene (ppb)					**Duration of test: 1 week**					
	18.1	4.1	12.8	4.6	2.8	4.2	25.0	11.1		9.4
Toluene (ppb)					**Duration of test: 1 week**					
	41.5	31.6	80.6	14.4	65.5	12.6	101.7	44.3		52
Radon (pci/l)					**Duration of test: 14 days**					
	3.4					1.2				

Table 10: Fairbanks Client Homes Post-remediation IAQ Summary

Fairbanks Client Homes Post-remediation IAQ Summary table

	DE	WIL	KN	CO	NA	SI	STILLV	FA	KH	MC
CO2 (ppm)		**Logging Interval:10 mins**			**Duration of test: 14 days**					
Max	2485	1753		1274	1841	2163		2251	1304	1772
Min	425	464		435	415	474		425	522	425
Avg	1440	688		798	824	1165		765	742	971
SD	428	144		117	205	295		274	144	194
CO (ppm)		**Logging Interval:30 mins**			**Duration of test:14 days**					
Max		8		8	9	4		17	9	8
Min		0		0	0	0		0	0	0
Avg		1		1	1	1		2	1	2
SD		2		1	1	1		2	1	2
RH (%)		**Logging Interval:10 mins**			**Duration of test: 14 days**					
Max	39	28		39	42	55	25	32	45	39
Min	23	23		23	23	23	24	23	23	23
Avg	26	23		24	27	25	24	24	24	26
SD	2	0		1	3	3	0	1	3	2
PM 2.5 (µg/m^3)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Max					48					
Min					11					
Avg					30					
SD					5					
Outdoor PM 2.5 (µg/m^3)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Max					83					
Min					0					
Avg					16					
SD					18					
PM 1 (pt/cc)		**Logging Interval:1 sec**			**Duration of test: 20 mins**					
Max					50651					
Min					3792					
Avg					16693					
SD					8766					
Outdoor PM 1 (pt/cc)		**Logging Interval:1 sec**			**Duration of test: 20 mins**					
Max					210583					
Min					3074					
Avg					43783					
SD					39638					
TVOC (ppb)		**Logging Interval:1 min**			**Duration of test: 20 mins**					
Max					3609					
Min					172					
Avg					682					
SD					349					
Temperature (°F)		**Logging Interval:10 mins**			**Duration of test: 14 days**					
Max	75	83		79	78	89	76	84	82	79
Min	44	48		42	64	57	60	64	48	52
Avg	69	71		74	70	76	64	73	66	73
SD	3	2		3	2	2	3	4	6	3
Formaldehyde (ppm)					**Duration of test: 8 to 24 hours**					
	0.16	0.07		0.08		0.09	0.27	0	0.09	0.1
Benzene (ppb)					**Duration of test: 1 week**					
	5.9	9.4		8.8		7.7			10.5	8.7
Toluene (ppb)					**Duration of test: 1 week**					
	23.7	73		28		29			30	42.2

Table 11: Fairbanks Control Homes Pre-remediation IAQ Summary

Fairbanks Control Homes Pre-remediation IAQ Summary table

	BR	HA	JO	KL	LO	WA	WI	AND
CO_2 (ppm)		Logging Interval:10 mins				Duration of test: 14 days		
Max	923	1694	1274	1274	1479	2212	1851	1792
Min	435	396	405	396	513	493	415	532
Avg	571	964	567	695	807	994	828	1104
SD	97	239	94	131	144	320	124	204
CO (ppm)		Logging Interval:30 mins				Duration of test:14 days		
Max	19	2	3	8	11	4	6	15
Min	0	0	0	0	0	0	0	0
Avg	2	1	1	1	1	1	3	2
SD	2	0	1	1	1	1	1	5
RH (%)		Logging Interval:10 mins				Duration of test: 14 days		
Max	48	45	24	31	27	43	73	58
Min	23	23	23	23	23	23	23	23
Avg	26	30	23	24	24	27	25	32
SD	3	6	0	1	0	5	2	3
PM 2.5 (µg/m^3)		Logging Interval:1 min				Duration of test: 20 mins		
Max	31	19	16	13	93	34	443	
Min	10	9	8	2	30	22	104	
Avg	18	15	11	4	49	26	196	
SD	7	3	2	3	14	2	103	
Outdoor PM 2.5 (µg/m^3)		Logging Interval:1 min				Duration of test: 20 mins		
Max	18	76	12	1	88	25	70	
Min	9	1	0	0	23	17	13	
Avg	12	17	2	0	46	21	38	
SD	2	18	3	0	13	2	12	
PM 1 (pt/cc)		Logging Interval:1 sec				Duration of test: 20 mins		
Max	181000	104000	89100	94300	500000	31200	254000	
Min	10600	15600	10000	10000	10000	17100	12500	
Avg	69817	30069	17672	23836	63539	22850	42418	
SD	55960	7097	11226	14195	54684	3746	24225	
Outdoor PM 1 (pt/cc)		Logging Interval:1 sec				Duration of test: 20 mins		
Max	193000		329000	89500	18200	351000	314000	
Min	13800		13300	10000	10000	14700	31400	
Avg	44509		22874	23298	12566	73801	87332	
SD	24862		17014	14699	1667	25006	31253	
TVOC (ppb)		Logging Interval:1 min				Duration of test: 20 mins		
Max	350	479		504	305	543	247	
Min	214	227		117	176	366	103	
Avg	288	380		314	231	448	180	
SD								
Outdoor TVOC (ppb)		Logging Interval:1 min				Duration of test: 20 mins		
Avg	60	63		511	55	112	69	
Temperature (°F)		Logging Interval:10 mins				Duration of test: 14 days		
Max	84	76	79	84	84	75	77	72
Min	51	58	55	52	66	43	36	42
Avg	69	71	70	68	75	70	71	68
SD	2	2	4	3	3	2	3	2
Formaldehyde (ppm)						Duration of test: 8 to 24 hours		
	0.03	0.06	0.05	0.02	0.03	0.03	0.02	0.09
Benzene (ppb)						Duration of test: 1 week		
	2.9	1.9	3.4	3.3	1.9	1.2	5.7	
Toluene (ppb)						Duration of test: 1 week		
	20.0	10.0	10.1	10.3	18.9	9.6	12.0	
Radon (pci/l)						Duration of test: 14 days		
	3.5	7.4	1.5	1.4	1.6	3.0	2.4	

Table 12: Fairbanks Control Homes Post-remediation IAQ summary

Fairbanks Control Homes Post-remediation IAQ Summary table

	BR	HA	JO	KL	LO	WA	WI	AND
CO2 (ppm)		**Logging Interval:10 mins**				**Duration of test: 14 days**		
Max	825	1509		1401	1616	2446	1831	1089
Min	435	464		444	571	513	562	444
Avg	496	816		694	915	953	1083	711
SD	61	154		188	168	342	206	117
CO (ppm)		**Logging Interval:30 mins**				**Duration of test:14 days**		
Max	5	6	4	4	3	6	6	5
Min	0	0	0	0	0	0	0	0
Avg	1	1	2	2	1	2	2	1
SD	1	1	1	1	0	1	1	1
RH (%)		**Logging Interval:10 mins**				**Duration of test: 14 days**		
Max	25	27	24	24	28	30	38	37
Min	23	23	23	23	23	23	24	23
Avg	24	23	24	24	24	24	29	24
SD	0	0	0	0	0	1	3	0
PM 2.5 (µg/m^3)		**Logging Interval:1 min**				**Duration of test: 20 mins**		
Max		5	5	4	35	45		
Min		3	2	1	19	8		
Avg		4	3	2	27	21		
SD		1	1	1	5	10		
Outdoor PM 2.5 (µg/m^3)		**Logging Interval:1 min**				**Duration of test: 20 mins**		
Max		39	43		9	159		
Min		4	1		1	4		
Avg		16	11		3	17		
SD		5	14		2	31		
PM 1 (pt/cc)		**Logging Interval:1 sec**				**Duration of test: 20 mins**		
Max		119000	70300	130000	90500	65100		
Min		8140	378	57500	1410	9060		
Avg		17815	3409	108643	10671	13897		
SD		10799	2655	9252	15824	6147		
Outdoor PM 1 (pt/cc)		**Logging Interval:1 sec**				**Duration of test: 20 mins**		
Max		407000	243000	70000	15500	123000		
Min		15300	4210	485	228	39300		
Avg		73291	12450	3858	1358	54140		
SD		34326	12090	7740	811	10234		
TVOC (ppb)		**Logging Interval:1 min**				**Duration of test: 20 mins**		
Max		183	232	299	4000	361		
Min		37	69	26	56	94		
Avg		130	173	178	481	293		
SD		36	42	116	755	74		
Outdoor TVOC (ppb)		**Logging Interval:1 min**				**Duration of test: 20 mins**		
Avg								
Temperature (°F)		**Logging Interval:10 mins**				**Duration of test: 14 days**		
Max	75	75	76	72	81	72	72	77
Min	72	69	70	57	68	67	67	62
Avg	74	71	74	60	75	68	69	71
SD	0	1	1	4	2	1	1	3
Formaldehyde (ppm)						**Duration of test: 8 to 24 hours**		
	0.03	0.02	0.02	0.01	0.04	0.02		0
Benzene (ppb)						**Duration of test: 1 week**		
	3.9	6.0	2.7	4.6	2.5	13.0	31.3	
Toluene (ppb)						**Duration of test: 1 week**		
	11.5	21.3	5.4	15.4	19.3	30.6	107.8	
Radon (pci/l)						**Duration of test: 14 days**		
			2.9	< 1.7	2.4	2.5		

Table 13: Fairbanks tape-lift results

Fairbanks Pre-Remediation tape-lift results

House#	Tape-lift Mycelial Fragments count/cm^2	Tape-lift Total Fungal Spores count/cm^2	Aspergillus/ Penicillum like
Fbks-BR (11-'03)	< 15	339	31
Fbks-HA (11-'03)	< 15	15	15
Fbks-JO (11-'03)	< 15	46	31
Fbks-KL (11-'03)	92	1940	1833
Fbks-LO (11-'03)	< 15	77	31
Fbks-WA (11-'03)	<15	31	15
Fbks-WI (11-'03)	15	31	15
Fbks-AND (11-'04)	<15	169	15
Fbks-DE (11-'03)	46	370	185
Fbks-WIL (4-'04)	<15	46	15
Fbks-KN (2-'04)	77	2310	1771
Fbks-CO(12-'03)	<15	77	15
Fbks-NA (3-'03)	2017	8023	139
Fbks-SI (11-'03)	46	46	15
Fbks-STILLV (11-'04)	<15	277	
Fbks-KH (10-'04)	<15	62	15
Fbks-MC (4-'04)	<15	46	46

Fairbanks Post-Remediation tape-lift results

House#	Tape-lift Mycelial Fragments count/cm^2	Tape-lift Total Fungal Spores count/cm^2	Aspergillus/ Penicillum like
Fbks-BR (4-'04)	15	62	
FBKS-HA (2-'04)	15	46	
FBKS-JO (2-'04)	<15	15	15
FBKS-KL (2-'04)	15	216	185
FBKS-LO (2-'04)	< 15	31	31
FBKS-WA (2-'04)	1417	7484	
Fbks-WI (4-'04)	15	15	15
Fbks-AND (12-'04)	<15	139	123
Fbks-DE (11-'04)	< 15	92	62

* Fbks-WA had Stachybotrys = 3465 Count/cm^2

** Client homes are in **BOLD**

Table 14: Date of testing in Fairbanks and outdoor temperature

Dates of homes tested in Fairbanks and outdoor Temperature

House no.	Type	Date tested	Outdoor Temp (F)
fbks-fa	**Client**	October-04	30
fbks-fa post	**Client**	December-04	-3
fbks-kh	**Client**	October-04	30
fbks-kh post	**Client**	December-04	-3
fbks-mc	**Client**	April-04	35
fbks-mc post	**Client**	November-04	7
fbks-stillV	**Client**	November-04	7
fbks-stillVpost	**Client**	January-05	-9
fbks-wil	**Client**	April-04	35
fbks-wil post	**Client**	November-04	7
fbks-co	**Client**	December-03	-9
fbks co post	**Client**	November-04	7
fbks-de	**Client**	November-03	10
fbks II-fall 04 de	**Client**	November-04	7
fbks-kn	**Client**	February-04	1
rental - post test not done	**Client**		
fbks-na	**Client**	March-03	9
fbks-na post	**Client**	November-03	10
fbks-si	**Client**	November-03	10
fbks-si post	**Client**	November-04	7
fbks-and	**Control**	November-04	7
fbks-and post	**Control**	December-04	-3
fbks-br	**Control**	November-03	10
fbks-br post	**Control**	April-04	35
fbks-ha	**Control**	November-03	10
fbks-ha post	**Control**	March-04	6
fbks-jo	**Control**	December-03	-9
fbks-jo post	**Control**	March-04	6
fbks-kl	**Control**	December-03	-9
fbks-kl post	**Control**	March-04	6
fbks-lo	**Control**	December-03	-9
fbks-lo post	**Control**	March-04	6
fbks-wa	**Control**	November-03	10
fbks-wa post	**Control**	March-04	6
fbks-wi	**Control**	December-03	-9
fbks-wi post	**Control**	April-04	35

