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INDOOR AIR QUALITY FIELD SURVEY STRATEGIES

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Abstract

Indoor air quality sampling strategies and analytical techniques have changed significantly in the past ten years. The changes reflect both the shifts in study objectives and the development of new forms of instrumentation. To illustrate these trends, this paper describes early field techniques for measuring indoor air quality using a heavily-instrumented mobile laboratory that is suitable for measuring one building intensively for up to four weeks. This style of measurement now is complemented by large field survey projects using passive samplers as the dominant instrumentation. Examples of the use of each type of field research are discussed.

Introduction

The past five years has witnessed a significant change in the way in which indoor air quality field research is conducted. Some of the reasons for the change relate to the natural growth of a research field; others to a change in focus among those who direct the research.

A Change in Strategies

The initial surveys of indoor air quality were conducted by outdoor air pollution scientists who were concerned with the amount of pollution found in the outdoor air that had penetrated into the living space within buildings (8). The advent of major building energy conservation programs changed this focus. Questions that began to dominate during the latter seventies included: Is there an air quality problem within buildings? If so, what is the nature of the problem? Will energy conservation programs that reduce ventilation air in buildings exacerbate any existing problem? What is the minimum ventilation rate needed for comfort and safety within a building? Field surveys conducted during this time made intensive measurements in a small number of buildings using real-time monitoring techniques (5). These studies helped to define the nature of the indoor air quality problem by delineating the relationship between the concentrations of indoor pollutants and their indoor sources.

Current survey designs reflect new questions, but some older issues are still of concern. An unresolved question is what effect weatherization programs that reduce air leakage in residences have on the indoor air quality in these structures. More recent issues that recognize the existence of many microenvironments of air quality and provide the basis for field survey designs include: what impact do indoor pollutants have on total personal exposures? and what is the distribution of pollutant concentrations in the housing stock of a particular region or country?

A Change in Instrumentation

A major technical change has also accompanied the shift in objectives of air quality field research. Until the early eighties, field measurements generally were made using large, expensive, real-time instrumentation. The change in emphasis of research objectives to personal exposure monitoring and large-scale building surveys has created a need for inexpensive, unobtrusive, reliable instrumentation. This equipment is now appearing (2,3,7) and field experience proving its utility is being obtained. The differences between what is possible now and what could only be hoped for in the past are striking. Examples will be presented by examining two distinctly different measurement projects: one involving a large mobile laboratory that used real-time instrumentation to investigate a large number of pollutants in detail in a small number of buildings; the other a survey of one pollutant in hundreds of houses.

Field Sampling with the EEB Mobile Laboratory

The EEB Mobile Laboratory, a large instrumented semi-trailer, was constructed and operated to meet several goals: to determine minimum ventilation rates needed to assure safety and comfort in buildings; to examine the relationship between indoor and outdoor pollutant concentrations; and to study the effects of energy conservation retrofits on air quality in residences. The mobile laboratory is extensively instrumented for real-time monitoring of concentrations of CO_2, CO, SO_2, NO, NO_x, O_3, indoor temperature and moisture, outdoor meteorological conditions, and infiltration. Time-averaged monitoring of concentrations of radon, formaldehyde and total aldehydes, selected organic compounds, and fine and coarse fractions of inhalable particles is also conducted (6).

An example of the use of the mobile laboratory is a weatherization retrofit study undertaken in Medford, Oregon with the cooperation of Pacific Power and Light Company (1). Nine houses were investigated before and after weatherization retrofits. Indoor air quality was monitored in two of the houses using the EEB Mobile Laboratory; the change in air leakage before and after retrofit was measured in the other seven houses to predict the potential change in indoor air quality due to changes in infiltration.

Air sampling lines were run from three sites within a house to the mobile laboratory. Sampling occurred sequentially from the three indoor locations and one outdoor reference location. Cycling through the four locations required a forty-minute interval; data from the ten-minute samples from each location were stored and averaged over two-week intervals before and after the retrofit.

