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Standard Practice for Evaluating Residential Indoor Air Quality Concerns¹

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1. Scope

1.1 This standard practice describes procedures for evaluating indoor air quality (IAQ) concerns in residential buildings.

1.2 The practice primarily addresses IAQ concerns encountered in single-family detached and attached (for example, townhouse or duplex design) residential buildings. Limited guidance is also included for low- and high-rise multifamily dwellings.

1.3 The IAQ evaluation procedures are comprised of interviews with the homeowner or resident(s) (including telephone interviews and face-to-face meetings) and on-site investigations (including walk-through, assessment, and measurements). For practicality in application, these procedures are dividing into three separate phases.

1.4 The procedures described in this standard practice are aimed at identifying potential causes contributing to the IAQ concern. Such findings should become a basis for recommending corrective measures. This standard practice does not describe problem resolution or corrective measures and the standard is not intended to evaluate the impact of corrective measures.

1.5 Implementation of procedures given in this standard requires the investigator (or investigative team) to have adequate background in several areas: general principles of IAQ; interviewing techniques; building design and construction practices; basic understanding of heating and cooling systems and appliances; use of IAQ measurement equipment; interpretation of IAQ data; and technical report writing.

1.6 Although many elements described in this standard practice may be useful in training of IAQ investigators, it should not be used as the sole basis for specifying or conducting such training.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applica-*

bility of regulatory limitations prior to use. For additional safety precautionary information, see Section 6.

2. Referenced Documents

2.1 ASTM Standards:²

- D1356 Terminology Relating to Sampling and Analysis of Atmospheres
- D1357 Practice for Planning the Sampling of the Ambient Atmosphere
- D4861 Practice for Sampling and Selection of Analytical Techniques for Pesticides and Polychlorinated Biphenyls in Air
- D4947 Test Method for Chlordane and Heptachlor Residues in Indoor Air (Withdrawn 2011)³
- D5197 Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology)
- D5438 Practice for Collection of Floor Dust for Chemical Analysis
- D5466 Test Method for Determination of Volatile Organic Chemicals in Atmospheres (Canister Sampling Methodology)
- D5952 Guide for the Inspection of Water Systems for Legionella and the Investigation of Possible Outbreaks of Legionellosis (Legionnaires' Disease or Pontiac Fever)
- D5955 Test Methods for Estimating Contribution of Environmental Tobacco Smoke to Respirable Suspended Particles Based on UVPM and FPM
- D6196 Practice for Selection of Sorbents, Sampling, and Thermal Desorption Analysis Procedures for Volatile Organic Compounds in Air
- D6271 Test Method for Estimating Contribution of Environmental Tobacco Smoke to Respirable Suspended Particles Based on Solanesol
- D6333 Practice for Collection of Dislodgeable Pesticide Residues from Floors
- D6345 Guide for Selection of Methods for Active, Integrative Sampling of Volatile Organic Compounds in Air

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

- E241** Guide for Limiting Water-Induced Damage to Buildings
- E609** Terminology Relating to Pesticides
- E620** Practice for Reporting Opinions of Scientific or Technical Experts
- E741** Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution
- E779** Test Method for Determining Air Leakage Rate by Fan Pressurization
- E943** Terminology Relating to Biological Effects and Environmental Fate
- E1186** Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
- E1554** Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization
- E1827** Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
- E1998** Guide for Assessing Depressurization-Induced Backdrafting and Spillage from Vented Combustion Appliances
- E2128** Guide for Evaluating Water Leakage of Building Walls

2.2 Other Documents:

- ASHRAE 62.2-2004** Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings⁴
- ASHRAE 119** Air Leakage Performance for Detached Single-Family Residential Buildings⁴

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminologies **D1356**, **E609**, and **E943**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *hypothesis, n*—a provisional theory set forth to explain certain indoor air quality problems or phenomena.

3.2.2 *pause point, n*—an interim step within a procedural sequence designed to allow subsequent actions to be based on the analysis and evaluation of recently collected data.

3.2.3 *stack effect, n*—buoyancy associated with the indoor-outdoor temperature differences.

4. Summary of Practice

4.1 IAQ-based complaints and problems in residential buildings include discomfort and health symptoms arising from exposure to indoor air pollutants, as well as unacceptable indoor environmental conditions such as mold growth or lingering odors.

4.2 This practice describes procedures for the systematic investigation of IAQ concerns using an iterative process that involves problem definition, information gathering, formulation of hypotheses, measurements (if necessary), and problem identification. It may include testing hypotheses by taking actions and evaluating their impact on the IAQ concern.

4.3 To enhance the effectiveness and management of an IAQ investigation, it is often conducted in three separate

phases: (1) initial meeting with the building owner and walk-through, (2) detailed assessment of the building and its systems, and (3) pollutant measurements, if necessary. Such phased investigations also allow informing the building owner or the cognizant party of the progress and seeking approval for ensuing work.

