CHAPTER 13 SECTION 1
GENERAL INDOOR ENVIRONMENTAL QUALITY INVESTIGATIONS

1. INTRODUCTION.
   The indoor environment is a result of the interaction between many factors - the building’s location, climate, construction methods and materials, renovations, occupant activities, furnishings - to name a few. With the focus on energy conservation in the 1970s came the idea that "tighter is better." Buildings were constructed to prevent infiltration and exfiltration, but compensation was not always made for the loss of natural ventilation. Consequently, the number of employee complaints of sickness in the workplace began to rise, and indoor environmental quality (IEQ) became an occupational health issue. This chapter is not an exhaustive IEQ reference. It is meant to provide general information and a list of references that should be read for a more thorough understanding of IEQ, sick building syndrome (SBS), and building related illness (BRI).

2. DEFINITIONS.
   a. Biological contaminants. Agents that are living or derived from living organisms, such as fungi, bacteria, viruses, and animal antigens. Such biologicals can be inhaled and may cause respiratory irritation and conditions, allergic reactions, hypersensitivity, and may exacerbate asthma. In rare instances, such agents may have caused infectious diseases. Also called microbials, bioaerosols, or microbiologicals.
   b. Building related illness (BRI). Illnesses for which there is a clinically defined etiology and for which there may be confirming laboratory and physical evidence. Examples include legionellosis, psittacosis, and hypersensitivity pneumonitis.
   c. Environmental Tobacco Smoke (ETS). The combination of side stream smoke from a lit tobacco or other smoking product and exhaled mainstream smoke and the emissions from electronic smoking devices. Also called second hand smoke.
   d. HVAC. Heating, ventilating and air conditioning.
   e. Indoor environmental quality (IEQ). The condition of the indoor environment, including such parameters as chemical and biological contaminants, physical hazards, and individual perceptions or reactions to these parameters. Also called indoor air quality (IAQ).
   f. Multiple chemical sensitivity (MCS). A condition whereby an individual experiences adverse reactions or sensitivity to multiple chemicals at extremely low concentrations. As related to IEQ, it is a controversial phenomenon without consensus about its existence, causes, or resolution. Also called environmental illness.
   g. Particulates. Particles, especially allergens and irritants that can be present in the air. They can usually be eliminated through good filtration methods. Particulates may serve as a core or carrier for volatile organic compounds (VOCs) or other chemicals. Also called airborne particulates and total particulates.
h. **Sick building syndrome (SBS).** A condition associated with complaints of discomfort that may include headache, nausea, dizziness, dermatitis, upper respiratory irritation, cough, fatigue, eye irritation, and difficulty concentrating. Specific causes for the symptoms are usually not identified, but may be a combination of chemical, physical, and biological factors, and/or individual differences in sensitivity. Symptoms generally appear after spending some period of time in the work place, but lessen or disappear after leaving the work site. Also called tight building syndrome.

i. **Volatile organic compounds (VOCs).** Refers collectively to the organic vapors that contaminate indoor air. More correctly, the total VOCs (TVOCs) detected during analysis include two subgroups: VOCs (boiling point less than 0 degrees centigrade (°C) to about 260°C) and semi-volatile organic compounds (SVOCs) with boiling points from about 260°C to 400°C. VOC sources include building materials, cleaners, paints, adhesives, cosmetics, solvents, and pesticides. Some VOCs typically associated with IEQ problems include benzene, xylene, toluene, methyl ethyl ketone, limonene, trichloroethylene, formaldehyde, carbon tetrachloride, and other chlorinated solvents. Also called volatiles.

