EFFECTS OF HOUSE WEATHERIZATION ON INDOOR AIR QUALITY

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Abstract

Forty Pacific Northwest existing homes were weatherized, including standard infiltration-reducing techniques, while before and after measurements of ventilation rates and indoor radon, formaldehyde, water vapor, nitrogen dioxide, carbon monoxide, and respirable suspended particle concentrations were conducted. Eight weatherized control homes were also monitored. Only radon and formaldehyde levels were elevated in some homes and were the result of high source-potential soils or interior finish materials. Standard weatherization practices resulted in a reduction of 15% in the specific leakage area from an initial average value of 5.9 cm^2/m^2. Indoor pollutant levels were only modestly affected and in some instances, radon concentrations were actually reduced due to the additional crawlspace ventilation installed as part of the weatherization process.

Introduction

In the public mind, indoor air quality problems have frequently been linked to energy conservation activities. Plausibility arguments support the contention that reducing ventilation in buildings, an important component of most conservation activities, causes a degradation of indoor air quality. However, little experimental evidence supports the plausibility arguments. Studies in North America of the effects of weatherization on indoor air quality have been reported by Berk et al., Offermann et al., Nagda et al., and Quackenboss et al.(1-4).

The Bonneville Power Administration(BPA) was instructed in the Northwest Power Planning Act of 1981 to seek new energy supply from conservation before constructing additional power plants. One major conservation activity that was begun was a weatherization program in residences in the four-state area served by BPA: western Montana, Idaho, Washington, and Oregon. The study reported here investigated changes in indoor air quality that resulted from these weatherization activities.

The study had three primary objectives:

1) Survey the indoor pollutant concentrations in unweatherized Pacific Northwest housing.
2) Measure the effect of standard weatherization on house tightness and ventilation rates.
3) Relate changes in indoor pollutant levels to changes in house tightness caused by weatherization.

Study Design

Screening survey

Study sample. One hundred sixteen (116) single family electrically heated houses were selected from utility weatherization logs. The houses were clustered in two regions having substantially different climates. The first was the Vancouver, WA area that has a mild, humid coastal climate; the second from the Spokane, WA -- Coeur D'Alene, ID area having a more severe climate characteristic of the great basin high plateau areas of the United States. Of 116 houses contacted, 68 were monitored in the Vancouver area, 43 in the Spokane area, and 5 chose not to participate.

Measurement protocol. After initial contact and acceptance, samplers for four different pollutants: radon, formaldehyde, water vapor, and nitrogen dioxide were mailed to participants with instructions for installation and retrieval. This was followed quickly by a telephone call to answer any questions the participants would have placing the samplers and a second call reminding the participants to collect the samplers and return them to the laboratory for analysis. Passive samplers for NO_2, HCHO, and H_2O were deployed at one location in the occupied space of the house for seven days. Radon samplers were deployed for a longer period of time (20 to 40 days). The participants answered a short questionnaire describing their house; this was supplemented by information provided by the utilities who had originally recommended these houses.

Sixteen houses in the Spokane area were monitored using continuous radon monitors only. This area had been identified in early results from the screening survey as a region of Washington containing high radon concentrations. The results of all the screening tests were used to select a subset for weatherization and intensive monitoring.

Weatherization and intensive monitoring

Study sample. Houses were chosen for the weatherization activities based upon representative construction characteristics and the presence of measurable pollutant concentrations. The values used for selection were of one of the following conditions: HCHO > 50 ppb, or radon > 400 Bq/m^3,or NO_2 > 10 ppb. The housing samples were divided between Vancouver and the Spokane - D'Alene areas; 20 houses were selected from each area. In addition, three control houses in the Vancouver area and five in the Spokane area were monitored without receiving weatherization.

Pollutants monitored. Many more measurements were made in the weatherization homes than were made in the screening samples. Indoor radon concentrations, indoor and outdoor temperatures, and wind speed and direction were monitored continuously. Time-averaged samples of respirable suspended particles and carbon monoxide were collected over a seven to ten day sampling period. Passive samplers were used to measure formaldehyde, nitrogen dioxide, and water vapor concentrations at three locations indoors and outdoors. The continuous injection, passive collection system using perfluorocarbon tracer gases was used to measure ventilation rates. Building tightness was measured using depressurization with a blower door.

Measurement protocol. Ten-day measurements of all pollutants were made before and after staged weatherization. Three different stages of weatherization were investigated. These included standard weatherization, i.e., weatherstripping, caulking, and adding storm windows and doors (applied to all test houses); wall insulation (applied to 14 houses); and intensive weatherization called "house doctoring" (applied to five houses). Thus all houses were monitored twice, some three times, and a few, four times during this study. Control houses were monitored monthly in the Vancouver area. In the Spokane area the control houses were monitored on a more irregular basis.

