Designation: D7297 – 14

Standard Practice for Evaluating Residential Indoor Air Quality Concerns[1]

This standard is issued under the fixed designation D7297; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 divided into three separate phases, which may occur over one or more site visits.

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 This practice describes a pathway for characterizing indoor air, though adherence to this practice does not guarantee that an investigator will be able to identify or resolve an IAQ complaint for one or more of the following reasons: *(1)* the diversity of sources and contaminants in indoor air; *(2)* other factors that may affect occupant perception and acceptance of indoor air quality, such as air temperature, humidity, noise, lighting, and psychological stress; *(3)* the range of susceptibility in the population.

1.6 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.

1.7 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.

1.8 *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 applicability 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
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

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.05 on Indoor 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.

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
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 62.2-2010 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings[3]

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 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(s) with the building owner or occupant, or both, and a 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. However, circumstances may require all three phases to occur during a single site visit.

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 legal advice in these matters.

5.4 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:

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

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

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

6.1.3 Microbiological contamination, and

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 or indoor environment, or both, 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 types 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 into 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, protista, and fungal 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**).[4]

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 often expressed 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 sources 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 generate 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 PAHs and other semivolatile organics can come from nearby roadways, industrial sites, and landfills (**3**).

7.3.3.5 Bioeffluents consist of CO_2 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. Microbial VOCs (MVOCs) may be present at levels above odor thresholds.

7.3.3.6 In addition to above groups of sources, chemical interaction between chemicals within the same or different

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

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.

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. The amount of air infiltration or air leakage into a building depends on complex interactions 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 "ranch style" versus a taller and narrower structure) influences the stack effect caused by the temperature differences and the impact of wind conditions. Such stack effects are increased with building features such open stairwells in a multi-floor building.

8.2.2 ASHRAE 62.2-2010 specifies minimum ventilation requirements 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).

8.3 *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 bring in outdoor air are limited, in the U.S. but are becoming more common. However, 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 and other contaminates 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 exhaust air directly 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 (**6**, **7**, **8**).

8.6.2 Most scientific studies of soil-gas entry are associated with indoor radon (**6**, **8**). 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 (**7**).

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 cracks that form in concrete. Soil-gas can also diffuse through intact concrete, though at a much slower rate than with pressure-driven flow (**6**, **8**, **9**).

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 (**10**).

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 (**11**). Contamination of domestic well water may be caused by industrial activities (for example, hazardous waste) as well as naturally occurring processes (for example, arsenic) (**11**).

8.7.3 Among indoor water uses, showering, bathing and hand washing of dishes or clothes provide the primary opportunities for dermal exposure (**10, 11**).

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 (**11, 12**).

8.8 *Sanitary Drains:*

8.8.1 Sewer gases have been of concern for the indoor environment since the inception of indoor plumbing (**13**). 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, though the IAQ investigator can provide recommendations for possible solutions and, if necessary, interim measures for temporary relief.)

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

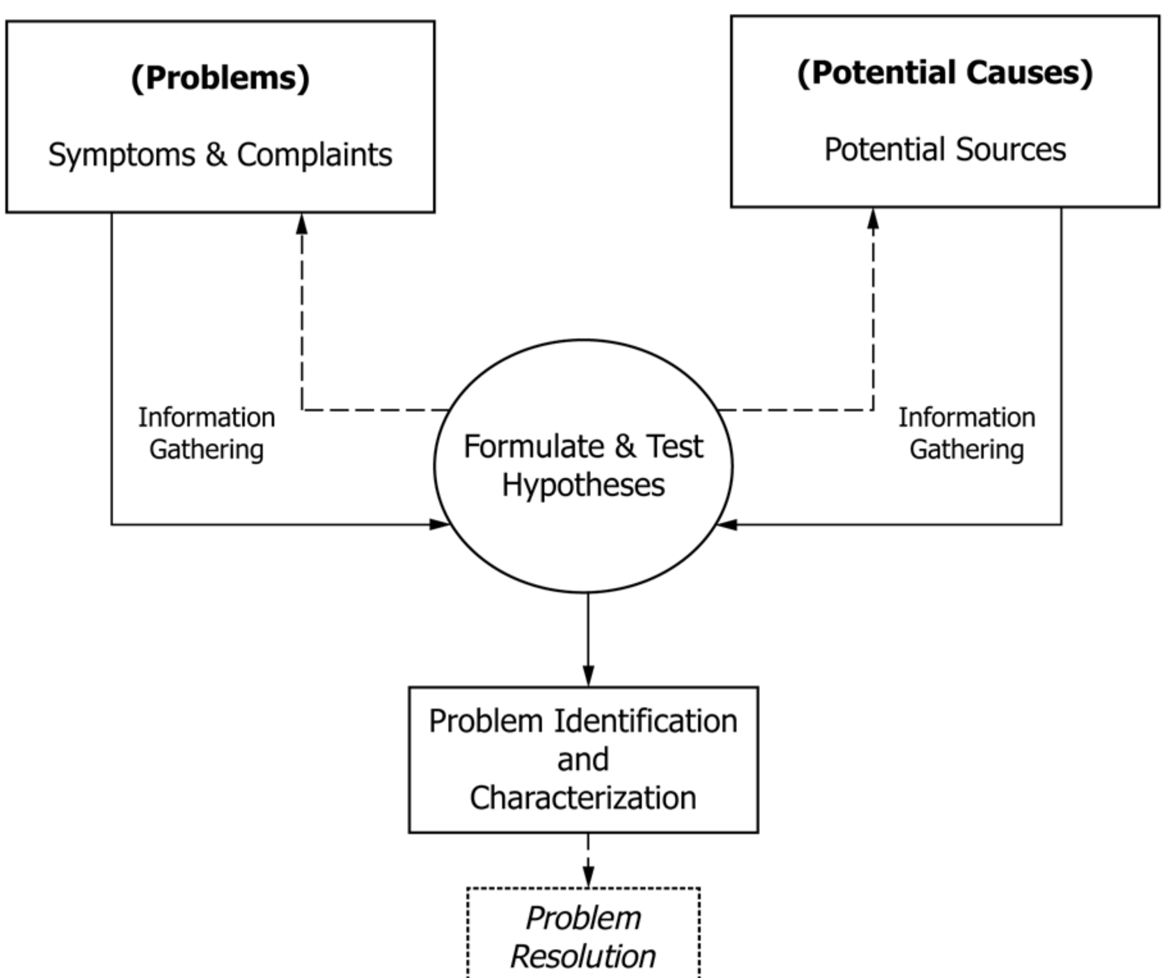

FIG. 1 Iterative Approach to Solving IAQ Problems

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 health professionals interviewing concerned individuals, compiling detailed medical histories and conducting physical examinations and tests.

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 hypothesis 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). 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. Developing plans for the next phase (Phase II), estimating resources required, and obtaining approval for the Phase II are also part of 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 cleanly and could be 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:*

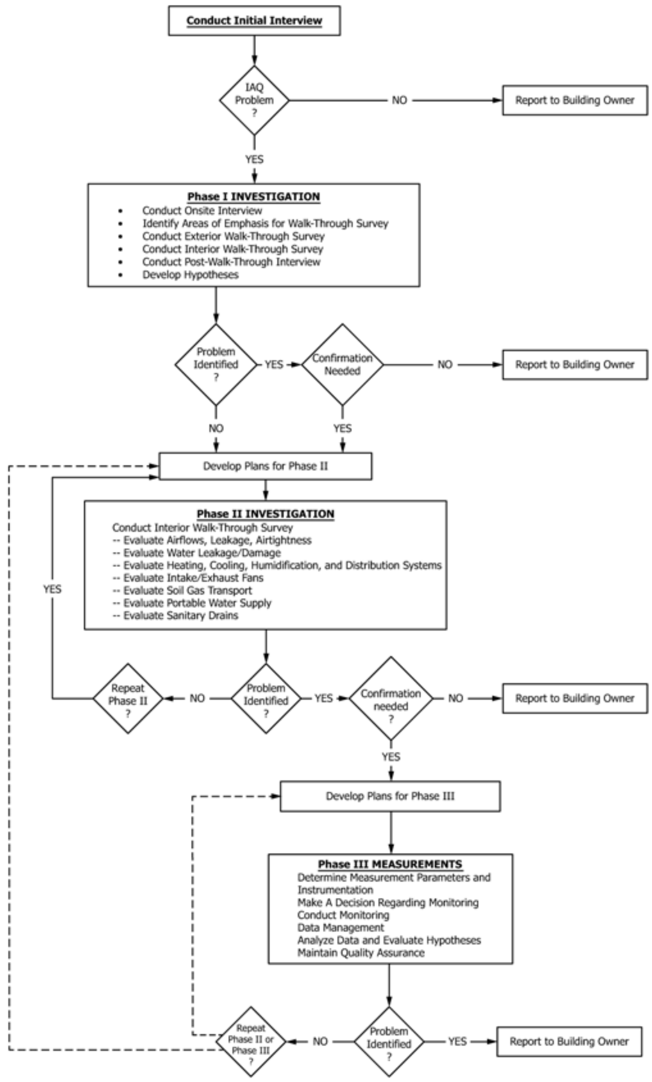

FIG. 2 An Illustrative Flow Diagram for IAQ Investigations

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 1. The intent of Table 1 is to emphasize critical purposes underlying each step in the investigation.