3. **IEQ INVESTIGATION GUIDELINES.**
   a. **General**
      (1) As detailed in reference 13.1-1, the IEQ investigation sequence is:

      (a) For buildings maintained by the Navy:

      1. Individuals report problems to their supervisors.
      2. Supervisors coordinate with the facilities maintenance activity, and activity or region safety manager to resolve or elevate to higher authority if needed.
      3. If local and regional assets are unable to determine the cause of the problem, the safety manager shall request assistance from the Naval Facilities Engineering Command (NAVFACENGCOM) for building-related issues.
      4. If employees in the building are having medical issues, the safety manager will request assistance from the cognizant Bureau of Medicine and Surgery (BUMED) occupational health service.
         a. Refer employees with medical complaints to the supporting occupational health department for evaluation.
         b. Industrial hygiene (IH) will provide assistance, as needed, to help facilities resolve IEQ issues.
      5. If unable to resolve the IEQ issues using the process above, the safety manager shall request further assistance through the cognizant regional NAVFACENGCOM or BUMED offices. For issues beyond the capabilities of the normal BUMED IH service provider, Navy and Marine Corps Public Health Center (NMCPHC) consultation can be requested on a case by case basis, but generally the requested IH support would performed by the cognizant BUMED industrial hygienist.
(b) In buildings where Navy personnel work but is maintained by a private enterprise, report all problems to the appropriate facilities maintenance organization. If they are unable to resolve the problems, contact the activity or region safety manager to resolve or elevate to higher authority, if needed, and continue the same sequence, described above, as for buildings maintained by the Navy.

(2) Facilities maintenance should respond to building issues. Occupational health (OH) should respond to employee complaints of occupational illness.

(3) IEQ evaluations require sound IH knowledge and practice. There is no "magic formula," nor can every investigation be conducted exactly the same way. The industrial hygienist will have to construct an evaluation plan based on employee complaints, visual inspection and professional experience. Most evaluations will involve SBS. BRI cases are less common.

(4) There is no clear definition for "good" IEQ. Reference 13.1-2 defines an acceptable thermal environment as one that a majority of the occupants would find acceptable, based on healthy adults spending fifteen minutes or more in the space. It also identifies six primary factors that affect comfort: metabolic rate (affected by the activity being performed), clothing insulation, air temperature, radiant temperature, air speed, and humidity. Reference 13.1-3 defines acceptable IAQ as “air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction”.

(5) In general, to inhibit any potential mold growth, relative humidity (RH) levels should be maintained below 60%. Additionally, relative humidity should be kept low enough to prevent condensation on windows and other surfaces. You will see varying ranges recommended for RH (e.g. - Environmental Protection Agency (EPA) 30-60% (ideally 30-50%); Centers for Disease Control (CDC) below 50%; Occupational Safety and Health Administration (OSHA) below 70% (preferably 25 - 60%). Reference 13.1-1 notes that unacceptable RH is generally recognized to be below 30% and above 60%.

(6) In most cases it is possible to determine if a problem exists in the complaint area, and to provide recommendations that will reduce or alleviate the problem. Do not dwell on identifying a specific cause for each IEQ evaluation.

(7) A three phase investigation approach is recommended.

(a) Phase 1 - Initial assessment: Evaluate complaints and determine if a problem exists. Rely on observation, interviews and minimum sample collection (usually screening samples such as temperature, RH, carbon dioxide and air flow assessment). Depending on the situation, sometimes, additional screening samples may be done for other chemicals such as carbon monoxide, formaldehyde, oxides of nitrogen, ozone, particulates, radon, sulfur dioxide and/or VOCs). General employee complaint forms or questionnaires and interviews may be useful. An example of such a complaint form would be the reference 13.1-4 Indoor Air Quality Complaint Form.
(b) **Phase 2 - Add detail:** This is warranted if the problem is not resolved with Phase 1, or if Phase 1 reveals that more detailed investigation is needed. Collect additional environmental samples and/or begin quantitative measurements. At this stage, consultation with other professionals for assistance may be needed for further assessment.

(c) **Phase 3 - Exhaustive study:** This step, though rarely needed, will be required when a problem exists but cannot be resolved using standard techniques. This phase entails in-depth and detailed measurement of all potential causative agents, conducting employee interviews, distributing and evaluating questionnaires tailored for the particular investigation, and asking employees to maintain daily logs of their symptoms. An example of such a diary form would be the reference 13.1-4 *Occupant Diary*. Questionnaires should be used sparingly, if at all, because it is difficult to interpret the questionnaire results. Employee interviews are preferred.