Outdoor temperature from: http://www.weatherunderground.com/history

Table 15: Percentage of test duration for which CO_2 measurements were at maximum recordable levels

Percentage of test duration for which CO2 measurements were at maximum recordable levels

HB Client Pre	HB 4002	HB 4003	HB 4004	HB 4005	HB 4006	HB 4007	HB 4008	HB 4009	HB 4010
%	2	1	7	20	2	44	2	1	0
HB Client Post-1	**HB 4002**	**HB 4003**	**HB 4004**	**HB 4005**	**HB 4006**	**HB 4007**	**HB 4008**	**HB 4009**	**HB 4010**
%	66	15	2	39	0	33	0	3	0
HB Control Pre	**HB 4064**	**HB 4066**	**HB 4062**	**HB 4063**	**HB 4070**	**HB 4045**	**HB 4071**	**HB 4048**	**HB 4068**
%	0	0	0	0	0	0	51	0	8

Table 16: Acceptable ranges of indoor temperature and RH during summer and winter

Acceptable ranges of temperature and RH during summer and winter

Relative Humidity	Winter Indoor Temperature	Summer Indoor Temperature
30%	68.5°F - 76.0°F	74.0°F - 80.0°F
40%	68.5°F - 75.5°F	73.5°F - 79.5°F
50%	68.5°F - 74.5°F	73.0°F - 79.0°F
60%	68.0°F - 74.0°F	72.5°F - 78.0°F

SOURCE: Adapted from ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy

Table 17: Summary statistics and results of t-test (paired) comparing "pre" and "post" parameters of Hooper Bay homes.

Summary statistics and results of T test (paired) comparing "pre" and "post" parameters

Hooper Bay Client

	Pre Mean	Pre SD	N	Post-1 Mean	Post-1 SD	N	P(T<=t) two-tail
CO2 (ppm)	1517	446	9	1437	385	9	0.6185
RH (%)	42	4	9	29	4	9	**0.0001**
ID PM 2.5 (ug/m^3)	27	13	8	79	110	8	0.2441
ID PM 1 (pt/cc)	49837	39610	8	30417	12762	8	0.1611
TVOC (ppb)	1362	1340	9	1468	1914	9	0.8917
Formaldehyde (ppm)	0.02	0.01	9	0.03	0.01	9	0.1160
Benzene (ppb)	14.27	10.39	9	8.57	4.33	9	0.1484
Toluene (ppb)	41.78	31.80	9	36.89	14.64	9	0.7108

Hooper Bay Client

	Pre Mean	Pre SD	N	Post-2 Mean	Post-2 SD	N	P(T<=t) two-tail
CO2 (ppm)	1529	488	7	1088	286	7	0.1042
RH (%)	19	4	7	50	7	7	**0.0223**

Hooper Bay Client

	Post-1 Mean	Post-1 SD	N	Post-2 Mean	Post-2 SD	N	P(T<=t) two-tail
CO2 (ppm)	1483	412	7	1088	286	7	**0.0307**
RH (%)	29	3	7	33	7	7	**0.0490**

Hooper Bay Control

	Pre Mean	Pre SD	N	Post Mean	Post SD	N	P(T<=t) two-tail
CO2 (ppm)	1396	489	6	1274	444	6	0.4127
RH (%)	36	3	6	37	6	6	0.5380

Table 18: Summary statistics and results of t-test (paired) comparing “pre” and “post” parameters of Fairbanks homes.

Summary statistics and results of T test (paired) comparing "pre" and "post" parameters

Fairbanks Client

	Pre Mean	Pre SD	N	Post Mean	Post SD	N	P(T<=t) two-tail
CO2 (ppm)	1054	315	8	924	258	8	0.4668
RH (%)	30	6	9	25	1	9	**0.0444**
Benzene (ppb)	8.08	6.02	6	8.10	1.37	6	0.9953
Toluene (ppb)	30.48	17.15	6	39.20	20.34	6	0.4554

Fairbanks Control

	Pre Mean	Pre SD	N	Post Mean	Post SD	N	P(T<=t) two-tail
CO2 (ppm)	852	184	7	809	195	7	0.5993
RH (%)	27	3	8	24	2	8	0.1579
ID PM 2.5 (ug/m^3)	21	17	5	11	12	5	**0.0494**
ID PM 1 (pt/cc)	28909	21381	5	21564	23230	5	0.6381
TVOC (ppb)	343	93	4	270	156	4	0.5559
Formaldehyde (ppm)	0.04	0.02	6	0.02	0.01	6	0.2435
AT-Radon (pci/l)	1.88	0.75	4	2.35	0.54	4	0.3275
Benzene (ppb)	2.90	1.48	7	9.14	10.40	7	0.1329
Toluene (ppb)	12.99	4.49	7	30.19	35.13	7	0.2536

Table 19: Table comparing constituents, from two different groups, for which the means were significantly different using t test assuming unequal variances.

t-test assuming unequal variances

	Group 1	Mean	SD	N	Group 2	Mean	SD	N	P(T<=t) two-tail
RH (%)	HB Client Pre	42	4	9	HB Control Pre	36	2	8	0.0062
Benzene (ppb)	Fbks Client Pre	10	8	9	Fbks Control Pre	3	2	7	0.0186
Toluene (ppb)	Fbks Client Pre	50	30	9	Fbks Control Pre	13	5	7	0.0065
CO2 (ppm)	HB Client Pre	1517	446	9	Fbks Client Pre	1013	308	10	0.0132
RH (%)	HB Client Pre	42	4	9	Fbks Client Pre	30	6	10	8.60E-05
RH (%)	HB Client Post 2	33	7	7	Fbks Client Post	25	1	9	0.0213
CO2 (ppm)	HB Control Pre	1350	427	8	Fbks Control Pre	817	198	8	0.0093
RH (%)	HB Control Pre	36	3	8	Fbks Control Pre	27	3	8	1.71E-05
RH (%)	HB Control Post	35	9	7	Fbks Control Post	24	2	8	0.0173

List of IAQ Figures

Figure 1: Hooper Bay Client Homes Maximum 1 hr CO

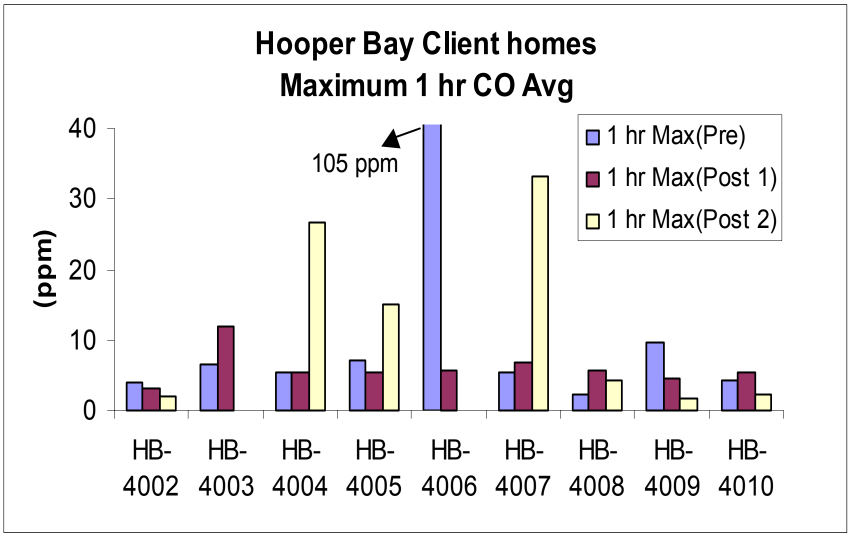


Figure 2: Hooper Bay Client Homes Maximum 8 hr CO

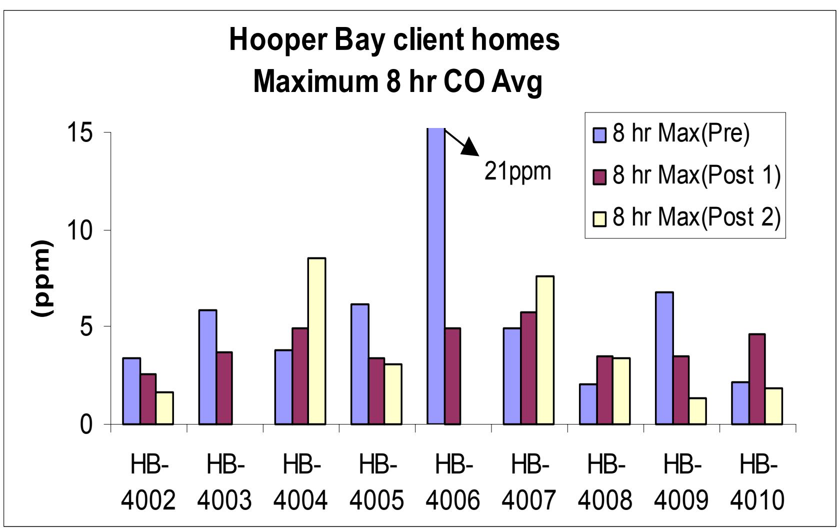


Figure 3: CO, CO_2 and Temperature vs time in Client home HB-4006 (April 2003)