9.5.3 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 2 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 generally conducted by telephone. The interview should include questions in the following areas: dwelling information; nature and the history 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 (**14**).

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).

TABLE 1 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 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 it 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 2 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.

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 The scope of work, including permission to perform a walk-through, should be discussed and agreed upon prior to arriving on site. The investigator should ask if there are any areas to be avoided or excluded during walkthrough. If there are areas such areas, the resident/owner shall be informed that this may impact the IAQ investigation, and limit the identification of sources or causes of IAQ problems.

10.5 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 conduct 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: circumstance when 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, confirm with the resident permission to conduct a walk-through, and identify the areas, if any, that should be avoided or excluded 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 speak with the 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 a 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 the 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

11.4.3.3 Characteristics of affected residents (and possibly visitors) that could relate to heightened sensitivity.

11.4.4 As necessary, seek clarification from the resident on above and related points.

11.4.5 Make brief notes relating to plans on the Investigation Questionnaire (see Annex A3). Such planning helps the IAQ Investigator to identify areas of the dwelling that will require emphasis.

11.5 *Conduct Exterior Walk-Through Survey:*

11.5.1 The exterior walk-through portion of the IAQ investigation is a *qualitative* evaluation of the building and its surroundings. With the exception of necessary activities associated with ascertaining dimensions of building elements and defining distances between building features, taking measurements is avoided during the exterior walk-through stage. The exterior walk-through should focus on identifying or characterizing biological and chemical sources of indoor air pollutants.

11.5.2 An example of a data collection form that could be used for the exterior walk-through is given in Annex A3.

11.5.3 In conducting the exterior walk-through, observe general conditions in the outdoor environment in the near-vicinity of the home.

11.5.3.1 Evaluate the neighborhood for possible sources of air pollutants that could be drawn into the home. Determine the proximity of the homesite to possible outdoor sources of air pollution that are beyond the property lines, including vehicular traffic, industrial activity, significant expanses of exposed soil, and agricultural activity.

NOTE 1—Substantive analysis of possible commercial/industrial sources beyond the fence-line may require information and insights from the appropriate local air quality authorities.

11.5.3.2 Examine the immediate vicinity of the building (the yard, sidewalks, and street) for the presence of possible sources of air pollutants. Note the presence of outdoor cooking facilities, outdoor wood-fired hydronic heaters, vehicular parking (especially carports, attached garage), and areas of inadequate grading, etc. Information on use of pesticides and other lawn and garden chemicals should be solicited from the resident.

11.5.3.3 Characterize the structure in terms of type of foundation, type of wall construction, sheathing, type of roof, etc.

11.5.3.4 Examine the building's foundations for evidence of structural/maintenance flaws related to possible entry of outdoor pollutants and accumulations of water. Note blocked gutters, condition of splash-blocks, presence of low spots, and standing water. Note all mechanical equipment intakes and outlets such as plumbing vents and dryer vents, chimneys, exhaust vents for bath and kitchen fans. Resolve any discrepancies between known indoor exhaust appliance and outlets found on the outside of the building, that is, each combustion device, exhaust fan, drier should have an outlet, each outlet should have an indoor device).

11.5.3.5 Examine the condition of building exterior. Note the presence and condition of designed apertures, adventitious openings, and structural flaws. Note flaws in cladding, windows, doors, and trim, especially as they relate to possible entry of outdoor pollutants, and water penetration. Note any signatures of current or past adverse conditions (for example, wood rot, mold/algae, blocked gutters, surface staining, etc.).

11.6 *Conduct Interior Walk-Through Survey—Phase I:*

11.6.1 The purpose of the Phase I walk-through survey is to note qualitative characteristics of each area of the building, building systems, appliances, and other features relevant to IAQ problems.

11.6.2 Observe and record general features of the home interior, layout, and contents, including number and placement of specific-use rooms (kitchen, baths, bedrooms, etc.), heating/cooling systems, water supply, air cleaners and other appliances, furnishings, sanitary drains, and other potential sources.

11.6.3 In each room (including closets), observe and record the presence of unexpected odors, excessive dust accumulation, excess moisture, evidence of water penetration, visible staining on walls, carpets, and other surfaces (be especially careful to note patterning of such stains as it relates to structural, thermal, and flow considerations) and other potential sources of airborne pollutants. Note any additional factors that may be associated with the underlying problem (for example, insect or rodent infestation, household pets).

11.6.4 For residences equipped with an integral garage, note any obvious flow paths that could connect the garage with the rest of the home (including condition and fit of connecting doorway, presence of supply/return ducts). Observe and record the presence of potential sources stored in the building or the garage (for example, gasoline, paints, garden chemicals, etc.).

11.6.5 In the basement, observe and record the general condition of the foundation, wall finishes and floor coverings, noting possible areas of soil gas entry, airflow/pressure patterns, floor drain, whether air is moving in floor drain, and doormat or track-off systems at entries.

11.6.6 Observe and record the location and general operating condition of the HVAC system(s) and other major appliances, including the following:

11.6.6.1 Central forced-air system(s) for heating and cooling (note control sequences, condition of filter(s) and drain pans, note whether cooling coil and drain pan have access to allow inspection and cleaning), any direct mechanical ventilation or outdoor air intakes, and location (mechanical closet, garage, crawlspace, or attic);

11.6.6.2 Humidification systems (integral to central HVAC system or portable); note evidence of inadequate maintenance general condition and, for integral systems, observe whether there is evidence of moisture carryover into the HVAC system;

11.6.6.3 Through-the-wall, and/or window-mounted air conditioner(s) (note condition of filter(s) and damper position for each appliance); and

11.6.6.4 Auxiliary space heaters (woodstoves, kerosene heaters, freestanding gas and/or electric).

11.6.7 Observe and record general operating condition of all fans (exhaust as well as recirculating). Note the color and apparent texture of any visible accumulations on fan housing, fan blades, and/or lint traps.

11.6.8 In the kitchen, observe operation of range hood (and/or ceiling exhaust), note condition of associated ductwork, note whether the design is of the recirculating type or exhausts to the outdoors.

11.6.9 In each bath, observe operation of exhaust fan for adequacy of flow. Note any evidence of surface mold or moisture accumulation.

11.6.10 In the laundry area, observe operation of automatic clothes dryer, note condition of associated vent (including exterior outlet). Note any stored chemicals, evidence of surface mold, or moisture accumulation in the laundry area.

11.6.11 Observe and record general operating condition of powered whole house fan (if present).

11.6.12 In the main residential area, observe and record type and condition of doormats and other track-off systems at each entry, furnishings, decorations and wall/floor coverings. Note any odors that could be correlated with residents' complaints. Note evidence of repairs, new furnishings, wall coverings, and/or carpet.

11.6.13 Sewer gas entry can be evaluated by direct inspection for odors and visual evidence of leaking waste pipes. Observe and record the condition of drain traps and that there is standing water in the traps.

11.6.14 Observe and record the type of water supply.

11.6.15 Observe and record the location of radon subslab depressurization system, if any. A significant body of practical diagnostic information has emerged from various studies of indoor radon. This information has been organized into reliable protocols to evaluate the potential for soil-gas entry in specific buildings (**15**, **16**, **17**). These references describe specific procedures to characterize conditions within buildings that may contribute to soil-gas entry. These procedures include visual inspection to identify critical building characteristics that relate to soil-gas entry (for example, large cracks in slabs, exposed earth in crawlspaces, open stairways to basements, continuously running HVAC fans and exhaust fans), as well as instrumented pressure communication testing to provide quantitative information on soil-gas transport.