4.4 Major steps recommended for IAQ investigations include an initial interview with the building owner or occupant, on-site meeting and walk-through, develop hypotheses on potential causes of complaints, determine measurement parameters and instrumentation, determine the need and feasibility of monitoring, if appropriate, conduct monitoring, analyze data and evaluate hypotheses, and develop report on findings. Critical purposes underlying these steps and procedures involved are described. The relationships among the steps are illustrated through a flow diagram.

4.5 The success of an IAQ investigation often depends on whether or not the investigator has taken the time to step back to assess all field observations and data that have been collected at any given point to determine or postulate potential causes. These interim evaluation points are called pause points and several such pause points are recommended during the investigation process.

5. Significance and Use

5.1 IAQ-based complaints and problems including discomfort/health symptoms and unacceptable indoor environmental conditions such as odors exist in residential buildings, but the frequency of the occurrence of IAQ complaints and problems is not known.

5.2 Characterization of IAQ concerns and identification of their underlying causes require systematic observations and measurements of the indoor environment, its occupants and contaminant sources. This practice provides background and procedures for the investigation of IAQ concerns.

5.3 Where the dwelling is not owner-occupied, formal permission to access certain areas of the property and to collect information essential to the IAQ investigation is often deemed essential to be obtained from the owner and, where applicable, from other tenants. An investigator should seek appropriate legal advice in these matters.

5.4 Certain stages of the IAQ investigation could benefit from a review of existing medical records. This requires specific written permission from the patient.

5.5 The stepwise and phased approach described in this practice allows for an investigation that is commensurate with the nature of the problem and the level of resources available for the investigation.

6. Hazards and Precautions

6.1 In the course of conducting on-site investigations, a variety of situations may arise that could pose a hazard to the investigator and residents. Examples include the following:

6.1.1 Improperly stored or uncharacterized household chemicals, and pesticides, etc.,

6.1.2 Fire hazards (for example, inappropriate storage of combustible material), and

⁴ Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, <http://www.ashrae.org>.

6.1.3 Microbiological contamination.

6.1.4 General safety (for example, weakened staircases, etc.).

6.2 Most potential hazards are recognized visually, and can be accommodated by asking the homeowner to remove the hazards.

6.3 If any testing or assessment planned to be conducted by the investigator (for example, use of smoke tracers) influences the occupants and/or indoor environment, risks related to such procedures must be reviewed with the resident and explicit permission of the resident should be obtained prior to initiating such testing.

6.4 Where applicable, use protective equipment (for example, eye protection, gloves, and masks), and safe procedures (that is, avoid direct inhalation of strong vapors) to reduce hazards that cannot be otherwise moderated.

7. Background on the Nature of Residential IAQ Problems, Contaminants and Sources

7.1 For successful diagnosis of IAQ problems, investigators need to have a thorough understanding of types of problems and their potential causes. This section provides an illustrative background on type of IAQ problems, contaminants, and indoor sources. For detailed discussion, refer to the documents listed in the bibliography ([Annex A7](#)). The next section (Section 8) gives background on building and system related IAQ problems.

7.2 IAQ Concerns and Problems:

7.2.1 IAQ concerns and problems can be grouped in two categories: those that adversely affect the residents' health, and those that create annoying circumstances. The first category is perceived symptom-based response (related to residents' health status or perception of well-being), and may or may not be detectable by the senses. The second category relates to acceptability of indoor environmental conditions, which relate to sensory phenomena, but may or may not be related to health concerns.

7.2.2 IAQ concerns that are based on symptom complaints include building-related illnesses whose symptoms can be identified and whose cause can be directly attributed to airborne building pollutants, as well as illnesses without known etiological origins.

7.2.3 IAQ concerns that are based on perceived acceptability of environmental conditions include disagreeable odors, visible deposits of soot-like residues, or mold growth on various surfaces, and excessive dust.

7.3 Contaminants and Indoor Sources:

7.3.1 Two major types of contaminants are biological and chemical contaminants. Bioaerosols represent a broad class of viable particles (viruses, bacteria, protozoa, and spores), and nonviable particles (that is, fragments of dead organisms and particulate waste products). Chemical contaminants can exist as gases, vapors, and aerosols that are or may become airborne. There are also chemical contaminants that originate from living organisms.

7.3.2 Indoor levels of biologically-derived pollutants may arise from biological contamination of the indoor environment

(for example, mold colonization), or from the transport of biologically-derived contaminants from other indoor airspaces, the outdoors, or from soil gas entry (**1**, **2**).⁵

7.3.3 Sources of chemical contaminants in indoor air are conveniently grouped as (1) activity-related, (2) material-related sources, (3) transport-related sources, (4) tracked-in dirt, and (5) bioeffluents.

7.3.3.1 Activity-related sources are characterized by process rates. The emission rate for aerosols and gases from combustion sources, for example, is usually postulated in terms of fuel consumption rate. Malfunctioning of such sources such as spillage from combustion sources relates to process rate and other factors such as depressurization. Other direct-discharge sources would include the use of pressurized consumer products as well as volatilization of chemicals from the water supply. Activity sources also include tobacco smoke, cleaning and bathing products, sweeping and vacuuming, use of home office equipment, hobbies, painting and varnishing and pest control efforts.