(8) Successful investigations often involve a team approach with other professionals (e.g., occupational and preventive medicine, IH, safety, engineering, facilities, maintenance, and/or risk communication staff).

b. **Documentation Review.** Before visiting the complaint site, request and review any existing written documentation pertaining to the IEQ problem. This could include employee complaints or memorandums, minutes of meetings held to discuss employee concerns, previous samples or surveys, pertinent medical information, building ventilation drawings, and building renovation history.

c. **Interviews.** Conduct interviews, as appropriate, with the employer, building or facility manager, employees, OH staff, building maintenance and housekeeping personnel, facilities engineers, and public works personnel.

(1) The goals of interviewing are to gain an understanding of the perceptions of the problem, to identify actual events that may have triggered or be contributing to the SBS or BRI, and to establish open communication with everyone involved.

(2) Use discretion when conducting interviews. It may be most advantageous to interview employees individually and in private. In other circumstances, employees may be more comfortable talking with you at their desks.

(3) Always be honest and non-judgmental. DO NOT show partiality to any group or individual’s side of the story. Only the facts are relevant, and the purpose is to resolve the problem to everyone’s satisfaction.

(4) An example an interview form and additional interview questions that are meant to serve as a starting point for the investigation would be the reference 13.1-4 *Occupant Interview*.

d. **Walk-Around Inspection.** Conduct a visual evaluation. Verify information obtained during the interview process and identify processes, equipment, or procedures that require further investigation. Using a checklist might be helpful. Appendix 13.1-A provides an example of information to inquire about during a walk-around inspection. This is meant as a basic template and information may need to be added or deleted depending on the individual situation.
(1) The walk-around inspection should cover both inside and outside of the complaint office or building, including the work spaces, roof, basement, attic, false ceiling spaces, equipment rooms, smoking areas, crawl spaces, outdoors area, etc... Look for potential contamination sources and problem indicators such as:

(a) Water damage to walls, ceilings and carpets.
(b) Ceiling tiles or wall panels that have been removed.
(c) Chemicals (e.g., copier additives, adhesives, solvents, cleaners, pesticides, perfumes, air fresheners, etc...).
(d) Types and locations of office equipment.
(e) Types and locations of other equipment that could affect the indoor environment (e.g., portable fans or heaters, ionizers, air cleaners, humidifiers, dehumidifiers, etc...).
(f) Check for appropriateness of venting and for leaks in any combustion appliances (e.g. gas water heaters, etc...).
(g) Presence of flickering fluorescent tubes.
(h) Presence of possible glare or other lighting problems.
(i) Presence of new building materials, furniture, carpets, partitions, etc....
(j) Presence of areas where cooking is done.
(k) Presence of areas producing a lot of water vapor (possibly showers, kitchens, etc...).
(l) Presence of laboratory, industrial, maintenance, warehouse, or other types of operations occurring in and around the building.
(m) Location of problem building in relation to adjacent industry, landfills, exhaust/emission sources, airport, agriculture, etc....
(n) Types and locations of any renovation work being done in or around the building.
(o) Location of building outdoor air intake vents (check for possible exhaust re-entrainment).
(p) Evidence of animals (e.g., nests, droppings, etc...).
(q) Odors, unsanitary conditions, poor housekeeping, blocked drains or vents, dry sanitary traps, etc....

(2) Check and record heating, ventilation and air conditioning (HVAC) information such as:

(a) Type of heating/cooling system.
(b) General state of repair/maintenance.
(c) Location and condition of HVAC equipment, including cooling towers, chillers, boilers, air handling units and the HVAC system in general (e.g. - outdoor air louvers/screens (clean/dirty/damaged); outdoor air dampers and settings (adjusted properly/working/blocked); plenums (dirty/clean) and plenum drains (clogged/dirty/clean); fans and motors (working/broken); combustion appliances (e.g. gas furnaces, etc...) (proper venting/improper venting/leaks); cooling and heating coils (dirty/clean); condensate or drain pans or drains (clogged/dirty/clean); humidifiers (dirty/clean); types, location and condition of filters (missing/dirty/clean); types, location and condition of air cleaners (working/broken/dirty/clean); types, location and condition of ducts (dirty/clean); type of duct insulation (none/exterior/interior); condition of duct insulation (dirty/deteriorated); condition of supply and return air grills (dirty/discolored); inappropriately located (e.g., outdoor air intake located near a loading dock) or blocked outdoor air intakes, returns, supply or exhausts; inappropriately located (e.g., in a closet) or blocked thermostats or humidistats, etc...).

