Indoor Air Quality Tools

Education, Prevention, and Investigation

INDOOR AIR QUALITY WORK GROUP

University of California

Indoor Air Quality Work Group

An Indoor Air Quality Guidance Document

February 2003

Version 2.0

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Introduction

University of California Indoor Air Quality Work Group

The University of California (UC) Indoor Air Quality Work Group (under the auspices of the UC Industrial Hygiene and Safety Committee) is comprised of industrial hygienists and safety professionals from UC campuses and UC National Laboratories. The purpose of the committee is to share on-going indoor air and environment quality (IAQ) investigative strategies and recommendations among its members and provide guidance to fellow IAQ responders. Consequences of poor indoor air or environment quality can be severe both from a health perspective and as an economic burden to the university. Many of these complaints have resulted in workers' compensation claims, litigation, investment of time and resources by employees, regulatory action, and media attention. UC Industrial Hygienists believe IAQ problems should be addressed in a consistent, scientifically sound manner following best practices. The knowledge base for good practice in IAQ investigations and problem mitigation is complex and rapidly evolving. UC Industrial Hygienists and Safety Committee believe there is value in having an ongoing work group of knowledgeable professionals review current IAQ issues and provide system wide guidance to field professionals responding to such complaints from building occupants. Often there is no clear cause and effect relationship found between air quality and a specific complaint during an IAQ investigation. The investigator has a responsibility to bring closure to the complaint and present findings to the complainant. There is no "yard stick" to measure when the investigator has gone "far enough" in reacting to complaints or guidance for differentiating between legitimate IAQ problems and other non-related workplace factors masked as IAQ problems.

In 1999 the UC Indoor Air Quality Work Group, (UCIAQC) wrote the guidance document titled, "Indoor Air Quality Tools - Education, Prevention and Investigation". It includes program elements and implementation strategy for a campus proactive IAQ program and recommends criteria for a consistent approach to reactive IAQ investigations.

Committee Project 2002-2003

1. Revise the existing guidance document to include industry recognized criteria for a consistent approach in responding to IAQ complaints.
2. Revise the existing document to include preventative measures to reduce the number of IAQ complaints.
3. Develop fact sheets for duct liner and duct cleaning.
4. Revise format/organization of the document.

Acknowledgements: The current members of the IAQ Work Group gratefully acknowledge the contributions of Tammy Gee and Brad Horton of UC Davis. Without their editing, word processing and organizational skills, the revision of this Guide would not have been possible.

Current Members 2002 -2003

Daphne Thaung	UC San Diego - Committee Chair
Brent Cooley	UC Santa Cruz
Debbie Decker	UC Davis
Kevin Kaboli	UC Santa Barbara
Paul Giering	UC Riverside
Jimmy Shaw	UC Los Angeles
Carole Fried	Laurence Berkeley National Laboratory
Laurel Davis	Laurence Livermore National Laboratory
Geoffrey Won	UC Berkeley
Alvin Samala	UC Irvine
Buddy Morris	UC Santa Cruz- EH&S Director Liaison

Past Members 2000- 2001

Phil Maynard	UC Berkeley – Committee Chair
Daphne Thaung	UC San Diego
Laurel Davis	Laurence Livermore National Laboratory
Paul Giering	UC Riverside
Kevin Kaboli	UC Santa Barbara
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Buddy Morris	UC Santa Cruz – EH&S Director Liaison

Past Members 1996 - 1999

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Daphne Thaung	UC San Diego
Phil Maynard	UC Berkeley
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Kevin Kaboli	UC Santa Barbara
Alvin Samala	UC Irvine
Gerry Langner	Los Alamos National Laboratory

CHAPTER 1

The information in Chapter 1 generally covers investigating or reacting to IAQ complaints. Subjects addressed include:

- A Protocol for Investigating IAQ Complaints
- Flow Charts that Graphically Represent Possible Phases of an IAQ Investigation
- Narrative Tool to Aid Cause Effect Hypothesis Development for Each Phase
- Forms to Document Findings During the Investigation

A PROTOCOL FOR INVESTIGATING INDOOR AIR QUALITY (IAQ) COMPLAINTS

INTRODUCTION

This chapter describes a practical, consistent, and objective approach to investigating indoor air quality (IAQ) complaints. The accompanying flow charts are based on an investigation protocol developed by the International Society of Indoor Air Quality and Climate (ISIAQ). Forms for documenting findings during an IAQ investigation are taken from various sources including the EPA book "Building Air Quality: A Guide for Building Owners and Facility Managers." The University of California Indoor Air Quality Work Group compiled this set of tools to provide a structured process to aid IAQ investigators in identifying and resolving underlying causes and contributing factors to indoor air quality concerns.

Using this investigation strategy is an incremental process that can involve three separate phases of work. With each progressing phase, data items and the extent of detail involved in the investigation, becomes more technical. It should be emphasized that elements of each phase and the extent of documentation are at the discretion of the investigator. Most UC Industrial Hygienists agree each investigation tends to be different in scope and so are the endpoints at which conclusions can be drawn and closure is reached.

The strategy begins by building a positive relationship with the customer and defining the problem through complaint characterization. As necessary, the heating, ventilating, and air conditioning (HVAC) system is evaluated and other pollutant sources or pathways are identified through a source inventory. Pollutant sampling may be conducted in later stages of the investigation to verify the existence of contaminants in the complaint area and document potential exposure.

The end of each phase affords the investigator the opportunity to develop and test a cause/effect hypothesis. Although a 100% correlation is not expected, findings and observations may reveal inconsistencies that indicate further investigation is necessary. The investigation then proceeds to the next phase. Alternatively, results may also indicate a non-IAQ problem that is cause for termination of the investigation. Communicating findings and next steps to the customer brings a defined closure to each phase of the investigation.

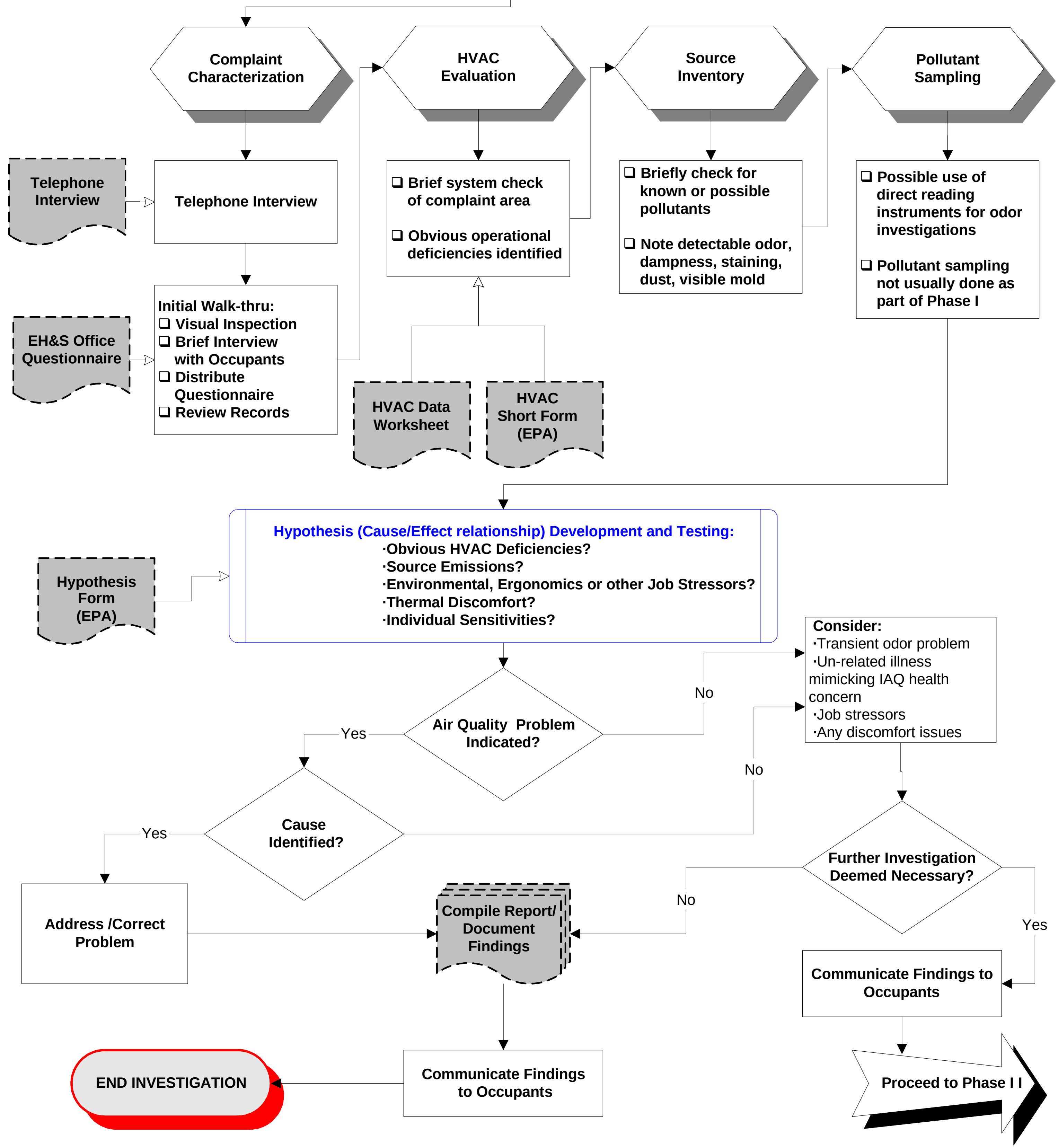
Flow Charts

The University of California Indoor Air Quality Work Group developed these flow charts to provide recommended structure to the IAQ investigation process. *UC IAQ investigators should not feel obligated to follow all steps and use all forms as presented below.* Some investigations may warrant a comprehensive level of detail while others may not. The charts and forms should be viewed simply as a set of tools to assist the investigator in completing a thorough IAQ investigation and are not intended to dictate inflexible criteria for IAQ investigations.

PHASE I - QUALITATIVE INVESTIGATION

UC Indoor Air Quality Program

Begin:
Even in the absence of clinical illness or obvious contamination, IAQ investigators should recognize IAQ concerns are real and potentially serious. Make every effort to effectively evaluate IAQ complaints and inform concerned persons of the investigation results. Clearly state objectives such as: 1) work with Employees, Supervisors and Building Coordinators to resolve short term or easily correctable IAQ problems; 2) initiate corrective actions for more difficult problems by involving other campus units and identifying special needs or controls; and 3) help ensure building occupants maintain a level of confidence in their building's air quality.



PHASE I

QUALITATIVE INVESTIGATION

1. Complaint Characterization

Tools/Forms:

- Telephone Interview (see page 23)
- Environmental Health and Safety Office Questionnaire (see page 24)
- AIHA's The Industrial Hygienist's Guide to Indoor Air Quality Investigations *Appendix D* "Common Problems and Solutions" (see page 20)

The first phase of the IAQ investigation should begin by building a positive relationship with the affected individuals and characterizing the complaint. The complainant may be interviewed using the questions in the "Telephone Interview". The area should be vacated if there is any indication of acute illness that appears to be directly related to the building air quality; if necessary, suggest medical attention and follow the appropriate injury reporting procedures.

A visual inspection of the complaint area should be conducted to check for pollutant sources (*see 3. Source Inventory on flow chart). If available, any complaint records should be reviewed to look for patterns. Brief on-site interviews with the area occupants should be conducted to determine the extent of the complaints. If the problem appears to be widespread, the "Environmental Health and Safety Office Questionnaire" should be distributed to affected personnel.

When used, results of the questionnaires should be tallied to search for patterns that allude to ventilation concerns, source pollutants, medical-related symptoms, or other clues on the causes of the complaints.

Heating, Ventilating, and Air Conditioning (HVAC) System Evaluation

Tools/Forms:

- HVAC Data Worksheet (see page 25)
- (EPA) HVAC Short Form (see page 26)

Conducting a brief evaluation of the HVAC system continues the qualitative phase of the investigation. A quick check of the system can reveal obvious problems such as the inadequate distribution of air, poor mechanical sanitation, and possible pollutant pathways. The "HVAC Short Form (EPA)" form may be used to evaluate some HVAC system elements such as:

a. Location of outside air intake (note proximity to exhaust vents/ducts, high vehicle traffic areas, loading docks, plant material, stagnant water pools, and other possible pollutant sources)
b. Presence of bird screens, if applicable, to deter wildlife from affecting the system;
c. Air volumes-both as specified by design and actual measurement;
d. System test and balance data if available;
e. Condition of the dampers and controls (note any signs of microbial growth, grime buildup, and obstructed operation);
f. Filter type, size, condition, and date of last change-out (note signs of microbial buildup,

proper fit, and an absence of gaps between filters);

g. Fan condition (note any signs of microbial growth, grime buildup, and obstructed operation);

h. Heating/cooling coil condition (note any signs of microbial growth, grime buildup, and deterioration);

i. Drain pans (note any signs of microbial growth, grime and rust buildup, and proper drainage);

j. Presence and adequacy of access panels for maintenance personnel;

k. General sanitation and other obvious HVAC deficiency discoverable by visual inspection.

Collecting system data from the complaint area can enhance the HVAC evaluation. The "HVAC Data Worksheet" (see Form 3, page 25) may be used to record the room volume, supply-air, and return-air volumes. These values are used to calculate the number of air changes per hour, which are then compared to recommended guidelines.