7.3.3.2 Material-related include volatilization of chemicals from liquid films (for example, drying paint, cleaners) and from solid media (for example, carpet backing, building materials, glues and paints). Air "fresheners" also results in volatilization of chemicals from solid or liquid media.

7.3.3.3 Transport-related sources of indoor air pollution bring contaminated air from other areas into the airspace of concern. Examples include infiltration of outdoor gases and aerosols, migration of combustion products (aerosols and gases) from attached garages, and soil gas entry. Heating, ventilating, and air-conditioning (HVAC) distribution system or ductwork also can be a conveyor of or a source of indoor air pollution. The improper maintenance or moisture accumulation in HVAC system can lead to colonization of organisms. Use of woodstoves and fireplaces can leave residues of polycyclic aromatic hydrocarbons (PAHs) indoors.

7.3.3.4 Tracked-in dirt by individuals, especially children, or pets coming from outside or the yard to indoors can be a source of contamination of lawn and garden chemicals such as herbicides, insecticides, fungicides, or fertilizers. Similarly PAH and other semivolatile organics can come from nearby roadways, industrial sites, and landfills (**3**).

7.3.3.5 Bioeffluents consist of CO₂ produced by respiration, and a large number of volatile organic compounds (VOCs), including compounds such as ethanol produced by metabolism. Each such VOC occurs in small concentrations with a modest sensory impact, but together provide the characteristic human body odor (**4**). Also VOC emissions from mold contamination could be considered under this category of sources.

7.3.3.6 In addition to above groups of sources, chemical interaction between chemicals within the same or different groups may need to be considered. Examples include interaction between chlorine compounds in bleach and other chemicals or interaction between nitrogen oxides or ozone and furnishings.

⁵ The boldface numbers in parentheses refer to the list of references at the end of this standard.

8. Background on Building and Building Systems-Related IAQ Problems

8.1 IAQ problems may result from elements of the building itself, the mechanical equipment used to condition and ventilate it and interactions between the occupants, the equipment, the envelope and outdoor conditions. Problems may arise from flaws in design, construction, operations or maintenance. This section provides a brief background on building and system related factors. The discussion below is not comprehensive but illustrative only.

8.2 Building Airtightness and Infiltration:

8.2.1 In residences, infiltration of outdoor air is the principal dilution mechanism for pollutants released from indoor sources. Amount of air infiltration or air leakage into a building depends on complex interaction among many variables including, indoor-outdoor pressure differences (which in turn depend on indoor-outdoor temperature differences and wind conditions) and the operation of exhaust appliances, for example, kitchen or bathroom fans, clothes dryers, and fireplaces (5). Window and door openings add to building air change rate. Imbalances in the air distribution of a forced-air heating/cooling system caused by barriers between supply and return or duct leakage contribute further to building depressurization and pressurization. Also, the physical layout of the building (for example, a flat one-story building versus a taller and narrower structure) influences the stack effect caused by the temperature differences and wind conditions. Such stack effects are exaggerated with building features such open stairwells in a multi-floor building.

8.2.2 ASHRAE 62.2-2004 specifies an air change rate of 0.35 h^{-1} for providing acceptable air quality in residential buildings. Leakage communication between the building and the outdoors can be qualitatively established using visual tracers and controlled pressurization and depressurization (Practices E1186).

8.2.3 ASHRAE Standard 119 classifies the envelope tightness of buildings and sets maximum leakage levels based on energy considerations in terms of 10 leakage classes as judged by fan pressurization testing (Test Method E779). Table 1 lists leakage classes along with ventilation guidance derived from ASHRAE 119 (6).

8.3 Water Leakage and Moisture Damage:

8.3.1 Unwanted water penetration into exterior walls, interior walls, and floors causes direct water damage to such components and areas as well as secondary damage including that resulting from mold growth. (An exterior wall system includes exterior and interior finishes, fenestration, structural components and structural components and perimeter units associated with heating, cooling, and ventilation.) Water penetration or leakage is considered problematic if it exceeds the planned resistance or temporary retention and drainage capacity is causing premature deterioration of a building or its contents, or is adversely affecting the performance of other components (Guide E2128). Plumbing leaks and condensation can result in extensive fungal growth.

8.4 Heating/Cooling Systems:

8.4.1 Central forced-air residential heating and cooling systems installed in dwellings are designed to recirculate air. The number of dwellings that are served by central HVAC systems designed to deliver a predetermined outdoor air volume are limited, but such systems when present may be equipped with air-to-air heat exchangers for energy conservation.

8.4.2 Humidification—Humidification systems may be integral to the central forced-air heating system, or may appear in the form of portable (room-sized) units. Humidification systems are designed to inject water vapor into the indoor air and, depending on details of design and maintenance, can become reservoirs for mold.

8.5 Intake and Exhaust Fans:

8.5.1 Local exhaust fans remove unwanted odors from specific areas such as the kitchen and bathrooms and, in some cases, area set-aside for specific hobbies (for example, woodworking, ceramics). It should be noted that many kitchen range hoods do not remove cooking odors to the outdoors. Rather, cooking emissions are recirculated through a grease trap/filter housed in the range hood.