Measurement Results

Control house and ventilation corrections. Concentrations in control houses were monitored during the weatherization experiments to determine the effects of non-weatherization factors on pollutant concentrations in the sample houses. Changes in concentrations of formaldehyde, water vapor, and radon in the control houses are plotted as a function of time in Figure 1. The values plotted are normalized to the concentrations measured in December. Over the course of the measurement period factors other than weatherization cause changes in the ventilation rates. The fourth curve of Figure 1 shows changes in ventilation rates of the control houses over time normalized to values measured during December. Two effects are shown. The first is the change in

the specific leakage area of the houses due to changes in building structure (the solid line) while the second is the change in predicted ventilation rates in the houses due to changes in leakage area and local environmental conditions (the dashed line).

Screening house results

Table 1 shows the values of formaldehyde, nitrogen dioxide, water vapor, and radon concentrations from the screening house sample.

Table 1

Screening Test Results

Pollutant	Radon Bq/m^3	HCHO ppb	H_2O g/kg	NO_2 ppb
Number of Samples	111	95	95	95
Geometric Mean (GSD)	85 (3.4)	36 (1.7)	5.6 (1.5)	5.1 (1.9)
Arithmetic Mean (ASD)	230 (600)	41 (20)	6.2 (4.3)	6.3 (4.3)

Weatherization results

Table 2 gives the change in building tightness associated with the weatherization process. The measured results are expressed in terms of the specific leakage area having units of cm^2/m^2. This is the leakage area in cm^2 evaluated at a pressure of 4 Pa normalized by the floor area of the structure measured in square meters.

Table 2

Effect of Weatherization on Building Tightness

Treatment	Number of Houses	Before Mean(SD) cm^2/m^2	After Mean(SD) cm^2/m^2	% change
Wall Insulation	14	7.4(5.4)	6.8(4.2)	8
Weatherization	40	5.9(3.8)	5.0(2.8)	15
House Doctor	5	8.8(6.5)	4.4(3.9)	50

The change in specific leakage area due to the addition of wall insulation is not statistically significant at the 20% level. On the other hand, both of the other weatherization treatments produce changes that are significant at the 10% level.

Figure 2 displays the pollutant concentrations and calculated ventilation in pre- and post-weatherization conditions for the 40 houses that received the standard weatherization treatment. The changes shown are changes in raw data only. No corrections have been applied for control house pollutant measurements or ventilation changes in control houses due to environmental effects.

Intensive weatherization results

Figure 3 displays the changes in pollutant concentrations that accompanied the intensive weatherization called house doctoring. Substantial changes (50%) in building

tightness and predicted ventilation occurred. Increases in concentrations of 58% were seen in formaldehyde concentrations and 29% in water vapor concentrations. Radon reductions are likely a result of 1) sealing the floor penetrations to the substructure, and 2) the effects of seasonal changes diminishing radon entry, as in the control homes. The error bars shown on the figure are standard deviations of the mean of each distribution.

Discussion and Summary

Screening survey results showed pollutant concentrations below commonly recognized guidelines. Radon, on the other hand, is a pollutant of concern in many of these houses. Subsequent work that we have done has shown that houses in the Spokane river valley of eastern Washington are subjected to a large source of radon in the soil of the region.

Building leakage areas were reduced 15% by the standard weatherization and, more dramatically, by 50% using house doctoring techniques. Reductions in house tightness due to wall insulation were not statistically significant in this sample.

On average standard weatherization and house tightening appear to have minimal impact on concentrations of indoor pollutants. The weatherization produces small changes in building tightness and calculated ventilation.

One expects to see modest changes in pollutant concentrations if standard weatherization produces a change in building tightness of 15%. House doctoring, on the other hand, produced a change of 50%. Therefore the changes in pollutant concentrations are expected to be substantial. Results from the house doctor measurements showed that this was true.

Acknowledgments

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References

1. Berk, J.V., Young, R.A., Brown, S.R., Hollowell, C.D. Impact of energy-conserving retrofits on indoor air quality in residential housing, Lawrence Berkeley Laboratory Report # LBL-12189.

2. Nagda, N.L., Koontz, M.D., Rector, H.E. Energy use, infiltration, and indoor air quality in tight, well-insulated residences, Final report EA/EM-4117 on Research Project 2034-1 to the Electric Power Research Institute, Palo Alto, CA. 1985.

3. Offermann, F.J., Girman, J.R., Hollowell, C.D. Midway house-tightening project: a study of indoor air quality, Lawrence Berkeley Laboratory Report LBL-12777, Berkeley, CA. 1981.

