Appendix A:

Results for Breathing Living and Learning in the Akwesasne Community: Tools for Improving Indoor Air Quality in the Home

Introduction

The program, Breathing Living and Learning in the Akwesasne Community: Tools for Improving Indoor Air Quality in the Home, used direct feedback from indoor air quality (IAQ) monitors to change human behavior and reduce exposure to indoor air pollutants. Five IAQ monitors were placed into forty homes in the Akwesasne Community, with baseline concentrations of particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO_2), relative humidity, and temperature measured throughout a 12-day pre-intervention period. Following this period, an intervention was conducted in which a home audit and mitigation strategies were provided with the aim to improve the indoor air quality. The monitors then continued to measure the six parameters for another two weeks. Throughout the study, the participants were asked to keep activity diaries which described what was happening in the home so that correlations could be made between peak concentrations and specific activities. Data analysis included a comparison of pre- and post-intervention levels of PM and VOCs as well as characterization of the specific activities causing peak concentrations. The study found several homes with critical IAQ problems (e.g., leaking stoves) that were corrected. Participants were asked to complete an exit survey, indicating their level of satisfaction with participation in the program, and the results showed that participants valued the mitigation strategies provided in person by the technician and the direct feedback from the monitors. Improvements in indoor air quality were made through the use of intervention in the homes in the Akwesasne Community, and the extent of those improvements can be seen through the analytical results.

Methodology

To analyze the effectiveness of the intervention strategy in the homes of the participants in the study, the data collected by the five AirAdvice® Model 5100B residential monitors was downloaded from the AirAdvice website. Full study files, containing both the pre- and post-intervention periods, were saved and evaluated to see what difference, if any, was evidenced by the concentrations of PM and VOCs during the two time periods. Each participant's data set is highly unique and the background concentrations of the parameters vary from one participant to the next.

For each participant, the median PM and median VOC concentrations were calculated for the pre- and post-intervention periods. To do this calculation, the measurements from the first day of data were not included in the data analysis to avoid inclusion of an initial VOC spike in the concentration, which is an artifact of the metal oxide VOC sensor. The first day was also removed for the post-intervention period, and the post-intervention concentrations were evaluated beginning one day after the intervention. The difference between the pre- and post-intervention concentrations was then determined, and an average PM difference and average VOC difference were obtained. Bar graphs of the pre- and post-intervention median concentrations for participants who completed both pre- and post-intervention periods were created to show the change after the intervention occurred. These graphs yielded some outliers in the results of participants who had very high or very low pre- or post- intervention median concentrations. In order to more accurately compare the pre- and post-intervention periods, the activity diaries were used to remove periods of data when no one was home for extended periods of time (at least one full day), as these periods falling within the pre- or post-intervention period would create a bias in the data. The focus of the study was to compare a similar pre-intervention period and post-intervention period to see if any change occurred after intervention strategies were given. Upon completion of the analysis using the activity diaries, new overall average PM and average VOC differences were calculated.

The exit surveys were analyzed to assess the program and make improvements for future studies. See Appendix B for more details.

Per the Quality Assurance Project Plan, the monitors were collocated before and after the study. The quality control activities took place in the laboratory to test the data quality indicators, including precision, bias, comparability and completeness. The data quality objectives were met for the study. See Appendix C for more details.

A statistical analysis of the pre- and post-intervention IAQ marker data was conducted. The Shapiro-Wilk normality test was applied and both the PM and VOC data failed this test. Thus, a non-parametric version of the paired t-test, the Wilcoxon signed rank test, was applied to determine whether the pre- and post-intervention results were statistically different. See Appendix D for more details.

Results

Figure 1 provides an example PM concentration time series for one participant. The vertical line shows where the intervention occurred. For this participant, the pre- and post-intervention time series looks similar except that the highest peaks, which are associated with cooking activities, are lower during the post-intervention period. This difference suggests that the participant may have reduced the concentrations using the exhaust fan or other ventilation.