11.6.16 Observe and record general operating condition of stove, refrigerator(s) and freezer(s).

11.6.17 Observe and record the general condition of special-use areas or equipment such as crawlspaces, attics, pools, enclosed hot tubs, pool equipment rooms, sump pumps, coal storage areas, condition of the vapor barrier (if present) in crawlspaces, or presence of crawlspaces with bare earth floor, etc.

11.7 *Conduct Interior Walk-Through Survey—Phase II:*

11.7.1 Analyze the information collected during the initial onsite meeting, exterior walk-through survey, and Phase I interior walk-through survey to develop plans for Phase II. The analysis focuses on identifying events in terms of times, places, people, activities and mechanisms that could be responsible for problems noted by the homeowners.

11.7.2 Phase II is an opportunity to obtain additional, specific information for areas identified in Phase I as important or relevant to the IAQ problem. The collected additional information includes additional observations as well as selected characterization measurements. Note that characterization measurements do not imply pollutant concentration measurements, but qualitative or quantitative measurements that provide insights into the problems or possible sources of the problem. These are briefly described below for different areas. Brennan (**18**) presents useful insights into characterization measurements, including tools and test equipment for measurements.

11.7.3 Leading parameters, issues and key circumstances are summarized in Table 3 under broad topics of Building Air Tightness and Airflows, Water and Moisture, Plumbing, and Potable Water Supply.

11.7.3.1 *Building Airtightness and Airflows*—The air tightness of the building envelope can be evaluated using controlled pressurization and depressurization (Test Methods E779 and E1827). Specific leakage pathways can be identified using visual tracers (Practices E1186). Actual transport of air across the building envelope and from room to room can be evaluated using chemical tracers (Test Method E741). Duct leakage from unconditioned spaces may contribute to IAQ problems and could be measured in conjunction with pressurization testing (Test Methods E1554). Handheld digital micro-manometers may be used to check which areas within a building are depressurized in comparison to general or other areas to provide clues for direction of airflows. Similarly, for evaluating the operation of the radon subslab depressurization system, micro-manometers may be used for pressure-continuity testing (**15**). Use of a smoke bottle and micromanometer to assess planned and unplanned airflows in buildings is described by Brennan (**18**).

11.7.3.2 *Water and Moisture Damage*—Staining associated with unwanted water penetration through the building envelope, plumbing leaks, and moisture condensation can be evaluated by direct inspection. Identification of thermal bridging defects in a building may lead to solution of condensation problems. Guide E241 provides a specific listing of visual signs for water damage. Guide E2128 provides specific guidance for evaluating water leakage of exterior walls in terms of design concepts, service history, inspection, and testing. In many cases, remediating condensation of excess water vapor is specifically related to spot ventilation (kitchen and bath) for moisture control (Guide E241). Use of temperature and relative humidity supplemented by moisture content measurements is very useful in determining the extent as well as, in certain cases, source of the moisture (**18**).

11.7.3.3 *Soil Gas Entry*—Testing related to measuring Building Air Tightness and Airflows can be adapted to evaluating soil gas entry. In some cases, indoor radon levels can be

TABLE 3 Parameters and Issues for IAQ Investigations

Parameter or Issue	Relevance	Key Circumstances	Means of Assessment	Guidance
Building Air Tightness and Airflows	Entry Of Outdoor Air Pollutants	Odors And Other Signs Of Outdoor Air Pollutants	Fan Pressurization, Tracer Gas, Visual Tracers	Test Method E779, Test Method E741, Practices E1186
Water and Moisture Damage	Water Penetration, Water Accumulation & Staining, Excess Humidification, Condensation.	Moisture, Odors, Mold Growth	Visual Inspection, Interview, Agent-Specific Standard Test Methods	Guide E241, Guide E2128, USEPA 2001 (**19**), USEPA 1991 (**17**)
Soil Gas Entry	Radon, Excess Moisture, VOCs	Moisture, Odors, Mold Growth, Radon	Visual Inspection, Agent-Specific Standard Test Methods	Little, et al. 1992 (**7**), Tanner 1994 (**8**), USEPA 1993 (**16**), USEPA 1994a (**15**)
Potable Water Supply	Water Leaks, Release of Water-borne Chemicals to Indoor Air	Odor, Legionnaires Disease or Pontiac Fever, Mold Growth	Testing of water sample by co-operating water quality experts	Guide D5952, USEPA 1994b (**20**)
Sanitary Drains	Sewer Gas Entry, Release of Dissolved Gases	Odors, Mold Growth, Municipal Sewer Versus Domestic Septic System	Visual Inspection, Code Adherence, Functioning of Drain Traps	USEPA 1991 (**17**)

quantitatively related to soil gas entry (**8**). Thus, in areas with moderate to high risk of radon, passive sampling with carbon canisters with follow-up analysis is recommended (see guidance from Federal agencies, for example, http://www.cdc.gov/niosh/pdfs/appene.pdf).

11.7.3.4 *Potable Water Supply*—Obvious leaks in the water supply can be identified visually and using moisture meters since the plumbing leaks are continuous and so the materials they wet are always damp. A non-intrusive meter effective depth of greater than ¾ in. is needed to determine whether there is water on the back side of gypsum board. Quantitative evaluation of water quality testing to associate odors and other signs with specific chemicals may require consultation with water quality specialists and laboratory testing. Guide D5952 contains specific guidance for identifying water quality problems associated with *Legionella* and other waterborne pathogens.

11.7.3.5 *Sanitary Drains*—All drains should be checked for drain traps and all drain taps (especially basement floor drains) should be evaluated for sufficient water. A significant body of practical diagnostic information has emerged from various studies of indoor radon. This information has been organized into reliable protocols to evaluate the potential for sewer gas entry (**17**).

11.8 *Conduct Detailed Post Walk-Through Interview:*

11.8.1 The purpose of the detailed post walk-through interview is to assemble and analyze the results of the initial interview, on-site meeting, exterior walk-through, and interior walk-through. This interview is accomplished in Phase I, but may be done in Phase II, if convenient to the building owner. The purpose is to: *(1)* identify missing data (if any), *(2)* evaluate the consistency between residents' perceptions of the problem and technician observations, and *(3)* identify likely causes and solutions.

11.8.2 An example of a data collection form that could be used for the detailed post walk-through interview is given in Annex A4.

12. Formulation of Hypotheses on Potential Causes of Complaints

12.1 As mentioned earlier (Section 9), developing hypothesis to explain potential causes of complaints needs to be an inherent part of the investigation. Developing hypotheses for IAQ investigations means developing one's best understanding about the potential causes or in other words "a theory" that may explain the problem. Given the nature of the problem, developing and testing such theories is an iterative process. The IAQ Investigator should review and analyze information gathered at various stages of the investigation from the initial interview through the walk-through to formulate hypotheses regarding the possible nature of the IAQ problem.

12.2 Review results of initial interview, on-site meeting, walk-through, and detailed post-walk-through interview at the end of each major investigation activity as well as after the post-walk-through interview for the following characteristics to develop hypotheses:

12.2.1 *Characterize* complaints (odor, occupant symptoms, actual medical opinion, etc.). This is critical. Also without trying to do medical evaluations, the complaints should be characterized by affected system (respiratory, dermal, gastrointestinal, CNS) to determine whether suspected air contaminant sources may be involved. *Ascertain* if complaints are intermittent or seasonal;

12.2.2 Relate odors, visible signs (dust accumulations, mold, etc.), and other indicators (structural flaws, malfunctioning equipment) to complaints;

12.2.3 Identify possible sources contributing to the problem (for example, allowing the automobile to idle in an attached garage);

12.2.4 Characterize possible microbial, chemical, and/or physical mechanisms;

12.2.5 Identify possible migration pathways for pollutant transport;

12.2.6 Identify contaminants of concern and contributing parameters (for example, airflows) that could be measured; and

12.3 *Develop* hypotheses relating possible sources to observed problems:

12.3.1 Under ideal conditions, developing a hypothesis implies that the IAQ Investigator has identified one or more specific pollutants and/or sources that can be tested to characterize and eventually solve the problem.

12.3.2 This ideal situation may not prevail because *(1)* environmental findings may coincide with symptoms without causing reported symptoms, *(2)* symptoms may be caused by other, unsuspected pollutants, and *(3)* concentrations of pollutants responsible for reported symptoms may vary over time.

