IMPORTANT DESIGN CONSIDERATIONS FOR RESIDENTIAL INDOOR AIR QUALITY STUDIES

Niren L. Nagda, Ph.D., and Harry E. Rector, B.S.
GEOMET Technologies, Inc., Rockville, Md., U.S.A.

Abstract

With recent advances in technology, choices among measurement strategies for indoor air quality investigations have become increasingly complex. Design must weigh objectives and available technology against resources to implement the design. This paper provides a systematic framework for making proper choices among critical design alternatives. Design considerations include types of instrumentation, location of probes, and number and frequency of measurements. Examples drawn from case studies will be presented to illustrate these considerations.

Monitoring Design

Indoor air quality is influenced by a variety of parameters such as infiltration rate, indoor generation, and decay of pollutants. Each of these parameters in turn depends on a large number of factors. For example, the infiltration rate is dependent on indoor-outdoor temperature difference, wind conditions, structural tightness, site characteristics, and other factors. Consequently, the nature and type of measurements required in indoor air quality studies can be very large and exceedingly resource-intensive. A well-developed monitoring design will enable a researcher to maximize the quality and utility of the resultant measurements.

As shown in Figure 1, nine general steps can be identified as a conceptual framework for the monitoring design (3). Initial activities (Steps 1 through 4) concentrate on developing a preliminary design that is responsive to problem needs. These steps consist of developing monitoring objectives by selecting pollutants and other measurement variables (Step 1), screening available technology for potentially useful instruments (Step 2), and developing broad options for the sampling frame in terms of such factors as sample size, geographical extent, and season (Step 3). This information is then assimilated to produce a preliminary design (Step 4) that is fine-tuned in subsequent steps to make final instrumentation selections (Step 5), establish a final sampling frame (Step 6), and develop cost estimates (Step 7). In some cases, design elements cannot be adequately balanced, and feedback to the preliminary level (Step 8) is necessary before a final design emerges (Step 9).

Although we have identified nine steps, investigators may vary the order of consideration or otherwise adapt elements of this sequence to their needs. Indeed, many indoor air quality problems, such as formaldehyde-related complaints, are frequently stated in a way that leads to a relatively rapid design sequence. Nonetheless, it is often useful to spend time in the preliminary stages to explore the need for additional measurement variables such as air change rates. Further, the use of standardized sampling conditions can strengthen the interpretation of collected data.

Instrumentation

Instrument options may be considered from the standpoint of mobility (i.e., stationary, portable, personal), operating characteristics (i.e., active versus passive), and output characteristics (i.e., analyzer versus collector). For example, indoor concentrations of nitrogen dioxide can be measured using gas phase chemiluminescence (i.e., photometric detection of the reaction between ozone and nitric oxide), triethanol amine adsorption followed by colorimetric analysis, gas phase/liquid phase chemiluminescence (i.e., photometric detection of the reaction between nitrogen dioxide and luminol), or electrochemical principles. Instrumentation options within these four approaches are listed in Table 1.

Table 1. Range of available instrumentation for measuring nitrogen dioxide concentrations.

Operating principle	Instrument mobility	Operating characteristics	Output characteristics
Gas-Phase Chemiluminescence	Stationary, portable	Active	Analyzer
Triethanol Amine Adsorption	Personal	Passive	Collector
Gas/Liquid Phase Chemiluminescence (under development)	Portable	Active	Analyzer
Electrochemical (under development)	Portable	Active	Analyzer

Performance characteristics such as lower detection limit, precision, accuracy, and unattended monitoring period are important considerations for instrument selection. For example, performance characteristics associated with the general range of nitrogen dioxide instruments are listed in Table 2. Because some instruments are under development, certain performance characteristics are unknown. Information in these tables is drawn from recent state-of-the-art summaries of instruments for indoor air quality measurements (1, 3).

Table 2. General range of performance characteristics for nitrogen dioxide instrumentation.

Operating principle	Lower detection limit	Precision	Accuracy	Unattended monitoring period
Gas-Phase Chemiluminescence	<0.01 ppm	<5%	1%	1 week
Triethanol Amine Adsorption	<1 ppm/hr (6 ppb for 1 week)	10%	20%	Hours to weeks
Gas/Liquid Phase Chemiluminescence (under development)	<1 ppb	Unknown	Unknown	Unknown
Electrochemical (under development)	<5 ppb	Unknown	Unknown	Unknown

Probe Location

Selection of representative probe locations for sampling is extremely important to meeting monitoring objectives. Depending on objectives, probe criteria are typically developed from one of two general perspectives: (a) to characterize indoor pollutant levels, and (b) to characterize personal exposure. Both perspectives may require an examination of responsible factors as well.