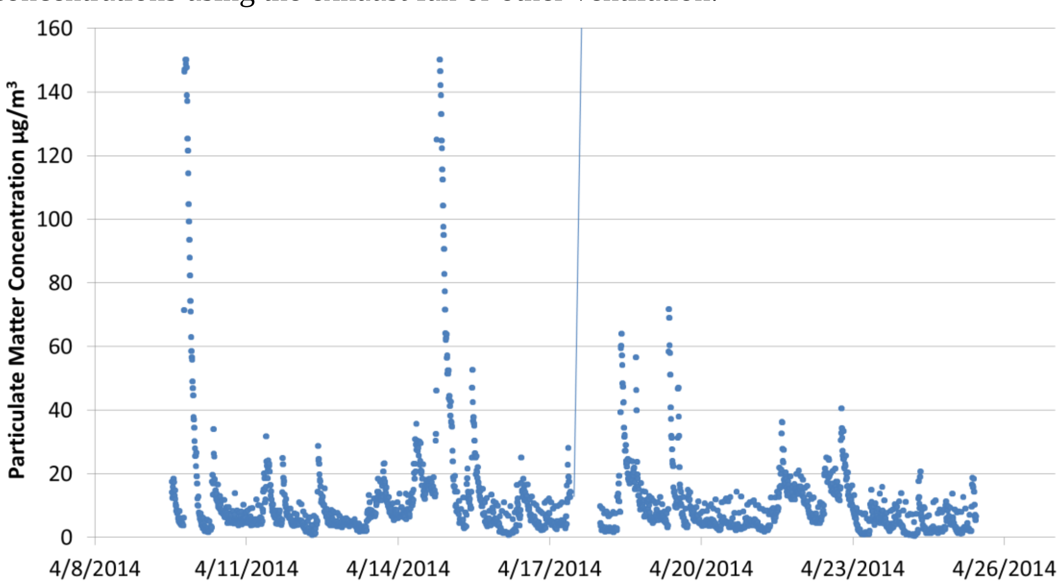

Figure 1: Example PM concentration time series for participant

Figures 2 and 3 show the median PM and median VOC concentrations, respectively, for the pre- and post-intervention periods. Among all participants completing the study, the pre- and post-intervention median PM concentration was statistically the same. Only half, 16 out of 33 participants, experienced decreases in PM concentration. Among participants who saw a decrease in PM concentration, the average difference after mitigation strategies were provided was a decrease of 4 $\mu g/m^3$.

Among all participants completing the study, the difference in the pre- and post-intervention median VOC concentration was statistically significant ($p=0.002$). The average change in VOC concentration was a decrease of 139 $\mu g/m^3$. Twenty-three out of thirty-three participants showed decreases in VOC median concentration after the intervention, while just ten experienced higher concentrations post-intervention. The average VOC difference for participants seeing a decrease in VOC concentration post-intervention was a 218 $\mu g/m^3$ decrease.