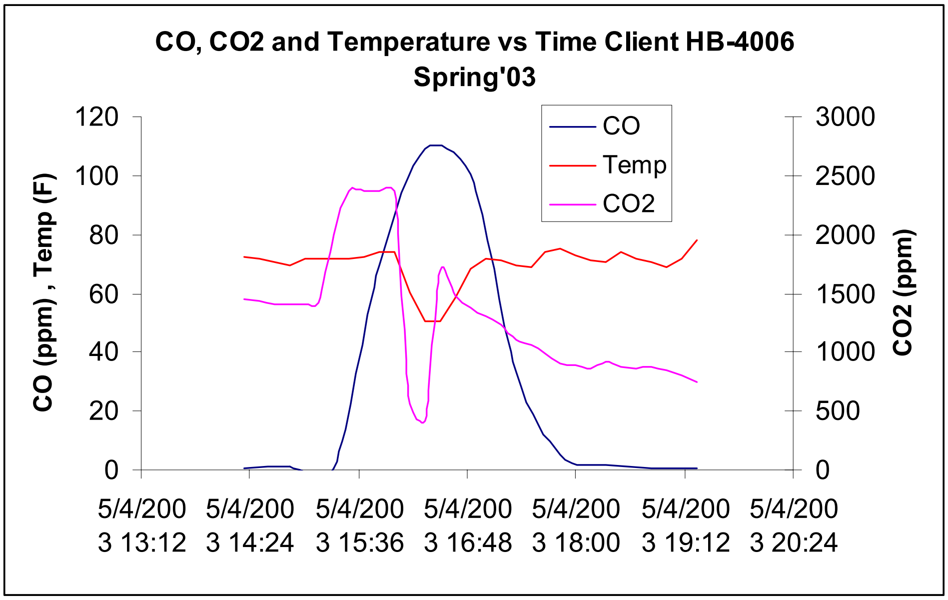


Figure 4: Hooper Bay Control Homes Maximum 1 hr CO

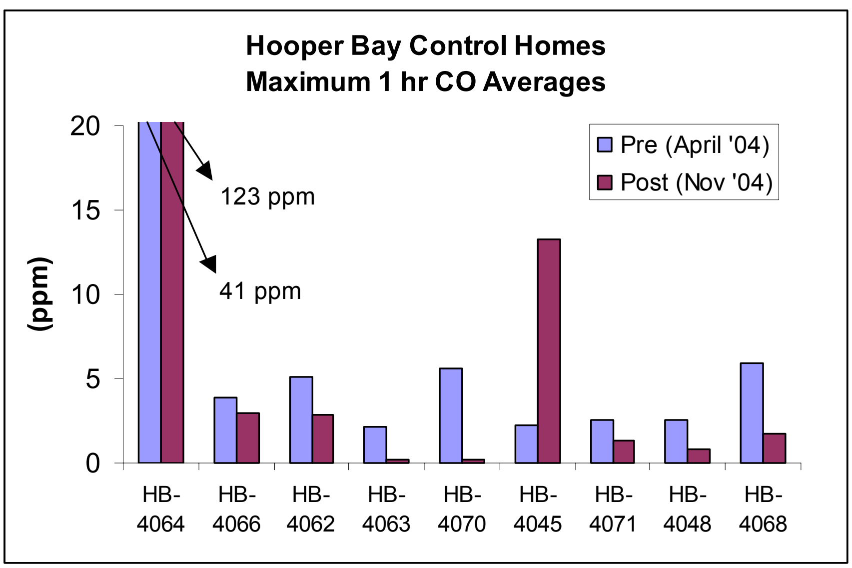


Figure 5: Hooper Bay Control Homes Maximum 8 hr CO

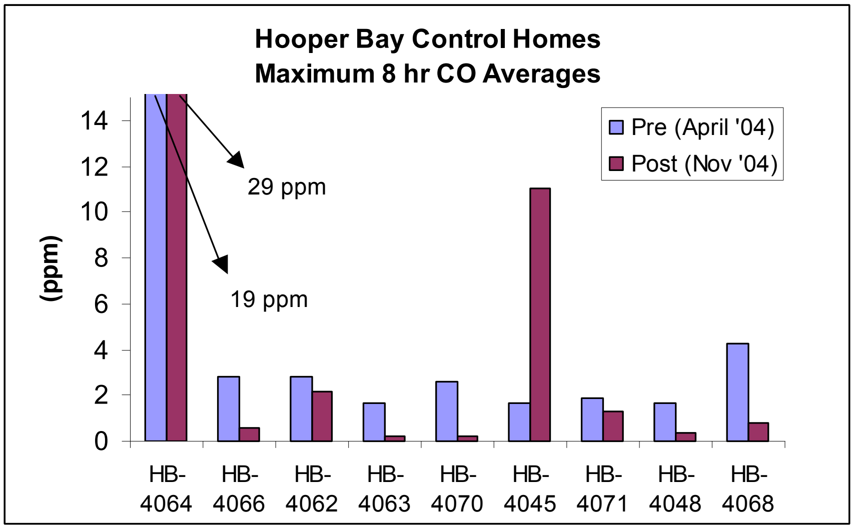


Figure 6: CO and CO_2 vs time in Control home HB-4045 (Nov 2004)

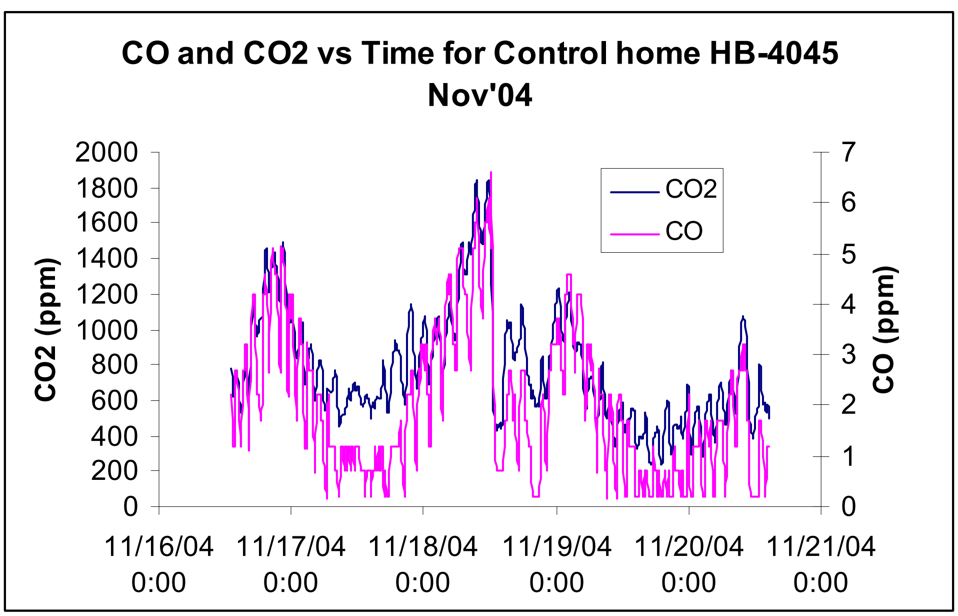


Figure 7: CO and Temperature vs time in Control home HB-4045 (Nov 2004)

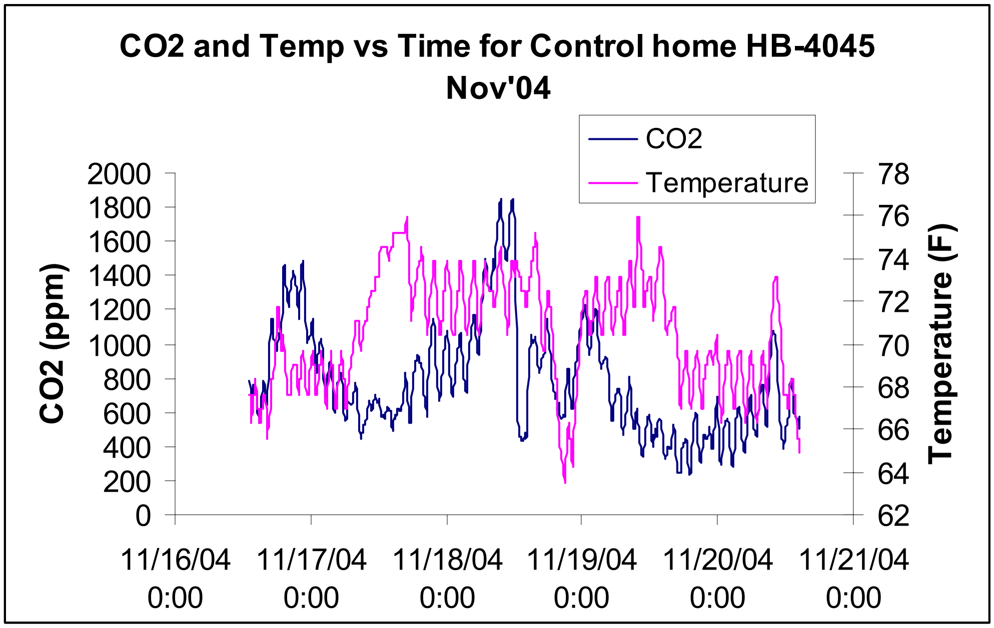


Figure 8: Fairbanks Client Homes Maximum 1 hr CO

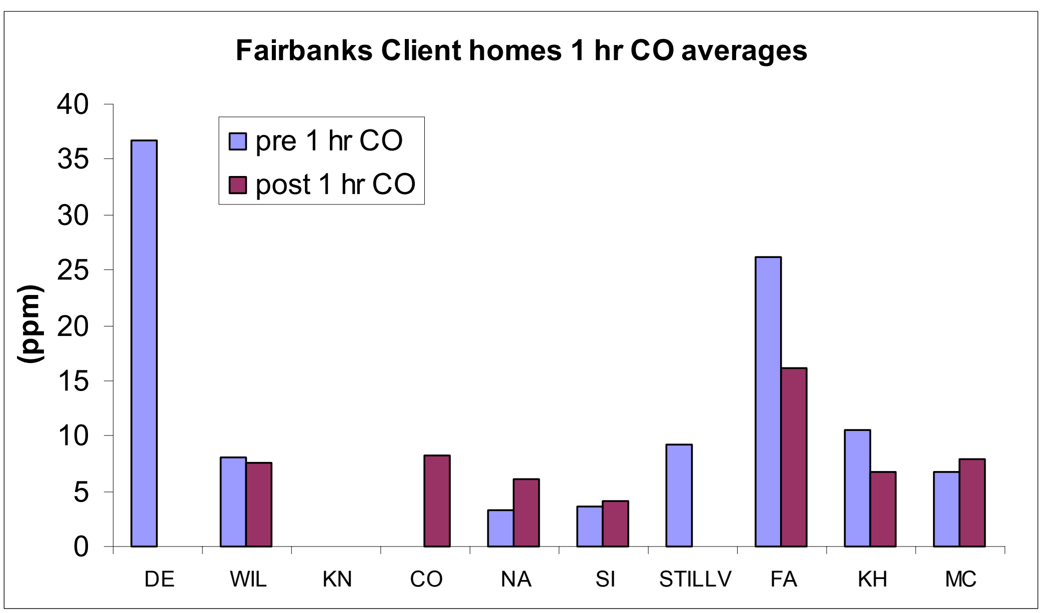


Figure 9: Fairbanks Client Homes Maximum 8 hr CO

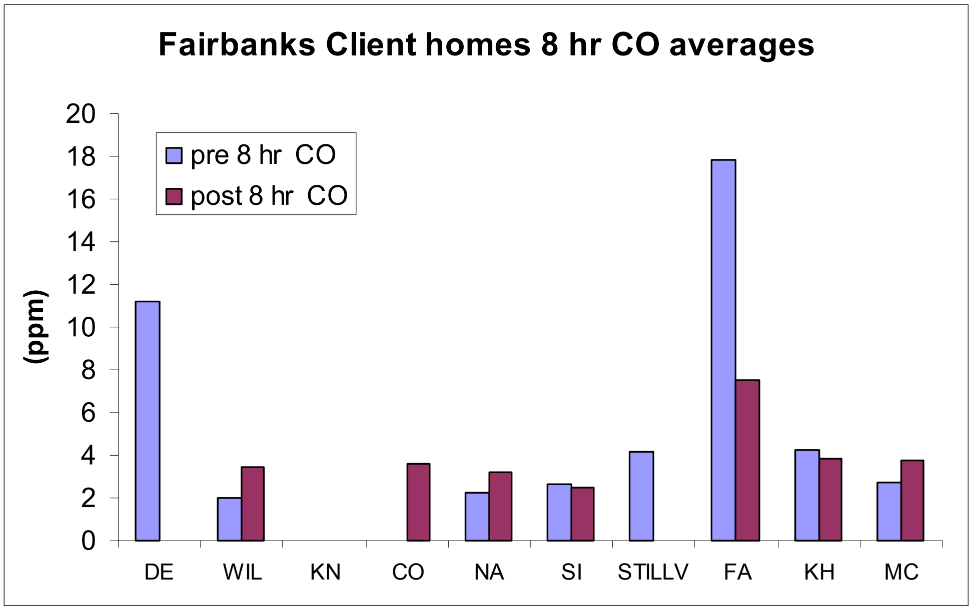


Figure 10: CO and CO_2 vs time in Client home Fbks-FA (Oct 2004)

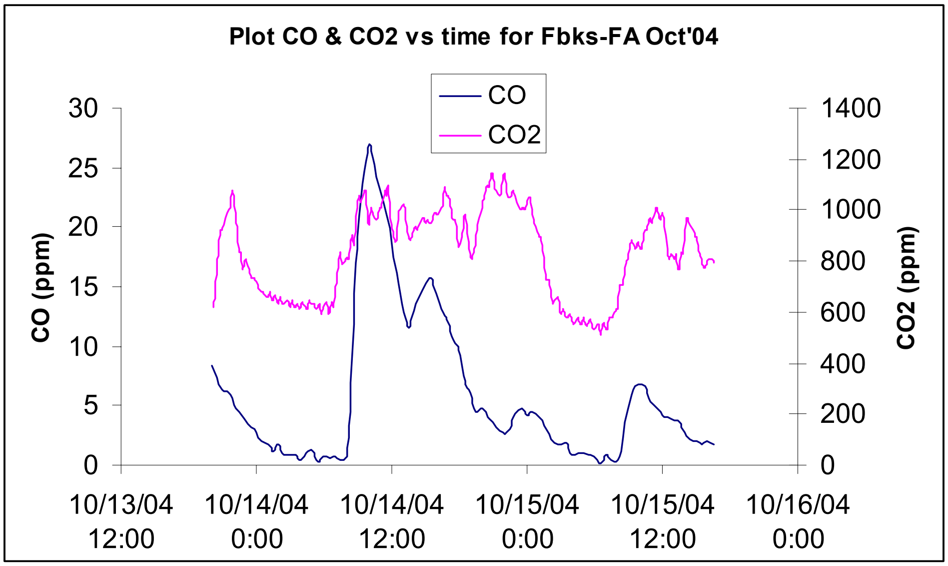


Figure 11: CO_2 and Temperature vs time in Client home Fbks-FA (Oct 2004)