2. Source Inventory

The investigator should look for an obvious source of contamination impacting the complaint area. A more detailed inventory of potential pollutant sources can be collected during the semi-quantitative phase of the investigation.

The initial HVAC evaluation will have already established the basis for a pollutant source inventory. All potential pollutant sources should be noted and may include:

a. Exhaust vents/ducts, high vehicle traffic areas, loading docks, plant material, stagnant water pools, animal nesting sites, and other possible pollutant sources near outside air intakes.

b. Degraded or deteriorated HVAC system elements such as fans, fins, coils, drain pans, filters, and duct and unit lining. These HVAC system elements can also serve as reservoirs for pollutants.

c. Detectable odors.

d. Signs of water intrusion or damage.

e. Dust accumulation.

f. Signs of poor housekeeping.

3. Pollutant Sampling

Generally, pollutant sampling is not conducted during the qualitative phase of the investigation. For odor complaints, direct reading instruments may be used to check for any detectable airborne pollutants and to determine if the odor is an immediate health and safety hazard.

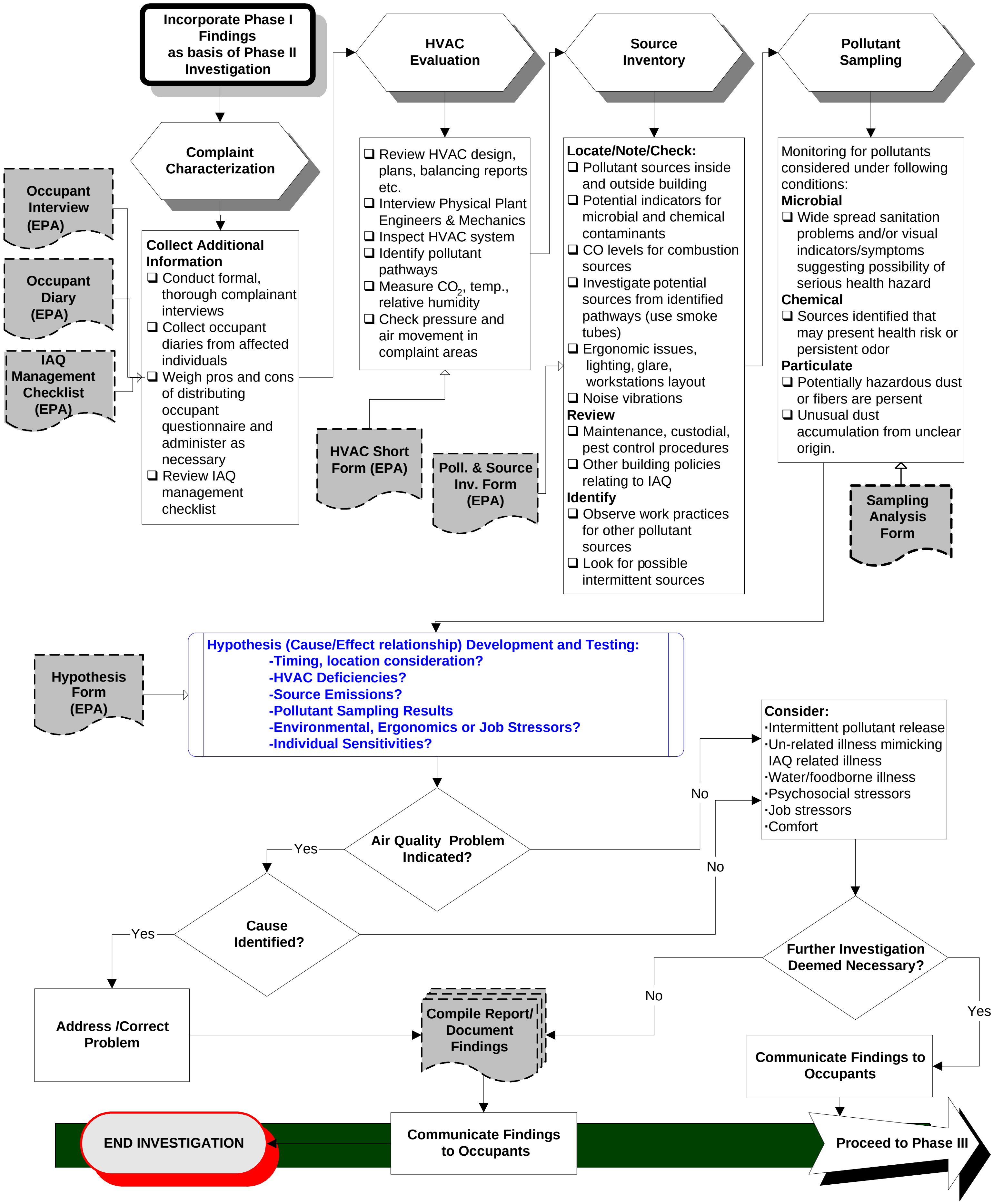
4. Cause Identification – Qualitative Phase

Tools/Forms:

- (EPA) Hypothesis Form (see page 31)

At this point in the Phase I investigation, preliminary data are available to formulate a cause/effect hypothesis. The investigator may proceed to the applicable section on <u>HYPOTHESIS DEVELOPMENT AND TESTING (page 18)</u>.

PHASE II - SEMI-QUANTITATIVE INVESTIGATION
UC Indoor Air Quality Program



PHASE II

SEMI-QUANTITATIVE INVESTIGATION

1. Complaint Characterization

Tools/Forms:

- (EPA) IAQ Management Checklist (see page 36)
- (EPA) Occupant Interview Form (see page 33)
- (EPA) Occupant Diary Form (see page 35)

Phase II investigations build on data already collected during the previous phase. Phase II investigations need only be performed when there is insufficient information gathered to resolve the complaint during phase I. As mentioned in the introduction, it is very important to effectively communicate to customers the status, findings and proposed new activities related to the investigation.

An appropriate time to determine if past complaint records are available and to develop an IAQ profile is at the beginning of a Phase II investigation. Any existing records of complaints should be reviewed and analyzed for trends or patterns. An IAQ profile can be developed by using the "(EPA) IAQ Management Checklist" and it should include information on:

a. HVAC design data, operating instructions, and manuals;
b. HVAC maintenance and calibration records, test and balance reports;
c. HVAC system components needing repair, adjustment, or replacement;
d. HVAC control settings and operating schedules;
e. Locations where occupancy, equipment, or building use has changed;
f. Areas where positive or negative pressure should be maintained;
g. Locations that need monitoring or correction;
h. Complaint locations;
i. List of responsible staff;
j. MSDSs for supplies and hazardous substances stored or used in the building.

Two options are available for further characterizing the complaint.

Option 1:

Conduct additional interviews with the known complainant(s) and a representative number of non-complainants. Use the "(EPA) Occupant Interview Form." Note any patterns or inconsistencies.

Option 2:

Distribute the "(EPA) Occupant Diary" form to selected occupants. Ask the occupants to note daily environmental conditions and their personal status for some period of time; e.g., two weeks or more. This method is useful for tracking transient odors that are not detected during a site visit and it gives ownership to the complainant in helping to resolve the problem. Upon return of the diaries, note any patterns or inconsistencies.

2. **HVAC System Evaluation**

Tools/Forms:

- (EPA) HVAC Checklist- Short Form (see page 26)

Additional information on the HVAC system should be collected by using the "(EPA) HVAC Checklist- Short Form". Some elements in the form were addressed during the qualitative phase of the investigation. This semi-quantitative evaluation of the HVAC system builds on the existing information by directing a more detailed inspection of the mechanical room, the major mechanical equipment, the air handling unit, the distribution system, and the occupied space. In summary, the semi-quantitative investigation involves:

a. More detailed review of the HVAC documentation such as design plans, balancing reports, etc.;
b. Interview of building Maintenance Mechanic/Engineer(s) for information on system operation, maintenance and history of the system;
c. Collection of environmental data on temperature, relative humidity, and carbon dioxide concentration during occupancy at representative locations over a period of a few hours;
d. Determination of pressure differential and air movement in the complaint area.

3. **Source Inventory**

Tools/Forms:

- (EPA) Pollutant and Source Inventory Form (see page 40)

As in the previous section on HVAC system evaluation, information on potential pollutants and pollutant sources should be collected to add to the current data. The "(EPA) Pollutant and Source Inventory Form" is useful. Check for items in the following source categories:

a. Sources outside the building i.e. contaminated outdoor air, emissions from nearby sources, soil gases, moisture or standing water;
b. Sources from equipment such as HVAC system equipment, office equipment or laboratory equipment
c. Sources from human activities such as food/cooking, smoking or cosmetic use; housekeeping or maintenance activities;
d. Sources from building components or furnishings like dusts or fibers; chemicals released from building components or furnishings like ozone or formaldehyde; unsanitary conditions or water damaged furnishings;
e. Other sources that involve accidental releases, special or mixed use areas, redecorating, repair, or remodeling.

Additionally, carbon monoxide levels should be measured to screen for combustion products. Smoke tubes or smoke candles may be used to track pollutant pathways. Lighting, ergonomic, or noise-related issues should be noted. Maintenance procedures of HVAC, Custodial, Pest Control, and other Facilities Management personnel should be reviewed. Also, building policies related to

IAQ should be reviewed. Work activities should be observed to identify other potential sources. During suspected near-peak emissions, the building should be re-inspected to identify intermittent sources.

4. Pollutant Sampling

Tools/Forms:

- Air Sampling & Analysis Request Form (see page 46)

Analytical samplings for pollutants are conducted to quantify or better identify potential pollutant sources. The decision to conduct pollutant sampling should be well thought through and a clear sampling strategy should be devised prior to collecting samples. Generally, pollutant source sampling may be considered as follows:

a. Widespread sanitation problems are indicated or symptoms suggest the possibility of a health hazard. In such a case, microbial sampling may be appropriate.

b. Persistent odors or chemical sources present a possible health risk. Chemical sampling may be in order.

c. Potentially hazardous dusts are present or there is an unusual accumulation of dust from an unknown origin. Particulate sampling may be appropriate.

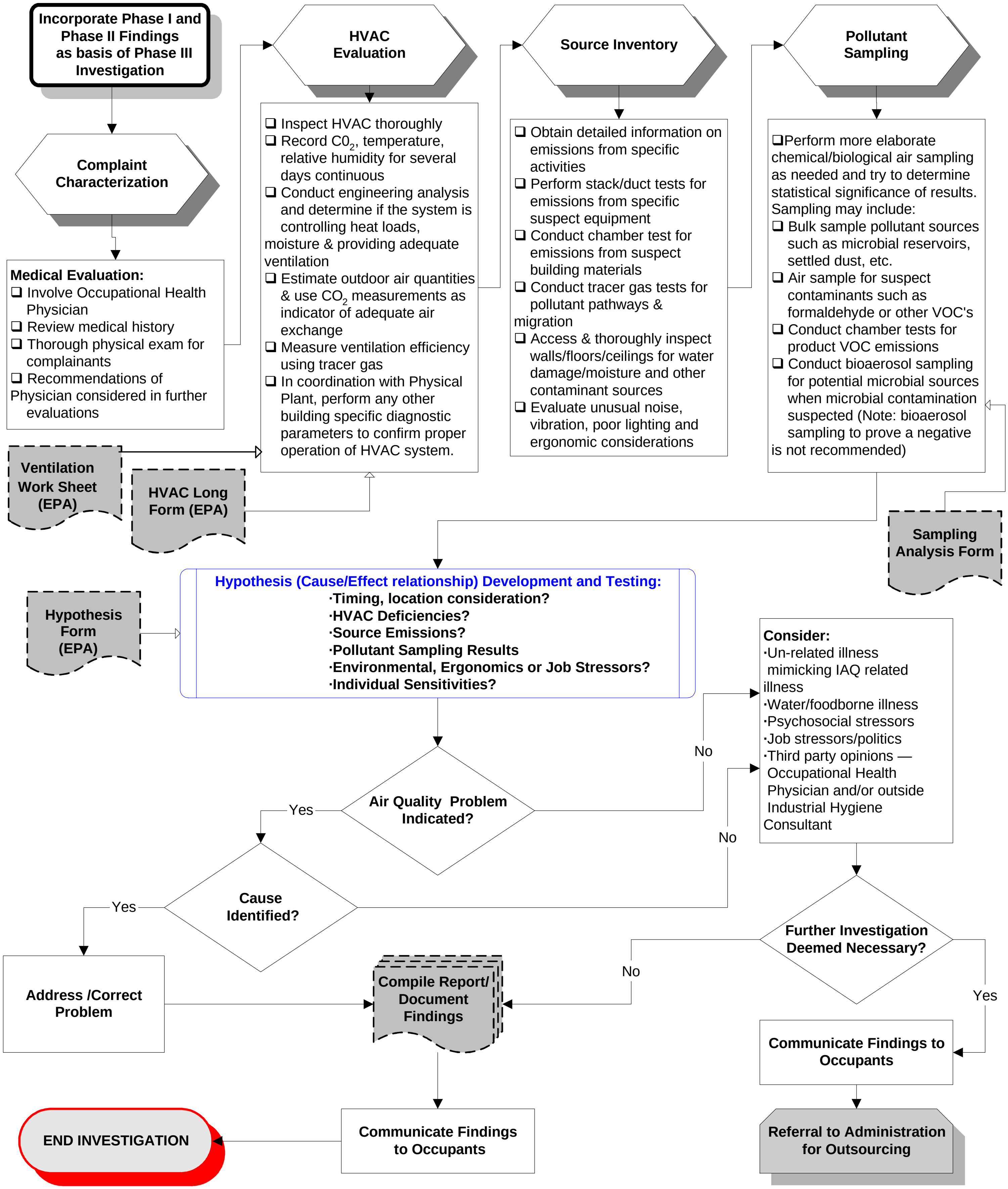
5. Cause Identification – Semi-Quantitative Phase

Tools/Forms:

- (EPA) Hypothesis Form (see page 31)

At this stage of the Semi-Quantitative Investigation, there may be additional data available to formulate a cause/effect hypothesis. The investigator may proceed to the applicable section on HYPOTHESIS DEVELOPMENT AND TESTING. (beginning on page 18)

PHASE III - QUANTITATIVE INVESTIGATION
UC Indoor Air Quality Program



PHASE III

QUANTITATIVE INVESTIGATION

1. **Complaint Characterization**

   The investigation should continue to build on all previous findings and customers should be kept informed. During Phase III, further complaint characterization can be deferred to medical personnel. The physician may choose to:

   a. Collect a detailed medical history of the complainant; or

   b. Perform a physical examination of the complainant and possibly use other area occupants as controls.