(3) Check actual HVAC function (outdoor air damper settings, outdoor air sensors, thermostats, humidistats, overrides or resets for computer-controlled dampers or thermostats or humidistats, economizer operation, fan speeds, filter or collector resistance, airflow, etc...) against design specifications and information obtained from maintenance and engineering personnel.

e. Sample Collection.

(1) In general, air samples should be taken only when there is evidence of an IEQ problem or when employee symptomatology is suggestive of a causative agent. Many investigations can be resolved with little or no sampling. If specific contaminants are suspected after completing the preliminary investigation, collect air samples for the indicated contaminant(s). Otherwise, collect screening samples, and use these results to decide if long-term sampling is warranted.

(a) Screening samples should include, as a minimum, temperature, RH, carbon dioxide, and air flow assessment. Additionally, carbon monoxide, formaldehyde, oxides of nitrogen, ozone, particulates, radon, sulfur dioxide and/or VOCs are sometimes included in the screening phase, depending on the situation.


(2) Samples should be collected at outdoor air intakes, near return air ducts, near potential indoor and outdoor contaminant sources, and in complaint and non-complaint employee work areas. At least one outdoor ambient air sample should be taken for reference. Sampling sites should be representative of complaint, control (i.e., negative), and contaminant source zones.

(3) Sampling should be done throughout the work day, such that both "worst case" and typical periods are likely to be sampled. It may be helpful to have employees keep Occupant Diary/Symptom Logs on sampling days to allow comparison of test results and complaints.
(4) Collecting biological contaminant samples, such as mold, is generally unnecessary, particularly when there is visible contamination. For information on biological contaminant sampling see Chapter 13 Section 2.

f. Ventilation System Testing

(1) Carbon dioxide is a common measurement in IEQ evaluations. It is used as a SURROGATE INDICATOR of ventilation adequacy. (As detailed in reference 13.1-3, a higher incidence of employee complaints has been associated with carbon dioxide levels above 700 parts per million (ppm) over the outdoor air concentrations. This is primarily based on the perception of human bioeffluents (body odor).)

(2) Evaluation of the HVAC system should include:

(a) Air temperature, RH, air flow, and carbon dioxide measurements.

(b) Noting times that the system is turned off

(c) Noting the type/frequency of inspections and maintenance.

(d) Inspection of the HVAC system, including mechanical rooms, control systems, cooling towers, chillers, boilers, air handling units, and HVAC system in general (e.g. - outdoor air louvers/screens, outdoor air intakes and surrounding areas, outdoor air dampers, settings and sensors, plenums and plenum drains, fans, motors, any combustion appliances, cooling and heating coils, condensate or drain pans, humidifiers, drains, filters, air cleaners, ducts, duct insulation, exhausts, returns and supply, air grills, thermostat and humidistat controls, etc...)

(e) Look for such things as poor outdoor air intake, return, supply or exhaust location, closed or blocked dampers, inoperable fans or motors, improper venting or leaks of any combustion appliances, dirty or contaminated coils, moisture problems (standing water or contamination in the condensate or drain pan, clogged drains, standing water, water damaged or contaminated plenums, air handlers or ducts), dirty or missing filters, inoperable or dirty air cleaners, dirty ducts, dirty or deteriorating insulation (particularly if the ducts are insulated on the inside), dirty or discolored supply or return air grills, poor thermostat or humidistat location, etc...