4. Quackenboss, J.J., Kaarakka, P., Duffy, C.P., Roher, K.M., Kanarek, M.S., Flickinger, J. Energy conservation through weatherization and indoor air quality, Final Report to Wisconsin Power and Light Co., 1985.

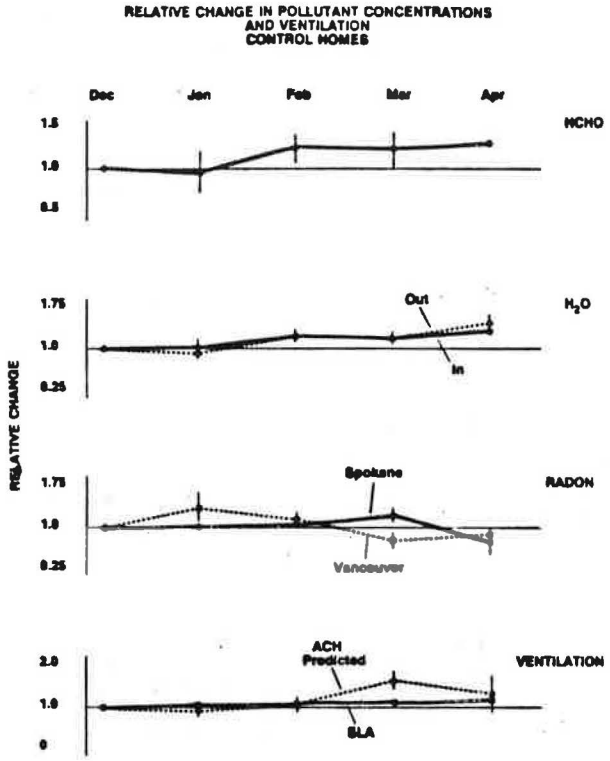

Figure 1

Changes in concentrations of formaldehyde, water vapor, and radon in the control houses as a function of time. The values plotted are normalized to the concentrations measured in December. The fourth curve shows changes in ventilation rates of the control houses over time normalized to values measured during December. Two effects are shown. The first is the change in the specific leakage area of the houses due to changes in building structure (the solid line) while the second is the change in predicted ventilation rates in the houses due to changes in leakage area and local environmental conditions (the dashed line).

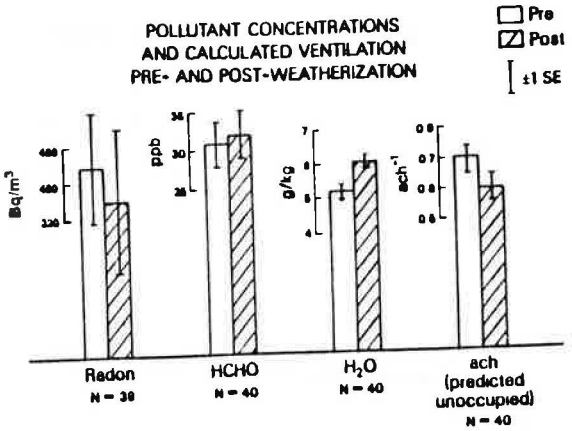

Figure 2

Pollutant concentrations and calculated ventilation in pre- and post-weatherization conditions for the 40 houses that received the standard weatherization treatment. The error bars shown on the figure are standard deviations of the mean of the distribution.

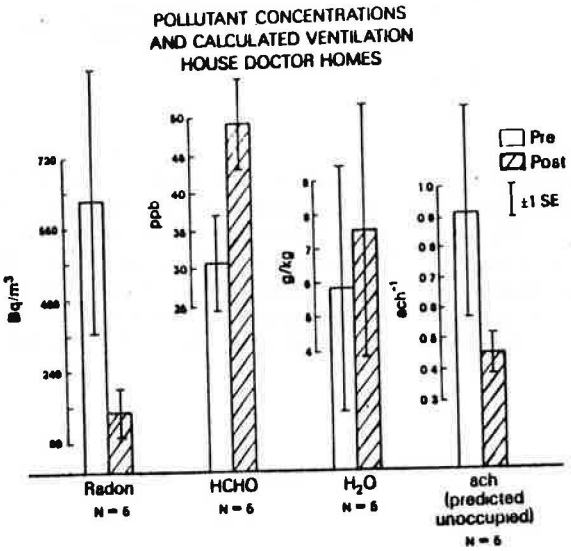

Figure 3

Changes in pollutant concentrations that accompanied intensive weatherization (house doctoring). Substantial changes (50%) in building tightness and predicted ventilation occurred. Increases in concentrations of 58% were seen in formaldehyde concentrations and 29% in water vapor concentrations. The error bars shown on the figure are standard deviations of the mean of the distribution.