   To assist in the evaluation, details of the investigation should be provided to the physician. The physician may be able to determine if any correlation exists between the health complaints and the building conditions.

2. **Heating, Ventilating, and Air Conditioning (HVAC) System Evaluation**

   Tools/Forms:

   - (EPA) HVAC Long Form (see page 47)
   - (EPA) Ventilation Worksheet (see page 61)

   Measuring or recording the temperature, relative humidity, and carbon dioxide levels over a period of three to seven days may enhance the environmental data profile. (Note: suggested sampling duration is arbitrary). An engineering analysis may be conducted to determine if the system is controlling heat loads, moisture and providing adequate outside air ventilation. Use the “(EPA) HVAC Checklist - Long Form” and the “(EPA) Ventilation Worksheet” to provide detailed guidance on items to examine. In some cases tracer gas analysis may be used to examine the ventilation dynamics of the space.

3. **Source Inventory**

   In areas with observable water intrusion, the walls, floors, or ceilings should be accessed to determine the extent of damage and to detect any microbial growth. The moisture content of the affected building component should be measured. During the quantitative source inventory, emissions from specific pieces of equipment may be documented by conducting an engineering evaluation or stack testing. As in the HVAC evaluation, tracer gas analysis may be used to determine pollutant pathways and the extent of pollutant migration.

   Any non-IAQ related elements should be noted for future investigation. These elements include inadequate work area illumination, poor ergonomic design, and excessive noise or vibration.

4. Pollutant Sampling

Tools/Forms:

- Air Sampling & Analysis Request Form (see page 46)

The scope of pollutant sampling that was started during Phase II should be expanded. A goal may be to validate sampling data with statistical significance.

5. Cause Identification – Quantitative

Tools/Forms:

- (EPA) Hypothesis Form (see page 31)

At this stage of the quantitative investigation, there may be additional data available to formulate a cause/effect hypothesis. The investigator may proceed to the applicable section on HYPOTHESIS DEVELOPMENT AND TESTING (page 18).

HYPOTHESIS DEVELOPMENT AND TESTING

Phases of Hypothesis Testing

1. General Considerations

Tools/Forms:
(EPA) Hypothesis Form
The Industrial Hygienist's Guide to Indoor Air Quality Investigations *Appendix D* "Common Problems and Solutions" (see page 20)

The "(EPA) Hypothesis Form" may be used as a guide for developing a hypothesis after each phase of the investigation. Additional information gained after each phase of the investigation may necessitate redefinition or expansion of the complaint. Consulting *Appendix D* "Common Problems and Solutions" of The Industrial Hygienist's Guide to Indoor Air Quality Investigations may help correlate complaints with a probable cause or give additional insight into the complaint.

2. Qualitative (Phase I)

At this early stage of the investigation, a hypothesis may be developed based on information provided by the complainant during the interview. Area occupants may be able to provide good insight on the causes and solutions of IAQ problems. Results from questionnaires may further aid hypothesis development by helping characterize specific concerns: reference to ventilation-related causes, source-related causes, medical-related causes, or other underlying causes or contributing factors. Information collected during the HVAC system evaluation and source inventory may support a ventilation or source-related cause hypothesis.

The investigator should consider all of the qualitative data and complete the "(EPA) Hypothesis Form." After evaluating available data, the investigator should consider if an air quality problem is indicated. If so, and a cause/effect relationship is evident, appropriate corrective action should be taken. If the data does not indicate an air quality problem or a cause/effect relationship cannot be made, the investigator should consider other confounding factors that may be affecting the complainants. At this point, the investigator should consider whether further investigation is necessary.

If the investigator chooses to pursue a more technical examination, the current findings should be communicated to the occupants before proceeding to Phase II, Semi-Quantitative Investigation.

If the investigator chooses not to proceed to Phase II, or the problem has been addressed and corrected, a report should be developed that compiles all the current findings, recommendations, or corrective actions. This concludes a Phase I investigation.

3. Semi-Quantitative (Phase II)

The semi-quantitative investigation should produce the following: additional information from observations, basic environmental measurements, data from preliminary testing of ventilation dynamics, and possibly, additional details from the complaint area occupants. These facts should be combined with information from the qualitative investigation and categorized based on similarities in location, timing, and possible cause. The patterns should also be correlated with the information found during the HVAC system evaluation and source inventory.

The "(EPA) Hypothesis Form" may be reworked to accommodate any additional information. Investigators should look for a consistent cause/effect relationship but not expect one hundred percent consistency. As in the Phase I investigation, investigators should consider if an air quality problem is indicated. If so, and a cause/effect relationship is evident, the appropriate corrective action should be taken. If the data does not indicate an air quality problem or a cause/effect relationship cannot be made, the investigator should consider other confounding factors that may be affecting the complainants. Once again, the investigator should consider if further investigation is necessary.

If the investigator chooses to pursue a more technical examination, the current findings should be communicated to the occupants before proceeding to Phase III Quantitative Investigation.

If the investigator chooses not to proceed to Phase III, or the problem has been addressed and corrected, a report should be developed that compiles all the current findings, recommendations, and corrective actions. This concludes a Phase II investigation.

4. Quantitative (Phase III)

The data from detailed sampling, engineering, and medical evaluation should be analyzed to determine their impact on any hypothesis developed thus far. The "(EPA) Hypothesis Form" should be reworked and revised, if necessary. Like the previous investigation phases, the investigator should consider if an air quality problem is indicated. If so, and a cause/effect relationship is evident, the appropriate corrective action should be taken. If the data does not indicate an air quality problem or a cause/effect relationship cannot be made, the investigator should consider other confounding factors that may be affecting the complainants. Once again, the investigator should consider if further investigation is necessary.

If the investigator chooses to pursue a more technical examination, the current findings should be communicated to the occupants before referring the case to management for investigation by an outside source.

If the investigator chooses not to conduct further investigation, or the problem has been addressed and corrected, a report should be developed that compiles all the current findings, recommendations, or corrective actions. This concludes a Phase III investigation.

5. Common Problems and Possible Causes

The table below is reproduced with permission from AIHA's The Industrial Hygienist's Guide to Indoor Air Quality Investigations *Appendix D* "Common Problems and Solutions", 1993.

Complaint	Symptoms might include	Possible causes	Predisposing factors	Prevalence
Sick building syndrome	Headaches, irritation, congestion, fatigue	Not related to sources of admission or contamination	Worst when and where insulation is inadequate	Common (a small number of cases may occur in well maintained buildings)
Allergic reactions	Swelling, itching, congestion, asthma	Unsanitary conditions (excessive dust or mold growth)	Individuals usually have history of allergies (about 10-20% of population)	Common
Hypersensitivity illness	Shortness of breath, fever, chills, fatigue	Repeated exposure to microbial aerosols	Initially sensitized to high level of microbial contamination	Rare
Irritation	Watering, burning or dryness of eyes, nose or throat, may be accompanied by other nonspecific symptoms such as headache, nausea, or fatigue	Excessive concentrations of volatile chemicals such as solvents or formaldehyde; might also be because of very dry air	Some people more sensitive; tends to be worse during peak in emissions or driest air	Moderate
Carbon monoxide poisoning	Headache, dizziness, discoloration, positive blood test, nausea, coma,	Uncontrolled combustion	Cardiac conditions in more sensitive individuals	Rare
Neurological	Headaches, tremors, loss of memory	Insecticide misuse	Some people more sensitive	Rare
Infections	Diagnosed infections such as Legionnaires' or Aspergillus	Should be related to specific contaminant and building	Previously weakened immune system	Rare
Comfort (thermal)	Too hot, too cold, too stuffy, too drafty	HVAC	"You can't please all of the people all of the time"	Common
Comfort (nuisance)	No symptoms, just concerned for unusual odor or other conditions	Inadequate control of sources missions or contamination	Psychosocial	Moderate
Psychosocial stressors	Headaches, fatigue, muscle aches	Poor labor relations, overcrowding, unrelated concerns	Poor communication	Common
Mass hysteria	Hyperventilation, fainting, scratching	Symptoms spread by power of suggestion	Direct contact between affected individuals	Rare
Ergonomic problems	Muscle aches, fatigue, eye strain	Uncomfortable seating, repetitive motion		Moderate
Lighting	Eye strain, headaches	Insufficient light, glare, flicker		Moderate
Noise	Headaches, hypertension	Annoying noise interferes with concentration		Moderate
Cluster of adverse health effects	Any disease or health event that occurs in a building	Might be contagious, hereditary, etc., Might not be related to IAQ	Occupants read about IAQ in media	Rare

Conclusion

A final report or compilation of documentation should be used to conclude the investigation. The report should include details of the procedures followed for the investigation, results of surveys or sampling, a discussion of results and recommendations, and steps taken to verify methods and findings.

Recommendations should always emphasize proactive measures as discussed in the sections that cover HVAC Operation and Maintenance, HVAC Design and Construction Considerations, Indoor Air Quality Issues Relating to Relocation, and Organizational Approach in Addressing IAQ Issues.

The purpose of this protocol is to provide a practical, consistent, and objective method for investigating indoor air quality (IAQ) complaints by identifying the underlying causes and contributing factors to each type of complaint. Specific recommendations on mitigation are beyond the scope of this protocol. However, the procedures and the tools used during the investigation provide some useful resources in designing a mitigation strategy.

Forms – Data Gathering and Inspections

Provided in this section are an assortment of forms. It should again be emphasized that elements of an investigation and the extent of documentation are at the discretion of the investigator. Most UC Industrial Hygienists agree each investigation tends to be different in scope and so are the endpoints at which conclusions can be drawn and closure is reached. Documentation can be an important part of the process especially when Worker Compensation Claims are made and attending physicians request information. The EPA book "Building Air Quality: A Guide for Building Owners and Facility Managers" is an excellent resource for documentation forms and the source of many of the forms provided in this section.

Form 1. Telephone Interview – UC Indoor Air Quality Program

Interviewee Name:______________________________ Date:__________________________________

Department:____________________________________ Extension:_____________________________

What is the problem? Symptoms, complaints?____

When?____ Where?_________________________________

What events triggered the problem?____

Source/Cause of IAQ problem?____

Suggested Controls?____

Other Info:____

____

____

____

Form 2. Office Questionnaire – UC Indoor Air Quality Program

Some individuals working in this building have registered health complaints. To help investigate the possible presence or absence of these complaints, this questionnaire is being distributed to all occupants. Your assistance is requested. Please complete this questionnaire as accurately as possible. Return it in a sealed envelope to EH&S. Thank you for your assistance!

1. Complaints: Select choices that may be related to your presence in this building. This is a random list- not all complaints have been noted in this building.