(f) An HVAC checklist could be used for gathering this information. An example of such an HVAC checklist form would be the reference 13.1-4 HVAC Checklist Short Form. Reference 13.1-4 also contains the HVAC Checklist Long Form which also provides useful information.
4. **INTERPRETATION OF IEQ SAMPLING RESULTS.**
   a. Do not collect samples unless prepared to interpret and explain the results. This is especially true when sampling for biological contaminants or when doing scans or "panels" for chemicals. Since there are no IEQ compliance standards, be careful what comparisons are used to interpret data. Use recommendations and guidelines with the understanding that there may be other physical factors (e.g., ergonomic design, noise, vibration, lighting, video display terminal usage, etc...) or less easily defined contributors (e.g., comfort level, stress factors, job satisfaction, psychosocial influence, etc...) involved. Although such factors can profoundly influence the IEQ evaluation, they cannot be easily addressed quantitatively.
   
b. **Appendix 13.1-C** lists some recommendations and guidelines for IEQ chemical and physical sources. Consult the cited references for further information and clarification. For information on interpreting IEQ biological source sampling results see Chapter 13 Section 2. Use extreme caution when interpreting any sampling results for IEQ physical, chemical or biological sources. Individual hypersensitivities can result in IEQ complaints even though sampling results are well below recommended levels.
   
c. Look for patterns in data, symptom onset, and complaint fluctuations (especially as related to changes in, or patterns of, processes within the building). Also, comparing and contrasting results - inside versus outside, complaint versus non-complaint, morning versus afternoon, etc... - are usually more helpful than strict comparison with recommendations.
   
d. Natural fibers (e.g., asbestos) and man-made fibers (e.g., fibrous glass, mineral wool, refractory ceramic, etc...) may be identified as a contaminant source during IEQ investigations. These topics are adequately addressed elsewhere (see references 13.1-8 and 13.1-9).

5. **REMEDICATION.**
   a. Successful IEQ remediation depends on reducing or eliminating air contaminant levels (if found) and addressing health complaints. Unfortunately, IEQ problems are often the result of a combination of factors, some of which may not be easily resolved (i.e., psychosocial influences). Remediation may also be tempered by economics. Inexpensive solutions are more likely to be accepted and implemented by building owners or employers.
   
b. There are “general” guidelines that may be useful, but good IH practice is usually sufficient to alleviate IEQ problems. Never hesitate to consult with engineers (HVAC, mechanical, design, etc...), maintenance personnel, or others who may have expert knowledge of building design, renovation, or maintenance. Solutions are usually a multi-disciplinary effort.
   
c. **IEQ Remediation Guidelines.**
      
      (1) **Ventilation**
      
      (a) Ensuring an adequate supply of fresh outdoor air is probably the single most effective way to resolve IEQ problems (see reference 13.1-3). This may be as simple as opening outdoor air intake louvers or dampers.
(b) Relocate/redesign outdoor air intakes that are entraining outside contaminants. If building exhausts are potential contaminant sources, it may be necessary to raise the stacks or relocate them away from all outdoor air intakes.

(c) Ensure all furnaces and combustion appliances, requiring venting, are properly vented to the outside and regularly checked for leaks to prevent carbon monoxide entering spaces.

(d) Air grills (diffusers) should be open and not blocked to ensure adequate delivery and mixing of air. It may be necessary to relocate desks, bookcases or room dividers to enhance room air mixing.

(e) Unblock or relocate any blocked or improperly located thermostat or humidistat controls.

(f) Routine HVAC preventive maintenance is a must. As a minimum, per reference 13.1-3, it should include inspection and maintenance for such items as: filters and air cleaning devices; outdoor air dampers and actuators; humidifiers; dehumidification coils; drain pans and adjacent surfaces; outdoor air intakes; outdoor air intake louvers, bird screens, mist eliminators and adjacent areas; sensors; air handling systems; cooling towers; and plenums and plenum drains floor drains. Reference 13.1-3 also lists checking the quantity of outdoor air flow provided to air handlers, equipment and component accessibility, visible microbial contamination and water intrusion and accumulation, as part of preventive maintenance. Checking such additional items as: fans, motors, belts, heat exchangers, burners, pilots, proper venting/leaks, compressors, refrigerant, ducts, return and supply air grills, safety devices, thermostat and humidistat controls, etc... are also sometimes included in preventive maintenance plans. (NOTE: Make sure that ALL filters in filter banks are changed during maintenance.)

(g) HVAC system component cleaning should be done following recommended guidelines and practices (see references 13.1-4, 13.1-10, and 13.1-11). Additional information is located at http://www.epa.gov/iaq/pubs/index.html. For information on remediation and cleaning for biological contaminants see Chapter 13 Section 3.