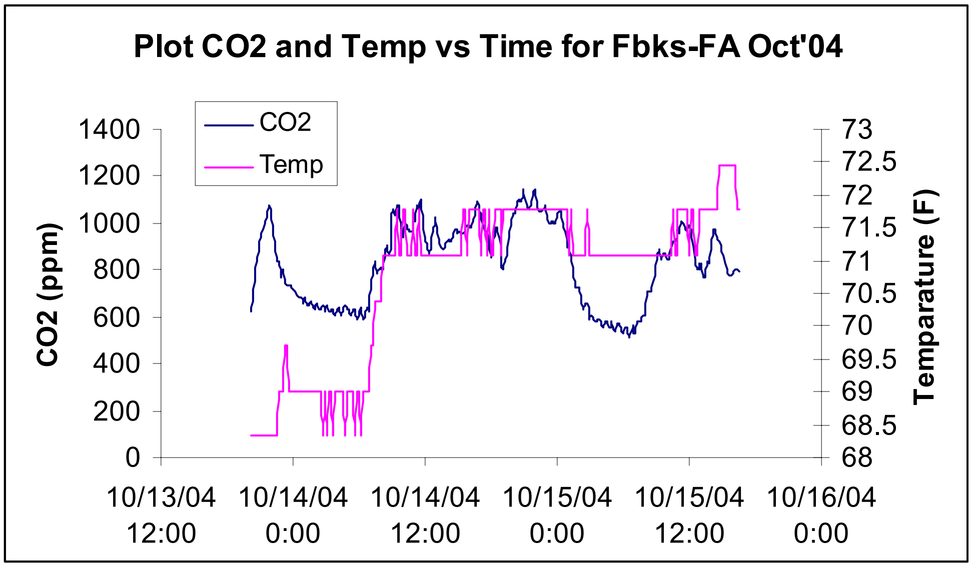


Figure 12: Met One Particulate levels at Fbks-stillv (Post)

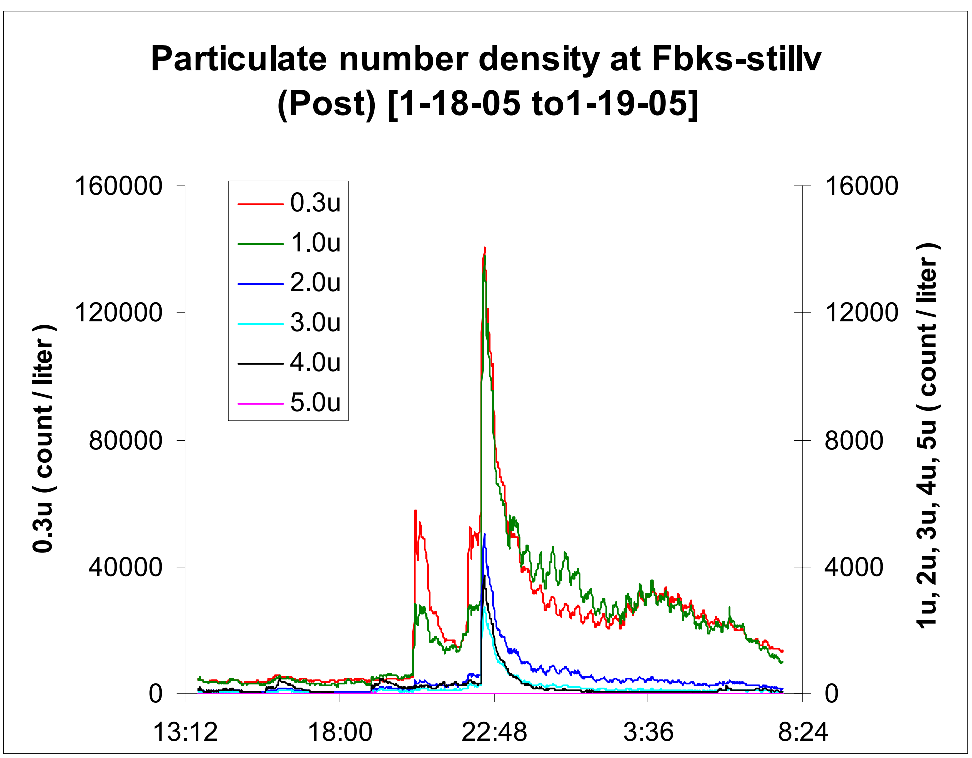


Figure 13: CO_2 and CO at Fbks-stillv (Post)

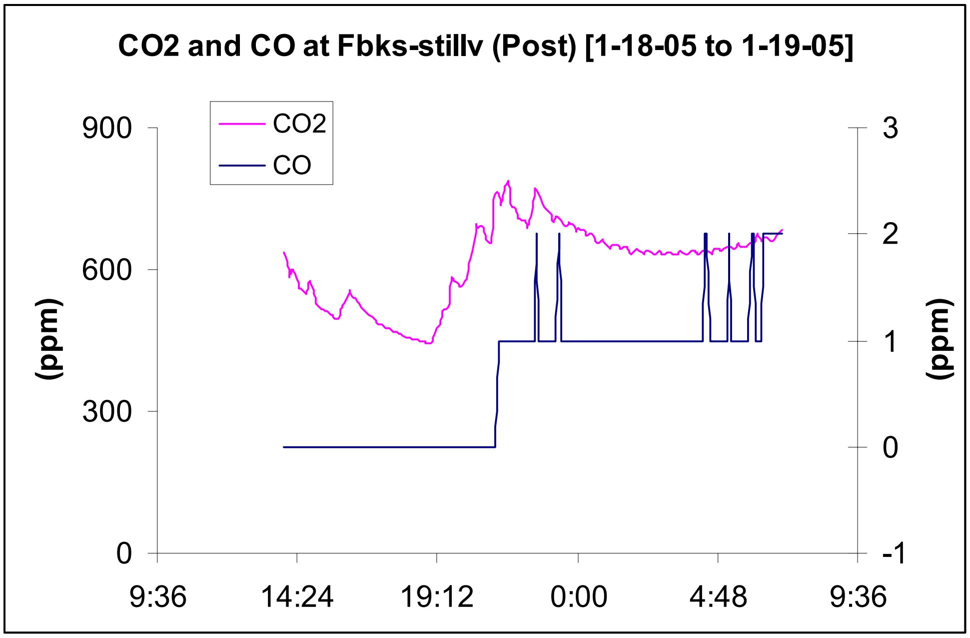


Figure 14: Indoor and Outdoor temperature at Fbks-stillv (Post)

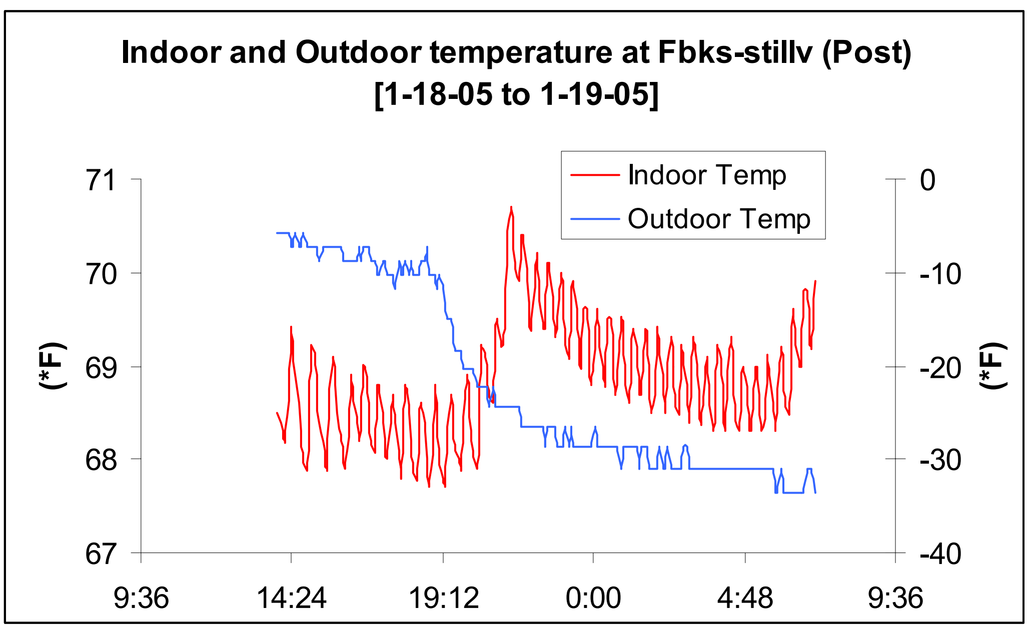


Figure 15: Fairbanks Control Homes Maximum 1 hr CO

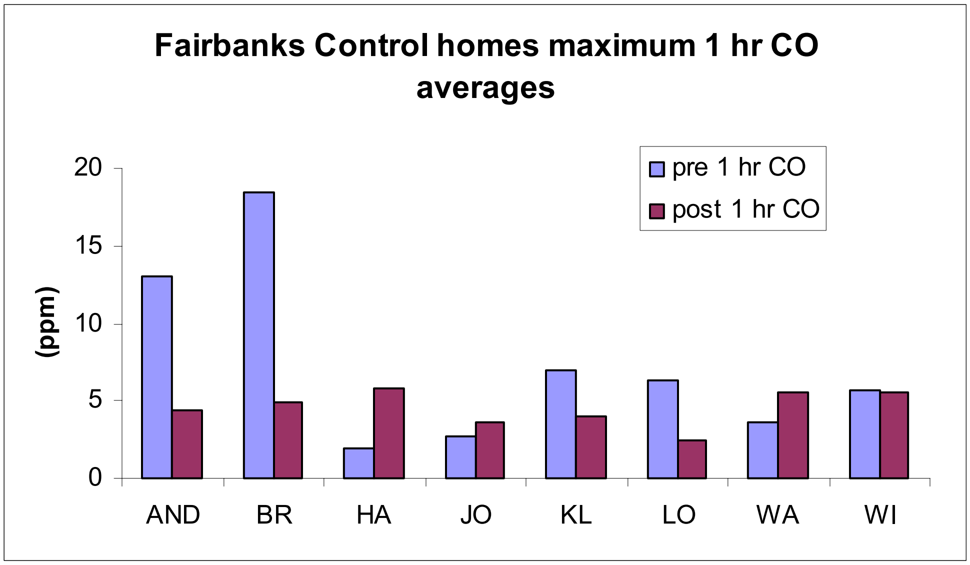


Figure 16: Fairbanks Control Homes Maximum 8 hr CO

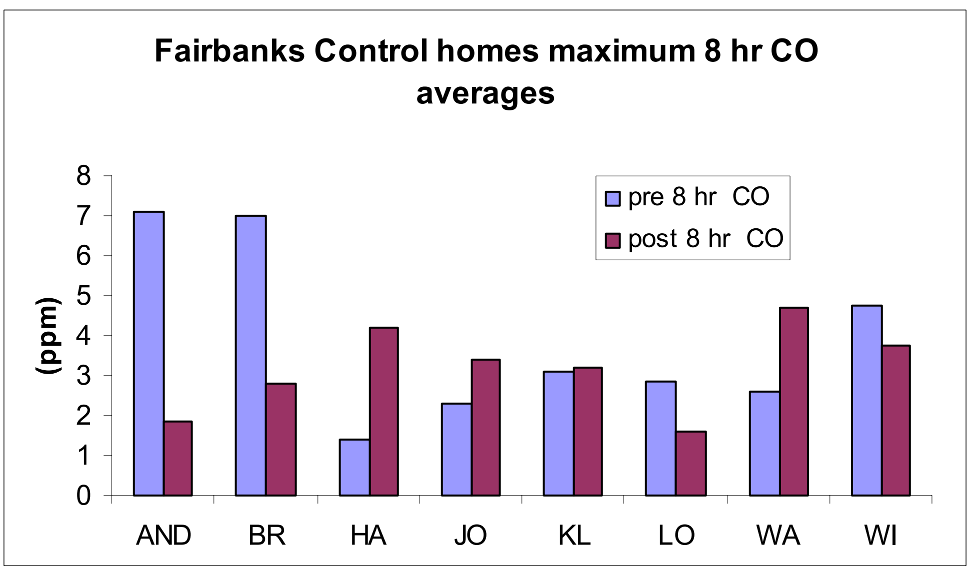


Figure 17: Total fungal spores/ cm^2 in Fairbanks tape samples (Pre)