8.5.2 Vent stacks associated with local exhaust fan(s) should be located to avoid re-entrainment of vented material, and the extraction efficiency of the exhaust fan(s) should be optimized by selecting proper flow capacity so that such fans do not depressurize the building. Depressurization of building could interfere with venting of combustion appliances and allow combustion products to spill into interior space.

8.5.3 Whole-house fans, operating via thermostat or user control, can significantly depressurize the building during operation.

8.6 Soil Gas Transport:

8.6.1 The pressure imbalances that drive infiltration/exfiltration also control contaminant entry via soil-gas transport through building surfaces in contact with the soil (7, 8, 9).

8.6.2 Most scientific studies of soil-gas entry are associated with indoor radon (7, 9). Even in areas judged to be of low radon potential, however, significant IAQ problems can prevail from VOCs and other gas phase contaminants present in the surrounding soil (8).

8.6.3 While basements are designed to provide some resistance to soil-gas entry, numerous pathways exist in the form designed joints as well as inadvertent openings.

TABLE 1 Characterization of Building Leakage

Leakage Class	Typical ACH ₅₀	Ventilation
A	1	Balanced ventilation system required
B	2	Balance ventilation system recommended
C	3	Ventilation system (balanced or unbalanced) recommended
D	5	Ventilation system (balanced or unbalanced) recommended for at least some areas of building
E	7	Unbalanced ventilation system possible
F	10	Unbalanced system recommended
G	14	Ventilation system unlikely to be required
H	20	No ventilation system required
I	27	Buildings in this range may be too loose

Source: Ref (6)

concrete. Soil-gas can also diffuse through intact concrete, though at a much slower rate than with pressure-driven flow (7, 9, 10).

8.6.4 Malfunctioning vented sub-floor and sub-slab depressurization systems used in high soil gas areas may add to intrusion of soil gas into indoor spaces.

8.7 Potable Water Supply:

8.7.1 Residential water supplies may carry chemicals to which occupants can be exposed through ingestion, dermal contact, or inhalation (11).

8.7.2 Chemicals conveyed to the indoor environment by the water supply include contaminants subject to volatilization during water use (for example, trichloroethylene, radon). Water delivered by municipal systems may contain disinfection by-products such as chloroform that are produced in the course of normal operations (12). Contamination of domestic well water may be caused by industrial activities (for example, hazardous waste) as well as naturally occurring processes (for example, arsenic) (12).

8.7.3 Among indoor water uses, showering, bathing and hand washing of dishes or clothes provide the primary opportunities for dermal exposure (11, 12).

8.7.4 The inhalation exposure potential for a given water use scenario depends on the source of water, the types and

extents of water uses, and the extent of volatilization of specific chemicals. Such inhalation exposure can occur during various types of residential water use including showering, bathing, toilet use, clothes washing, dishwashing, and faucet use (12, 13).

8.8 Sanitary Drains:

8.8.1 Sewer gases have been of concern for the indoor environment since the inception of indoor plumbing (14). In modern buildings, sanitary drains can become conduits for sewer gas if water in the drain trap evaporates due to infrequent use. If the building interior is under negative pressure, sewer gas can be drawn indoors through the dry drain trap or in the event of sewer line leaks outside the building may be drawn in as part of the soil gas.

9. Overall Strategy and Steps in IAQ Investigations

9.1 Conceptually, the investigation of IAQ concerns is an iterative process that involves information gathering, formulation and testing of hypotheses, problem identification, and problem resolution (Fig. 1). (As stated in section 1.4, problem resolution is not within the scope of this document and thus is shown as box with dotted lines in Fig. 1.)