12.3.3 In some cases, it may be possible to artificially control the source(s) and contributing factors and thus establish comparisons over relatively brief periods of time. Exhaust fans may be operated in sequence to pressurize or depressurize a complaint area relative to areas that contain suspected sources.

12.3.4 In other cases, the activity of sources and contributing factors may be inherently sporadic, requiring significant time periods to experience one or more source episodes. Mold growth, for example, is controlled by the moisture availability in the substrate where the growth takes place, and the moisture availability changes more slowly than relative humidity of the indoor atmosphere (**21**).

12.4 In certain cases, it may be useful to perform simple experiments to test the hypothesis. Experiments that allow causing the problem effects to appear and disappear at will are good experiments. Placing suspect odor sources in canning jars and doing a sniff test is a good test of hypothesis, depressurizing a portion of a house (crawlspace, garage, attic, basement) is a way to test a hypothesis about the location of sources. Removing furnishings and masking walls, floors and ceilings with plastic film is another way of testing. A proposed remediation strategy can sometimes be temporarily installed to test a hypothesis. Contaminant measurements before and after trial interventions may be part of testing a hypothesis.

12.5 Document hypotheses for subsequent use. A data collection form that could be used for this purpose is given in Annex A5.

13. Conduct Measurements for Evaluating Possible Causes for Complaints—Phase III

13.1 As a follow-up to Phases I and II, contaminant measurements provide the means to evaluate or confirm possible causes of IAQ complaints. The measurement process can be divided into several steps involving: determining measurement parameters, evaluating instrumentation; and deciding whether or not to make measurements. If measurements are undertaken, then data analysis should concentrate on evaluating the hypothesis developed under Section 12 and, where appropriate, developing and testing additional hypotheses. The steps related to contaminant measurements outlined below are also applicable to other measurements associated with IAQ investigations. For example, even in qualitative investigations of moisture problems associated with mold formation, points described below addressing measurement parameters, instrumentation, data quality objectives, making a decision on monitoring, and conducting monitoring are applicable and should be consulted.

13.2 *Determine Measurement Parameters and Instrumentation:*

13.2.1 Based on hypotheses developed during the investigation, identify potential contaminant(s) of concern that relate to potential sources and identify contributing factors to observed effects manifested in residents' complaints and symptoms.

13.2.2 For each contaminant of concern, determine measurement requirements (**1, 22, 23**). The basic approach entails the following:

13.2.2.1 Identify measurement criteria for each parameter under consideration. Parameters may include building tightness, environmental conditions, contaminant concentrations, and backdrafting. Measurement criteria of particular importance include the level of concern, the analytical range, as well as precision, and accuracy. This type of information is contained in relevant ASTM Standards (see 2.1 and Table 3) as well as in the references listed in Annex A7 and cited throughout this standard practice.

NOTE 2—The measurement criteria for each parameter must be developed based on the problems as observed or inferred from the interviews and walk-through surveys before seeking to identify monitoring equipment. If satisfactory systems cannot be identified, or if the cost of such equipment exceeds practical affordability, it is usually better to forego the measurement than to collect data that fails to represent the problem (**23**).

13.2.2.2 Identify data quality objectives for each measurement parameter in terms of allowable precision, accuracy, analytical range and detection limits.

NOTE 3—Objectives established for precision and accuracy should be sufficient to provide acceptable statistical confidence when comparing a measured value with the level of concern. Similarly, detection limits are well below the level of concern (usually by a factor of ten), and the analytical range extends far enough (usually to at least twice the level of concern) to provide acceptable statistical confidence to judge whether or not a measured value is above the level of concern.

13.2.2.3 Identify contributing factors such as air change, air temperature, operation of mechanical equipment, occupant behavior, etc. that may control underlying processes. For each contributing factor, determine basic measurement requirements and data quality objectives using guidance contained in references (**1, 22, 23**).

13.2.2.4 For each measurement parameter, define monitoring objectives in terms of environmental characteristics to be represented. Include considerations of temporal detail (that is, data reporting intervals for continuous data, sampling periods for integrated data), and spatial detail (that is, number of indoor and/or outdoor locations).

13.2.2.5 Evaluate performance characteristics of available instruments for each measurement parameter in terms of the following:

(1) Data Quality—Precision, accuracy, detection limit;

(2) Sampling Rate and Time—Continuous, point-in-time, or integrated;

(3) Representativeness—Appropriateness of measurement parameter (for example, aerosol size range, specificity of chemical characterization);

(4) Mode—Active (requiring a pump or aspirator) or passive (relying on diffusion);

(5) Output—Continuous, point-in-time, or time-weighted average;

(6) Data Recording—Electronic signal, field observation, or laboratory report;

(7) Mobility—Handheld, portable, or stationary;

(8) Power Requirements—Battery, standard alternating current;

(9) Calibration—Standard atmospheres, co-located references, laboratory, and/or factory procedures;

(10) Equipment Costs—Purchase/lease of equipment;

(11) Facilities Costs—Current/new/outsourcing laboratory and other support; and

(12) Personnel—Training requirements for current staff, new hires, and outsourcing.

13.3 *Make a Decision Regarding Monitoring:*

13.3.1 Based on characteristics of available instrumentation, determine whether or not monitoring should be attempted. Also, consider whether or not critical parameters can be identified and measured and whether or not results can be explained to the resident. As noted above, if satisfactory systems cannot be identified, or if the cost of such equipment exceeds practical affordability, it is usually better to forego the measurement than to collect data that fails to represent the problem (**23**).

13.3.1.1 Available measurement systems may be judged unsatisfactory on technical grounds (for example, unacceptable detection limits, precision, or accuracy; no continuous measurement system available, or integrated sampling is unrepresentative of hypothesized cause-effect mechanisms).

13.3.1.2 Available measurement systems may be judged unsatisfactory on practical grounds (for example, purchase expense, need for additional staff training or outsourcing).

13.3.1.3 If satisfactory system(s) cannot be identified, it is the responsibility of the IAQ Investigator to determine whether or not data collected by less-than-ideal measurement systems has technical value.

13.3.2 If the IAQ Investigator cannot discover acceptable means to accommodate insufficiencies evident from the evaluation of available instrumentation, it is more reasonable to forego a particular measurement than to collect data that fails to represent the problem. If satisfactory system(s) cannot be identified, characteristic odors and other qualitative measures may nonetheless provide adequate information for hypothesis testing.

NOTE 4—Technical and practical evaluations of available instruments should consider measurement parameters in functional groups. A decision to forego contaminant measurements due to inadequate precision and accuracy, for example, would likely lead to similar decisions for affiliated parameters like airflow, even if available instruments were found to be suitable. Such hypothesis testing would lose technical value due to lack of information on related parameters.

13.3.3 Record the parameters selected for monitoring and instruments judged to be satisfactory along with the rationale for decisions. A data collection form that could be used for this purpose is given in Annex A6.

13.4 *Conduct Monitoring:*

13.4.1 If decisions to attempt monitoring are reached and satisfactory measurement systems are identified, then select instruments and assemble support equipment and supplies.

13.4.1.1 As stated earlier, identify and note measurement criteria for each parameter to be measured.

13.4.1.2 Identify standard methods, practices, and guides that define monitoring operations in the field and in the laboratory. For example, the following test methods, practices, and guides published by ASTM merit attention: D4861; D5197; D5438; D5466; D5955; D6196; D6271; D6333; and D6345.

NOTE 5—Additional ASTM test methods, practices and guides are being developed by the cognizant subcommittee (D22.05 on Indoor Air) and all are updated on a five-year schedule. Thus, the ASTM web site (www.astm.org) should be consulted for the latest publications. Examples of additional sources of information that may be useful, but are not updated on a regular basis include a US EPA-published compendium of IAQ-specific method, practices, and guides (**22**). Other references (**1, 23**) contain additional guidance for indoor air quality measurements. Water quality tests may be coordinated through the water utility (if the residence is served by municipal water) and/or appropriate local government agencies (for example, Public Works, Health Department) or through a qualified private contractor laboratory. Water samples should be collected and analyzed in conformance with relevant standard methods, and state regulations if applicable (see, for example, Ref (**20**)).

13.4.1.3 Define field data collection forms that meet the needs of hypothesis testing and monitoring objectives developed previously.

13.4.1.4 Define support equipment and field supplies necessary to conduct IAQ monitoring. Depending upon specific methods selected, support equipment and field supplies will include sample collection media, and data collection forms.

13.4.2 Select monitoring locations and measurement periods that conform with problem history and monitoring objectives. As appropriate, follow guidance offered in Practice D1357.