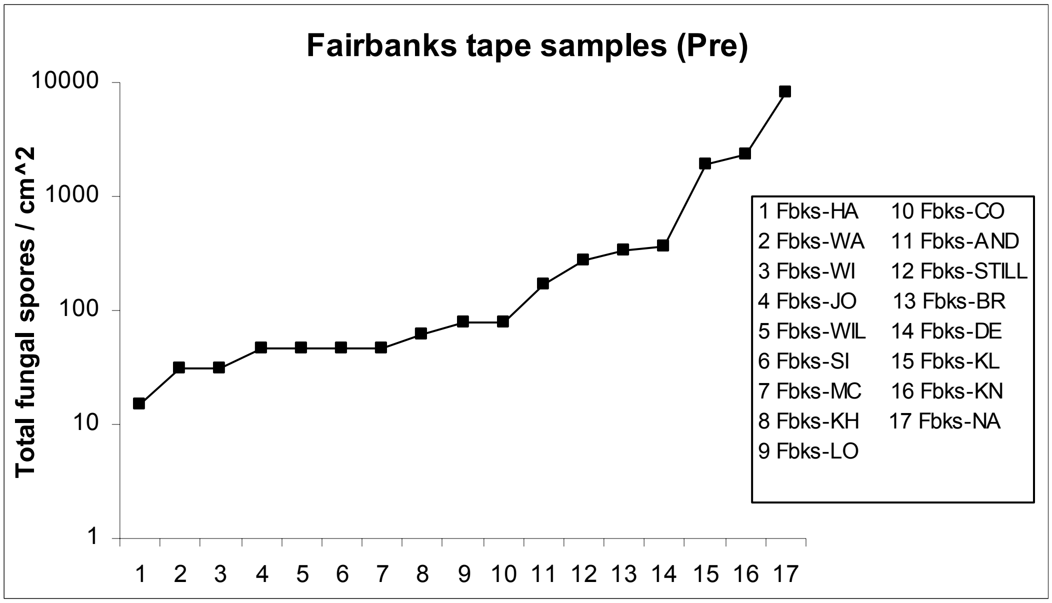


Figure 18: Total fungal spores/ cm^2 in Fairbanks tape samples (Post)

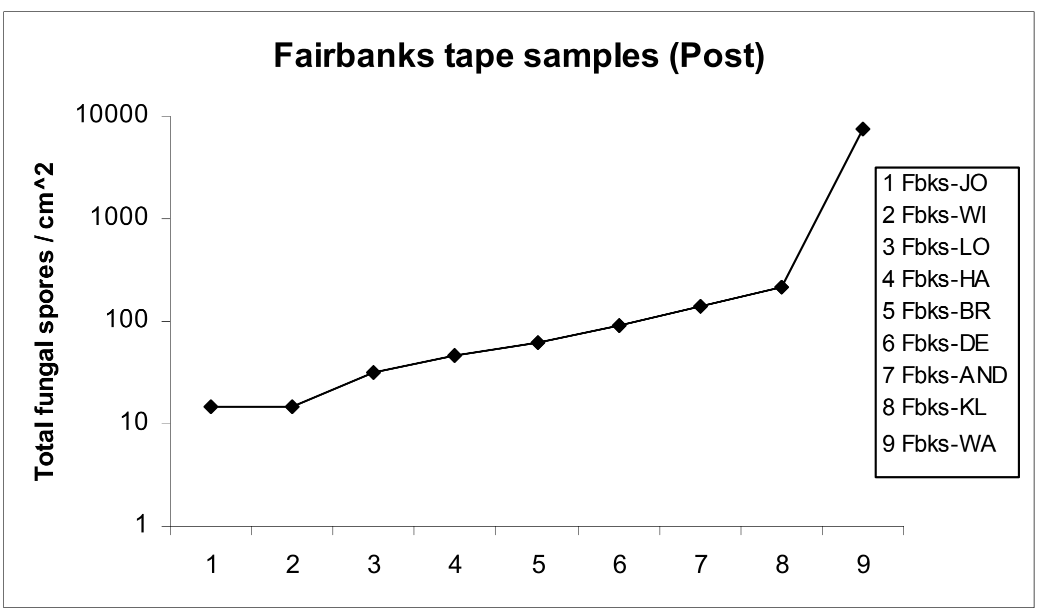
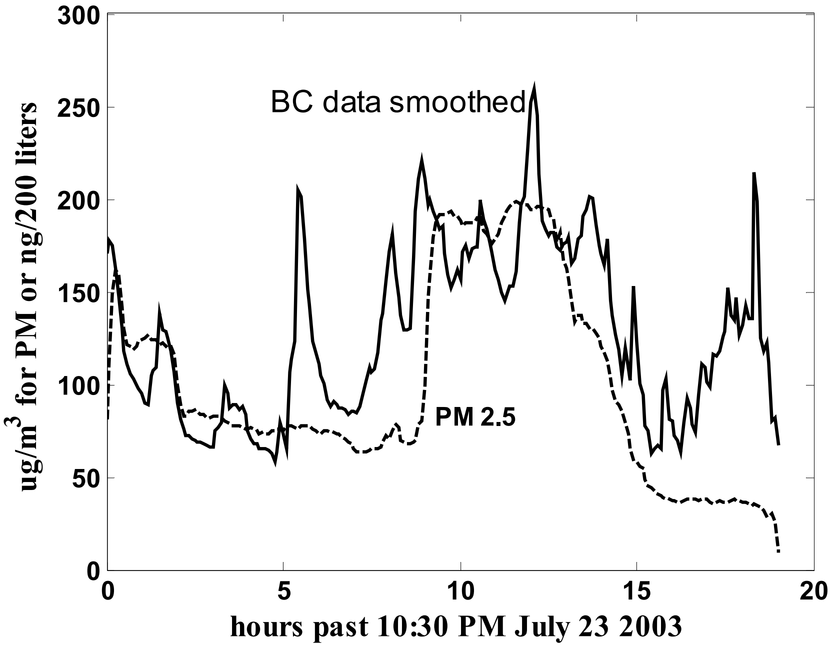


Figure 19: Plot illustrating variation of $PM_{2.5}$ and BC over a period of 20 hrs (Johnson et al 2005)



RESULTS& DISCUSSION
D-1. Remediation of Homes in Hooper Bay

Ralph Lee, (RurAL CAP Weatherization)

During the initial visits to houses selected to participate in the program, the visual inspection played a major role in determining the measures that should be addressed as part of the Healthy Homes Initiative. Improvements to the indoor air quality were the primary concern to try to mitigate circumstances that might have an effect on asthma and upper respiratory problems.

There was minimal evidence of visual mold and mildew in the houses, mainly because the walls and ceilings had plywood or laminate-covered paneling rather than sheetrock. There was evidence of moisture-related deterioration of the plywood and paneling, particularly along the bottom of the exterior walls where condensation collected. This was exasperated by household items stacked on the floor along the exterior walls. In most cases, the windows also had severe rotting, especially along the bottom sill from moisture collecting on the glass during cold weather.

Most of the houses were very small, considerably less than 1,000 square feet. All were quite crowded as well with seven to ten occupants. The houses had indoor temperatures in the low to mid 70s. Outside temperature during the evaluation was mainly in the 20s. Upon entering virtually every house, glasses would fog over. This indicated excess moisture inside.

Most families have small washing machines that they fill with hot water, heated on the cook stove. To dry the clothes, they hang them on lines suspended across the ceiling. They also usually keep a pot of soup or stew simmering on the stove as well as another pot for "hot water". None of the houses have plumbing, so the only way to get hot water is to heat water on the cook stove. Along with the moisture generated by the people, this was the reason for including clothes dryers and exhaust fan/pop-open Fresh 80 vents to mitigate as much moisture as possible.

Most every family had a lot of household items, clothes, etc "piled" on the floor, mainly along outside walls. This prevented air from circulating and created cold spots at the floor edge condensing moisture—and during typical winter cold weather, freezing as frost or ice. In a couple of instances clothes were frozen to the floor or wall. This was the reason to install shelving, coat hooks, closet rods to get the "stuff" off the floor and allow better air circulation.

Sleeping arrangements in these small houses usually consisted of mattresses spread on the floor and contributed to the lack of air circulation along the outside walls. We elected to put bunk beds into many houses to get the occupants off the floor, to help with air circulation and also keep occupants away from the dust, other possible contaminates, irritants, etc. that build up on the floors.

Some mattresses were also replaced because they were very deteriorated and dirty and were collectors for dust and other possible irritants. Same for the cloth fabric sofas that were replaced with leather covered sofas. These sofas would be deemed “totally unusable” by most people, but served as beds as well as for sitting.

A couple of the houses had plywood or paneling walls that were very rough with gouges and holes. This made them virtually impossible to keep clean and could trap contaminants. We installed FRP (plastic) panels on these walls to make a cleaner environment.

During a monitoring trip in December, 2003, the project was progressing quite well. The dryer additions look good provided a space big enough for both the dryer and the honey buckets (as well as some shelving). Installation of the clothes dryers seemed to have pretty well eliminated clothes hanging from the ceiling to dry—the only clothes hanging were coats and outerwear.

Crews were installing tile on the floors and shelving, coat hooks, closet rods, bunk beds, mattresses, sofas, etc. . The floor tile should really improve the ability of the homeowner to clean the floors than with the original plywood or damaged vinyl/tile. Families were encouraged to keep clothes and stuff off the floor as much as possible, especially near the outside walls to prevent cold spots and condensation around the perimeter. After the work was finished, the houses were a lot more organized than when we did the initial assessments.

Exhaust fans and pop-open vents (Fresh 80s) were installed (some during the Enhanced Weatherization). The need to use the fans was stressed, emphasizing it be turned on whenever the family is cooking/boiling food on the stove and when there is any indication of excess moisture, explaining that usually the first indication will be condensation on windows.

Client 4028 said that the work seemed to help her son’s asthma. “He just got over a cold and didn’t get any asthma. He almost always did before.”

Enhanced Weatherization was completed prior to the start of the Healthy Homes Initiative measures. EWX+ included repairs to the foundations as needed, upgraded windows and doors, additional insulation to floors, walls and ceiling/attics as necessary, air sealing to reduce air infiltration and some ventilation systems consisting of an exhaust fan and pop-open air vents (Fresh 80s).

During a Monitor trip in June, 2004 with Dale Darrow, we were able to get into nine of the 10 houses and talk with the occupants/owner. All seemed very pleased both with the quality of work and improvement in living conditions. Most every family indicated warmer houses and significant savings on stove oil the previous winter (primarily because of the weatherization measures). Many also felt that the indoor air was better, some saying that their child with asthma/respiratory problems improved significantly

One homeowner said that previously he had to keep the heater turned up to 78 degrees or more during the winter to stay warm and after the work could turn it down to mid 60s at night and still be comfortable. The family also had a noticeable improvement in moisture control. The 18 year old son with breathing problems seemed to be doing better with almost no asthma issues—he quit using an inhaler. Also, the youngest child used to have fevers but none since work completed last fall.

Two other families reported that their child's asthma improved. One said the 12 year old "hardly uses his inhaler." Another with a six year old son said that he seems to be recovering from his asthma.

Another homeowner said that five gallons of stove oil would last about 8 days when very cold outside—before it would only last about a day.

The houses for the most part were much more organized and cleaner than when initially checked at the start during the initial assessment and even during the pre-testing. Several of the families had reduced the amount of "stuff" inside—we encouraged them during the assessments, and particularly during the work stages—to get the "stuff that they don't need" out of the way (even providing the trailers for them to haul it to the dump).

In addition to getting rid of some things, the shelving, coat hooks, etc. helped in most cases to get clothes and other items off the floor. Installation of the flooring definitely made the houses look cleaner, although a couple of families didn't seem to do a lot of mopping.