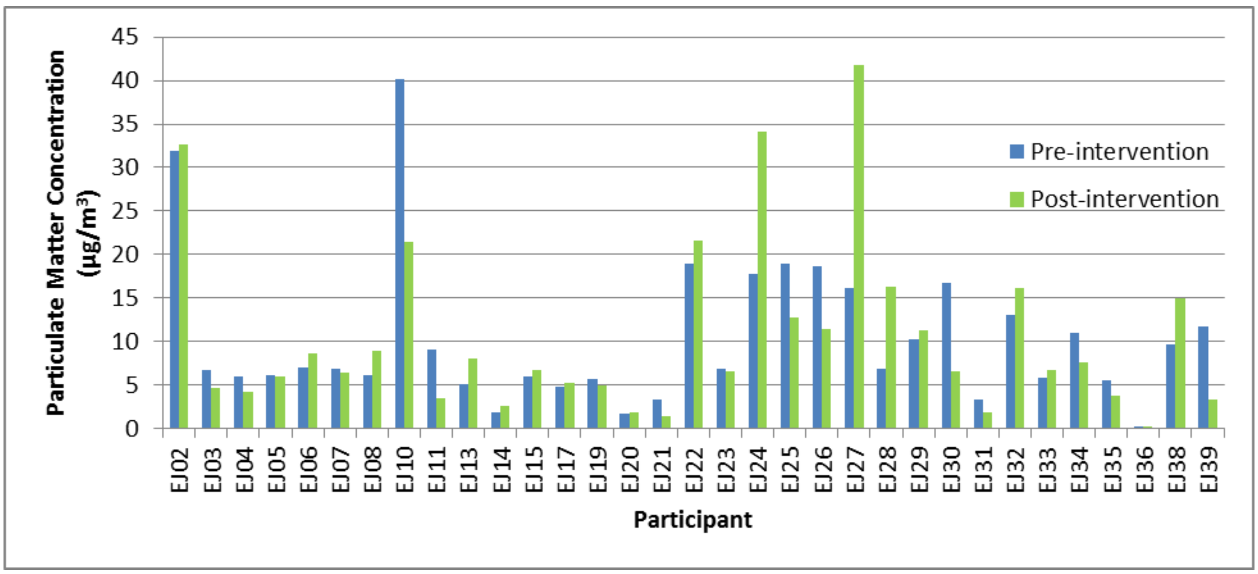

Figure 2: Pre vs. Post Intervention Median Particulate Matter Concentrations

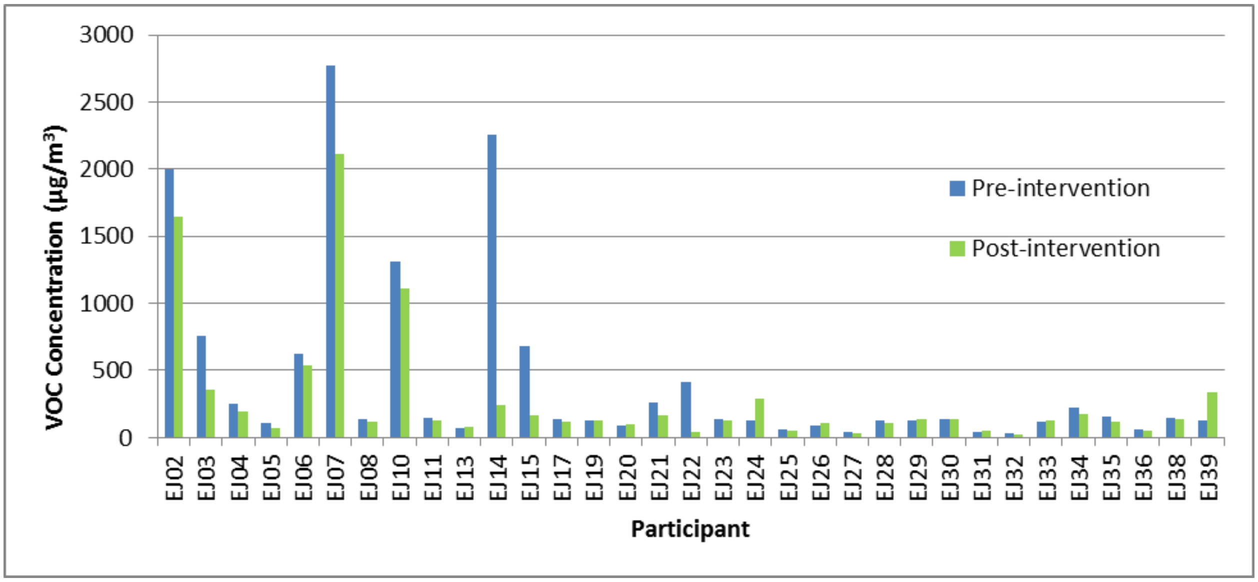

Figure 3: Pre vs. Post Intervention Median Volatile Organic Compound Concentrations

The main indoor particle and VOC sources were found to be cooking and smoking, consistent with previous studies. Figure 4 shows the difference in indoor PM and VOC concentrations during cooking events as compared with concentrations when there were no known indoor sources (background concentrations). Elevated concentrations were also observed when people were present without reported combustion sources, which is consistent with human activity induced particle resuspension.