13.4.3 Conduct field measurements in conformance with standard methods, practices, and guides and in conformance with the quality assurance plan given in Section 16.

13.5 *Data Management:*

13.5.1 Electronic spreadsheets can be used to reduce and compile the measurement data with minimal data entry steps. In particular, many data acquisition systems are designed to transfer stored continuous data directly into desktop computer systems for summary analysis.

13.5.1.1 Convert raw data, as needed, to engineering units in accordance with calibrations.

13.5.1.2 As necessary, calculate engineering parameters, such as air change rates.

13.5.1.3 Review data records for consistency and range limits.

14. Analyze Data and Evaluate Hypotheses

14.1 Evaluate hypotheses developed during the investigation. As emphasized earlier, the development of potential causes and their evaluation based on observations and data collected during any and all phases of investigation is a continuous process.

14.2 If the data collection and analysis leads to the identification of offending sources, note so and examine the need for confirming data. Sometimes the data do not identify the source, but rather may identify a control strategy. In that case, it is not essential to identify a source or contaminant if the problem can be solved.

14.3 If the data collection and analysis fails to identify offending sources, consider developing new hypotheses to explain observed effects, and/or evaluate the need for expanded data collection.

14.4 If the data collection and analysis fails to identify offending sources, reconsider the overall strategy (Section 9), including the use of other cases and use of controls.

14.5 In either case, notify the homeowner of results and provide advice with regards to possible solutions and, as necessary, interim measures that provide temporary relief.

15. Special Considerations for Multifamily Dwellings

15.1 The types of multifamily dwellings include low-rise (up to four stories) and high-rise (more than four stories) design.

15.2 From an IAQ perspective, the major differences between single-family and multiple family dwellings relate to the design of central air handling systems, and the nature of leakage pathways connecting adjoining units. In addition, access to other apartments, common areas, and owner spaces may be limited resulting in a situation where the source of the contaminant or the transport mechanism is outside the spaces available for the investigation.

15.3 If a central forced-air system serves more than one housing unit, general advice derived from experience in commercial buildings is applicable (**24, 25**). These references should be consulted for IAQ investigations of multifamily dwellings to augment the information sought for strategies and investigation procedures described in Sections 9 through 14.

15.4 If the heating/cooling system serves each dwelling unit independently, then the information provided earlier could be applicable, provided the following points are considered:

15.4.1 Interactive airflows can transport air from one dwelling unit to another through various leakage pathways in response to pressure differences created by exhaust fans, differential shading, etc.

15.4.2 Leakage pathways include doorways that open onto common areas (hallways, stairwells and foyers), as well as service chaseways for plumbing and wiring.

16. Maintain Quality Assurance

16.1 A quality assurance plan ensures that defined standards of quality are met. Specific guidance for developing and implementing quality assurance plans is provided in references (**26, 27, 28**). The investigator should have a quality assurance plan in force prior to any field operations (including initial interviews). Such plan should address the following issues:

16.1.1 *Data Quality Objectives*—Quantitative statements of precision, accuracy, method detection limit, representativeness, completeness, and comparability for each measurement parameter;

16.1.2 *Assessment of Data Quality*—Define how the achievement of data quality objectives is measured;

16.1.3 *Documentation Standards*—Define the use of all notebooks and preformatted forms to be utilized in data collection;

16.1.4 *Standard Operating Procedures*—Describe all operations to be carried out in the field, in the lab, and in the office;

16.1.5 *Internal Quality Control Checks*—Describe routine calibrations and performance evaluations necessary to proving reliability;

16.1.6 *System, Performance, and Data Audits*—Describe how the measurement systems are evaluated against independent standards and reference materials;

16.1.7 *Document Control*—Identify what goes into the formal record, and where the records are kept; and

16.1.8 *Corrective Measures*—Describe how data quality problems are recognized and resolved.

17. Report Findings

17.1 The report will typically summarize information for the dwelling, construction characterization, location, and external environment, including type of outdoor sources. Discussions will address *(1)* the Nature of the problem (symptoms and/or complaints, extent of the problem, history, any previous diagnostic or remedial actions), *(2)* Findings (qualitative observations and, as necessary, quantitative measurements), and *(3)* Recommendations (implications for preventive and/or remedial actions be taken to reduce immediate hazard).

17.2 If remedies are proposed, the report should note that subsequent testing may be indicated to verify the success of remedies.

NOTE 6—If subsequent testing indicates that remedial actions are not successful, then further investigations would be required to discover causes.

17.3 Reports produced for IAQ investigations that are associated with litigation support should be completed in conformance with Practice E620.

18. Keywords

18.1 biological contaminants; chemical contaminants; HVAC systems; IAQ investigations; indoor air quality (IAQ); indoor materials; indoor sources; measurements; odor; survey; ventilation; water leakage

ANNEXES

(Mandatory Information)

A1. EXAMPLE FORMAT FOR INITIAL TELEPHONE QUESTIONNAIRE

Hello, my name is ____________. Based on your request/complaint regarding indoor air quality concerns, we would like to help in identifying and diagnosing the problem. A clear diagnosis can go a long way toward potentially resolving the problem. As a first step, can I have a few minutes of your time to find out some general information about your home and the indoor air quality problem that you are facing?

1. a. Which of the following best describes the building in which you live?
   1 [ ] A one-family house detached from any other house
   2 [ ] A one-family house attached to one or more houses
   3 [ ] A high-rise apartment/condominium building (number of stories: ____)
   4 [ ] A low-rise apartment/condominium building (number of stories: ____)
   5 [ ] A mobile home or trailer

2. About when was this building originally built?
   Indicate year built if known ______. Otherwise, check one box below:
   1 [ ] 1995 or later   2 [ ] 1990 to 1994   3 [ ] 1980 to 1989
   4 [ ] 1970 to 1979   5 [ ] 1960 to 1969   6 [ ] 1950 to 1959
   7 [ ] 1949 or earlier

3. Do you own your home or do you rent?
   1 [ ] Owned or being bought by someone in the household
   2 [ ] Rented

3 [ ] Other (specify: ______________________________)

4. Now I'd like to ask you a few questions concerning the indoor air quality problem in your home.
a. Please describe the problem that you have experienced or noticed:
____
____
b. When did you first notice the problem? ____________________________
c. Who are affected? ____
d. What are the symptoms? ____
e. Are certain areas of house affected? If so where? ______________________
f. Do you notice odors? ______________________________________
g. Is the problem present all of the time or does it come and go? ________________
h. Have you or anyone else in the household visited a physician in response to these symptoms? [ ]Yes [ ] No
i. If yes, any health related information pertinent to the indoor air quality problem that you can share with us: __________________
____

5. a. Has there been any remodeling or construction since you moved into the house?
1 [ ] No (skip to Q6) 2 [ ] Yes (continue with parts b and c)
b. When was the last remodeling or construction? _____________________
c. What remodeling and construction activities were involved?____________________
d. Have you noticed any problems since that time? ____________________

6. Has anyone else investigated this problem?
1 [ ] No
2 [ ] Yes → What type of individual or organization did the investigation? ____
____
When was the investigation performed? ____
What did they do? ____

7. As I mentioned at the beginning, we would like to help you in identifying and hopefully solving any problem. As part of this investigation, we would like to visit your home. Our visit will last about 3-4 hours and will involve us recording some information inside and outside your building, taking some pictures, and taking some simple measurements.
Would it be OK for us to make an appointment to visit you?
1 [ ] No
2 [ ] Yes → What days of the week and times would be most convenient? ____

8. What is the address for your home (this building)?
(Obtain as much information as permitted by respondent.)
Telephone: ____
Street Address: ____
City: _______________________ State: _____ Zip: _______
Nearest Intersection (include one major road): ____________________________

Additional Notes and Observations:
____
____
____
____
____

A2. EXAMPLE FORMAT FOR INITIAL ON-SITE INTERVIEW/MEETING

Hello. My name is __________ and I am with __________. Regarding the indoor air quality concerns that you have expressed earlier, we would like to first understand the problem and its history. Next we will conduct a walk-through and decide on what measurements to take. Is that OK? May I begin with a few questions?