For the most part, the bunk beds got children's mattresses off the floor and the exterior walls are more exposed so it should cut down on cold spots/condensation. (One family did say though, that the children usually pulled the mattresses off the bed at night to sleep on the floor because "it was too hot up on the bed.")

Dryers seemed to decrease the prevalence of clothes hanging from the ceiling to dry and a couple families said they used the dryers a lot and think it helps keep the moisture down. Most also said they used the exhaust fans / Swedish Fresh 80 vent regularly, some almost continuously. One said that they had water build up on the windows (small house, eight people) when cold outside. They said that turning on the fan seemed to help decrease the condensation.

RurAL CAP typically sends two to three permanent seasonal project and/or field supervisors to a village and hires temporary carpenters, helpers and laborers locally. The employees receive general worksite safety training and instruction on the use of hand, air and power tools; hazardous substances; use of ear protection, safety glasses/goggles, respirators; refueling vehicles; unloading materials from airplanes, barges, etc. Then, during the course of the project, they receive on-the-job training on proper installation of materials, tools, etc. One goal of RurAL CAP's weatherization program is to teach workers new techniques and skills to enhance future employment.

During the 2003 weatherization portion of the project RurAL CAP employed a total of 11 local employees, paid more than $43,000 in wages. This portion of the project started the end of July and finished in early October. Five of these workers received promotions during the summer.

Five of these local employees continued with the Healthy Homes project. This included Harvey Mann, carpenter; Joseph Lake, Victor Night and Douglas Lee, carpenter helpers; and Lester Green, laborer. The Healthy Homes portion started mid November and wrapped up by mid December. A total of more than $16,000 was paid in local labor.

Seven of the original 11 weatherization and four of the five HHI employees were rehired during 2004on the second phase of the weatherization program which included 31 homes. Victor was promoted to a carpenter position mid-way through the summer.

Hooper Bay is located in the Wade-Hampton Census District of Alaska. This area has one of the highest unemployment rates in the country, and is also recognized as an underserved region by most government funded programs. Other than a few jobs with the city, school, post office or clinic, most employment in the village is seasonal—typically construction or fishing related work that only lasts short periods during the summer months.

Conclusion:
The houses that participated in the Healthy Homes portion of the project were some of the smallest homes in the village and also had the most occupants (See attached chart). Houses in the HHI averaged 658 square feet floor area and 4,924 cubic feet volume. This compares to the control houses that had 1,000 square feet and almost 7,100 cubic feet. The small HHI houses averaged 7.8 people each ranging from seven to ten people. The control houses averaged 5.33 people each ranging from two to thirteen in the houses. These are all typical houses in remote rural Alaska—small with sometimes high occupant loads. 500 to 1,000 square feet with two to ten or more people, depending on family size

Comparing the blower door diagnostics of houses in the two portions, as would be expected, the smaller houses had less before work CFM of air leakage than the larger control houses, but actually had slightly higher average air changes per hour. Most of the HHI houses were below recommended ventilation rates based on the high occupant load even before work started. Almost all houses received reductions (some quite significant) in air leakage during the project. Every house received a 50-cfm low-sone fan as part of the project to help alleviate moisture and provide ventilation.

The families all indicated much more comfortable homes with improved indoor air. Moisture levels appeared to be less, even though the houses were typically tighter. The families were able to maintain adequate heat in the house and at the same time seeing a reduction in the amount of fuel needed.

Further research is needed to find an alternative approach to ventilation. Maybe develop / try different strategy for a minimal (no?) maintenance, minimal mechanical system that would be relatively inexpensive. When we returned to Hooper Bay in the spring we installed dehumidistat switches. The installation of humidistats to control the "run-time" for the exhaust fan should help alleviate relying on the homeowner to turn the exhaust fan on/off when required. The ventilation fan in conjunction with the clothes dryer to control a significant portion of the moisture that used to be release inside the houses seems to have improved the indoor air.

Chronology of Project:

December, 2002

The primary focus of activity was identifying the rural village that potentially has enough families meeting the criteria needed for the study—village had not received prior weatherization program (not allowed to reweatherize homes), families that meet the income guidelines, and families that have children with diagnosed asthmatic conditions.

In the preliminary proposal, we had targeted Noorvik, but found out through the regional health organization that there were very few identified cases of asthma. We tried to find another village in the Northwest region, but the best candidates had already received weatherization. Dr. Giordian began talking with medical contacts in the Yukon-Kuskokwim region of Western Alaska. There seemed to be a higher prevalence of asthmatic conditions in this area. We suggested Hooper Bay and Emmonak as the largest villages in the region that had not been previously weatherized.

Although we had not seen actual numbers of children diagnosed with asthma in Hooper Bay, it was felt that there will be enough families for the study.

March, 2003

The primary focus of activity was working with the village of Hooper Bay, getting a Resolution from the Council signed and doing initial outreach.

June, 2003

The primary focus of activity was to visit and assess the homes for weatherization and working on idea's to incorporate into the Healthy Homes portion. Phil Kaluza set up the monitoring equipment during April to test the houses.

December, 2003

Materials were ordered, shipped and installed in the ten houses participating in the Healthy Homes Initiative portion of the project in Hooper Bay, Alaska. During the late summer, prior to starting the Healthy Homes portion of the project, these houses received the Enhanced Weatherization Program to improve the energy efficiency, safety and durability.

The Healthy Homes project included small additions to four very small houses to accommodate clothes dryers to alleviate moisture created when clothes were hung inside the home to air dry. Other measures on the houses included, as appropriate: electric clothes dryer; replace cloth covered furniture (sofa, chairs) mattresses, bedding, etc.; install shelving, etc.; install new sub floor and vinyl tile; repair, upgrade electrical system as needed to accommodate breakers needed for the electric clothes dryers.

The first portion of the materials for building the dryer room additions, vinyl flooring, painting, etc. arrived in Hooper Bay in early November. The dryers, furniture, shelving, etc. arrived early December. All work was completed by about December 15, 2003.

March, 2004
The material tracking, freight, labor, etc. costs for each of the 10 houses involved in the Hooper Bay project was completed and submitted. We are awaiting results from the follow-up air quality testing and monitoring to see if any other measures may be needed. At a meeting in Fairbanks that included all of the partners in the project to discuss progress to date and plan for the indoor air quality "after work complete" testing with the initial group and "before work begins" testing for 10 homes that will only receive weatherization this coming summer. These ten homes will be the control group.

June, 2004
Completed most punch list items: Painted the dryer room addition exteriors. (Weather was below freezing when the additions were built last November.)

September, 2004
<u>Significant events:</u>
Installed humidistat switches to hopefully provide more continuous use of the ventilation fans. The humidistat turns the fan on when the humidity inside the house exceeds the recommended 50 percent level. (When Phil and Jack did the follow-up air testing in April '04, they found that the fans were not being used as much as we had hoped to control the humidity in the houses.)

Client 4008, Morgan Lake moved into one of the new housing units built by the Housing Authority this year. (His son had significant reduction in asthma/respiratory problems when we visited the house in June.) His brother's family moved into this house.

Client 4002, Patrick Hale: We visited this house with Mimi Burbage, AHFC Wx Program Manager, during a monitoring trip for Weatherization in September. Mrs. Hale said that everything was working fine. She added that the son, Patrick II now age 5, hasn't had to go to the clinic because of asthma/respiratory symptoms or use his inhaler since the work was completed last fall. He's much healthier.

We also looked as a couple of other houses. The shelving and wall hooks, installed during the project, are very well utilized. In each house the shelves were full. Also, the clothes lines that were still strung across the ceiling in the houses were mostly empty—none or very little clothing hanging to dry—the dryers were being used regularly.

Hooper Bay - Healthy Homes - Blower Door Testing

Healthy Homes Houses				Blower Door		Air Leakage		
Client	Floor Area	House Volumn	# of People	Before CFM50	After CFM50	ACH50 before	ACH50 after	ACH after natural
4001	560	3976	7	651	331	9.82	4.99	0.28
4002	768	6144	7	677	736	6.61	7.19	0.40
4003	960	7440	7	980	734	7.90	5.92	0.33
4004	732	5490	8	775	591	8.47	6.46	0.36
4005	400	3000	8	307	257	6.14	5.14	0.29
4006	560	4060	8	728	461	10.76	6.81	0.38
4007	384	2880	9	242	215	5.04	4.48	0.25
4008	1002	7264	7	1511	1363	12.48	11.26	0.63
4009	480	3720	7	532	360	8.58	5.81	0.32
4010	736	5269	10	1079	902	12.29	10.27	0.57
Average	**658.20**	**4924.30**	**7.80**	**748.20**	**595.00**	**8.81**	**6.83**	**0.38**

Control Houses				Blower Door		Air Leakage		
Client	Floor Area	House Volumn	# of People	Before CFM50	After CFM50	ACH50 before	ACH50 after	ACH natural
4045	1176	8682	6	1150	603	7.95	4.17	0.23
4048	1152	8444	5	665	487	4.73	3.46	0.19
4062	1128	7600	8	1209	833	9.54	6.58	0.37
4063	704	5210	2	902	532	10.39	6.13	0.34
4064	864	6333	3	837	641	7.93	6.07	0.34
4066	1728	11784	2	1250	701	6.36	3.57	0.20
4068	712	4913	5	828	487	10.11	5.95	0.33
4070	864	6333	4	917	614	8.69	5.82	0.32
4071	672	4590	13	986	651	12.89	8.51	0.47
Average	**1000.00**	**7098.78**	**5.33**	**971.56**	**616.56**	**8.73**	**5.58**	**0.31**

RESULTS & DISCUSSION
D-2 Remediation of Homes in Fairbanks

Jim Lee (Interior Weatherization, Inc.)

A total of 17 homes were involved in the program, 7 control homes that received typical weatherization work and 10 homes that were both weatherized and additional tasks completed to see if the activities improved the indoor air quality of the home. The goal of the program was to develop and implement low cost approaches to address common health concerns seen in single-family residential structures in interior Alaska.

The project was separated out into 4 different stages:

- *Client recruitment and education*
- *Assessment and scope of work*
- *Crew education*
- *Client responses and conclusions*

Each one of the stages is explained below. Overall, work included typical weatherization work and additional work dealing with moisture, ventilation, cleanable surfaces, and filtration. These areas were identified as a high priority due to the severe climate of the interior, the number of hours children spend inside homes and past experience with housing stock in Fairbanks. The client's final responses were very encouraging concerning the work completed, not one client said the children's health was worse and the vast majority said the health was better or much better.

CLIENT RECRUITMENT AND EDUCATION

Recruiting of qualified clients who met the income, medical and age requirements turned out more difficult than anticipated. Every effort was made to have 10 households that met the weatherization eligibility requirements and also a home with a child between the ages of 5 and 17 with diagnosed asthma or chronic upper respiratory illness. We met our requirements in 9 of the 10 projects (priority 1), the only project that did not comply with the above requirements was a household that qualified for weatherization and had a child age 2 with asthma (priority 2).

Each client (including the control homes) attended a 2 hour workshop concerning weatherization and moisture topics. The workshop covers:

- Health and safety

- Moisture, condensation and mold causes and prevention
- Air movement and blower door operations
- Home maintenance
- Energy upgrades that make sense

The workshop is presented at our office; educating the client in a classroom atmosphere instead of their home allows us to avoid competing with the normal distractions of day-to-day life (meals, kids and the television). Through the class, we supply the client with education materials which include:

- The class folder which covers
    - Condensation problems, causes and solutions
    - Energy saving tips
    - Carbon monoxide information
    - Home fire prevention and exit drill importance
- Gimme Shelter – published by Alaska Housing Finance Corporation dealing with Alaska specific housing problems
- Insulate and Weatherize like a Pro
- How to Save Energy coloring book
- "Do Your Part" be energy smart – weatherization information booklet
- Consumer Guide to Home Energy Savings
- Smoke alarm information and fire safety for disabled people
- Several University of Alaska Cooperative Extension fact sheets
- Help Yourself to a Healthy Home, Protect Your Children's Health

In addition to the above educational materials, the 10 healthy home clients received a copy of "Prescriptions for A Healthy House". The book is a practical guide for homeowners on causes and cures for a "sick" home.

