# HUD 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

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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.

work to be done and its relation to the energy-conservation, safety, and health goals of the project.

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**

<u>IAQ testing (Ron Johnson, et al, University of Alaska Fairbanks)</u>

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.

<u>Remediation Work at Hooper Bay (Ralph Lee, RurAL CAP)</u>

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.

<u>Remediation Work in Fairbanks (Jim Lee, Interior Weatherization, Inc.)</u>
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

[3] Reynolds W, C Cahill, and J Connor; *Remediation of Smoke Particles in Fairbanks Homes, June-August 2004*; unpublished CCHRC report, Oct. 2005

- 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.

Medical Testing (Mary Ellen Gordian, University of Alaska Anchorage)
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 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

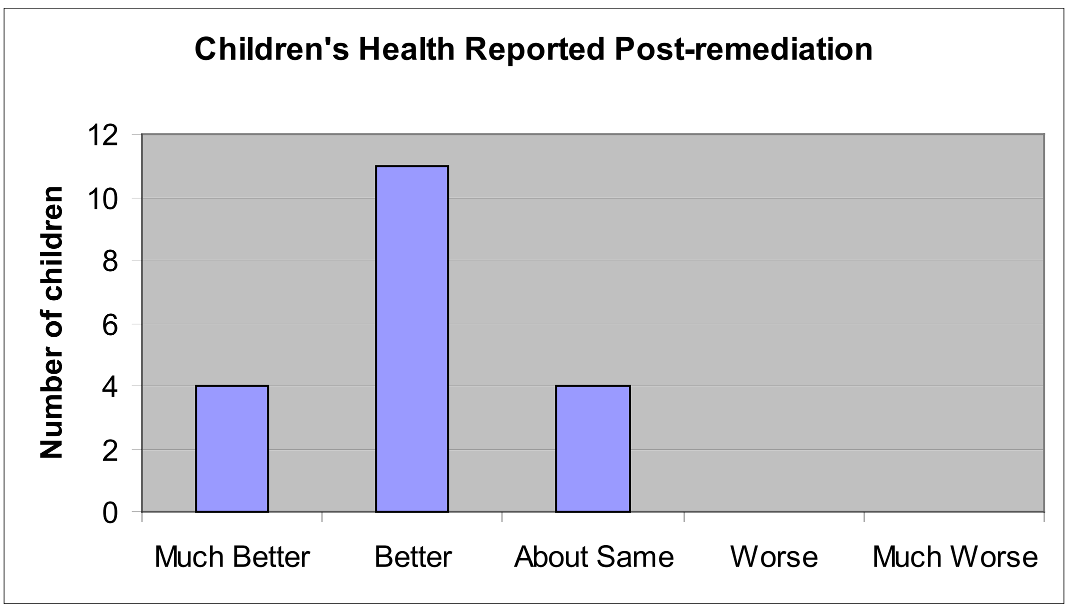
| | Paired Differences | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t | df | Sig. (2-tailed) |

| | | | | 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.

<u>Satisfaction Questionnaire (Scott Waterman, Alaska Housing Finance Corporation)</u>
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.

<u>Homeowner Guide (Ginny Moore, Alaska Building Science Network)</u>
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.