1. When was this building built?
Year Built: ____________
If unknown → How old do you think the building is? ____________

2. Tell me about the indoor air quality problem(s) you've had in this building:
a. About when did the problem start?
____
____
b. In what area(s) has the problem mainly been occurring?
____
____
c. Can you elaborate on the problem and its possible causes?
____

____
d. What type of treatment(s) have you tried to address the problem?
____
____
e. Who did the work?
1 [ ] Resident
2 [ ] Someone else → What type of contractor?
____
f. Does the problem reappear? If so, how soon?
____
____
g. Have you or anyone else in the household visited a physician or health-care practitioner in response to these symptoms?
[ ]Yes [ ] No
If so, would you write a letter to let him/her know about this indoor air quality investigation and give the doctor and us permission to discuss this further?
[ ]Yes [ ] No
If yes, could we have the telephone number for your doctor?
____
h. Are there any particular areas that you would like us to avoid during our inspection of the building?
[ ]Yes [ ] No
If, yes, why should these areas be avoided?
____
____

3. Now we will begin a walk-through and inspection, which will be followed by sample collection. After that we would like to sit down with you and ask some more questions to improve our understanding of the problem. The question and answer session will take about 30 minutes. Is that O.K.? ______ Yes ______ No.

A3. EXAMPLE FORMAT FOR EXTERIOR/INTERIOR WALK-THROUGH INVESTIGATOR'S QUESTIONNAIRE AND NOTES

Notes from Plans for Walk-through
(The section numbers refer to subsections in the protocol. These are reproduced here for the convenience of the investigator.)
(11.4.3) In particular, the analysis should identify times, places and people as they relate to the residents' perception of the problem:
- Affected areas within the home that can be compared to nonaffected areas,
- Nature of contributing factors (seasonality, timing and location of triggering events), and
- Characteristics of affected residents (and possibly visitors) that could relate to heightened sensitivity.

EXTERIOR WALK-THROUGH
General Neighborhood
(11.5.3.1) Evaluate neighborhood for possible sources of air pollutants that could be drawn into the home. Determine proximity of the homesite to possible outdoor sources of air pollution that are beyond the property lines, including vehicular traffic, industrial activity, significant expanses of exposed soil, and agricultural activity. Note: Substantive analysis of possible commercial/industrial sources beyond the fence-line may require information and insights from the appropriate local air quality authorities.

1. General character of neighborhood/vicinity
1 [ ] Industrial 2 [ ] Commercial
3 [ ] Urban/suburban 4 [ ] Rural
2. Traffic density near the home
1 [ ] High 2 [ ] Moderate 3 [ ] Low
Approximate distance (miles) and compass direction to nearest major highway/artery _____________
3. Are there any notable sources of air pollution in the general vicinity of the home? (as necessary, drive around the local area.)
1 [ ] No
2 [ ] Yes → Type(s) of source _____________________________________
Proximity (miles) and compass direction ___________________

Immediate Vicinity
(11.5.3.2) Examine the immediate vicinity of the building (the yard, sidewalks, and street) for the presence of possible sources of air pollutants. Note the presence of outdoor cooking facilities, vehicular parking (especially carports, attached garage), use of pesticides and other chemicals in the yard, areas of inadequate grading, etc.

a. Are there any notable sources of air pollution in the immediate vicinity of the home? (Go around the home and the yard.)
1 [ ] No
2 [ ] Yes → Type(s) of source _____________________________________
Proximity (feet) _____________________________________
b. Ask the resident about use of lawn and garden chemicals including types, brands, generic names if available and frequency of applications.
____
____

Structure/Exterior Envelope
(11.5.3.3) Characterize the structure in terms of type of foundation, type of wall construction, sheathing, type of roof, etc.

a. Draw a schematic diagram of the outer perimeter of the home in the box below:

(Show north)

(Front of the property)

b. Type of Building

[ ] Single family detached	[ ] Townhouse	[ ] Duplex/Triplex
[ ] Low-rise apartment	[ ] High-rise	[ ] Mobile Home
[ ] Other ____________		

c. If single family detached, type of home:

[ ] Ranch	[ ] Colonial	[ ] Split Foyer

d. Number of stories:
Dwelling unit __________________
Above Ground: __________
Basement (Interior Access): __________
Basement (Walk-out): __________
The entire building (if an apartment building) ______________

e. Foundation

[ ] Crawlspace	[ ] Slab-on-Grade	[ ] Basement

Condition: ____

f. Wall construction

[ ] Frame	[ ] Masonry	[ ] Brick

Condition: ____

g. Siding/sheathing

[ ] Vinyl	[ ] Wood	[ ] Aluminum	[ ] Brick

h. Roof

[ ] Sloped	[ ] Flat

Condition: ____

i. Attic
1 [ ] Unfinished 2 [ ] Finished
Condition related to potential rainwater penetration:
____
Condition related to insulation:

____

j. Garage/carport

1 [ ] None	2 [ ] Carport	3 [ ] Detached garage
4 [ ] Attached garage		5 [ ] Integral/underground garage

k. Fraction of exterior doors/windows with storms, double/triple-pane glass, or protective coverings such as plastic during the winter (verify with occupant)

1 [ ] All	2 [ ] Most	3 [ ] About half
4 [ ] A few	5 [ ] None	

Conditions around windows:

____

l. Chimneys/Flues

Number	Type	Location(s)
____	Masonry	_________
____	Brick	_________
____	Masonry	_________
____	Other	_________

Potential for water accumulation and penetration:

____

Drainage

(11.5.3.4) Examine the building's foundations for evidence of structural/maintenance flaws related to possible entry of outdoor pollutants and accumulations of water. Note blocked gutters, condition of splash-blocks, presence of low spots, and standing water. Note all mechanical equipment intakes and outlets such as plumbing vents and dryer vents, chimneys, exhaust vents for bath and kitchen fans.

(11.5.3.5) Examine the condition of building exterior. Note the presence and condition of designed apertures, adventitious openings, and structural flaws. Note flaws in cladding, windows, doors, and trim, especially as they relate to possible entry of outdoor pollutants, and water penetration. Note any signatures of current or past adverse conditions (e.g., wood rot, mold/algae, blocked gutters, surface staining, etc.).

Gutters/downspouts adequate? _________________

Splashblocks adequate? _________________

Standing water or damp soils near building? _________________

Summary of General Conditions Pertaining to Entry of Air Pollutants and Penetration of Water Through the Exterior Envelope

Potential for outdoor air pollutants in the vicinity:

____

____

Potential for air-pathways through the envelope (siding, foundation, garage, etc.):

____

____

Potential for water accumulation:

____

____

Potential for water penetration (roof, siding, foundation, etc.):

____

____

INTERIOR WALK-THROUGH

General Layout

(11.6.2) Observe and record general features of the home interior, layout, and contents, including number and placement of specific-use rooms (kitchen, baths, bedrooms, etc.), heating/cooling systems, water supply, air cleaners and other appliances, furnishings, sanitary drains, and other potential sources. *Use the floor plan sketch form.*

Potential IAQ Problems

(11.6.3) Using the floor plan sketch form, observe and record the presence of unexpected odors, excessive dust accumulation, excess moisture, evidence of water penetration, visible staining on walls, carpets, and other surfaces (be especially careful to note patterning of such stains as it relates to structural, thermal, and flow considerations) and other potential sources of airborne pollutants in each room (including closets). Note any additional factors that may be associated with the underlying problem (e.g., insect or rodent infestation, household pets).