- ❑ Aching joints
- ❑ Muscle twitching
- ❑ Back pain
- ❑ Hearing disturbances
- ❑ Dizziness
- ❑ Dry, flaking skin
- ❑ Discolored skin
- ❑ Skin irritation/itching
- ❑ Heartburn
- ❑ Nausea
- ❑ Throat irritation
- ❑ Noticeable odors
- ❑ Sinus congestion
- ❑ Sneezing
- ❑ Chest tightness
- ❑ Eye irritation
- ❑ Problems w/ contact lenses
- ❑ Headache
- ❑ Fatigue/drowsiness
- ❑ Temperature too hot
- ❑ Temperature too cold
- ❑ Other (specify)

How long have you been experiencing the above:____

2. When do these complaints occur?
   - ❑ Morning
   - ❑ Afternoon
   - ❑ All day
   - ❑ Daily
   - ❑ Specify day(s) of the week.
   - ❑ No noticeable trend

3. When do you experience relief form these complaints?__________________________________

____

4. Do you have any of the following? Please check positive responses.
   - ❑ Hay fever/pollen allergies
   - ❑ Skin allergies/ dermatitis
   - ❑ Other allergies
   - ❑ Cold/flu
   - ❑ Sinus problems

5. Do you smoke tobacco? ❑ Yes ❑ No Amount: _______________

6 On what floor of the building are you located?____

In what department or area?____

How long have you been working in this area?____

7. Are you near any office equipment or lab equipment (specify)?__________________________________

8. Comments or observations:____

Name (optional):____ Date:_________________

Form 3. HVAC Data Worksheet – UC Indoor Air Quality Program

Location:________________________________ Date/Time:________________________

Contact person/Extension: ____

Number of occupants in space:_______________________

ROOM/SPACE DATA

Length:________ Width:______________ Height:______________

Room Volume:_____________________

ENVIRONMENTAL DATA

Temp:_______________ Rel. Humidity:_______________ (CO_2):_______________

Other: (   )________________ (   )_____________________

Temp (mixed air):_____________ Temp (return air):_____________

Temp (outside air)_____________ % Outside air:_______________

Supply Volume Flow Rates:

Return Volume Flow Rates:

Outside air/Person:_____________

Air changes/Hour:_____________

Other information:____

Form 4. HVAC Checklist – Short Form

Building Name:______________________________________ Address:____

Completed by: ______________________________________ Date: ________________ File Number: ________________

MECHANICAL ROOM

- Clean and dry? ___________________________ Stored refuse or chemicals? ______________________________
- Describe items in need of attention ____

MAJOR MECHANICAL EQUIPMENT

- Preventative maintenance (PM) plan in use? ____

Control System

- Type ____
- System operation ____
- Date of last calibration ____

Boiler

- Rated Btu input ____________ Condition ____
- Combustion air: is there at least on square inch free area per 2,000 Btu input? ___________________________________
- Fuel or combustion odors ____

Cooling Tower

- Clean? no leaks or overflow? ______________________________ Slime or algae growth? _______________________
- Eliminator performance ____
- Biocide treatment working? (list type of biocide) ____
- Spill containment plan implemented? ________________________ Dirt separator working? _____________________

Chillers

- Refrigerant leaks? ____
- Evidence of condensation problems? ____
- Waste oil and refrigerant properly stored and disposed of? ____

Form 4. HVAC Checklist – Short Form

Building Name:____ Address:____

Completed by: ____ Date: _________________ File Number: _________________

AIR HANDLING UNIT

- Unit identification _________________________________ Area served ____

Outdoor Air Intake, Mixing Plenum, and Dampers

- Outdoor air intake location ____
- Nearby contaminant sources? (describe) ____
- Bird screen in place and unobstructed? ____
- Design total cfm ____________ outdoor air (O.A.) cfm __________ date last tested and balanced ____________________
- Minimum % O.A. (damper setting) ___________ Minimum cfm O.A. $\frac{\text{total cfm x minimum \% O.A.}}{100}$ = ___________________
- Current O.A. damper setting (date, time, and HVAC operating mode) ____
- Damper control sequence (describe) ____
- Condition of dampers and controls (note date) ____

Fans

- Control sequence ____
- Condition (note date) ____
- Indicated temperatures supply air ______ mixed air ______________ return air ______ outdoor air ____________
- Actual temperatures supply air ______ mixed air ______________ return air ______ outdoor air ____________

Coils

- Heating fluid discharge temperature __________________ ΔT ___________________

  cooling fluid discharge temperature __________________ ΔT ___________________
- Controls (describe) ____
- Condition (note date) ____

Humidifier

- Type _____________________________________ If biocide is used, note type ____________________________________

Form 4. HVAC Checklist – Short Form

Building Name:____ Address:____

Completed by: ____ Date: _________________ File Number: _________________

Humidifier (continued)

- Condition (no overflow, drains trapped, all nozzles working?) ____
- No slime, visible growth, or mineral deposits? ____

DISTRIBUTION SYSTEM

Zone/Room	System Type	Supply Air		Return Air		Power Exhaust		
		ducted/ unducted	cfm	ducted/ unducted	cfm	cfm	control	serves (e.g. toilet)

Condition of distribution system and terminal equipment (note locations of problems)

- Adequate access for maintenance? ____
- Ducts and coils clean and obstructed? ____
- Air paths unobstructed? supply _________ return _________ transfer _______ exhaust _______ make-up _______
- Note locations of blocked air paths, diffusers, or grilles ____
- Any unintentional openings into plenums? ____
- Controls operating properly? ____
- Air volume correct? ____
- Drain pans clean? Any visible growth or odors? ____

Form 4. HVAC Checklist – Short Form

Building Name:_______________________ Address:_______________________

Completed by: _______________________ Date: ____________ File Number: ____________

Filters

Location	Type/Rating	Size	Date Last Changed	Condition (give date)

OCCUPIED SPACE

Thermostat types ___________________________

Zone/Room	Thermostat Location	What Does Thermostat Control? (e.g., radiator, AHU-3)	Setpoints		Measured Temperature	Day/Time
			Summer	Winter		

Humidistat/Dehumidistat types ___________________________

Zone/Room	Humidistat/ Dehumidistat Location	What Does It Control?	Setpoints (%RH)	Measured Temperature	Day/ Time

Form 4. HVAC Checklist – Short Form

Building Name:______________________________________ Address:____

Completed by: _______________________________________ Date: ________________ File Number: ________________

Humidistat/Dehumidistat (continued)

- Potential problems (note location) ____
- Thermal comfort or air circulation problems (drafts, obstructed airflow, stagnant air, overcrowding, poor thermostat location)

____

____

- Malfunctioning equipment ____
- Major sources of odors or contaminants (e.g., poor sanitation, incompatible uses of space)

____

Form 5. Hypothesis Testing Form– UC Indoor Air Quality Program

Building Name:______________________________________File Number:_________________________

Address:____

Completed by:____

Complaint Area (may be revised as the investigation progresses)

____

____

____

Complaints (e.g., summarize patterns of timing, location, number of people affected)

____

____

____

HVAC: Does the ventilation system appear to provide adequate outdoor air, efficiently distributed to meet occupant needs in the complaint area? If not, what problems do you see?

____

____

____

Is there any apparent pattern connecting the location and the timing of the complaints with the HVAC system layout, condition, or operating schedule?

____

____

____

Pathways: What pathways and driving forces connect the complaint area to locations of potential sources?

____

Are the flows opposite to those intended in the design?____

Sources: What potential sources have been identified in the complaint area or in locations associated with the complaint area (connected by pathways)?

____

Is there a pattern of complaints consistent with any of these sources?________________________________

Form 5. (Continued)

Hypothesis: Using the information you have gathered, what is your best explanation for the problem?

____

____

____

____

Hypothesis testing: How can this hypothesis be tested?____

____

____

If measurements have been taken, are the measurement results consistent with the hypothesis?__________

____

____

Results of Hypothesis Testing:____

____

____

____

Additional Information Needed:____

____

____

Form 6. Occupant Interview – UC Indoor Air Quality Program

Occupant Name:_______________________ Title:__________________________

Department:__________________________ Phone:_________________________

Building Name:________________________ Work Location:_________________

*Completed by (if other than Occupant):*________________________ *Title:*______________

SYMPTOM PATTERNS

What kind of symptoms or discomfort are you experiencing?

Are you aware of people with similar symptoms or concerns? Yes______ No ______

If so, what are their names and locations?_______________________________________

Do you have any health conditions that may make you particularly susceptible to environmental problems?

- ❑ Contact lenses
- ❑ Chronic cardiovascular disease
- ❑ Undergoing chemotherapy or radiation
- ❑ Allergies
- ❑ Chronic respiratory disease
- ❑ Immune system suppressed by disease or other causes
- ❑ Chronic neurological problems

Form 6. (Continued)

TIMING PATTERNS

When did your symptoms start?

When are they generally worse?

Do they go away? If so, when?

Have you noticed any other events such as weather events, temperature or humidity changes, or activities in the building that tend to occur around the same time as your symptoms?

SPATIAL PATTERNS

Where are you when you experience symptoms of discomfort?

Where do you spend most of your time in the building?

ADDITIONAL INFORMATION

Do you have any observations about building conditions that might need attention or might help explain your symptoms (e.g., temperature, humidity, drafts, stagnant air, odors)?

Have you sought medical attention for your symptoms?

Do you have any other comments?

Form 7. Occupant Diary

Occupant Name: ______________________________ Title: _______________________ Phone: ______________________

Location: ____ File Number: ________________________________

On the form below, please record each occasion when you experience a symptom of ill-health or discomfort that you think may be linked to an environmental condition in this building.

It is important that you record the time and date and your location within the building as accurately as possible, because that will help to identify conditions (e.g., equipment operation) that may be associated with your problem. Also, please try to describe the severity of your symptoms (e.g., mild, severe) and their duration (the length of time that they persist). Any other observations that you think may help in identifying the cause of the problem should be noted in the "Comments" column. Feel free to attach additional pages or use more than one line for each event if you need more room to record your observations.

Time/Date	**Location**	**Symptom**	**Severity/Duration**	**Comments**

Form 8. IAQ Management Checklist

Building Name:____ Date:_________________________________

Address: ____

Completed by (name/title): ____

Use this checklist to make sure that you have included all necessary elements in your IAQ profile and IAQ management plan.

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
IAQ PROFILE			
Collect and Review Existing Records			
HVAC design data, operating instructions, and manuals			
HVAC maintenance and calibration records, testing and balancing reports			
Inventory of locations where occupancy, equipment, or building use has changed			
Inventory of complaint locations			
Conduct a Walkthrough Inspection of the Building			
List of responsible staff and/or contractors, evidence of training, and job descriptions			
Identification of areas where positive or negative pressure should be maintained			
Record of locations that need monitoring or correction			
Collect Detailed Information			
Inventory of HVAC system components needing repair, adjustment, or replacement			
Record of control settings and operating schedules			
Plan showing airflow directions or pressure differentials in significant areas			
Inventory of significant pollutant sources and their locations			

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
MSDSs for supplies and hazardous substances that are stored or used in the building			
Zone/Room Record			
IAQ MANAGEMENT PLAN			
Select IAQ Manager			
Review IAQ Profile			
Assign Staff Responsibilities/Train Staff			
Facilities Operation and Maintenance			
■ confirm that equipment operating schedules are appropriate			
■ confirm appropriate pressure relationships between building usage areas			
■ compare ventilation quantities to design, codes, and ASHRAE 62-2001			
■ schedule equipment inspections per preventive maintenance plan or recommended maintenance schedule			
■ modify and use HVAC Checklist(s); update as equipment is added, removed, or replaced			
■ schedule maintenance activities to avoid creating IAQ problems			
■ review MSDSs for supplies; request additional information as needed			
■ consider using alarms or other devices to signal need for HVAC maintenance (e.g., clogged filters)			

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
Housekeeping			
■ evaluate cleaning schedules and procedures; modify if necessary			
■ review MSDSs for products in use; buy different products if necessary			
■ confirm proper use and storage of materials			
■ review trash disposal procedures; modify if necessary			
Shipping and Receiving			
■ review loading dock procedures (*Note*: If air intake is located nearby, take precautions to prevent intake of exhaust fumes.)			
■ check pressure relationships around loading dock			
Pest Control			
■ consider adopting IPM methods			
■ obtain and review MSDSs; review handling and storage			
■ review pest control schedules and procedures			
■ review ventilation used during pesticide application			
Occupant Relations			
■ establish health and safety committee or joint tenant/management IAQ task force			
■ review procedures for responding to complaints; modify if necessary			
■ review lease provisions; modify if necessary			

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
Renovation, Redecorating, Remodeling			
■ discuss IAQ concerns with architects, engineers, contractors, and other professionals			
■ obtain MSDSs; use materials and procedures that minimize IAQ problems			
■ schedule work to minimize IAQ problems			
■ arrange ventilation to isolate work areas			
■ use installation procedures that minimize emissions from new furnishings			
Smoking			
■ eliminate smoking in the building			
■ if smoking areas are designated, provide adequate ventilation and maintain under negative pressure			
■ work with occupants to develop appropriate non-smoking policies, including implementation of smoking cessation programs			

Form 9. Pollutant and Source Inventory

Building Name:____Address:____

Completed by: ____Date: ________________ File Number: _________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
SOURCES OUTSIDE BULDING				
Contaminated Outdoor Air				
Pollen, dust				
Industrial contaminants				
General vehicular contaminants				
Emissions from Nearby Sources				
Vehicle exhaust (parking areas, loading docks, roads)				
Dumpsters				
Re-entrained exhaust				
Debris near outside air intake				
Soil Gas				
Radon				
Leaking underground tanks				
Sewage smells				
Pesticides				

Form 9. Pollutant and Source Inventory

Building Name:_______________________________________Address:____

Completed by: _______________________________________Date: ________________ File Number: _________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
Moisture or Standing Water				
Rooftop				
Crawlspace				
EQUIPMENT				
HVAC System Equipment				
Combustion gases				
Dust, dirt, or microbial growth in ducts				
Microbial growth in drip pans, chillers, humidifiers				
Leaks of treated boiler water				
Non HVAC System Equipment				
Office Equipment				
Supplies for Equipment				
Laboratory Equipment				

Form 9. Pollutant and Source Inventory

Building Name:____Address:____

Completed by: ____Date: ________________ File Number: _________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
HUMAN ACTIVITIES				
Personal Activities				
Smoking				
Cosmetics (odors)				
Housekeeping Activities				
Cleaning materials				
Cleaning procedures (e.g., dust from sweeping, vacuuming)				
Stored supplies				
Stored refuse				
Maintenance Activities				
Use of materials with volatile compounds (e.g., paint, caulk, adhesives)				
Stored supplies with volatile compounds				
Use of pesticides				