Current Field Survey Strategies

Several studies are in progress or are planned to:

1. Study the impacts of weatherization on indoor air quality (Wisconsin Power & Light/University of Wisconsin; Bonneville Power Administration/Lawrence Berkeley Laboratory).

2. Measure the distribution of concentrations of pollutants in the housing stock of a region (Bonneville Power Administration/Lawrence Berkeley Laboratory).

3. Examine personal exposures to combustion-related pollutants (Gas Research Institute/Harvard School of Public Health).

4. Study the health impacts of unvented kerosene heaters, gas appliances, and sidestream tobacco smoke (Consumer Product Safety Commission/J.B. Pierce Foundation).

Each of these studies is unique. However, they have common features that demonstrate the changes in the range and scope of recent field surveys. These changes are exemplified by a planned field survey in the Pacific Northwest region of the United States sponsored by the Bonneville Power Administration. The objective of the study is to characterize the distribution of concentrations of indoor pollutants in the housing stock in the region to establish a baseline for modeling the impact of weatherization retrofits on indoor air quality.

The design of the study is evolving -- current design requires selecting a random sample of houses and monitoring radon in each. Approximately 2000 houses are to be selected and stratified by geological area and foundation type. The geological areas are to be chosen based on the results of an analysis of an aerial survey of the uranium resource of the region. A subsample of approximately 400 houses will also be chosen from the larger sample and sampled for formaldehyde and nitrogen dioxide. This subsample will be stratified by building age and presence or absence of urea-formaldehyde foam insulation and the presence or absence of a major combustion process within the house.

Passive samplers will be used to measure pollutant concentrations. In order to minimize costs while maximizing the sample size, the samplers will be sent to occupants with instructions for use and return. Quality control in the measurement process will be obtained by using staff members to deploy the samplers in a subset of houses -- the occupants will mail the samplers back to the Laboratory for analysis.

A pilot study using radon passive samplers was recently completed in the Pacific Northwest. Samplers were mailed to 290 employees of Bonneville Power Administration with instructions for use. A response rate of 93% was obtained.

Comparison of Results

Medford Weatherization Retrofit Study

No substantial differences in air quality were seen in the two houses before and after weatherization retrofit. The first house of the pair that were monitored was occupied by an adult smoker; statistically higher particle concentrations (especially the fine particle fractions) occurred when smoking was allowed than when it was restricted. These differences occurred both before and after retrofit and were not changed by retrofit.

The air leakage measurements in the other seven houses revealed erratic changes in air leakage with retrofit. Some of the houses were heated using forced air. The air distribution ductwork is located in unconditioned spaces (crawlspace or attic) in these mild climate houses and leaked excessively. Repairing these leakage sites is not a standard weatherization retrofit procedure. However, the procedure is required for a successful retrofit in this housing type.

Passive Sampler Radon Survey

Figure 1 shows the distribution of radon concentrations obtained in the sample of 270 houses. The highest concentration measured within the living space is shown for each house. While the results do not come from a radom sample of houses and sampler deployment was not checked by field personnel, the distribution results are consistent with other field samples taken elsewhere in the United States (4). In particular, the observation that three percent of the houses in the sample have concentrations above 10 pCi/l is further confirmation of the wide-spread nature of the radon problem in the housing stock.

Conclusion

Changes in research goals and the availability of new instrumentation allows new types of studies to be conducted. The examples in this paper point out the advantages and disadvantages of each type of study. While intensive monitoring is expensive and is limited to small sample sizes, its detailed measurements can reveal valuable information about source behavior and pollutant interactions.

Large-scale surveys, on the other hand, yield broad information about the weighted-average pollutant concentrations and are better suited for studies of the effects of regional or construction differences on indoor air quality. In large-scale surveys, the effects of occupant activities are automatically included. A detailed study can suggest that a ventilated crawl space implies a lower radon concentration in the living space of a house while a large survey can test the hypothesis statistically. The large survey designs do not replace the intensive, detailed studies. Rather they augment one another and broaden the capabilities of researchers investigating the indoor air quality problem.