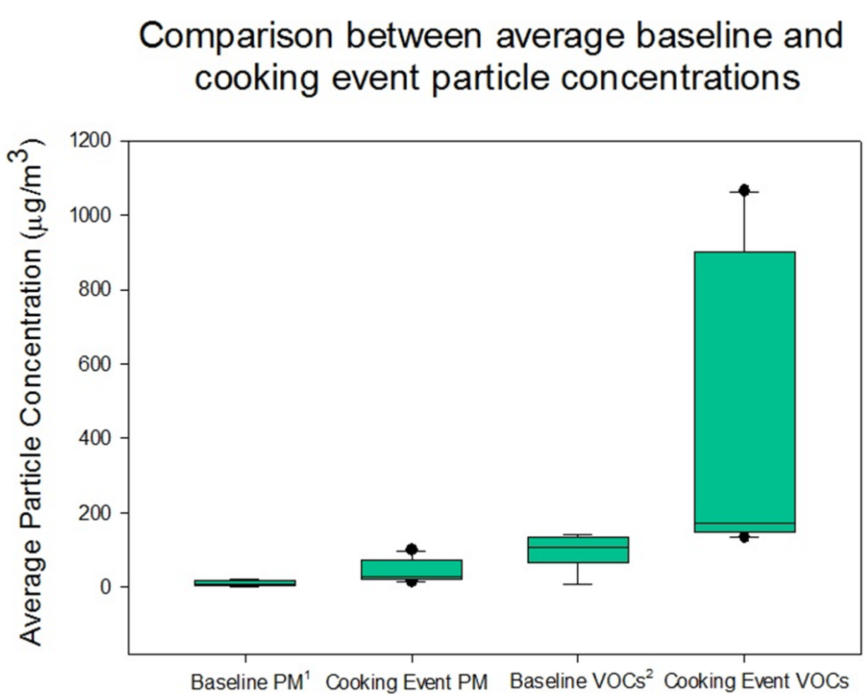

Figure 4: Participant EJ31 CO Concentration

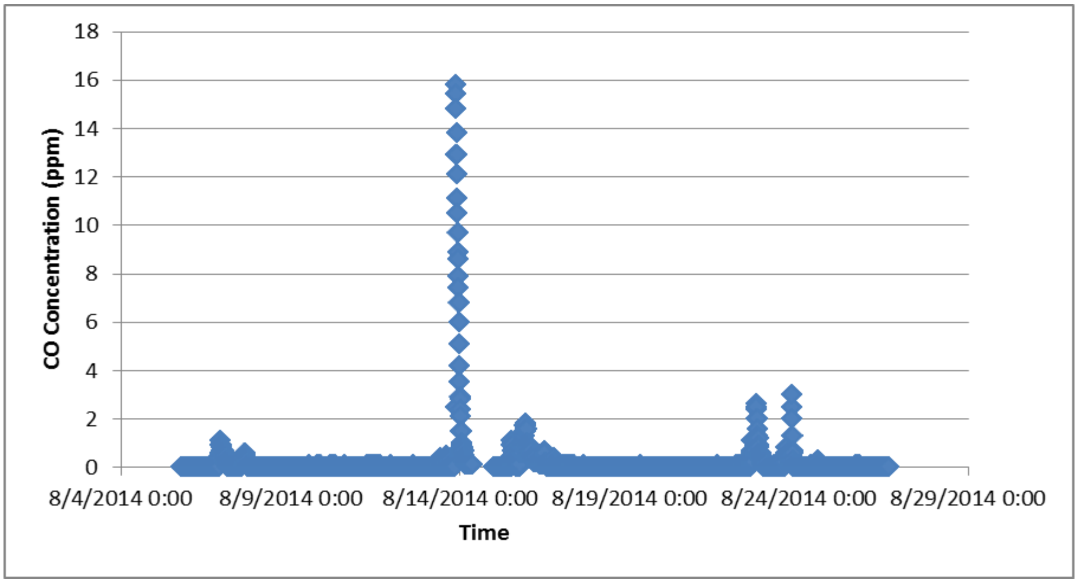

Figure 5: Participant EJ31 CO Concentration

The monitors placed in the home had the ability to provide evidence of any alarming situations that needed to be ameliorated. As an example, participant EJ31 had a spike in CO concentration of 15.8 ppm during their pre-intervention period (Figure 5). This spike signaled to the homeowner that their stove should be checked and they were able to replace the stove to eliminate the danger.

A final highlight, shown by the monitor placed in the home of EJ16, was evidence of the effectiveness of a heat recovery ventilator (HRV). Very low concentrations were observed from this home as it was circulating larger volumes of relatively clean outdoor air. The study validated the investment that this participant had made, and demonstrated the potential improvement that other participants could realize with a similar project, although the capital costs of an HRV installation are relatively high (~$3K).

Discussion

Thirty-three out of 40 participants completed the study. The participants who decided to drop out did so after their intervention. For the most part, these participants felt that they had learned enough from their pre-intervention period and did not want the additional burden of filling out the activity diary and running the monitors in their homes for the post-intervention period. In one case, the monitor moved locations from the home during the pre-intervention period to the participant's place of work for the post-intervention period, which did not allow for assessment of the effectiveness of the intervention.

Numerous factors affect the pre- vs. post-intervention concentrations of PM and VOCs seen in the homes in the Akwesasne community. The presence of visitors to the home during one of the periods, but not the other, would account for greater PM concentrations during the period including the visitation. On the other hand, lack of identification of periods when no one was home for an extended period of time in the activity diary (at least one full day) would lead to a period when the concentration was significantly lower than the rest of the time (both in the pre- and post-intervention periods), and as such would cause an inaccuracy in the difference between pre- and post-intervention PM and VOC concentrations. Another