Flow Paths

(11.6.4) For residences equipped with an integral garage, note any obvious flow paths that could connect the garage with the rest of the home (including condition and fit of connecting doorway, presence of supply/return ducts). Use the floor plan sketch form. Observe and record the presence of potential sources stored in the building or the garage (e.g., gasoline, paints, garden chemicals, etc.). *Use the floor plan sketch form.*

Basement

(11.6.5) In the basement, observe and record the general condition of the foundation, walls, and floor coverings. Note possible areas/points for soil gas entry and water intrusion. Note whether the basement is finished or unfinished. *Use the floor plan sketch form.*

Floor Plan Sketch

Floor ______		Observe all floors, walls, and ceilings and note the following. (Use symbols given below to indicate potential problem areas.) **D** Dust accumulation **F** Potential flow paths for air intrusion **G** Potential for soil gas entry **I** Insect / rodent infestation **M** Mold/Mildew Or excess moisture **N** New furnishings **R** Recent remodeling **S** Potential sources of air pollution **W** Potential points for water intrusion
Floor ______		
Floor ______		
Floor ______		

HVAC System

(11.6.6) Observe and record the location and general operating condition of the HVAC system(s) and other major appliances, including the following:

• Central forced-air system(s) for heating and cooling (note control sequences, condition of filter(s) and drain pans (if accessible), any direct mechanical ventilation, and location (mechanical closet, garage, crawlspace, or attic);
• Humidification systems (integral to central HVAC system or portable); note evidence of inadequate maintenance general condition and, for integral systems, observe whether there is evidence of moisture carryover into the HVAC system;
• Through-the-wall, and/or window-mounted air conditioner(s) (note condition of filter(s) and damper position for each appliance); and
• Auxiliary space heaters (woodstoves, kerosene heaters, freestanding gas and/or electric).

a. Observe and record the location and general operating condition of the HVAC system(s) and other major appliances, including the following:
• Central forced-air system(s) for heating and cooling (note control sequences, condition of filter(s) and drain pans (if accessible), any direct mechanical ventilation, and location (mechanical closet, garage, crawlspace, or attic);
• Humidification systems (integral to central HVAC system or portable); note evidence of inadequate maintenance general condition and, for integral systems, observe whether there is evidence of moisture carryover into the HVAC system;
• Through-the-wall, and/or window-mounted air conditioner(s) (note condition of filter(s) and damper position for each appliance); and
• Auxiliary space heaters (woodstoves, kerosene heaters, freestanding gas and/or electric).
Use the floor plan sketch form.

b. How many heating/cooling systems are there? ________________________

c. Zonation (use for central forced-air systems only):
Number of heating/cooling zones: ______________________________
Locations of return vent(s): ________________________________
Rooms with no supply vent:__________________________________
Additional Notes: ____

d. Put “1” that best describes the main heating system. Put “2” that best describes the second heating system:
1 [ ] Hydronic (Steam or hot water)
2 [ ] Electric Baseboard
2 [ ] Central forced-air furnace with ducts to individual rooms

3 [ ] Electric heat pump with ducts to individual rooms
4 [ ] Other built-in electric units or portable electric heaters
5 [ ] Floor, wall, or pipeless furnace
6 [ ] Room heaters with a flue, burning gas, oil, or kerosene
7 [ ] Room heaters without a flue, burning gas, oil, or kerosene
8 [ ] Fireplaces, woodstoves, or coal stoves
9 [ ] No heating equipment

e. Which fuel is used most for heating? Put "1" for main and "2" for the second heating system:
1 [ ] Pipeline (natural) gas 2 [ ] Bottled, tank, or LP gas
3 [ ] Electricity 4 [ ] Fuel oil
5 [ ] Kerosene 6 [ ] Wood
7 [ ] Coal or coke 8 [ ] No fuel used

f. Air Conditioning System:
1 [ ] Central forced-air with ducts to individual rooms
2 [ ] Through-the wall units: ________________________________
3 [ ] Window-mounted units: ________________________________
4 [ ] No air-conditioning equipment

g. Heating/Cooling Equipment (Located on Story: ______)
(Nameplate Data)
Furnace make/model: ____________________
Filter type and condition: ____________________
Filter Last Changed/Cleaned ____________________
Boiler make/model: ____________________
Electric Resistance make/model: ____________________
Central Air Cond. make/model: ____________________
Filter type and condition: ____________________
Filter Last Changed/Cleaned ____________________
Heat Pump make/model: ____________________
Filter type and condition: ____________________
Filter Last Changed/Cleaned: ____________________
Window Air Cond. make/model: ____________________
Filter type and condition: ____________________
Filter Last Changed/Cleaned ____________________
Additional Notes: ____

h. Duct lining (use for central forced-air systems only):
1 [ ] Flex Duct 2 [ ] Sheet Metal 3 [ ] Fiber Board
4 [ ] Composite 5 [ ] Other ___________

i. Humidifier (Integral to Central Furnace) Unit 1 of __
Make: ____________________
Model: ____________________
Capacity: ____________________
Location: ____________________
Additional Notes: ____

j. Humidifier (Portable or room-sized) Unit 1 of __
Make: ____________________
Model: ____________________
Capacity: ____________________
Location: ____________________
Additional Notes: ____

k. Humidifier (Portable or room-sized) Unit 2 of __
Make: ____________________
Model: ____________________
Capacity: ____________________
Location: ____________________
Additional Notes: ____

l. Humidifier (Portable or room-sized) Unit 3 of __
Make: ____________________
Model: ____________________
Capacity: ____________________
Location: ____________________
Additional Notes: ____

m. Water Heater Unit 1 of __
Make: ____________________
Model: ____________________
Capacity: ____________________
Story: ____________________
Unit 2 of __
Make: ____________________
Model: ____________________
Capacity: ____________________
Story: ____________________
Additional Notes: ____

Fans

(11.6.7) Observe and record general operating condition of all fans (exhaust as well as recirculating). Note the color and apparent texture of any visible accumulations on fan housing, fan blades, and/or lint traps.

(11.6.8) In the kitchen, observe operation of range hood (and/or ceiling exhaust), note condition of associated ductwork, note whether the design is of the recirculating type or exhausts to the outdoors.

(11.6.9) In each bath, observe operation of exhaust fan for adequacy of flow. Note any evidence of surface mold or moisture accumulation.

a. Ventilation:
Fresh Air Intake Location:_____________
Air-to-Air Heat Exchanger (if present)
Make: ____________________ Model: ____________________
Nameplate Rating: ___________
Filter type and condition: ____________________
Filter Last Changed/Cleaned: ____________________
Additional Notes:
____
____

b. Range:
1 [ ] Electric 2 [ ] Gas w/o pilots (electronic ignition) 3 [ ] Gas with pilots
Make: ____________________ Model: ____________________
Story: ____________________
Additional Notes:
____
____

c. Kitchen Exhaust Fan
1 [ ] None 2 [ ] Ceiling fan
3 [ ] Wall fan 4 [ ] Downflow exhaust
5 [ ] Hood (vented) 6 [ ] Hood (recirc)
Make: ____________________
Model: ____________________
Capacity: ____________________
Comments:
____
____

d. Bathroom Fans:

	Location (Story)	Fan Present?	Fan Operable?	Moisture Accumulation?
[ ] Master	_____	_____	_____	_____
[ ] Hall	_____	_____	_____	_____
[ ] Half	_____	_____	_____	_____

Additional Notes and Observations:
____
____

Washer/Dryer
(11.6.10) In the laundry area, observe operation of automatic clothes dryer, note condition of associated vent (including exterior outlet). Note any stored chemicals, evidence of surface mold, or moisture accumulation in the laundry.
Laundry Area
Story: ____________________

Clothes Washer
Make: ____________________
Model: ____________________
Moisture Accumulation?_______________

Clothes Dryer
Make: ____________________
Model: ____________________
Story: ____________________
Vented to outside? 1 [ ] No 2 [ ] Yes

Whole House Fan
(11.6.11) Observe and record general operating condition of powered whole house fan (if present).
If there is a whole house fan, note condition:
____

New Furnishings
(11.6.12) In the main residential area, observe and record type and condition of doormats and other track-off systems at each entry, furnishings, decorations and wall/floor coverings. Note any odors that could be correlated with residents' complaints. Note evidence of repairs, new furnishings, wall coverings, and/or carpet.
Note any evidence of new furnishings, carpet, wall coverings, etc:
____
____
____

Sanitary Drains
(11.6.13) Sewer gas entry can be evaluated by direct inspection for odors and visual evidence of leaking waste pipes. Observe and record the condition of drain traps. Confirm that all drains have drain traps and that there standing water in the draps.
Evidence of sewer gas entry? _____ Drain Traps Full? ______
Evidence of drain overflows? ____________________________
Additional Notes: ____

Potable Water System
(11.6.14) Observe and record the type of water supply
Source: [ ] municipal [ ] domestic well [ ] Other ______________________

Radon mitigation system(s)
(11.6.15) Observe and record the location of radon subslab depressurization system, if any. A significant body of practical diagnostic information has emerged from various studies of indoor radon. This information has been organized into reliable protocols to evaluate the potential for soil-gas entry in specific buildings (USEPA 1994a, 1993, 1991) (**15**, **16**, **17**). These references describe specific procedures to characterize conditions within buildings that may contribute to soil-gas entry. These procedures include visual inspection to identify critical building characteristics that relate to soil-gas entry (e.g., large cracks in slabs, exposed earth in crawlspaces, open stairways to basements, continuously running HVAC fans and exhaust fans), as well as instrumented pressure communication testing to provide quantitative information on soil-gas transport.