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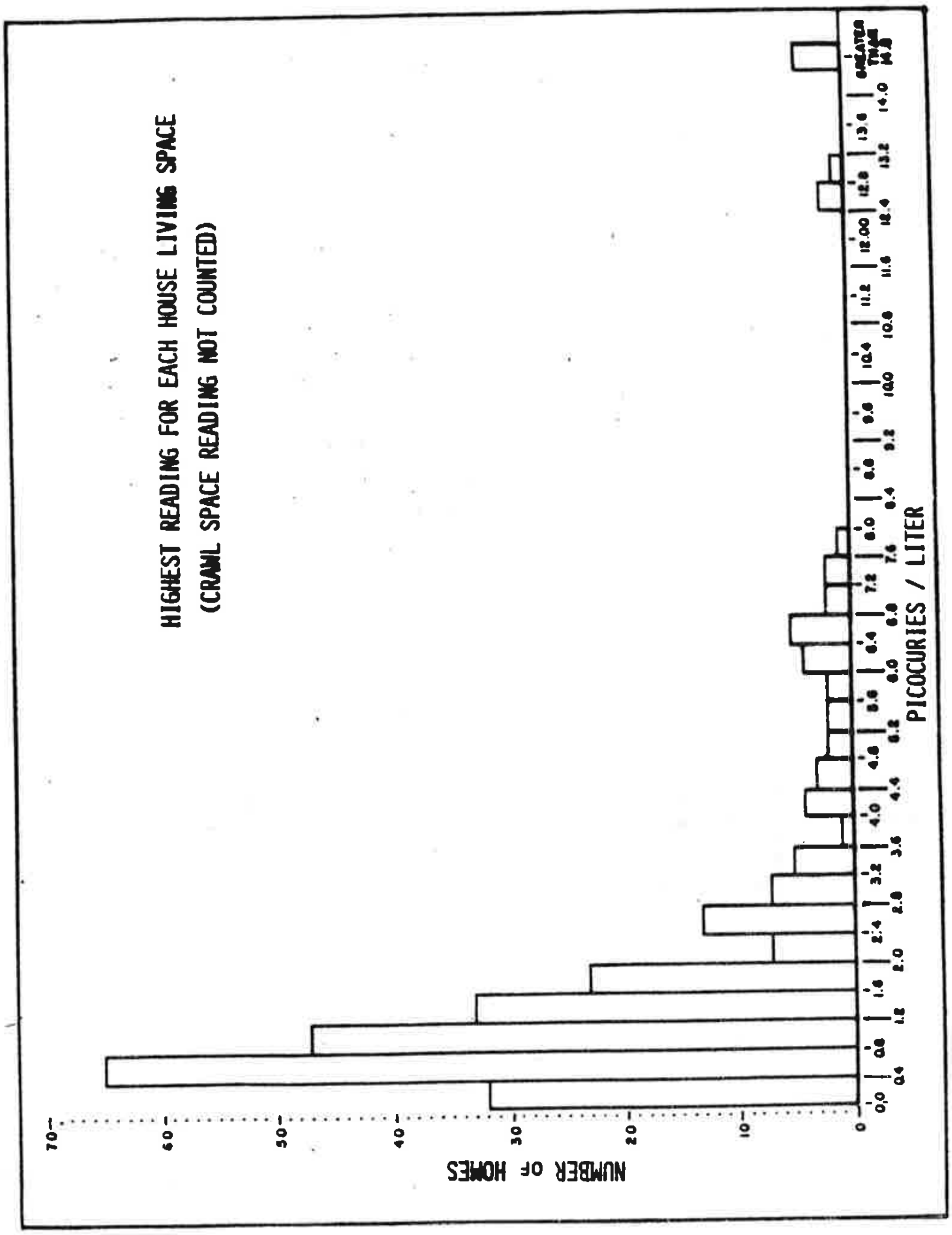

Figure 1. This histogram shows the number of houses in which the highest radon concentration occurs within a bin having a width of 0.4 pCi/ℓ. A total of 267 house results are reported in this figure.