Selecting a probe location is a two-step procedure. The first step entails selecting an indoor zone (a general area such as an upper floor or specific rooms). Indoor zones for characterizing pollutant levels may be identified by the presence of indoor sources related to objectives. Indoor zones for characterizing personal exposure are further related to occupant activity patterns.

A preferred but more resource-intensive approach to selecting monitoring zones involves premonitoring surveys with tracers to examine zone-to-zone differences in air exchange rates for patterns related to monitoring objectives (2, 4). Figure 2 illustrates the results of such a survey to determine a single probe location for characterizing average indoor levels (2).

Air exchange rates were measured at a number of indoor locations with the circulation fan of the central forced-air heating and cooling system on auto (upper diagram, A) and with the circulation fan off (lower diagram, B). These experiments showed that as long as interior doors are open, the upper level of this particular house can be treated as a single zone for measuring average concentrations. Based on this result, a probe location (denoted by an asterisk in both diagrams in Figure 2) was selected for ease of access and avoidance of areas with greater in-home traffic.

Concluding Remarks

This paper has introduced selected design considerations that have emerged from indoor air quality research conducted by GEOMET and a number of other organizations over many years. A more detailed treatment of each of the nine areas of monitoring design is included in our book, Guidelines for Monitoring Indoor Air Quality, to be published by the Hemisphere Publishing Corporation of New York this year.

References

(1) Harvard School of Public Health. Workshop on Evaluation of Monitoring Equipment for Personal Exposure Assessment. Harvard University, Cambridge, Mass., 1983.

(2) Nagda, N.L., and Koontz, M.D. Energy use, infiltration, and indoor air quality in tight, well-insulated residences--some results of prebaseline monitoring. Prepared for EPRI under Contract Number RP 2034-1. GEOMET Technologies, Inc., Rockville, Md., 1983.

(3) Nagda, N.L., and Rector, H.E. Guidelines for Monitoring Indoor Air Quality. National Technical Information Service, NTIS #PB-83-264465, Springfield, Va., 1983.

(4) Woods, J.E., and Maldonado, E.A.B. Development of a field method for assessing indoor air quality in single-family residences. Engineering Research Institute, Iowa State University, Ames, Iowa, 1982.