In interior Alaska, one of the main sources of mold and rot in a home is cold surfaces condensating water. This is often seen at windows, doors, toilet tanks and basements. One way to prevent this condensation from occurring is to monitor relative humidity and control it from getting too high. Every client who attends the workshop receives a Hygro-Thermometer. The features include a dual display for relative humidity and temperature; and maximum and minimum memory. In the class we define relative humidity and how conditions for condensation depend on surface temperature and humidity levels. A copy of the workshop and educational material listed above are attached. The workshop has been very successful in educating clients on home maintenance and ways to provide a healthier home. Each attendee is asked to fill out an evaluation at the end of the workshop providing us with feed back on how to improve in the future. Comments are very positive, for example:

"I didn't know anything about cold weather housing, the workshop was very informative"

"The class was very educational on what weatherization does for the client. Thank you for being here to help make our life safer, warmer & happier"

"Important stuff – smoke alarm and carbon monoxide - was new to me, everybody at work wants me to tell them all the great tips learned."

Client education continues as the assessment is completed, work performed and inspection. The more repetitive the educational message is, the more the client remembers.

ASSESSMENT AND SCOPE OF WORK

The initial inspection included diagnostic testing and visual inspection. The inspection was guided by finding sources and pathways of pollutants that may trigger asthma. The homes varied in size from 700 square feet to over 3,000 square feet. 60% of the homes had attached garages and each garage could be accessed directly from the living space. 40% of the homes had basements, 30% crawlspaces and the remaining 30% were elevated off the ground by piers or blocking. General pollutant sources found in homes included: attached garages, moist crawlspaces, plumbing problems, pets, dirty carpets, cleaning chemicals, smokers, condensation related mold, and exposed fiberglass batts.

Pressure envelope and air tightness testing was key to determining if ventilation was needed or where and how much air sealing was required. 60% of the healthy home clients' blower door tests indicated that the home was under ventilated. Through past experience, we know that homes in interior Alaska that are underventilate have much higher rates of moisture and mold occurrences. In the case of the 10 healthy home clients, every home had visual mold present on inspection. Mold amounts varied from small amounts at windows and baseboards to crawlspaces fully covered in mold.

The sources of moisture allowing mold growth varied from ground moisture, poor drainage, broken plumbing, humidifiers, and under ventilation. For example, the owner in project F-01 created a gray water system for the washing machine. The system consisted of plastic flex pipe from the crawlspace to

the outside and released water approximately 3” outside the house (see picture). The water saturated the ground and worked its way back into the crawlspace.

70% of the homes had no working mechanical ventilation system installed or the installed fans were inoperative. In project F-12, she recently had a bath fan installed in the upstairs bathroom and the installer never vented the fan properly and the warm, moist air was being vented into the attic. None of the homes had a central ventilation system installed. 90% of the homes had condensation occurring at windows and/or doors during the winter months.

30% of the homes had humidifiers operating; when asked why they had humidifiers running, one client commented that the air was dry and the doctor recommended at least one humidifier per home. No home had any type of filtration system for particles or organic compounds.

Housekeeping of the homes varied from extremely tidy and clean to dirty dishes, trash overflowing and dirty clothes all over. 40% of the homes had pets that lived inside and had full range of any room in the house, including sleeping on the child’s bed.

Below is a table comparing the initial inspection for the 7 control homes and the 10 healthy homes.

	Control homes (total of 7)	Healthy Homes (total of 10)
Visual mold	14% (1)	100% (10)
Under ventilated per blower door targets	43% (3)	60% (6)
Indoor pets	43% (3)	40% (4)
Smokers live in home	14% (1)	50% (5)
Carpet in household	86% (6)	90% (9)
Working mechanical ventilation	71% (5)	30% (3)
Dryer ducted	71% (5)	20% (2)
Plumbing problems	0%	60% (6)

Furnace heating	71% (5)	50% (5)
Attached garage	14% (1)	60% (6)
Lead present	14% (1)	10% (1)
Condensation occurring on windows and/or doors	29% (2)	90% (9)
Humidifiers in use	0%	30% (3)

As seen above, the homes in the control homes compared to the healthy homes batch on initial inspection where clearly different in many aspects. The asthma homes showed higher occurances of mold, smokers, non existant or inoperable ventilation systems, unvented dryers, plumbing problems, attached garages, condensation occurring on windows and doors, and use of humidifiers.

In general, the scope of work addressed moisture and mold issues, ventilation and filtration, mitigation of indoor air quality pollution sources and installation of cleanable floor surfaces. Moisture and mold issues were addressed by installing ground vapor barriers, correcting drainage around the house, preventing condensation on pipes and toilets, repairing plumbing problems, and controlling relative humidity by installing ventilation systems.

Depending on the home and occupancy, ventilation was performed by spot ventilation (bath fans and/or rangehoods) and in some cases whole house heat recovery ventilators. 70% of the homes with asthma children in them had no form of mechanical ventilation working. Filtration was provided in 2 forms, first if a heat recovery ventilator was installed an added electro magnetic filter was installed to clean the outside air as it entered the home. Second, stand-alone hepa/charcoal filters where installed in bedrooms of the children. Indoor air quality pollutants came in different forms ranging from exposed fiberglass insulation to attached garages.

In the case of attached garages, we airsealed the separating wall and installed a fan in the garage to create a small negative pressure between the garage and house, thus any air flows would be in the direction of the house to the garage. In several of the homes, carpet was removed and replaced for hard surface flooring. The flooring of choice was sheet vinyl due to its wear ability, water resistance and ease of cleaning.

Each home was inspected for proper smoke alarms and carbon monoxide detectors.

CREW EDUCATION

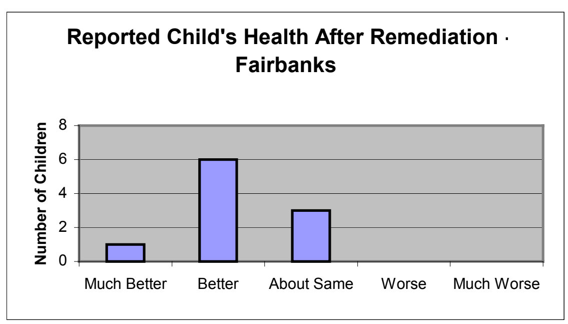
Work was completed utilizing local weatherization crews and specialized subcontractors (electrical, heating, etc…). Prior to starting work, weatherization crews attended trainings dealing with mold, ventilation, insulation and pressure diagnostics. Mold training included mold sampling, effects of mold on a person, mold growth environment and mold identification. Ventilation training included proper technique of installing bath fans and rangehoods, protocols on how to test actual airflow and proper sizing of equipment. Ventilation training also included installation and testing of heat recovery ventilators (HRV). In addition to the above training, Assessor's received specialized training in healthy home inspections, typical questions to ask clients, general sources and mitigation procedures for moisture and mold problems and how to educate clients in making small behavior changes to allow for a healthier home.

CLIENT RESPONSES AND CONCLUSIONS

At the completion of work each client filled out a questionnaire to provide feedback on housing improvements, occupant health and comfort. The responses are summarized in the questionnaire attachment. In general:

- 80% of the respondents stated their children's health was better than before the work was accomplished
- 90% stated less condensation on the windows
- 100% stated they were more comfortable in their home
- 50% were very satisfied with the program and 40% stated satisfied

Client satisfaction and noticeable changes in both health and comfort were significant. In addition to client responses, the crew commented that this was the best project they had participated in. The crew felt great satisfaction in knowning that they had made adjustments in people's housing that directly affected their health. The crew was very disappointed to find out that the healthy homes funds were not an annual grant.



Many lessons were learned from the healthy homes grants that could effect the way we provide the weatherization and HOME programs. These would include:

- By air sealing a home, pollutant and moisture problems could be made worse if not ventilated correctly.
- When there is an attached garage, you have to be concerned about air exchange with the house. Forced air furnaces should never heat both the garage and house.
- Filtration (hepa and charcoal) is effective in lowering particle amounts in air (as seen by forest fire smoke in summer of 2004)
- Every home needs working, mechanical ventilation
- Mechanical ventilation needs to be sized and installed correctly to be effective
- When installing mechanical ventilation, assessment of where make-up air comes from must be evaluated (attached garages, moldy – wet crawlspaces, etc…)

- Work crews are motivated to do a good job when they realize they are helping the client's health
- Moisture sources and pathways into the home should be assessed on all weatherization and HOME projects.
- Client and crew education are vital in the success of a project.

RESULTS & DISCUSSION
E. Individualized guide for homeowners
Ginny Moore (Alaska Building Science Network)

The guide *Help Your Family to a Healthy House* was produced as a spiral-bound booklet and distributed to all of the clients in this study. In addition, it has been made available to all of the weatherization agencies and housing authorities in Alaska. Due to its size it is not included directly in this document. It is provided as a separated document on this CD. The cover can be viewed in the Executive Summary.

RESULTS & DISCUSSION
F. Questionnaire on Client Satisfaction
Scott Waterman (Alaska Housing Finance Corporation)

The following questionnaire was given to clients after the work was done.

HEALTHY HOMES/WEATHERIZATION QUESTIONNAIRE Summary Of 19 homes

Please circle the answer that is closest to your feelings or understanding of the question. Add comments in the blank spaces if you can explain or have problems or concerns.

1. Is there more or less condensation on the windows since the work was done?

Much more	More	About the same	Less		Much less
		1	8	0	10

2. Is it easier or more difficult to clean your house since the repairs were done?

Much easier	Easier	About the same	More difficult	Much more difficult
2	10	7		

3. How has your children's health been after the work was done?

Much better	Better	About the same	Worse	Much worse
4	12	3		

Describe: Fewer Dr. Visits, Less use of inhale, No Inhaler, Less illness - Fewer Colds

2 5 2 3 0 3

4. Did the inspector tell you ways to help keep your home a healthy place?

Yes	No	No Answer	Can you recall any? _
10	6	3	

5. Do you know how to operate all the fan, ventilation, or heating systems installed?

Yes	No	No Answer	Any problems?
18	0	1	

6. Do you know how to maintain (clean, oil, change filters) everything that was installed?

Yes	No	no answer	Any concerns? ____________
15	1	3	

7. Do you know what the new round plastic vents in your wall are for and how to open and close them?

Yes	No	not applicable	no answer	Any concerns? __One home had the vents taped shut
7	0	10	2	

8. Do you run the bath or kitchen fan when you feel high moisture in your home, or when you are drying clothes, or when you see water or ice forming on windows?

Yes	No
13	6

9. Has the carbon monoxide alarm gone off in your home?

Yes	No	no answer
7	11	1

10. Have you kept your smoke alarms working? Yes No

Yes	No	no answer
12	7	

If not, why? Units missing or inoperative. Weatherization Contractor installed working detectors in each home prior to leaving project

11. Have you discussed fire safety with your children and practiced with them what to do if a fire starts?

Yes	No	no answer
8	5	6

12. If you have a gas cook stove, do you run your kitchen fan while cooking? Yes No

Yes	No	no answer
4	5	10

If not, why? Mostly electric stoves used in this project

__

13. Are you more comfortable in your home since this work was done? Yes No

Yes	No	no answer
18	0	1

Why or why not? Home stays warm when power went out

14. How do you feel overall about the Healthy Homes/Weatherization work in your home?

Very satisfied	Satisfied	Okay	Unsatisfied	Very unsatisfied		no answer
8	4	2	0	0	0	5

RESULTS & DISCUSSION
G. Health Outcomes

Mary Ellen Gordian (University of Alaska Anchorage)

I. Background

The Healthy Homes Project was designed to test whether improving the indoor environmental quality of homes for children with asthma might improve their health. Only children who lived in low-income homes were eligible, and the parent or guardian of the child was required to own the home so remediation of potential asthma triggers would be undertaken. Because few low-income families can afford to own their own homes, the number of eligible subjects was limited.

This is a report on the health findings. The project was disseminated among several groups, including the University of Alaska Fairbanks for in home environmental assessments, weatherization services in both Hooper Bay and Fairbanks, medical care providers Tim Foote of Tanana Valley Health care in Fairbanks and Yukon Kuskokwim Healthcare Corporation in Hooper Bay, and the University of Alaska Anchorage for data analysis.

The client children were seen by a medical doctor before and after remediation. They had a physical examination and laboratory tests. The laboratory tests included pulmonary function tests, skin prick tests for allergy (or RAST testing in Hooper Bay children), serum immunoglobulin E (IgE) level, and complete blood counts. Parents also provided a medical history on their child, with an emphasis on respiratory health. The physical exam, lab tests, and medical history questions were selected to allow a determination of the severity of he children's asthma.

