STATEMENT

Synopsis of Research Report 162

HEALTH EFFECTS INSTITUTE

Wood Stove Replacement, Air Quality, and Health

BACKGROUND

Recent decades have seen substantial gains in air quality in the United States and Western Europe, with downward trends in concentrations of several major pollutants, including particulate matter (PM). These gains have been achieved largely through increasingly stringent air quality regulations and control measures. However, it is important to verify that regulations to improve air quality have indeed resulted in improved air quality and health.

The study led by Dr. Curtis W. Noonan evaluated a relatively large-scale program to replace about 1200 older, more polluting wood stoves with new, less polluting stoves in a rural mountain community (Libby, Montana), where residential wood combustion had been identified as a major source of fine PM ($PM_{2.5}$) during the heating season. Exposure to wood smoke is associated with increased respiratory symptoms in children and adults, decreased lung function in children, and increased emergency department visits and hospitalizations. In addition, wood smoke has been classified as "probably carcinogenic in humans" by the International Agency for Research on Cancer. Noonan and colleagues hypothesized that the intervention would substantially reduce community exposure to $PM_{2.5}$ derived from wood smoke, and thereby reduce children's respiratory symptoms and illness-related school absences.

APPROACH

Noonan and colleagues collected air quality and health data during four consecutive winters starting in 2005, the first year of the changeout program. The majority of changeouts took place during the second and third winters; the fourth winter constituted the post-changeout phase. Additional data were collected retrospectively, to cover two baseline winters before the start of the program.

The investigators measured $PM_{2.5}$ and some of its components outdoors, inside schools during different seasons, and in about 20 homes (before and after stove changeout) during the winter. They focused on compounds suggested to be specific markers for wood smoke, such as levoglucosan, abietic acid, and dehydroabietic acid, and evaluated whether these compounds could be used to track source-specific changes in air quality inside homes as well as in ambient air.

In parallel, they tracked illness-related school absences in children and parent-reported respiratory symptoms. Changes in wintertime reporting of symptoms and variations in school absences were also evaluated in relation to changes in ambient $PM_{2.5}$ concentrations in successive years.

RESULTS

Ambient winter concentrations of $PM_{2.5}$ gradually declined over the study period and were 30% lower in the final winter after the changeout program (year 4) than in the baseline years. By the end of the study period, Libby was no longer out of compliance with the National Ambient Air Quality Standard for $PM_{2.5}$.

Concentrations of levoglucosan, a fairly well-validated marker for wood smoke, were lower during the first three winters of the program than during the baseline winters, but increased again during the final winter. Concentrations of other potential markers, such as abietic acid and dehydroabietic acid, did not decrease in association with the changeout program. After stove changeout, indoor $PM_{2.5}$ concentrations were lower in a majority of the homes sampled, although there was substantial variability within and between homes. At the elementary and middle schools, indoor concentrations of markers for wood smoke and $PM_{2.5}$ were variable and not consistent with the timing of the changeout program.

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Curtis W. Noonan of the University of Montana–Missoula and colleagues. The complete report, *Assessing the Impact of a Wood Stove Replacement Program on Air Quality and Children's Health* (© 2011 Health Effects Institute), can be obtained from HEI or our Web site (see next page).

Based on about 1700 surveys filled out by parents during the four years, there was a significant reduction in childhood wheezing associated with lower winter ambient $PM_{2.5}$ concentrations. The most robust associations were for itchy or watery eyes, sore throat, bronchitis, influenza, and throat infection. There were no differences in health outcomes (notably, wheezing) between children from homes with wood stoves and children from homes with other types of heating. School absence data showed that lower average ambient winter $PM_{2.5}$ concentrations were associated with fewer illness-related absences among older students, but with higher absence rates among students in grades 1 through 4.

INTERPRETATION

The wood stove changeout program should be considered a success because 95% of older, high-polluting wood stoves in Libby were replaced with more efficient certified wood stoves or with heating systems that did not burn wood. In its independent evaluation of the study, the HEI Review Committee thought the study had demonstrated that ambient $PM_{2.5}$ concentrations in the community were reduced during the course of the changeout program, and that this reduction was sustained over subsequent winters.

The 30% reduction in ambient $PM_{2.5}$ concentrations at the end of the intervention may be considered encouraging. However, although the newer stoves that were introduced in Libby were certified, they did not necessarily represent the cleanest technology available at the time. Moreover, even certified, lower-emitting stoves make substantial contributions to ambient PM concentrations — particularly when not operated optimally — as compared with heating systems using cleaner fuels. Certified wood stoves have been found to emit $PM_{2.5}$ at rates (about 2–7 grams per hour) that are one to two orders of magnitude higher than those associated with oil (0.07 g/hr) or gas (0.04 g/hr) furnaces.

Sampling from about 20 homes showed that indoor $PM_{2.5}$ concentrations generally decreased after the stove was replaced, but results were not consistent; a few homes actually had increased concentrations, which may be due to incorrect stove usage or other indoor sources of pollution.

Although the study demonstrates an impact of the changeout program on ambient $PM_{2.5}$ concentrations (even if relatively modest), the Committee concluded that there was weak evidence that such air quality changes were associated with improved respiratory health outcomes (wheezing) and fewer symptoms associated with wood smoke exposure, such as itchy or watery eyes. The lack of high-quality health outcomes data was considered the most limiting aspect of the study design.

The Committee thought Noonan and colleagues had chosen appropriate statistical methods to evaluate the intervention, although the study was limited by inherent challenges, such as the seasonal nature of the intervention, the small size of the Libby community, and the availability of only one year of pre-intervention survey data.

The investigators found no differences in health outcomes between children from homes with wood stoves and those from homes with other types of heating. This finding suggests that exposures may be more closely determined by the overall contribution of wood stoves to ambient air quality than by their contributions to air quality in individual homes, a result that is consistent with other studies in the literature.

CONCLUSIONS

In summary, the study showed that wood stove changeout programs can contribute to community-level improvements in ambient air quality. Generally, air quality inside homes also improved, but stoves remain relatively high emitters compared with oil or gas furnaces, and proper stove operation is an important determinant of emissions. This study provided some evidence of improved children's health in the community, with reduced rates of parent-reported wheezing, itchy or watery eyes, sore throat, bronchitis, influenza, and throat infection. Further research using hospital admission data or more direct health outcomes, such as medication use, or biomarkers of exposure and effect would be useful. In addition, more research is needed to identify reliable markers for wood smoke exposure.

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