9.2 The IAQ investigation is the principal means of gathering information on IAQ concerns (symptoms and complaints

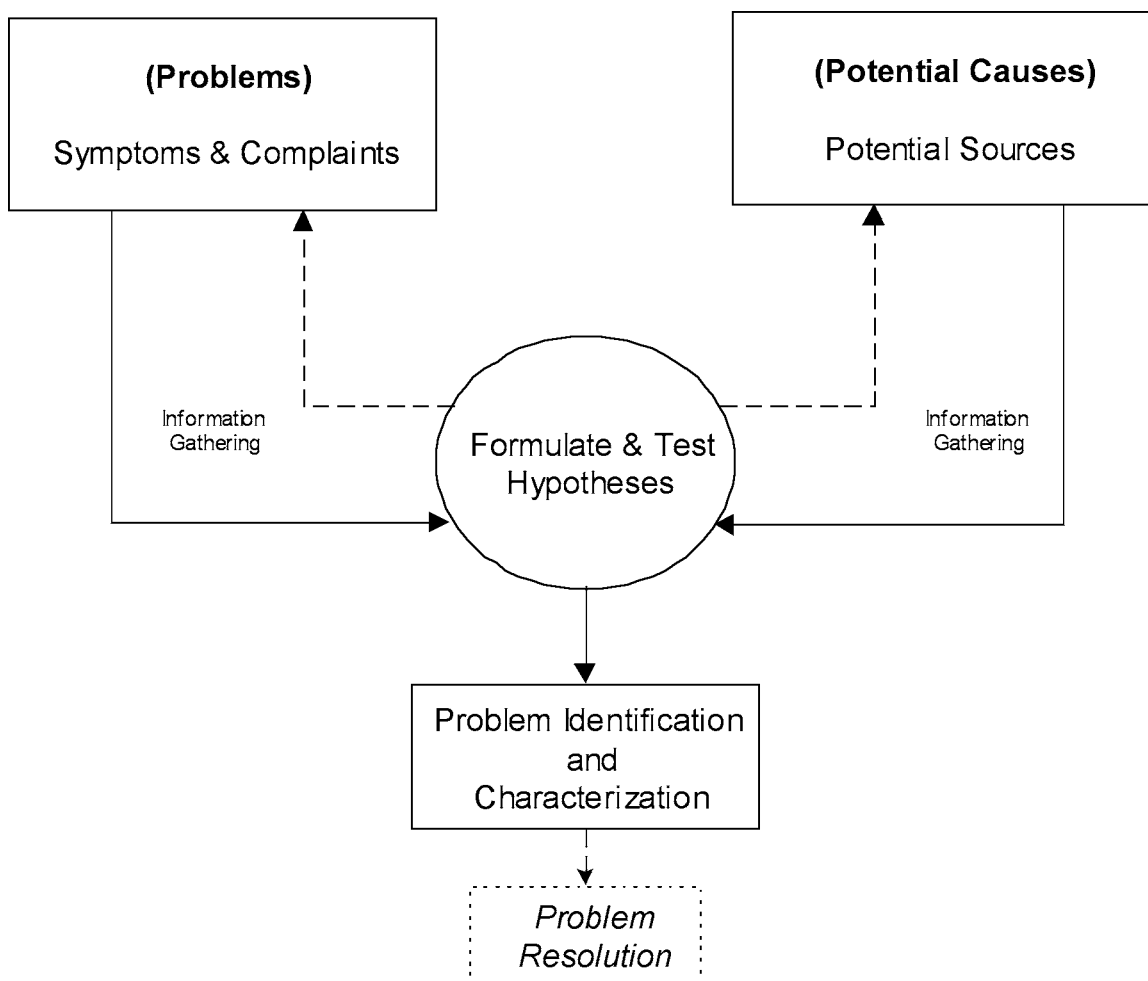


FIG. 1 Iterative Approach to Solving IAQ Problems

elicited through interviews and observation) and information relating to potential causes (as observed or based on measurements conducted by the IAQ Investigator).

9.2.1 Information on IAQ problems and potential sources can be obtained in various ways: (1) from the occupant through interviews, (2) on-site observations by the IAQ Investigator(s), (3) discussion with management and maintenance personnel (for tenant-occupied premises) and (4) on-site testing/monitoring. The concept of testing and monitoring includes medical evaluation as well as environmental monitoring. To diagnose a health problem, medical evaluations are conducted by physicians or other health professionals to assess residents' symptoms, observations by health professional, and results of clinical tests. Environmental monitoring is conducted by the IAQ Investigator to measure air concentrations of selected contaminants.

9.2.2 Reports of allegations of building-related illness may require a physician's diagnosis and assessment of potential exposures. Such medical evaluations may involve interviewing concerned individuals, compiling detailed medical histories, conducting physical examinations and tests by health professionals. IAQ investigators can assist the physician in assessing potential exposure.

9.2.3 Adequate information from both areas—IAQ concerns and potential sources—is necessary for the formulation of hypotheses on potential causes for complaints and for subsequent testing of each hypothesis to accept or reject each provisional theory of causes for complaints. While hypothesis testing leads to problem identification, more than one iteration of hypothesis development and testing may be required, and more than one problem may be identified.

9.3 Development and testing of hypotheses is probably the most challenging part of the IAQ investigation. It requires extensive understanding of factors affecting indoor air quality, and understanding of the practical realities of building systems.

9.3.1 Hypothesis testing is a useful design tool for data interpretation, such as judging the magnitude of measured values compared to criteria. Traditional hypothesis testing is a procedure for deciding whether to accept or reject a statement. The full statement of the statistical hypotheses has three major parts: the hypothesis being tested, a null hypothesis (that is, the statement to be accepted or rejected), and an occasional alternative hypothesis (that is, the statement to be accepted if the null hypothesis is rejected) (15). In both parts, a population parameter is compared to either a fixed value or another population parameter. The population parameter is a quantitative characteristic of the population that the investigator wants to estimate using the data, such as the mean value. Considering that IAQ investigations are not research projects, it is not possible to recommend that the project adhere to statistical hypothesis testing. However, the concepts underlying the development of hypothesis and testing provides a good platform for sharpening the thinking process for the investigation.

9.3.2 For residential IAQ complaints and problems, developing and evaluating hypotheses involves review and analysis of information from various steps or phases of the investigation. In particular, it involves comparing one condition with

another; such that the impact of suspected sources and contributing factors could be identified.