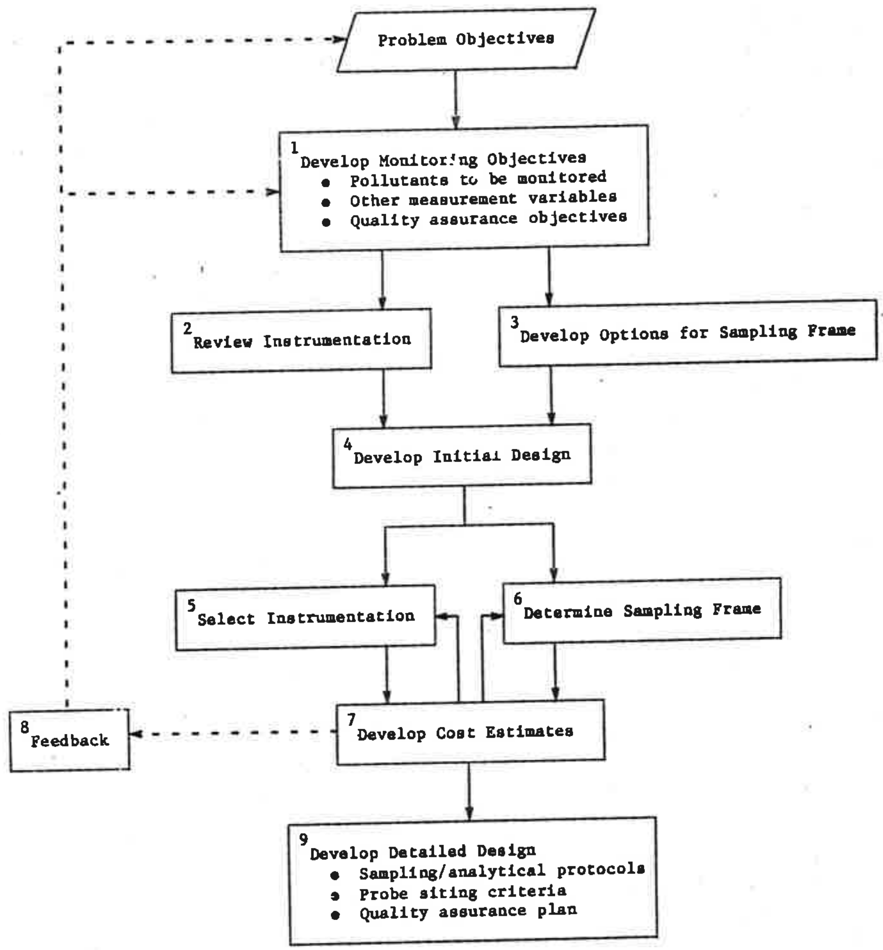

Fig. 1. Conceptual framework for developing a monitoring design.

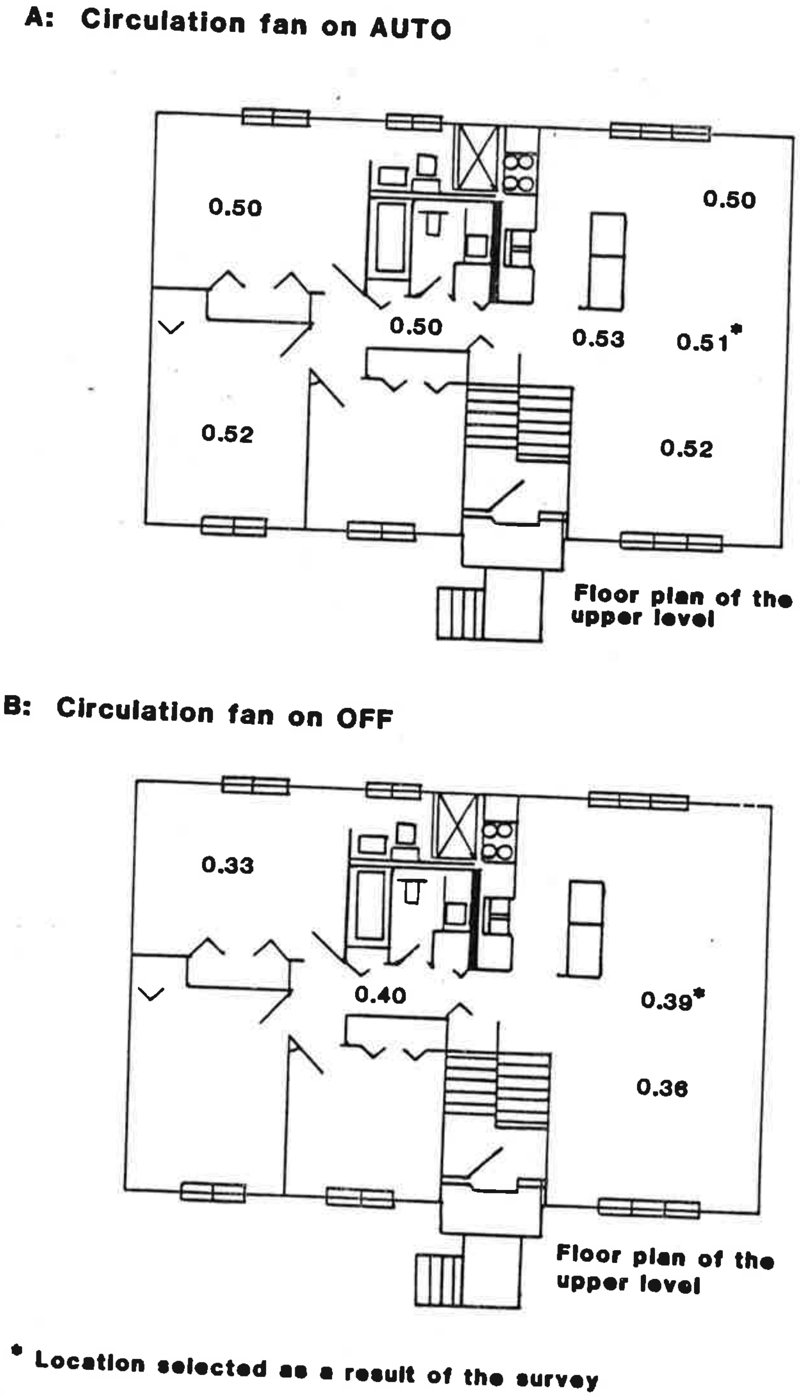

Fig. 2. An example of premonitoring tracer-gas decay survey (indicated values are in air changes per hour).

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