aspect to consider in the comparison between pre- and post-intervention is the high background concentration present in several homes due to outdoor sources. For one participant, EJ22, whose post-intervention period included July 1, 2014, fireworks were taking place that evening. These fireworks would have influenced the particulate matter concentration within the home, as a source that the participant could not prevent or control. In another instance, the outdoor wood boiler near participant EJ02 was significantly contributing to the background concentration observed by the monitor placed inside the home. Even when the residents of the home were away, the PM and VOC concentrations were elevated, providing evidence that an outdoor source was heavily influencing the background concentration within the home. The outdoor source is an example of a factor that this participant could not control, and caused the participant to have a median PM concentration both pre- and post-intervention that were higher than most of the other participants.

Conclusion

While the overall data analysis did not show significant decreases in median PM and VOC concentrations for all of the participants, successes of the program were achieved through the changes that were made in individual homes. Leaking stoves were identified and repaired and the unsafe high carbon monoxide concentrations that were being emitted daily were corrected through direct feedback from the data viewed during the study. Participants were able to see correlations between utilization of aerosol products, smoking, or cleaning activities and the peak concentrations observed for their homes. Participants were educated on how their activities affected their exposures to indoor pollutants and they could see marked improvements by source reduction and ventilation, such as opening windows when cooking or utilizing a stove vent. The benefits of the study were not all quantifiable; the participants cited in their exit surveys that the intervention methods were effective for better air quality and that they planned to keep using the intervention methods in their homes after the completion of the study. This is important because the participants will be able to apply what they have learned through the study into the future and can share the knowledge they have gained with others to help them to improve their indoor air quality as well.