9.4 The IAQ investigation is conducted in separate phases to enhance the effectiveness and management of the investigation. Such phased investigations allow informing the building owner or the cognizant party of the progress and seek approval, including budget approvals, for ensuing work. IAQ investigations are often conducted in phases:

9.4.1 *Phase I*—An on-site interview followed by a walk-through of the building and its surrounding is conducted. The purpose is to understand the problem and identify, to the extent feasible, potential causes. Also developing plans for the next phase (Phase II), estimating resources required, and obtaining approval for the Phase II are also part this effort.

9.4.2 *Phase II*—The purpose is to conduct a detailed assessment of various possible problem areas such as water leakage and systems such as heating/cooling appliances and forced-air distribution. Some of the aspects surveyed in Phase I may need to be repeated to obtain detailed understanding of the building and its systems. Also, certain on-site evaluations such as pressure mapping are conducted to provide insights into potential problems. IAQ problems are often identified in this phase. If they are not identified, then plans are to be developed either to continue further Phase II evaluations or, as necessary, develop hypothesis and plans for contaminant measurements (Phase III). The resources required for Phase III are to be estimated for obtaining necessary approvals.

9.4.3 *Phase III*—Measurement of contaminant levels may aid in identification or confirmation of IAQ problem. Systematic development of measurement and data quality objectives is very important part of Phase III measurements. The results may indicate the need for repeating Phase III or even Phase II.

9.4.4 Fig. 2 provides a flow diagram for the three phases of investigations and emphasizes the iterative process involved in an IAQ investigation. The following steps that are applicable to one or more phases are shown in the figure:

- 9.4.4.1 Conduct initial interview,
- 9.4.4.2 Conduct on-site meeting,
- 9.4.4.3 Identify areas of emphasis for walk-through,
- 9.4.4.4 Conduct exterior survey,
- 9.4.4.5 Conduct interior survey,
- 9.4.4.6 Conduct post-walk-through interview,
- 9.4.4.7 Develop hypotheses,
- 9.4.4.8 Determine measurement parameters and instrumentation,
- 9.4.4.9 Make decision regarding monitoring,
- 9.4.4.10 Conduct monitoring,
- 9.4.4.11 Analyze data and evaluate hypotheses,
- 9.4.4.12 Quality assurance, and
- 9.4.4.13 Report findings.

9.4.5 Note that while analysis of data and evaluation of hypotheses is described in a separate section near the conclusion of the investigation, in actual practice, the analysis of observations and data, evaluation of hypothesis, and their interpretation is a continuous process associated with all steps and substeps of the investigation. It should also be noted that the phases may not always be divided clearly and

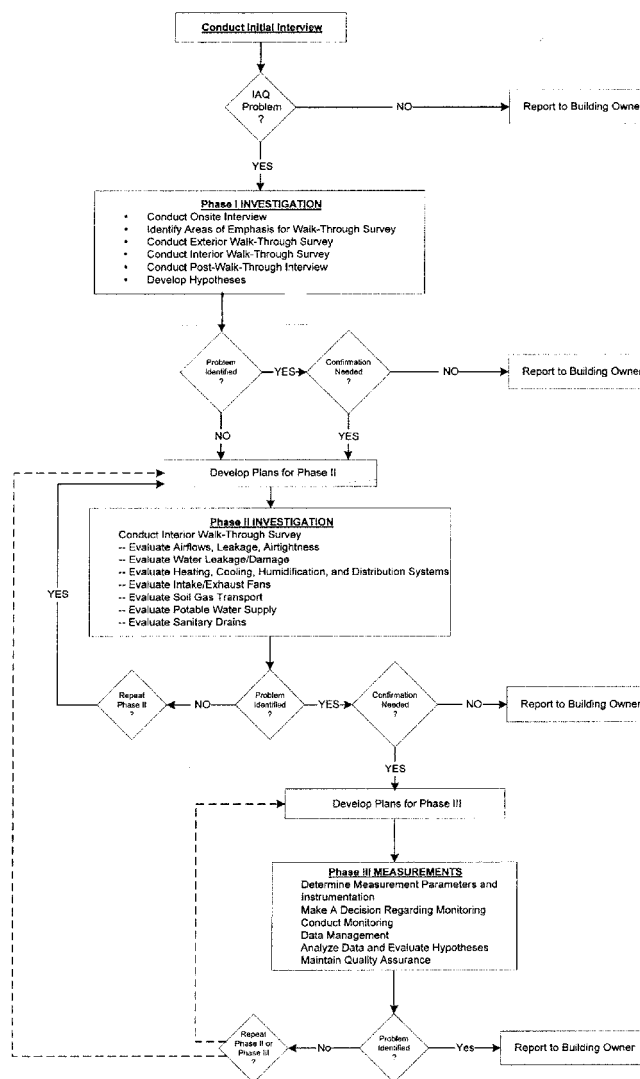


FIG. 2 An Illustrative Flow Diagram for IAQ Investigations

somewhat enmeshed. For example, combining some characterization measurements with inspection and hypothesis testing with detailed inspection may be necessary to limit the number of visits. In any case, the principle of phasing is very important in conducting successful investigations and, thus, any deviation from phasing should be recognized by the investigator in order that the concept itself is not compromised.