Form 9. Pollutant and Source Inventory

Building Name:_______________________________________Address:____

Completed by: ____Date: ________________ File Number: _________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
BUILDING COMPONENTS FURNISHINGS				
Locations Associated with Dust or Fibers				
Dust-catching area (e.g., open shelving)				
Deteriorated furnishings				
Asbestos-containing materials				
Unsanitary Conditions/Water Damage				
Microbial growth in or on soiled or water-damaged furnishings				

Form 9. Pollutant and Source Inventory

Building Name:____Address:____

Completed by: ____Date: ________________ File Number: _________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
Chemicals Released From Building Components or Furnishings				
Volatile compounds				
OTHER SOURCES				
Accidental Events				
Spills (e.g., water, chemicals, beverages)				
Water leaks or flooding				
Fire damage				

Form 9. Pollutant and Source Inventory

Building Name:_______________________________________Address:____

Completed by: _______________________________________Date: _______________ File Number: ________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
Special Use/Mixed Use Areas				
Smoking lounges				
Food preparation areas				
Underground or attached parking garages				
Laboratories				
Print shops, art rooms				
Exercise rooms				
Beauty salons				
Redecorating/Repair/Remodeling				
Emissions from new furnishings				
Dust, fibers from demolition				
Odors, volatile compounds				

University of California
Environmental Health & Safety

Form 10. Sampling & Analysis Request– *UC Indoor Air Quality Program*

Send Results to:____________________

____

____

____

____

Lab Name:____________________

Lab Phone# ____________________
Lab Address:

____

Page _____ of ____________________

Sampled by:____________________

Site of Sampling:____________________

____

Date of Sampling: ____________________

Date Submitted:____________________

Sample #	**Sample Location/Description**	**Flow Rate ST/SP (LM)**	**Time ST/SP**	**Sample Vol (L)**	**Analyze For**
	____________________				
	____________________				
	____________________				
	____________________				

Instructions:

Form 11. HVAC Checklist – Long Form

Building:____ File Number:_____________________________

Completed by: ____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Outside Air Intake				
Location ____________________ ____________________________				
Open during occupied hours?				
Unobstructed?				
Standing water, bird droppings in vicinity?				
Odors from outdoors? (describe) ___________________ ____________________________				
Carryover of exhaust heat?				
Cooling tower within 25 feet?				
Exhaust outlet within 25 feet?				
Trash compactor within 25 feet?				
Near parking facility, busy road, loading dock?				
Bird Screen				
Unobstructed?				
General condition?				
Size of mesh? (1/2 ″ minimum)				
Outside Air Dampers				
Operation acceptable?				
Seal when closed?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Actuators operational?				
Outdoor Air (O.A.) Quantity *(Check against applicable codes and ASHRAE 62-1989.)*				
Minimum % O.A. _____________				
Measured % O.A. _____________ *Note day, time, HVAC operating mode under "Comments"*				
Maximum % O.A. _____________				
Is minimum O.A. a separate damper?				
For VAV systems: is O.A. increased as total system air-flow is reduced?				
Mixing Plenum				
Clean?				
Floor drain trapped?				
Air tightness				
■ of outside air dampers				
■ of return air dampers				
■ of exhaust air dampers				
All damper motors connected?				
All damper motors operational?				
Air mixers or opposed blades?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:_____________________________

Completed by: ____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Mixed air temperature control setting _____________°F				
Freeze stat setting _____________°F				
Is mixing plenum under negative pressure? *Note: If it is under positive pressure, outdoor air may not be entering.*				
Filters				
Type ______________________				
Complete coverage? (i.e., no bypassing)				
Correct pressure drop? *(Compare to manufacturer's recommendations.)*				
Contaminants visible?				
Odor noticeable?				
Spray Humidifiers or Air Washers				
Humidifier type				
All nozzles working?				
Complete coil coverage?				
Pans clean, no overflow?				
Drains trapped?				
Biocide treatment working? *Note: Is MSDS on file?* _________				
Spill containment system in place?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Face and Bypass Dampers				
Damper operation correct?				
Damper motors operational?				
Cooling Coil				
Inspection access?				
Clean?				
Supply water temp. ____________°F				
Water carryover?				
Any indication of condensation problems?				
Condensate Drip Pans				
Accessible to inspect and clean?				
Clean, no residue?				
No standing water, no leaks?				
Noticeable odor?				
Visible growth (e.g., slime)?				
Drains and traps clear, working?				
Trapped to air gap?				
Water overflow?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:_____________________________

Completed by: ____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Mist Eliminators				
Clean, straight, no carryover?				
Supply Fan Chambers				
Clean?				
No trash or storage?				
Floor drain traps are wet or sealed?				
No air leaks?				
Doors close tightly?				
Supply Fans				
Location ___________________				
Fan blades clean?				
Belt guards installed?				
Proper belt tension?				
Excess vibration?				
Corrosion problems?				
Controls operational, calibrated?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Control sequence conforms to design/specifications? (describe changes)				
No pneumatic leaks?				
Heating Coil				
Inspection access?				
Clean?				
Control sequence conforms to design/specifications? (describe changes)				
Supply water temp. ____________°F				
Discharge thermostat? (air temp. setting _______°F)				
Reheat Coils				
Clean?				
Obstructed?				
Operational?				
Steam Humidifier				
Humidifier type _______________				
Treated boiler water?				
Standing water?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:_____________________________

Completed by: ____________________________ Title: ____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Visible growth?				
Mineral deposits?				
Control setpoint ________°F				
High limit setpoint _____________°F				
Duct liner within 12 feet? (If so, check for dirt, mold growth.)				
Supply Ductwork				
Clean?				
Sealed, no leaks, tight connections?				
Fire dampers open?				
Access doors closed?				
Lined ducts?				
Flex duct connected, no tears?				
Light troffer supply?				
Balanced within 3-5 years?				
Balanced after recent renovations?				
Short-circuiting or other air distribution problems? Note location(s) ____________________ __________________________				
Pressurized Ceiling Supply Plenum				
No unintentional openings?				
All ceiling tiles in place?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:_____________________________

Completed by: ____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Barrier paper correctly placed and in good condition?				
Proper layout for air distribution?				
Supply diffusers open?				
Supply diffusers balanced?				
Noticeable flow of air?				
Short-circuiting or other air distribution problems? *Note location(s) in "Comments"*				
Terminal Equipment (supply)				
Housing interiors clean and unobstructed?				
Controls working?				
Delivering rated volume?				
Balanced within 3-5 years?				
Filters in place?				
Condensate pans clean, drain freely?				
VAV Box				
Minimum stops ________%				
Minimum outside air ___________% *(from page 2 of this form)*				
Minimum airflow _______cfm				
Minimum outside air ____cfm				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: ______________________ Date Checked: _______________

Component	OK	Needs Attention	Not Applicable	Comments
Supply setpoint _____°F (summer) _____°F (winter)				
Thermostats				
Type _______________________				
Properly located?				
Working?				
Setpoints __________ °F (summer) _________ °F (winter)				
Space temperature _____________°F				
Humidity Sensor				
Humidistat setpoints ________%RH				
Dehumidistat setpoints ______%RH				
Actual RH _____ %				
Room Partitions				
Gap allowing airflow at top?				
Gap allowing airflow at bottom?				
Supply and return each room?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: _____________________ Date Checked: ______________

Component	OK	Needs Attention	Not Applicable	Comments
Stairwells				
Doors close and latch?				
No openings allowing uncontrolled airflow?				
Clean, dry?				
No noticeable odors?				
Return Air Plenum				
Tiles in place?				
No unintentional openings?				
Return grilles?				
Balancing capabilities?				
Noticeable flow of air?				
Transfer grilles?				
Fire dampers open?				
Ducted Returns				
Balanced within 3-5 years?				
Unobstructed grilles?				
Unobstructed return air path?				
Return Fan Chambers				
Clean and no trash or storage?				
No standing water?				
Floor drain traps are wet or sealed?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: ______________________ Date Checked: _______________

Component	OK	Needs Attention	Not Applicable	Comments
No air leaks?				
Doors close tightly, kept closed?				
Return Fans				
Location ____________________				
Fan blades clean?				
Belt guards installed?				
Proper belt tension?				
Excess vibration?				
Corrosion problems?				
Controls working, calibrated?				
Control sequence conforms to design/specifications? (describe changes)				
Exhaust Fans				
Central?				
Distributed (locations) __________ ___________________________				
Operational?				
Controls operational?				
Toilet exhaust only?				
Gravity relief?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: ______________________ Date Checked: _______________

Component	OK	Needs Attention	Not Applicable	Comments
Total powered exhaust ______ cfm				
Make-up air sufficient?				
Toilet Exhausts				
Fans working occupied hours?				
Registers open, clear?				
Make-up air path adequate?				
Volume according to code?				
Floor drain traps wet or sealable?				
Bathrooms run slightly negative relative to building?				
Smoking Lounge Exhaust				
Room runs negative relative to building?				
Print Room Exhaust				
Room runs negative relative to building?				
Garage Ventilation				
Operates according to codes?				
Fans, controls, dampers all operate?				

Building:____ File Number:________________________________

Completed by: _______________________________ Title: _______________________ Date Checked: _______________

Component	OK	Needs Attention	Not Applicable	Comments
Garage slightly negative relative to building?				
Doors to building close tightly?				
Vestibule entrance to building from garage?				
Mechanical Rooms				
General condition?				
Controls operational?				
Pneumatic controls:				
■ compressor operational?				
■ air dryer operational?				
Electric controls? Operational?				
EMS (Energy Management System) or DDC (Direct Digital Control):				
■ operator on site?				
■ controlled off-site?				
■ are fans cycled “off” while building is occupied?				
■ is chiller reset to shed load?				
Preventative Maintenance				
Spare parts inventoried?				
Spare air filters?				
Control drawing posted?				

Form 11. HVAC Checklist – Long Form

Building:____ File Number:______________________________

Completed by: _____________________________ Title: ______________________ Date Checked: _______________

Component	OK	Needs Attention	Not Applicable	Comments
PM (Preventative Maintenance) schedule available?				
PM followed?				
Boilers				
Flues, breeching tight?				
Purge cycle working?				
Door gaskets tight?				
Fuel system tight, no leaks?				
Combustion air: at least 1 square inch free area per 2000 Btu input?				
Cooling Tower				
Sump clean?				
No leaks, no overflow?				
Eliminators working, no carryover?				
No slime or algae?				
Biocide treatment working?				
Dirt separator working?				
Chillers				
No refrigerant leaks?				
Purge cycle normal?				
Waste oil, refrigerant properly disposed and spare refrigerant properly stored?				
Condensation problems?				

Form 12. Ventilation Worksheet

Building Name: ____ File Number: _____________________

Address: ____

Completed by (name): ____ Date: ____________________

The ventilation recommendations of ASHRAE Standard 62-2001 were developed for the purpose of preventing indoor air quality problems. Formulas are given below for calculating outdoor air quantities using thermal or CO_2 information. For additional information, refer to *Appendix A* and *Appendix* B of the EPA Building Air Quality Guide.

The equation for calculating outdoor air quantities **using thermal measurements** is:

$$\text{Outdoor air (in percent)} = \frac{T_{\text{return air}} - T_{\text{mixed air}}}{T_{\text{return air}} - T_{\text{outdoor air}}} \times 100$$

Where: T = temperature in degrees Fahrenheit

The equation for calculating outdoor quantities **using carbon dioxide measurements** is:

$$\text{Outdoor air (in percent)} = \frac{C_s - C_r}{C_o - C_r} \times 100$$

Where: C_s = ppm of carbon dioxide in the supply air (if measured in a room), or
C_s = ppm of carbon dioxide in the mixed air (if measured at an air handler)
C_r = ppm of carbon dioxide in the return air
C_o = ppm of carbon dioxide in the outdoor air

Use the table below to estimate the ventilation rate in any room or zone. *Note:* ASHRAE 62-2001 generally states ventilation (outdoor air) requirements on an occupancy basis; for a few types of spaces, however requirements are given on a floor area basis. Therefore, this table provides a process of calculating ventilation (outdoor air) on either an occupancy or floor area basis.

Zone/Room	**Percent of Outdoor Air** **A**	**Total Air Supplied to Zone/Room (cfm)** **B**	**Peak Occupancy (number of people) or Floor Area (square feet)** **C**	$D = \frac{B}{C}$ **Total Air Supplied Per Person (or per square foot area)** **D**	$E = (A \times 100) \times D$ **Outdoor Air Supplied Per Person (or per square foot area)** **E**

IAQ Prevention Tools

The information in this section generally deals with IAQ problem prevention. Subjects addressed include:

CHAPTER 2

HVAC DESIGN AND CONSTRUCTION CONSIDERATIONS

HVAC Design Priorities

All buildings are different in use, location and architectural design; however, the order of general priorities in designing an HVAC system should be:

- Provide a healthy environment with good indoor air quality for occupants;
- Provide comfort to the occupants;
- Minimize total cost, considering energy conservation and life cycle expenses.

Mechanical Ventilation Design

1. Core Design Standards and Guidelines

Mechanical ventilation systems should be designed to meet:

- California Code of Regulations Title 24 (Fire and Life Safety, and Energy Efficiency requirements) and Title 8 (Occupational Health and Safety requirements);
- California Mechanical Code;
- The American Society of Heating Refrigeration and Air-Conditioning Engineers Standard 62 -Ventilation for Acceptable Indoor Air Quality (ASHRAE-62-2001);
- ASHRAE 55-1992 Thermal Environmental Conditions for Human Occupancy, which establishes acceptable temperature, relative humidity and air movement rates for occupied spaces.