Location(s) of subslab penetration(s): ________________________
Location of vent stack(s) :_________________________________
Installation data: ____
Fan capacity (nameplate data) _____________
Gage reading: __________________________
Evidence of soil-gas entry? _______________
Additional Notes: ____

Kitchen Appliances
(11.6.16) Observe and record general operating condition of stove, refrigerator(s) and freezer(s).
____
____

Air Cleaning Devices
(11.6.17) Observe and record general operating condition of any air cleaning devices
____
____

Special Use Areas
(11.16.18) Observe and record the general condition of special-use areas or equipment such as crawlspaces, attics, pools, enclosed hot tubs, pool equipment rooms, sump pumps, coal storage areas, etc.
____
____

Note: Due to the specialized nature of the PHASE II Investigation forms for Phase II will need to be developed by the investigator on a case-by-case basis.

A4. EXAMPLE FORMAT FOR DETAILED RESIDENT QUESTIONNAIRE

1. On the average, about how often are the following items used in your home?

a. Tobacco → ____ (packs) per	1 [ ] day	2 [ ] week	
b. Candles → Weekdays ____ per	1 [ ] day	2 [ ] week	3 [ ] month
Weekends ____ per	1 [ ] day	2 [ ] week	3 [ ] month
c. Oil lamps → Weekdays ____ per	1 [ ] day	2 [ ] week	3 [ ] month
d. Printers → ____ pages per	1 [ ] day	2 [ ] week	3 [ ] month
e. Copy machines → ____ pages per	1 [ ] day	2 [ ] week	3 [ ] month
f. Clothes dryer → ____ loads per	1 [ ] day	2 [ ] week	
g. Kitchen stove → ____ meals per	1 [ ] day	2 [ ] week	
h. Hair spray → ____ times per	1 [ ] day	2 [ ] week	
i. Oven cleaner → ____ times per	1 [ ] month	2 [ ] year	

2. On the average, about how often is a vehicle started in your garage?
____ days per 1 [ ] week 2 [ ] month

3. Have there ever been any fires in your home?
1 [ ] No 2 [ ] Yes → About how long ago? _____ years or _____ months

4. Have you experienced any flooding or water damage in your home?
If so, please describe what happened and when

Burst Pipes:	1 [ ] No	2 [ ] Yes → About how long ago? ____ years or ____ months
Flooding:	1 [ ] No	2 [ ] Yes → About how long ago? ____ years or ____ months
Leaking Roof:	1 [ ] No	2 [ ] Yes → About how long ago? ____ years or ____ months
Windows:	1 [ ] No	2 [ ] Yes → About how long ago? ____ years or ____ months
Doors:	1 [ ] No	2 [ ] Yes → About how long ago? ____ years or ____ months

Additional Notes:
____
____

5. How often are your humidifiers used? ____

6. About how old is your main heating system?

1 [ ] Less than 2 years	2 [ ] 2-4 years	3 [ ] 5-9 years
4 [ ] 10-19 years	5 [ ] 20 years or older	6 [ ] Don't know

7. Comments/notes on thermostat settings/changes/programming:
Heating: ____
____
Cooling: ____
____

8. Do you have (and use) any of the following supplemental heating appliances?

	No	Yes	Use
Fireplace	1 [ ]	2 [ ]	3 [ ]
Woodstove	1 [ ]	2 [ ]	3 [ ]
Gas log in fireplace	1 [ ]	2 [ ]	3 [ ]
Unvented gas space heater	1 [ ]	2 [ ]	3 [ ]
Kerosene space heater	1 [ ]	2 [ ]	3 [ ]
Electric space heater	1 [ ]	2 [ ]	3 [ ]
Other (specify ________)	1 [ ]	2 [ ]	3 [ ]

9. About how often are the following appliances used in your home?

	Daily	Several x/week	Several x/month	Less often	Never
Fireplace/woodstove	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
Gas log/space heater	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
Kerosene space heater	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
Electric space heater	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
Humidifier	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
Dehumidifier	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]

10. Do you ever notice the smell of the fireplace in your home (that is, the smell of burnt wood or smoke) during times when it is not in use?
1 [ ] Often 2 [ ] Sometimes 3 [ ] Rarely 4 [ ] Never 5 [ ] Not applicable
Comments:
____
____

11. Which fuel is used for your water heater?

1 [ ] Underground (natural) gas	2 [ ] Bottled, tank, or LP gas
3 [ ] Electricity	4 [ ] Fuel oil
5 [ ] Kerosene	6 [ ] Wood
7 [ ] Coal or coke	8 [ ] No fuel used

12. About how old is your water heater?

1 [ ] Less than 2 years	2 [ ] 2-4 years	3 [ ] 5-9 years
4 [ ] 10-19 years	5 [ ] 20 years or older	6 [ ] Don't know

13. When it is cold or windy outside, how often do you notice or feel drafts around …

a. Doors?	1 [ ] Often	2 [ ] Sometimes	3 [ ] Rarely	4 [ ] Never
b. Windows?	1 [ ] Often	2 [ ] Sometimes	3 [ ] Rarely	4 [ ] Never
c. Wall outlets?	1 [ ] Often	2 [ ] Sometimes	3 [ ] Rarely	4 [ ] Never

14. a. During the winter, how often do you notice condensation on your windows?
1 [ ] Almost every day
2 [ ] Only when it is very cold outside
3 [ ] Never
b. When you notice condensation, on how many windows do you usually notice it?
1 [ ] All or most
2 [ ] Some or about half
3 [ ] Few or none
4 [ ] Not applicable
c. Which rooms experience condensation?
[ ] All or most
____
____

15. Are the interior doors in your home mostly kept open or closed?
1 [ ] Open 2 [ ] Closed 3 [ ] Combination of open/closed
Comments:
____
____

16. What pesticides are used?
____
____

____
How often is your home treated with pesticides indoors?
1 [ ] Monthly 2 [ ] Quarterly 3 [ ] Annually 4 [ ] Less often
Comments:
____
____

17. What cleaning products are used, and how often?
____
____
____

18. Has there been any major remodeling or construction activity since you moved here?
1 [ ] No 2 [ ] Yes → When? _______________
Comments:
____
____

19. Have any of the following appliances been replaced in the past 5 years?

Central furnace	1 [ ] No	2 [ ] Yes → When? _______________
Central AC	1 [ ] No	2 [ ] Yes → When? _______________
Water heater	1 [ ] No	2 [ ] Yes → When? _______________
Range/oven	1 [ ] No	2 [ ] Yes → When? _______________
Clothes dryer	1 [ ] No	2 [ ] Yes → When? _______________

20. Have any new furnishings been brought into the house in the past 3 months?
1 [ ] No 2 [ ] Yes
Comments:
____
____

21. Has there recently been any painting or wallpapering in your home?
1 [ ] No 2 [ ] Yes → When? _______________
Comments:
____
____

22. Are any of the following hobbies done in your home?

	Often	Sometimes	Rarely	Never
Woodworking	1 [ ]	2 [ ]	3 [ ]	4 [ ]
Photographic processing	1 [ ]	2 [ ]	3 [ ]	4 [ ]
Artwork	1 [ ]	2 [ ]	3 [ ]	4 [ ]
Lawn/garden work	1 [ ]	2 [ ]	3 [ ]	4 [ ]
Use of lawn/garden chemicals	1 [ ]	2 [ ]	3 [ ]	4 [ ]

Comments:
____
____

23. Provide comments/notes on the history of indoor air quality problems in the home:
____
____

24. If your home is previously owned, provide comments/notes on the history of any staining problems in the home prior to your ownership:
____
____

25. Additional Notes and Observations:
____
____

A5. EXAMPLE FORMAT FOR RECORDING HYPOTHESES

1. Brief description of the problem:
____
____
____
____

2. All possible causes for such problems:
a ____
b ____
c ____
d ____
e ____

3. Likely causes in this case:
a ____
b ____
c ____
d ____
e ____

4. Additional notes and observations:
____
____
____
____

A6. EXAMPLE FORMAT FOR RECORDING DECISIONS REGARDING MONITORING

Parameter	Importance	Availability of Instrumentation that Meet Criteria	Practicality	Benefit

Is there a reasonable chance that monitoring will shed light on the problem and its causes?

Parameter	Yes	No
_______________	[_]	[_]
_______________	[_]	[_]
_______________	[_]	[_]
_______________	[_]	[_]
_______________	[_]	[_]
_______________	[_]	[_]
_______________	[_]	[_]
Decision to monitor:	[_]	[_]

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