9.4.6 Additionally, note that while the steps noted above and described in this practice are focused on IAQ investigations, these procedures may provide a uniform basis for conducting relevant IAQ research.

9.5 Understand Critical Purposes Underlying Major Steps in the Process for Evaluating Residential IAQ Concerns:

9.5.1 Although IAQ investigations to identify a source of the problem described in this practice may give an appearance of being a set of simple or straightforward steps, successful investigations can be very challenging. Thus, to carry out investigations to achieve reliable outcomes, it is essential that investigators understand the *critical purpose* for each major step.

9.5.2 The major steps in the evaluation process outlined above are listed in Table 2. The intent of Table 2 is to emphasize critical purposes underlying each step in the investigation.

9.5.3 Recognize the importance of repeatedly assessing the problem, field observations and potential causes through the investigation. The success of an IAQ investigation often depends on whether or not the investigator has taken the time to step back to assess all field observations and data that have been collected at any given point to determine causes or postulate potential causes.

9.5.4 These evaluation points are called *pause points* and five such pause points are recommended during the investigation process. Table 3 lists these pause points and the type of information, observations, and results to be evaluated.

10. Conduct Initial Interview of Residents

10.1 The initial interview is most likely conducted by telephone. The interview should include questions in the following areas: dwelling information; building history

TABLE 2 Critical Purposes Underlying Various Steps in the Approach for Evaluating Residential Indoor Air Quality Problems

Section	Step	Underlying Critical Purpose
10	Conduct initial interview	To obtain basic information about the complaint, the dwelling, and residents and to confirm the likely existence of an IAQ problem.
11	Conduct on-site meeting	To gain confidence of the residents, and to get their first-hand impressions of the problem, including perceived potential causes.
11.4	Develop plans for walk-through	Pause to focus attention for elements of walk-through based on a best understanding of the perceptions of the problem, its history and its impact on the residents.
11.5	Conduct exterior walk-through survey	To review immediate and nearby surroundings to examine if any of the exterior factors may contribute to the IAQ problem under investigation.
11.6, 11.7	Conduct interior walk-through survey	To review in a comprehensive manner the building envelope, HVAC, appliances, furnishings, drains, water supply, etc., to judge their impact on IAQ and a role in the IAQ problem under investigation. Review Table 1 and related information.
11.8	Conduct post walk-through interview	To gain insights into the resident practices that may have an impact on IAQ and a role in the IAQ problem under investigation.
12	Develop hypotheses	Pause to assemble all information collected thus far into a systems perspective to track IAQ problems back to its possible origin(s) and to develop a specific statement of the problem.
13.2	Determine measurement parameters and instrumentation	To select instrumentation for evaluation of hypotheses.
13.3	Decisions Regarding Monitoring	Pause to evaluate whether or not to conduct measurements based a review of how measurements will help in the evaluation of hypothesis and the investigation in general. If affirmative, establish criteria for measurement parameters.
13.4	Conduct monitoring	To obtain primary data to test the hypotheses.
14	Analyze data and Evaluate hypotheses	To analyze data for testing hypotheses. To accept or reject hypotheses based on the collected data. Based on the outcome either to identify causes of the IAQ problem or to construct new hypotheses for testing and returning to section 12 above.
16	Maintain Quality Assurance	To ensure that defined standards of quality are met; a quality assurance plan should be in force prior to any field operations.
17	Report Findings	To develop the report in a manner that would be appropriate for a court proceeding, if needed, and to share with the resident known details of the investigation and results.

TABLE 3 Pause Points and Problem Assessment

No.	Pause Points	Stages in Problem Assessment: The Type of Information, Observations, and Results to be Evaluated
1	After initial on-site visit and interview	Summary of the problem(s); potential areas to be investigated; plans for walk-through.
2	After walk-through (Phase I) and before proceeding to building and systems characterization	Problem observations; identification, if any at this stage, of potential causes. Proposal for building/systems characterization.
3	After building/system characterization (Phase II)	Identification, if any at this stage, of potential causes of complaints. Rationale, strategy, measurement plan including criteria, and resources for proposed monitoring for Phase III.
4	After completion of Phase III investigation and measurements and analysis	Results of the measurements and comparison with criteria. Conclusions drawn from measurements.
5	After an overall and final evaluation of the problem	Nature of problem(s) discovered, relationship of the problem(s) to the symptoms and complaints, qualitative degree of confidence in such relationships.

of the problem; resident information; and contact and address information. Since the interview is conducted by telephone, the questionnaire scope must be constrained to accomplish information-gathering without unduly burdening the respondent. Note that practical experience has shown that fairly detailed telephone questionnaires can be administered to gather information relating to residential IAQ in time periods that consume no more than 15 to 20 minutes of respondent time [\(16\)](#).

10.2 The initial interview should collect information on the following:

10.2.1 The type of building, year of construction and remodeling, number of bedrooms, and type of major appliances (cooking, water heating, space heating and cooling).

10.2.2 Household characteristics, including number of persons, ages of children and adults, and particular health problems experienced by each person.