2. Outdoor Air Volumes

HVAC systems should be designed to provide outdoor air volumes that meet or exceed minimum requirements of ASHRAE-62. In general this requires a minimum of 15-20 CFM (8-10 L/s) per person of outside air throughout the occupied zone at all times the building is in normal use.

3. Ventilation Rates

- Minimum outside air ventilation should be at least 10% of the total supply air, 20 cfm/person, or makeup for exhaust air, whichever is the greatest. (1)
- Restrooms should have ventilation rates of 50 CFM (25 L/s) per toilet or urinal, and should be negative pressure with respect to the rest of the building. Exhaust air from restrooms, toilet rooms, shower facilities or locker rooms should not be recirculated. (1)
- Air velocity should be 30 to 50 feet per minute at each workstation when practical. (2)
- Laboratories should have at least 6 air changes per hour. (10)

4. Duct Lining

- Ventilation ducts should only have thermal insulation on the exterior of duct. (7)
- Fiberglass should not be used to insulate the inside of ducts. (6, 12)
- Where noise attenuation is necessary, it should be of a material that will not degrade, or trap

dust and water. Sound baffles can be used for noise attenuation.

- Insulation should not be installed inside ducts immediately downstream of cooling coils where condensation over-spray could promote microbial growth.

5. Re-circulation

Re-circulation of general ventilation is permitted for energy conservation, only when re-circulated air is harmless and the minimum quantity of outdoor air is supplied per ASHRAE-62. Re-circulated ventilation is prohibited for room types listed below:

- Laboratories where hazardous materials are used or stored; (8)
- Shop areas where hazardous materials are used or stored; (8)
- General storage rooms where hazardous materials are used or stored; (8)
- Animal areas; (10, 11)
- Rest rooms; (1)
- Janitor closets; (1)
- Athletic locker rooms; (1)
- Rooms where smoking is permitted; (1)
- Autopsy/necropsy rooms. (1)

6. Safety Considerations

All fan and belt drives should have proper safety guarding in place. (7)

7. Laboratories/Hazardous Materials Use Locations

- Should have separate local exhaust (i.e. fume hoods) or dilution ventilation that is not recirculated. (8, 10)
- Space should have negative ventilation pressure relative to other areas, such as hallways and offices. (8, 10)

8. High Volume Copy Rooms

Dedicated high volume copy rooms should have negative pressure with respect to the surrounding area and room exhaust should not be recirculated. (1)

9. Cooling Towers

Should be at least 15 feet from building intakes. (1)

10. Heating/Cooling Coils

Tempering coils should be constructed of copper with copper fins (Cu/Cu), because aluminum coils will oxidize and degrade. (6)

11. Energy Management Systems

Ventilation systems should be tied into a central monitoring station with direct digital controls, to alert maintenance personnel when HVAC systems are not operating properly. (12)

12. Air Temperatures and Humidity

Winter air temperatures should be maintained between 68-75 °F (20-24 °C), and summer temperatures be kept between 73-79 °F (23-26 °C). Humidity should be maintained between 30% to 60%, relative humidity, to minimize growth of allergenic or pathogenic organisms. Temperatures other than 72 ± 2 °F (22 ± 1°C) often result in comfort complaints. (1, 2, 3)

13. Radon

Where soils contain high concentrations of radon, ventilation practices that place crawlspaces, basements, or underground duct work below atmospheric pressure (which could increase radon concentrations in buildings) should be avoided. (1)

Air Intakes and Exhaust Outlets/Stacks

1. Air intakes (2)

- Locate intakes away from ground-level pollution sources and building exhausts. Intakes should not be placed near loading docks, parking garages, busy streets, trash areas, exhaust stacks, ground level vegetation, or other potential sources of contaminants.
- Intakes should be at least 8' above grade.
- Preferred location is high up on prevailing wind (upwind) side of building.

2. Exhaust stacks (2, 8, 11, 12)

- Are ideally located on the upper two-thirds of the building or top of the building.
- Exhaust outlets and stacks should be placed on the predominant downwind side of the building.
- Place exhaust stacks as far away from intakes as possible; 50 feet separation is considered adequate for non-hazardous/general exhaust.
- Avoid aesthetic enclosures of exhaust outlets located on the roof. If required by local code, they should be of the open-louvered type and constructed to allow horizontal winds to flush the enclosure.
- Exhaust stacks should not be located within the aesthetic enclosures with air intakes. Also generally avoid placing stacks so their openings are within aesthetic enclosures, copses of trees, or other areas where diluting air circulation is blocked.

- Avoid the use of rain caps which direct the flow of exhaust air back towards the roof. These caps can greatly reduce the dilution of exhausted air.
- Provide ample exhaust stack height.
  - The Uniform Building Code suggests that stacks should be at least 10 feet away and 2 feet above an air intake. A general guideline is exhaust stacks within 50 feet of the roofline or an air intake should be 10 feet tall.
  - Exhaust stacks exhausting hazardous materials should be not less than ten feet above the highest part of the roof or equipped with other controls, so to protect maintenance people working near the stacks. Ejection velocities from exhaust stacks exhausting hazardous materials should be at least 3,000 fpm.
- Where entrainment of hazardous exhaust into a neighboring building is a potential concern, a wind engineering study with modeling and risk assessment should be performed.

Air Filters

Intake Screens

There should be a bird screen to capture large objects, leaves and sticks, etc.

1. Air Filter Banks (1, 2)

- The filters should be situated so that rain water will not contact the filters.
- There should be no gaps in the air filters and they should be well seated. The filter frames should be of a corrosion resistant material.
- The height of the filter bank should be limited to 8 feet.
  - Where a higher filter bank is unavoidable, a permanent ladder and catwalk should be installed to allow for inspection and maintenance.
- Provide electrical lights in the filter area to inspect and replace filters.
- Provide dial-type magnehelic gauges for all filter banks. Provide a sign below each gauge giving values of anticipated "clean" and "dirty" readings.

2. Filter Plenums

- Provide filter plenums with drains to allow wash down.
- Plenum floors are to be waterproof and sloped at least ¼" per foot to floor drains.
- Each plenum equipped with a floor drain is to have a hose bib.
- Where plenum floors are concrete, filter bank is to be installed on a 6" concrete curb.

3. **Filter Standards (13)**

In 1999, ASHRAE published Standard 52.2, Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size. This new Standard allows a user to evaluate a filter based on the ability of that filter to remove a specific contaminant with a defined particle size. All filters are classified into 16 Minimum Efficiency Reporting Value (MERV) groups. However, for the foreseeable future, filters will continue to be tested under this Standard and the previous version of Standard 52.2

- In the absence of code requirements to the contrary, in an office building application, filters are to have a MERV rating of at least 7 (20-25 % efficiency, with >90 arrestance - roughly equivalent to 30/30 filters).
- For laboratory buildings, hospital applications, and other applications with higher filtration requirements, filters should have a MERV rating of at least 10 (50-55% efficiency, >95 arrestance).

Commissioning HVAC Systems

1. **General Considerations for Commissioning**

- As part of the ventilation system commissioning process, the contractor should put the HVAC system into operation and adjust all controls and equipment to obtain optimal and design operating conditions. In addition, the contractor should be responsible for providing training to designated maintenance personnel on specific aspects of the installation, operation and maintenance of the system. It is a good idea to request at least 3 copies of the "As-Built" ventilation balancing report from the contractor for future reference.
- As a goal each campus should strive to comply with the ASHRAE Guideline 4-1993 on "Preparation of Operating and Maintenance Documentation for Building Systems." These guidelines recommend O&M documentation that should include Operating Manuals, Factory Test Reports, and Construction Test Results for each piece of building equipment, supply fan, exhaust fan, boiler, chiller, cooling tower, heat exchangers, etc. This equipment documentation helps develop maintenance schedules and proper operating ranges for each piece of building equipment installed. ASHRAE Guideline 4 operating information should be accumulated before or as soon after the construction period as possible.
- University EH&S or Plant Operations personnel should spot check the air supply and exhaust volumes in rooms throughout the building to ensure the ventilation is working correctly.

2. New Building Vent-Outs and Bake-Out

- Newly constructed buildings should be ventilated continuously at the highest practical rate for 2-7 days before occupancy. This will reduce the initial contaminant concentrations that are commonly released from new synthetic construction materials and uncured adhesives. Operation of the ventilation system without a night time shut-down cycle will further reduce the initial VOC contaminant concentrations during the first 1-3 months of occupancy.(5)
- The process of building "bake-outs" to remove chemical contaminants from new construction is not currently recommended. The use of low emitting building materials has been found to be more effective and should be selected as an alternative to "bake-out."

New Materials – Construction and Renovation Considerations

1. Finishing Materials Emissions

- Materials low in pollutant emissions should be used where ever possible especially if used in large quantities.
- To decrease the likelihood of high concentrations of VOC building up, the following installation procedures should be considered for interior finishing and construction materials:
  - Review material safety data sheets and emissions prior to installing finishing materials, (especially adhesives or solvents).
  - Require vendors to unpack and store finishing materials in a dry, well-ventilated location prior to installation. This is particularly important for materials with large surface areas, like new carpets, wall coverings, or new partitions. Be aware that unpacking and "airing" of finishing materials may increase cost and the likelihood of damage.
  - Provide maximum outdoor air ventilation when installing finishing materials.
  - Restrict the quantities of adhesives and solvents used during installation to that which is essential.
- Contaminants from stationary local sources within the building should always be controlled by collection and removal as close to the source as practical with local exhaust, instead of relying on general ventilation. (8)

2. Renovations

During partial building renovations and/or construction, air from construction areas should not be allowed to recirculate or spread to occupied areas. Air from the construction areas should be exhausted directly to the outside using temporary exhaust fans and not the general building exhaust; also construction areas should be maintained under negative ventilation pressure relative to other occupied areas. (4)

3. **Green Buildings/Sustainable Design**

   There is a new movement in environmental architecture that is referred to as "Green Buildings or Sustainable Design". It could be referred to as "architecture that minimizes the use of natural resources, toxic materials, and emissions of waste and pollutants over the lifecycle of a building." Buildings that are designed as green buildings are made of materials that minimally off-gas or emit vapors like formaldehyde and VOC's, or negatively affect IAQ of a building. Furthermore, a "Green Building" should be designed with a more environmentally holistic concept, by using passive heating, energy conservation, no use of rare wood products, etc., in an effort to "uphold the health, welfare, and safety of people and future generations that shall live and breathe and dwell upon this earth." Additional information on "Green Buildings" is available from the US Green Building Council (www.usgbc.org) through their Leadership in Energy and Environmental Design (LEED) program and the Environmental Protection Agency.

Microbial Contamination Prevention

1. **General Recommendations for Preventing Microbial Contamination (See Also Chapter 4)**

   - Microbial contamination in buildings is often a function of moisture intrusion from sources such as stagnant water in HVAC air distribution systems and cooling towers.
   - All ventilation systems should be designed so that there is no standing water.
   - Air-handling unit condensate pans should be designed to collect all condensate and have self-drainage to preclude the buildup of microbial slime. (2)
   - Provision should be made for periodic in-situ cleaning of cooling coils and condensate pans.
   - Air-handling and fan coil units should be easily accessible for inspection and preventative maintenance.
   - Steam is preferred as a moisture source for humidifiers, but care should be exercised to avoid contamination from boiling water or steam supply additives. If cold water humidifiers are specified, the water should originate from a potable source, and not be recirculated. (1)
   - Relative humidity in habitable spaces should be maintained below 60% to minimize the growth of allergenic or pathogenic organisms, and above 30% to increase comfort. (3)
   - The combination of high relative humidity (exceeding 70%), low velocity ducts, or low velocity plenums, significantly increases the risk of fungal contamination.
   - Special care should be taken to avoid entrainment of moisture drift from cooling towers into the makeup air and building vents.

Specialty Rooms

1. **Cold rooms**

   Should be designed to provide acceptable amounts of fresh air and not entirely recirculated air.

2. **Animal Rooms**

   Must meet the ventilation requirements of USDA and the recommendations of American Association of Animal Laboratory Care which are incorporated into the “Guide for the Care and Use of Laboratory Animals”, by the National Research Council, published by National Academy Press, Washington, DC in 1996, ISBN 0-309-05377-3.

3. **Smoking**

   All buildings in California are non-smoking and outside air intakes should not be located at locations where people might regularly smoke. Smoking should be prohibited in outdoor areas within twenty feet (or more depending on special circumstances) of entrances, exits and any other locations where smoke may be brought into a facility. Measurements of fugitive tobacco smoke in ventilation systems is of little value due to the lack of standard protocols for measuring levels of tobacco combustion product exposure or evaluating the results of such measurements.

4. **Health Care Facilities**

   Examination and patient rooms where “suspect” active TB patients are examined and treated must comply with the Cal/OSHA Policy & Procedure Interim TB Control Enforcement Guildelines (4/11/97). These guidelines require air recirculated from exposure source areas to be HEPA-filtered, exposure source rooms are negative to other occupied spaces, a minimum of 12 air changes per hour will be provided, and exhaust ducts from exposure sources to be sufficiently separated from outside air intakes and passersby.

REFERENCES

(1) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); *Ventilation for Acceptable Indoor Air Quality*, ASHRAE 62- 2001; ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329; Telephone (404) 636-8400.