(h) Remove and discard any damaged or damp insulation in the ventilation system. Ventilation ducts should be wrapped with foil-backed insulation rather than using ducts with internal insulation.

(2) Air Treatment

(a) Maintain temperature and humidity as recommended by reference 13.1-2. Also, the Centers for Disease Control and Prevention (CDC) Mold Basic Facts and Environmental Protection Agency (EPA) Mold Resources pages and reference 13.1-12, make a general recommendation of keeping the RH level above 30% (EPA) and below 60% (EPA) and ideally below 50% (CDC and EPA). Generally, RH levels <60% will inhibit mold growth. Additionally, RH should be kept low enough to prevent condensation on windows and other surfaces. Also, reference 13.1-13 notes that studies indicate RH greater than approximately 50% increases indoor dust mite levels.
(b) If contaminants are being introduced from outside, consider additional filtration in the HVAC system. Filters may be needed for particulates, gases, or both. Electronic cleaning devices provide an alternate or additional removal system. (NOTE: If not properly installed and maintained, such electronic devices may generate ozone.) Reference 13.1-3 has guidelines for filters or air cleaners, as needed for HVAC systems located in areas where outdoor air concentrations exceed certain PM10 or PM2.5 particulate or ozone levels.

(3) Source Control

(a) Isolate any areas being renovated, painted or carpeted. Consider having isolated construction areas under slight negative pressure. Consider checking to see that the HVAC system for construction area does not entrain dusts or other contaminants from the renovation and carry them to occupied areas. If isolation is not feasible, consider having the work done when the building is not occupied.

(b) Adjust combustion sources (e.g., furnaces, water heaters) to ensure proper fuel burning. Ensure they are properly vented, regularly checked for leaks and that preventive maintenance is performed.

(c) If contributing to IEQ problems, install local exhausts as necessary to control contaminants generated by specific processes.

(d) Control tobacco use. The Navy and Marine Corps vision is to be tobacco free. Reference 13.1-14 and 13.1-15 prohibit the use of tobacco on all Navy facilities and Navy controlled spaces, except as noted in reference 13.1-15. Reference 13.1-15 describes policy requirements for designated smoking areas, including being located away from building air intakes and points of ingress and egress, etc....

(e) Perform good housekeeping routinely.

(f) Remove chemical emission sources and/or provide non-irritating, “green” environmentally friendly substitutes for building products, furnishings, carpets, paints, cleaners, etc... Recommend using low odor cleaning products.

(g) To control excess moisture, install and use exhaust fans in areas where a lot of water vapor is produced (e.g. – possibly showers, kitchens, bathrooms, etc...). Also, if possible vent any appliances that emit water vapor outside.

(h) Immediately repair any sources of leaking water (water supply pipes, condensers, drains, roof leaks). Ensure buildings have proper grading and drainage to move water away from the building. Eliminate all standing water, especially in air handling units, plenums, condensate or drain pans or ducts. Whenever possible, discard water damaged materials or furnishings (e.g., carpet, wallboard, ceiling tiles, upholstered furniture, insulation, etc...). Thoroughly clean and disinfect remaining water damaged areas. For information on remediation and cleaning for biological contaminants see Chapter 13 Section 3.
6. **FOLLOW-UP.**

a. ALWAYS conduct follow-up assessments. Contact by phone or site visit is recommended within 2-3 weeks following completion of the investigation.

b. If problems persist, consider the following options:

   (1) Revisit the site. Determine which recommendations have been implemented. Is there any change in employee complaints, attitudes or perceptions of employer assistance? Are there any new problems since the initial evaluation?

   (2) Offer additional assistance, particularly if the building manager/employer is unsure of where or how to get started. You may be able to help prioritize recommendations, participate in planning solution strategies, or provide IEQ training.

   (3) Begin Phase 2 or 3 evaluation, if needed.

c. If IEQ problems cannot be resolved locally with facilities maintenance, safety, NAVFACENGCOM, or cognizant BUMED occupational health service resources, request further assistance through the cognizant regional NAVFACENGCOM or BUMED offices, as outlined in reference 13.1-1.

7. **REFERENCES.**


13.1-11