A total of sixteen children were examined—for a variety of circumstantial, logistic and cultural reasons only three in Hooper Bay and thirteen in Fairbanks. The children's ages ranged from 2 to 15 years, with five females and eleven males. Four of the children were Alaska Native/American Indian, two were Asian, and nine were white. No race was indicated for one child.

Fourteen children had a diagnosis of asthma, one had encephalopathy, and another had no diagnosis (the medical history form was not available).

The three children from Hooper Bay were flown to Bethel for the examination. They were all under five years of age (outside of the priority-1 range of 5-17). The children were too young to have pulmonary function tests done, and examinations were unremarkable except for the severe encephalopathy in one child, which was not related to asthma. One child had elevated IgE. No follow-up examinations were done in Hooper Bay because there was nothing to learn. Ten children from Fairbanks were seen in follow-up.

II. Medical Examinations

A. Pulmonary Function Tests

Ten children from Fairbanks had pulmonary function tests done, and all had normal forced vital capacity (FVC) ranging from 70% to 127% of predicted value for their age. Two children had a forced expiratory volume in one second (FEV1) that was below 70% of predicted value. Less than 70% of predicted value is considered abnormal. Forced expiratory flow between the 25th to 75th percentile of FVC (FEF_{25-75}), which is thought to be an indicator of small airway function, was reduced in four children. In total, six of the ten children tested (60%) had one or more of the parameters of pulmonary function testing in the abnormal range.

B. Indications of Allergy IgE and Skin Prick Test

Twelve children were tested by skin prick for allergies. Three of these had no allergies to any of the antigens tested. The other ten were skin test positive to more than one allergen. Hooper Bay children did not receive skin prick tests, but RAST testing for common allergens was done for two children. One of the Hooper Bay children had elevated specific IgE to four allergens, and the other child had no evidence of allergy.

Initial IgE levels were done on nine children in Fairbanks and two in Hooper Bay. Ten of the children had follow-up examination including IgE levels. This included three children who did not have an initial IgE level. Four of these, or 31%, had elevated (>300 units) levels, one as high as 1600 units. Because IgE was done in different laboratories, the normal range for each age is not given; however, >300 is unequivocal elevation in any laboratory.

IgE level was a strong predictor of allergy. Four children had IgE levels below 100 units. Three of these children also had skin prick test which showed no reaction to common allergens. One had mild (1+) reaction to alder and birch, but to no other allergens. All children who had strong reactions to skin prick tests also had elevated IgE.

C. Interval between Examinations

The average time between the first examination and the follow-up examination was a little more than a year. The range was from 90 days to 4 years. The mean age of the children was nine years, with a range of 3 to 15 years.

D. Initial Medical History

Twelve children had a diagnosis of asthma, one had a diagnosis of allergies, one had a diagnosis of encephalopathy, and one had no medical history form filled out. Ten children had had previous hospitalizations of which nine (56%) were for respiratory problems. Six of the children had missed more than 5 days of school in the current semester due to coughing illness. Ten children had a daily cough, eleven had coughing with exercise, twelve had a cough during the night, and ten had had five or more respiratory illnesses in the last year.

All of the children used albuterol inhalers, ten were on inhaled steroids, and six had had a course of oral prednisone which is used for intractable asthma. Thirteen children were taking daily medications, but only one of these listed an inhaled steroid as their daily medication; three listed albuterol. On the initial examination, eleven children reported using an inhaler daily in the last three months. Nine reported having episodes of wheezing, coughing, and/or shortness of breath more frequently than twice a week in the last three months. Six children were awakened with coughing almost nightly in the last three months, and an additional two had this symptom more than twice a week. Six children had been taken to the Emergency Room in the last three months, three of them on more than one occasion.

None of the children smoked or chewed tobacco, and none of them lived in homes where smoking was allowed indoors, although four had a smoking parent. Seven children lived in homes with wood burning stoves. Eight children had furred or feathered pets living in the home.

III. Follow-up examinations

Ten children in Fairbanks were seen for follow-up. Of these ten, four had been hospitalized for respiratory problems since their previous visit. It is unknown whether these hospitalizations occurred before, during, or after the home remediation.
Three children reported a daily cough, three reported post-exercise cough, and four reported coughing at night. All but two used albuterol inhalers regularly, five used inhaled steroids regularly, and four had been on oral prednisone, including two who were not on inhaled steroids. Three reported using an inhaler daily, two reported using it intermittently, and four reported not using an inhaler at all. None reported taking oral medication regularly. Seven reported having attacks of coughing, wheezing, and/ or breathlessness more than twice a week, including two who said they never used inhalers. Only three children reported frequent night symptoms in the last three months, and all three of these used inhalers daily. In the last three months, two of the ten had been taken to the emergency room once, and two more said that it was needed but they did not go to the emergency room.

A. Physical Examinations

Physical examinations were unremarkable for both the initial examination and the follow-up. Two children had wheezes on initial examination, and only one of them was seen in follow-up when no wheezes were heard. There were no abnormal findings on physical examination in the follow-up examinations. Only seven children had both initial and follow-up examinations that included anthropomorphic information and vital signs. The average height increased by 1.3 inches, the average weight increased by 14.3 pounds, the average heart rate went down by 13.7 beats per minute, and the average respiratory rate went down by 1.7 breathes per minute. Blood pressure data was only available for four children. The average systolic pressure decreased by 7 points, and diastolic pressure decreased by 3 points. These changes in vital signs can be explained by increased familiarity with the procedures and the medical office rather than improvements in the home environment.

B. House Pollutant measurements

Control houses were significantly different from participants' houses in Fairbanks. In control houses, carbon dioxide levels were 20% lower, carbon monoxide levels were 25% lower, and benzene levels were 70% lower. Average mycelia counts were an order of magnitude lower in control homes than participants' houses; however, one home had exceedingly high levels which accounted for the large difference. Nevertheless, both average mycelia and spore counts from the tape lifts were 4 times lower in control houses compared to participant houses even after removing counts that exceeded about 4 standard deviations from the average. It is not clear whether control homes were being occupied at the time that the measurements were done. If they were indeed occupied homes with similar familial groupings, then there may be good evidence that the homes of asthmatic children are higher in indoor air pollutants.

	Average Pre-remediation Values				Average Post-remediation Values			
	CO_2	CO	benzene	toluene	CO_2	CO	benzene	toluene
Control Homes	816	1.5	2.9	13	964	1	9.1*	30.2
Participant homes	1070	2	10.2	49.7	911	1.3	8.8	37

*this value includes one home with 31 ppb benzene

Because particulate measurements were done as grab samples over less than 30 minutes indoors with particle counters, these measurements would be unusable for health effects research. Benzene and toluene were measured with passive badges exposed over one week time indoors to get an average value for each house.

IV. Pre and Post Evaluations

Post evaluations showed a non-significant reduction in benzene in participants' houses, and a non-significant increase in toluene. There was no correlation between indoor benzene and toluene, indicating that they are probably coming from different sources. Pre and post- benzene levels for the same house were significantly correlated. Although the Pearson's correlation coefficient was always negative for every respiratory indicator, there were no statistically significant correlations of any physical parameter with indoor benzene or toluene levels.

There was improvement of all health related laboratory parameters from pre remediation to post remediation, but none reached statistical significance.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	initial IgE	215.00	7	172.556	65.220
	follow-up IgE	172.71	7	134.888	50.983
Pair 2	initial FVC%predicted	103.83	6	8.886	3.628
	follow-up FVC%predicted	111.17	6	11.197	4.571
Pair 3	initial FEV1%predicted	90.33	6	14.208	5.800
	follow-up FEV1%predicted	96.33	6	15.756	6.433
Pair 4	initial FEF% predicted	75.67	6	29.811	12.170
	follow-up FEF% predicted	77.83	6	25.349	10.349

Paired T-test

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
initial IgE - follow-up IgE	42.29	54.04	20.42	-7.69	92.26	2.07	6.00	0.08
initial FVC%predicted - follow-up FVC%predicted	-7.33	7.84	3.20	-15.56	0.89	-2.29	5.00	0.07
initial FEV1%predicted - follow-up FEV1%predicted	-6.00	6.32	2.58	-12.64	0.64	-2.32	5.00	0.07
initial FEF% predicted - follow-up FEF% predicted	-2.17	15.52	6.34	-18.46	14.12	-0.34	5.00	0.75

V. Discussion/Conclusion

The results of this study are inconclusive due to the small number of research subjects and the multifactorial nature of asthma. However, there are some interesting suggestive results.

- It is possible that the homes of children with asthma have higher levels of indoor air pollution than the homes of similar people without asthma.
- The remediation may have helped to improve the pulmonary function tests and the IgE levels of asthmatic children, although the numbers were not sufficient to reach statistical significance.

CONCLUSIONS and RECOMMENDATIONS

Conclusions

The Healthy Homes in Alaska project was a complex, difficult, and important study. It asked the two-part question: "Can we improve indoor air quality by augmenting the standard weatherization protocol and can that improved IAQ lead to better health for children with asthma who live in the homes that are remediated?" While there are many factors involved in both questions and the study was limited by funding to a small number of test cases and control houses, we can give a qualified "Yes" as the answer to both parts of the question. To understand the scope of the work done and the range of conclusions reached in each phase of this project it is necessary to read the details in each of the main sections of this report. However, there are some consistent threads that run through each sub-report.

The overall picture that emerges is that the houses in which the asthmatic children are living have generally worse IAQ than that found in the control houses where there were no asthmatic children present. The augmented protocol in the client houses and the standard protocol in the control houses resulted in homes with similar post-remediation IAQ. That is, the augmented protocol appears to have improved houses with much worse IAQ to an IAQ comparable to that reached in the control houses using the standard weatherization protocol.

The situation in Hooper Bay is different from that in Fairbanks. In Hooper Bay the main problem appears to have been a high moisture load driven by high occupancy and inadequate ventilation. The amount of mold seems to have been limited by the building materials. The strongest correlation in the IAQ data is a reduction in RH. Both the occupants and the workers commented on the improvement in the moisture conditions in the homes. Many of the remediation items were focused on improving the ventilation and removing moisture sources from the client homes.

In Fairbanks, while there were similar moisture problems, there also appear to have been issues related to attached garages and improperly installed furnaces. The strongest correlation in the IAQ data is a reduction in benzene and toluene; these are often related to pollution from an attached garage. Again, while many of the remediation items were focused on improving the ventilation and removing moisture sources from the client homes they also focused on reducing pollution from the garage and furnaces and on filtering the indoor air.

There remain many questions as to the efficacy of each step of the remediation protocol developed for each house. The sample sizes are small and most of the correlations do not rise to the level of statistical significance. Nevertheless, it does appear from the IAQ data, the medical data, the observations of the weatherization workers, and those of the parents that the IAQ in the client homes and the health of the children both improved after the Healthy Homes remediation work was done.

Recommendations
Programmatic lessons learned and recommendations are as follows:

1. It is feasible to augment the standard weatherization protocol using the Healthy Homes strategies to improve occupant health by improving indoor air quality.
2. An important part of the protocol is training the workers and subcontractors in not only the techniques of the program, but also the goals for improving health. This seems to by an important motivator to do good work.
3. Also important is training the homeowner in the both the operational details of the equipment installed and the building science reasons for using the equipment properly.
4. For rural Alaska, especially, there is a need for a simple mechanical ventilation system that needs little maintenance or operator attention and is inexpensive to operate.

Building science lessons learned and recommendations are as follows:

1. By air sealing a home, pollutant and moisture problems could be made worse if not ventilated correctly.
2. When there is an attached garage, you have to be concerned about air exchange with the house. Forced air furnaces should never heat both the garage and house.
3. Filtration (HEPA and charcoal) is effective in lowering particle amounts in air (as was demonstrated by CCHRC during the forest fire smoke in summer of 2004)
4. Every home needs working, mechanical ventilation (as is now required by ASHRAE 62.2).
5. Mechanical ventilation needs to be sized, installed, and balanced correctly to be effective.
6. When installing mechanical ventilation, assessment of where supply air comes from must be done (attached garages, moldy – wet crawlspaces, etc…).
7. Moisture sources and pathways into the home should be assessed on all projects.
8. The design of interior systems such as wall surfaces, shelving, closets, and bed frames can be important to the ability to maintain a mold free environment.