(2) American Conference of Governmental Industrial Hygienists (ACGIH); *Industrial Ventilation: A Manual of Recommended Practice*, 23rd Edition, 1998; ACGIH, 1330 Kemper Meadow Dr., Cincinnati, OH 4520-1634; Telephone (513) 742-2020.

(3) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); *Thermal Environmental Conditions for Human Occupancy*, ASHRAE 55-1992; ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329; Telephone (404) 636-8400.

(4) California Department of Health Services, IAQ section, Reducing volatile organic compounds from office building construction materials: non-binding guidelines, 1996.

(5) California Code of Regulations, Title 8, Section 5154: Ventilation Requirements for Laboratory-Type Hood Operations.

(6) University of California Industrial Hygienists/Safety Committee, Indoor Air Quality Workgroup guidance document on Duct Lining. (See Appendix H)

(7) California Code of Regulations, Title 8, Section 4184: Hazardous Parts of Machinery.

(8) National Research Council; *Prudent Practices in the Laboratory;* published by National Academy Press, Washington, D.C., 1995; ISBN 0-309-05229-7.

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(10) Alaimo, Robert J., editor; *Handbook of Chemical Health and Safety*; published by Oxford University Press, Inc. 198 Madison Ave., NY, NY 10016; 2001; ISBN 0-8412-3570-4.

(11) National Research Council; *Guide for the Care and Use of Laboratory Animals;* published by National Academy Press, Washington, DC, 1996; ISBN 0-309-05377-3.

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CHAPTER 3

HVAC OPERATION AND MAINTENANCE

Why Maintain Ventilation Systems

Proper maintenance and operation of building mechanical heating ventilation and air conditioning (HVAC) systems is very important for the following reasons:

- HVAC systems are the primary means of providing a comfortable and healthy indoor environment for building occupants. If the HVAC system is not functioning properly it is likely the indoor environment will be unsatisfactory and possibly unhealthy for some occupants. University policy is to provide a healthy environment for students, faculty, staff, and visitors. Thus, it has a commitment to maintain and properly operate its buildings' mechanical HVAC systems.
- Title 8 of California Code of Regulations, Section 5142 (Cal/OSHA) requires mechanical ventilation systems to be maintained and operated properly (see below).
- When an acceptable indoor environment is provided, the occupants will be more comfortable and thus more effective in meeting the mission of the University.
- The HVAC system must be properly maintained, to help prevent degradation of the quality of the indoor air. As indoor air quality degrades, occupants will justifiably object and insist on assessment of the indoor air. Monitoring and assessment pulls valuable personnel and economic resources from other health and safety issues.

Proper Operation of a HVAC System

1. Operating Standards and Guidelines

- The airborne concentration of pollutants may never exceed the Cal/OSHA permissible exposure limits as defined in Title 8 CCR §5155.
- The mechanical HVAC system should be operated to meet the recommendations of ASHRAE 62-2001 "Ventilation for Acceptable Indoor Air Quality."

2. Temperature and Humidity

For occupant comfort the temperature of occupied space should meet ASHRAE 55-1992 "Thermal Environmental Conditions for Human Occupancy."

- ASHRAE 55 recommends an acceptable range of 68-75°F in the winter and 73-79°F in the summer. Most individuals consider a temperature range of 70°F - 75°F to be comfortable.
- The relative humidity of occupied space should be maintained below 60% to prevent condensation and microbial growth, but above 30% for comfort. The air velocity at the affected occupant should be 30 - 50 linear feet per minute (lfpm); air velocities over 50 lfpm may result in complaints of draftiness.

3. Duration of Operation

- For energy conservation, building ventilation may be turned off when the building is not occupied; however, the ventilation should be turned on to suitably pre-heat and ventilate the building prior to general occupancy. The building should have at least three complete air changes prior to general occupancy (typically at least one hour).

- Buildings that contain hazardous materials or that have ventilation designed to operate constantly should not have the ventilation turned off for energy conservation.

4. Building Operating Pressure

- The building ventilation pressure should be slightly positive to the outdoors (0.1-0.3 inches of water), so that outdoor air is not drawn into the building except through the HVAC system.
- Restrooms, shower rooms, copy rooms, food service, spaces using hazardous materials, and other locations that might produce objectionable odors should be kept under negative pressure relative to "clean," public locations.

How to Properly Maintain a HVAC System

Responsibilities

The Owners/Administrators need to understand the advantages of preventative maintenance and providing acceptable indoor air quality compared to the costs and consequences of responding to occupant indoor air quality concerns. Environmental Health & Safety should proactively advocate the importance of proper HVAC maintenance programs to Owners/Administrators and work cooperatively with Physical Plant to ensure proper maintenance is routinely performed.

5. Cal/OSHA - Operating Criteria

At a minimum, each campus shall comply with 8 CCR §5142 "Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation", which requires existing HVAC systems to be operated continuously during working hours (except for emergency or mechanical shutdowns) and that there be an inspection and maintenance program. "The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time." Inspections and maintenance of the HVAC system shall be documented in writing and the records shall be maintained for 5 years.

6. ASHRAE - Operating Criteria

- As a goal, each campus should meet the ASHRAE guideline for the "Preparation of Operating and Maintenance Documentation for Building Systems" Guideline 4-1993. This guideline recommends O&M documentation including Operating Manuals, Factory Test Reports, and Construction Test Results for each piece of building equipment (i.e., supply fan, exhaust fan, boiler, chiller, cooling tower, heat exchange). This equipment documentation allows the building owners to determine the maintenance schedule and the proper operating range for each piece of building equipment. The ASHRAE-Guideline 4 recommends the accumulation of equipment information before, or soon after, the construction period.
- In the absence of the documentation referenced in ASHRAE-Guideline 4 the University should consult with qualified maintenance and engineering staff to suggest an appropriate schedule for HVAC maintenance. At a minimum, the HVAC maintenance program must meet the annual requirements of 8 CCR §5142.

HVAC Maintenance Schedule

Below is a *suggested* maintenance schedule.

Inspections

- Inspect the HVAC system at least monthly to ensure the system is operating within specification. Problems should be reported and corrected in a timely manner.
- Visually inspect the supply fan systems monthly to ensure that standing water does not accumulate and allow the growth of microorganisms.
- Document inspections and corrective actions. Records on the HVAC system should be maintained for at least five years and should be readily available to employees and/or government inspectors upon request.

7. Preventive Maintenance Schedule for HVAC Equipment

<u>Fans Supply and Return</u>

Monthly:	✓ Check fan operation for excessive noise, vibration, belt tightness, and temperature of supply air. ✓ Check that the actuators for the economizer return dampers and the outdoor air dampers are operating properly, and an adequate minimum amount of outside air is always being provided. Lubricate as needed.
Quarterly:	✓ Lubricate fan bearings. ✓ Check and tighten all set-screws and loose bolts.
Annually:	✓ Check motor nameplate for lubrication requirements. Note: Some motors have sealed bearings that do not require lubrication. ✓ Clean outside air screen. Clean outside drains to prevent standing rain or landscape water from accumulating.

<u>Exhaust Fans</u>

Quarterly:	✓ Check fan belt tension and alignment. ✓ Check set-screws and bolts for tightness.

	✓ Check for excessive noise, vibration and temperature. ✓ Lubricate fan bearings
Annually:	✓ Check motor nameplate for lubrication requirements. ✓ Clean fan scroll, if needed.

Air Handling Equipment Package Units

Weekly:	✓ Check for excessive noise, vibration and temperature.
Monthly:	✓ Check bearings to be sure all set-screws and bolts are tight. ✓ Check v-belts for wear and belt tightness. ✓ Check seismic snubbers and spring isolators to see if they are grounded out. Check at 60 to 80% speed of the fans. Fan flex connections should not be strained. ✓ Clean condensate drain pans and drains. ✓ Clean outside air screens, dampers, damper motors and linkage. Lubricate as needed. ✓ Check, replace filters as prescribed by particular manufacturer, or when the total pressure drop through the prefilters and filters exceeds 1.5 inches water gauge.
Quarterly:	✓ Grease bearings as required with the proper grease. ✓ Inspect operation of motor starters and wiring. ✓ Check amperage and voltage to motors and compare with nameplate rating.
Annually:	✓ Grease motors as required. ✓ Check v-belt alignment, proper belt tension, belt wear and dirt. ✓ Check motor and fan sheaves for proper alignment, replace v-belts if worn. ✓ Check and clean fans and scrolls. ✓ Check heating and cooling coils for dirt; clean as required.

Fan Powered Boxes

Quarterly:	✓ Check motors. ✓ Check filters.

Fan -Coil Units and Convectors

Semi-Annually:	✓ Check filter, change or replace. ✓ Lubricate and clean motor.

Air Filters Inspections

Monthly:	✓ Check filter manometers for pressure drop across filter bank.

Air Filter Changes

Every Six Months or as needed:	✓ Change air filters when the pressure drop across the filter reaches the maximum recommended by the manufacturer, or ✓ When the pressure drop across the filter is twice the pressure drop of new filters, or

	✓ On a regular schedule, based on visual inspections and pressure measurements.
When Damaged	✓ Change filters if they become wet, if microbial growth on the filter media is visible, if they collapse, or become damaged to the extent that air bypasses the media.

Other Air Filter Maintenance Considerations

Filtering Media Specifications	✓ Install filters with a minimum of 60% dust arrestance (ASHRAE 52.1). The filters should be properly fitted to prevent by-pass. Recommend higher efficiency air filters be installed if occupant's symptoms warrant (i.e. 95% bag filters). Higher efficient air filters may increase resistance and decrease volume of air provided by supply fan system. ✓ Do not use filters made of fiberglass. The UCIAQ Work Group recommends polyester fiber filters. ✓ Turn off supply fans when changing the filters to prevent debris from entering the downstream duct work.
Cleaning	✓ Clean and wash down the filter area while fans are off.

Filter Manometers

Quarterly:	✓ Check calibration on manometers and magnehelics.

Backdraft Dampers

Semi-Annually:	✓ Clean and check for free operation. ✓ Lubricate bearings if required.

Fire Dampers

Quarterly:	✓ Inspect linkage and freedom of operation.

Dampers

Semi-Annually:	✓ Inspect, clean with wiping cloth, and lubricate.

Air Balancing

Air balancing needs to be done during the start-up period of construction, and after modifications are made to the air handing system such as addition of duct work, zoning, diffusers, or any other systems that affect air flow. Note: Proper testing and balancing should be conducted to ensure that HVAC systems meet design, comfort and health requirements, as well as, minimize energy consumption. The building should be balanced by a professional to design specifications as called out in the mechanical systems "As-Built" drawings. Airflow rates should be measured in accordance with ANSI/ASHRAE Standard 111-1988 or other approved procedure. If airflow rates are found to differ from current design airflow rates by more than 10%, these findings should be brought to the attention of the responsible party.

No ventilation changes should be made without the proper test equipment to measure changes.

Ventilation balance reports should be supplied with the building manual and should contain all of the final balanced readings.

The balance report should be updated if any changes are made. These reports serve as a valuable reference to help trouble shoot any problems that might develop.

Plenums/Ducts

Variable Air Volume (VAV) control boxes should be checked periodically to verify minimum damper position still provides acceptable volume of outside air.

Supply and return air plenum systems (in representative locations) should be inspected periodically for cleanliness, obstructions that block the air paths, water damage, visible microbial growth, or hazardous materials. Corrective action should be taken to correct any unsatisfactory situations.

Accumulated dust or debris in a supply ventilation system may not require removal. If the duct debris is thought to be transported into the occupied space where it is a hazard or a nuisance, or there is a possibility that the debris is in contact with water and could become a microbial hazard, duct cleaning should be considered. See Appendix G.

Cooling Towers

Cooling tower water systems should be treated to control the growth of microbial contaminants. Provide inspection and maintenance record or log for the water treatment program.

Microbial control in cooling tower water systems should involve water treatment:

- To limit corrosion
- To prevent the build-up of scale and sediment
- To reduce the amount of bacteria, including Legionella, and other microorganisms.

Microbiocidal control commonly involves the use of biocides and/or use of physical methods to kill microorganisms plus routine cleaning and disinfection. Routine treatment with a biocide known to be effective against Legionella, coupled with good cleaning practices, should be effective in controlling the amplification of Legionella. A testing program may be considered to verify the effectiveness of the water treatment program.

Minimum horizontal separation distance between cooling towers and outdoor air intakes, and other areas where people may be exposed should be considered. ASHRAE-62, 2001 recommends a minimum separation of 15 feet between cooling tower and building intake.

To reduce emission of aerosols:

- Equip cooling towers with highly efficient drift eliminators.
- Construct the cooling tower pond to facilitate drainage of sludge, silt, and debris during periodic cleaning.
- Construct the tower with materials that are resistant to bio-deterioration.
- Install coarse mesh screens over the air intake components of the cooling tower to reduce the entrance of coarse debris.

Digitally Controlled Systems

Periodically check and calibrate the temperature, pressure, and air velocity sensors per the manufacturer’s recommendations.

CHAPTER 4

MICROBIAL GROWTH and SAMPLING METHODS

Microorganisms such as bacteria, viruses and fungi are ubiquitous and are therefore readily found in our indoor and outdoor environment. Excessive proliferation or distribution of microbial growth inside buildings have been known to cause respiratory related ailments as well as skin rashes and in the case of Legionella, fatalities. This chapter is intended to provide an introduction to microbial growth as it relates to IAQ and an overview of sampling methods. Exhaustive literature in the form of books and research papers is readily available where more in depth information is needed by the IAQ investigator.