10.2.3 The nature and history of the problem as perceived by the resident(s), including any activities or environmental changes that may coincide with the IAQ concern, and any medical evaluations.

10.2.4 The possible outdoor sources known to the resident, such as nearby streets and street intersections, airports, and commercial/industrial facilities.

10.2.5 Other IAQ problem cases and unaffected (that is, control) residences in the neighborhood as far as practical. (The information on other cases and use of controls would be useful if the initial iteration of on-site investigation fails to produce results.)

10.3 The initial telephone interview should request or confirm address and contact information to facilitate subsequent on-site activities.

10.4 An example questionnaire suited to use in the initial telephone interview is given in [Annex A1](#). It should be recognized that this Annex and other Annexes provide *example* questionnaires. Before initiating an investigation, these should be carefully reviewed and modified by the investigator to make them more relevant for the situation. It is also important to recognize that factors other than those related to IAQ can be causing effects or symptoms perceived by residents as IAQ related. Consequently, it is important to recognize that while pre-prepared questionnaires enable data collection in an organized format, any question and answer sessions with residents should be in an open-ended forum so that all information relevant to an investigation is collected.

11. Conduct On-Site Investigation

11.1 The on-site investigation should be composed of the following: (1) initial on-site meeting, (2) walk-through, and (3) detailed interview. This sequence is important because the IAQ investigator needs to engage the resident(s) in the definition and resolution of the problem, and maintain that interest throughout the on-site investigation. This sequence also generally assists in gaining the confidence of the household members that is necessary for acquiring answers later to potentially sensitive questions relating to such as personal habits and possible culpability during the detailed resident interview.

11.2 Support equipment and field supplies necessary to conducting the On-Site Investigation include field data collection forms, a camera, a flashlight, small hand tools like screwdrivers, and a stepladder. Also as detailed later, a few IAQ investigation tools such as a smoke bottle, moisture meter, and temperature gauge could provide useful information during the walk-through without consuming substantial time or resources.

11.3 Conduct Initial On-Site Meeting:

11.3.1 The initial meeting sets the overall tone of cooperation and inquisitiveness for the on-site investigation. This gains the confidence of the resident, and presents the best available information to the IAQ Investigator. The initial meeting also allows the IAQ Investigator to probe into the nature and the history of the problem beyond the initial interview of the resident described above.

11.3.2 Gather the following information during the initial meeting: age of the building, circumstance when was the problem was first noticed, continuous or intermittent nature of the problem, frequency of occurrence, suspected causes, details

on any prior investigations and their results, and any remediation steps undertaken. While collecting such information it should be kept in mind that the central purpose of the meeting is to collect the reasons and clues that lead the occupants to believe that there is a building problem, for example, odors, stains, and/or physiological symptoms that occur when in the building. Toward the conclusion of the initial meeting, solicit the resident's permission to conduct a walk-through, and identify any areas that should be avoided during the walk-through. An example of a data collection form that could be used for the initial on-site meeting is given in [Annex A2](#).

11.3.3 If the IAQ concern is symptom-based, the residents should be asked if they have seen a physician and, if so, written permission should be sought to review results and, if possible, speak with doctor.

11.3.4 If the interviewee has health concerns or asks for medical advice, then they should be encouraged to consult a physician or health-care provider of their choice. (The IAQ investigator should indicate to the interviewee that findings of this IAQ investigation when completed might be appropriate to be shared with the health-care provider, as needed.)

11.3.5 This initial onsite visit is very important opportunity to get an understanding of the nature of the IAQ problem and to gain further insights. Questions on variation in the intensity of the problem with time, season, or a particular situation or condition should be explored with the residents. Similarly, efforts should be made to clarify the problem to the extent possible. For example, if the problem is an offensive odor, but otherwise there are no symptoms (headaches, sinus problems, skin rash), it should be noted that no symptoms accompany the odor that occurs in this building.

11.4 Identify Areas of Emphasis for Walk-Through:

11.4.1 As indicated in Section 9 (Overall Strategy), the walk-through is an integral part of Phase I and, as necessary, for Phase II. The Phase I walk-through involves noting visual observations of qualitative characteristics of each area of the building relevant to the IAQ problem and the Phase II walk-through includes further detailed and semiquantitative investigation with appropriate tests. For example, in Phase I, the investigator is to observe if there are obvious leakage pathways between an integral garage and the remainder of the house, but in Phase II, the investigator can run qualitative tests (for example, visual tracers) to test for air migration. As the line between Phase I and II is not rigid, it is up to the investigator to decide the scope of the walk-through for each phase.

11.4.2 Briefly analyze the information collected through initial interview and initial on-site meeting to identify areas of emphasis for walk-through. This should be done on-site after the on-site meeting to develop investigation strategies that are appropriate to the residence.

11.4.3 In particular, the analysis should identify times, places and people as they relate to the residents' appreciation of the problem:

11.4.3.1 Affected areas within the home that can be compared to nonaffected areas,

11.4.3.2 Nature of contributing factors (seasonality, timing and location of triggering events) and