Controlling Microbial Growth

Microbial contamination in buildings is often a function of moisture intrusion from sources such as stagnant water in HVAC air distribution systems, cooling towers and leaks through the building envelope. In an attempt to minimize and control microbial growth, the following items should be considered:

1. **Relative humidity.**
   - Relative humidity in habitable spaces should be maintained below 60% to minimize the growth of allergenic or pathogenic organisms and above 30% to maintain comfort.
   - The combination of high relative humidity (exceeding 70%) and low velocity ducts or plenums, significantly increases the risk of fungal contamination.
2. **Remove moisture sources.**
   - There should be no standing water in the ventilation system.
   - Building materials and furnishings that may become wet should be dried out rapidly (within 24-36 hours) or discarded. (Note: Materials that become wet from sewage or gray water should be discarded.)
   - Pursuant to Title 8, California Code of Regulations, Section 3362 (g), when exterior water intrusion, leakage from interior water sources, or other uncontrolled accumulation of water occurs, the intrusion, leakage or accumulation shall be corrected because of the potential for these conditions to cause mold growth.

4. HVAC design

- Place outdoor air intakes in a predominantly upwind direction and at least 25 feet from external bioaerosol sources (cooling towers, evaporative condensers) to eliminate water entrainment from outside due to weather conditions.
  - Special care should be taken to avoid entrainment of moisture drift from cooling towers into the makeup air and building vents.
- Dehumidification improves comfort and prevents mold growth. Minimize water droplets from coils on surfaces in mechanical ventilation system and do not allow water to accumulate. Another method for controlling humidity is to place reheat coils or desiccants downstream from the heat exchanger.
- Ensure humidifier sumps drain automatically or continuously. Sumps should be part of an ongoing maintenance program to keep them clean and operable.
  - Humidifiers that use recirculated water are not recommended in office HVAC systems.
  - Water spray humidifiers are not recommended in office buildings.
- Design and construct drains and drain pans for efficient drainage.
  - Air-handling unit condensate pans should be designed to collect all condensate and have self-drainage to preclude the buildup of microbial slime.
- Upgrade the efficiency of particulate filter or air cleaners. Filters with an efficiency of 50% to 70% will adequately remove microorganisms larger than 2µm from the air (MERV rating of at least 7). Low efficiency prefilters should be used to remove coarse dust and to extend the life of the more efficient filter.
- Install efficient filters downstream of the heat exchanger to protect occupants from bioaerosols generated downstream in cooling deck coils, humidifiers, and water spray systems.
- Avoid using fiberglass insulation inside ducts. If internal insulation is used, make sure it is protected with a plastic or other waterproof lining.
- Place access panels strategically along the duct for periodic inspection.

5. HVAC Operation and Maintenance

- Clean out drain pans by physically removing slimes, fungal growth and bio-film. Simply using biocides for disinfection may not be adequate.
- Remove any stagnant water accumulating in or near condensate pans, fan-coils and air handlers.
- Replace particle filters periodically (see Air Filters, Chapter 2) and replace water damaged filters as needed.
- Operate cooling coils during the summer so that spores and substrate impacting on the coils are washed away by condensed water.
- Turn off HVAC system to prevent distribution of microbial reservoirs during system cleaning.
- Remove chlorine compounds or other biocides used for disinfection prior to reactivating HVAC system.

6. Water Treatment in Cooling Towers

- Use bromides, chlorides (alkyl dialkylbenzyl ammonium chloride salts), or other biocides to control slime, algae, plankton bacteria and other microorganisms in cooling towers. Cooling tower water should be regularly tested to ensure the proper amounts of biocides and corrosion inhibitor are maintained.
- Install coarse mesh screens over the air intake components of the cooling tower to reduce the entrance of coarse debris.
- Equip cooling towers with highly efficient drift eliminators.
- Construct cooling tower pond to facilitate drainage of sludge, silt, and debris during periodic cleaning.
- Use materials that are resistant to bio-deterioration when constructing the tower.

7. Carpets

- Concrete floors should be sealed with a water barrier solution before carpet is installed.
- Carpet and pads should not be installed over damp materials. The adhesive backing and dust that accumulates in the pile of carpets provide nutrients for microorganisms and dust mites.
- Vacuum carpet at least weekly to minimize microbes and dust mites. Use a HEPA vacuum in areas where allergic occupants reside.
- Carpets should be cleaned by steam extraction at least annually - more often, if carpet becomes deeply soiled. Use heat and fans to quickly dry carpet when cleaned with steam or water.

REFERENCES

(1) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); *Ventilation for Acceptable Indoor Air Quality*, ASHRAE 62- 2001; ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329; Telephone (404) 636-8400.

(2) *Bioaerosols: Assessment and Control;* Edited by, Janet Macher; American Conference of Governmental Industrial Hygienists, Cincinnati, OH. (1999).

Microorganism Sampling Methods

Things to Remember:

Environmental sampling for microorganisms should only be conducted after the development of hypotheses about potential sources of agents and mechanisms by which individuals may be exposed. (See chapter 1) It is important to understand that results from bioaerosol sampling may be inconclusive and sometimes misleading. Bioaerosols describe airborne particulate matter of microbiological origin like viruses, bacteria, fungi and their spores and protozoans.

It is not possible to collect and evaluate all microorganisms using only one sampling method. Airborne agents may be collected for viable sampling on agar plates for culturing and speciation or collected for total microorganism counts and identification on a sticky surface. Different sample collection and analysis methods can produce different estimates of the relative concentrations of culturable or countable microorganisms.

Why Collect Air Samples?

- Detect and quantify bioaerosols present
- Identify if bioaerosols are being released from sources
- Assess the potential for human exposure
- Monitor effectiveness of control measures

Air Sampling Methods

1. Air Sampling: Total Counts (Viable and Non-Viable)

Sampling Principle:

- Spore impaction samplers
- Retrieval of fungal spores and pollen
- Impaction onto sticky surface
- Microscopic analysis
- Examples:
  - Burkard Impactor - Burkard Manufacturing Co., Ltd., Rickmansworth, England
    - Personal slide impactor sampler, sampling time 1-15 minutes
    - Spore trap sampler, sampling time 24 hr and 7 day sampling heads
    - Flow rate 10 liters/min
  - Zefon Aerosol Cassettes
    Flow rate 15 liters/min (can use any high volume pump or Zefon –specific Mini or Bio-Pump with fixed 15 l/min flowrate)
    - Sampling time 1-10 minutes

2. Air Sampling: Viable Samples

<u>3 Sampling Principles:</u>

Principle I: Impaction onto Agar media

- Retrieval of culturable bacteria and fungi
- Agar impaction surface (malt extract agar-MEA, dichloran glycerol-18-DG18, potato dextrose agar-PDA, corn meal agar-CMA, tryptic soy agar-TSA, blood agar plates-BAP…)
- Culture based analysis
- Examples:
  - Andersen Multi and Single Stage Sampler - Graseby Andersen Instruments Co., Atlanta, GA
    - Bioaerosol size information (multistage)
    - Require separate vacuum pump and electrical source
    - Flow rate: 28 liters/min, sampling time 2-5 minutes
    - Collection onto agar-filled 100 mm Petri plate
    - Coincidence correction needed
  - Aerotech 6™ Viable Microbial Particle Sampler-Aerotech Laboratories, Phoenix, AZ
    - Requires separate vacuum pump, flow meter and electrical source
    - Flow rate: 28.3 liters/min, sampling time 2-5 minutes
    - Collection onto agar plate
  - Biotest RCS and RCS Plus Samplers Biotest Diagnostics Corp., Denville, NJ.
    - Hand-held, portable samplers
    - Internal battery powered motor
    - Selection of volume of air and sampling time
    - Agar filled wells mounted in a continuous strip
    - Flow rate 50 liters/min
  - Spiral Biotect, Bethesda, MD
    - Hand-held, portable samplers
    - Internal battery powered motor
    - Fixed flow rate
    - Selection of sampling or volume depending on model
    - Coincidence correction needed
  - Slit-to-Agar Samplers - New Brunswick Scientific Co., Edison, NJ
    - Rotating 150 mm agar-filled Petri plate
    - Culturable bacteria and fungi
    - Variable time

Principle II: Impinger Samplers (Impinging air into liquid)

- Microscopic, culture or molecular biology analysis

- Retrieval of airborne bacteria and fungi
- Collection of sample into liquid matrix (choose liquid based on target organisms)
- Variety of analytical assays possible (microscopy, biochemical or immunological assays, inoculate onto culture medium…)
- Examples:
  - All-glass impinger- AGI-30, Ace Glass, Vineland, CA
    - Possible breakage of sampler due to glass construction
    - Sonication during sampling, may affect culturablility of stressed cells and may release clumps of organisms
    - Flow rate: 12 liters/min
    - Require separate vacuum pump and electrical source

Principle III: Filtration Sampling

- Collection onto filter matrix (sterile microporous filters –typically MCE 0.4um or 0.8um pore size, 37-mm diameter or polycarbonate, 0.8um pore size)
- Desiccation stress - if used for extended time period. Sampling time less than 30 minutes.
- Minimal equipment needed; filter cassettes and vacuum pump

Surface Sampling Methods

1. Contact Plate Sampling

- Culture analysis for bacteria and fungi (viable sampling)
- Convex agar surface (manufacturers: Biotest Hycon, Difco, Falcon Nunc, Becton Dickinson)
- Primarily used for smooth sampling surfaces

2. Tape Sampling

- Use clear adhesive tape with good optical quality
- Microscopic analysis (non-viable sampling)
- Primarily used for smooth surfaces (good for fungal spore and hyphae, pollen grain and other large distinctive particle identification)

3. Swab Sampling (Surface Wash)

- Uses microscopy, culture, biochemical or molecular biology analysis
- Used for smooth, roughened and irregular surfaces (diffusers, desks, windows, walls etc.)
- Retrieval of culturable bacteria and fungi with isolation to agar media (aseptic methods)

Bulk Sampling Methods

A portion of material is removed and tested to determine if it contains or is contaminated with biological agents. Examples of bulk materials include: wallboard, duct lining, carpet, air-handling filters, settled dust and wallpaper, etc.

- Can be used for both viable and non-viable bioaerosols.
- Useful in identifying sources of contamination so that they can be remediated.

a. Sample is cut or aseptically removed from source. Dust samples may be collected using a variety of suction methods (vacuums and bags, microvacuums, open–faced personal cassettes, etc.) Consult analytical laboratory for quantity of sample required and collection method.
b. Place in clean, new or sterilized container (sterile jars or bottles, new paper bags subsequently placed in plastic bag with dessicant, sealable plastic bags, etc.)
c. Analysis: Culture-based (viable)- inoculate agar with bulk sample and incubate or; Non-Culture based (non-viable)-microscopic examination, biological or chemical assays.

REFERENCES

(1) *Bioaerosols: Assessment and Control;* Edited by, Janet Macher; American Conference of Governmental Industrial Hygienists, Cincinnati, OH. (1999).

(2) *Field Guide for the Determination of Biological Contaminants in Environmental Samples, An AIHA Biosafety Guide*; Editors: Dillon, Heinsohn & Miller; AIHA Biosafety Committee, 1996.

(3) *IAQ Sampling Guide;* Aerotech Kalmar Laboratories Inc., 2002

CHAPTER 5

USEFUL IAQ RESOURCES AND REFERENCES

This section is a general resource on organizations related to indoor air quality. These organizations include government agencies, professional associations, research groups, testing laboratories, manufacturers' associations, and international organizations. This chapter provides web addresses and brief descriptions of the organizations, and in some cases, summaries of selected publications or key information. These resources and references have been found by many IAQ professionals to be useful. However, mention of a particular organization in this document does not constitute an endorsement or guarantee of the information provided by that organization. While every effort is made to provide information only from reputable organizations, individuals using this document must consider the information source prior to use.

ACGIH – American Conference of Governmental Industrial Hygienists
www.acgih.org

TLVs® and BEIs® – Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (2003 or current edition)

TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. They are intended to be used as *guidelines* or *recommendations* to assist in the control of potential health hazards.

Almost without exception, atmospheric monitoring in office environments reveals chemical contaminant concentrations far below TLVs. The TLVs may, however, serve as a useful point of reference for occupants when educating them about possible causes and solutions during IAQ investigations.

Starting with the 2001 edition, ACGIH now publishes a section on biologically derived airborne contaminants. While TLVs for such contaminants do not exist, ACGIH provides guidance for assessing bioaerosol exposures and advises of the difficulty in gaining useful information from bioaerosol monitoring.

ACGIH offers many other publications related to ventilation, indoor air quality, bioaerosols, including ones from SMACNA, US EPA, and the Jeff Burton workbooks. See the ACGIH website or publications catalog for more information. Some of the more well-known publications include:

- **Industrial Ventilation: A Manual of Recommended Practice (24th, or current edition)**
  Chapter 8, "Ventilation Aspects of Indoor Air Quality," provides general information and recommendations including an overview of HVAC components and system types, HVAC system potential problems, and references to various ASHRAE guidelines and technical documents.
- **Bioaerosols: Assessment and Control (1999)**
  This is a revised edition, replacing Guidelines for the Assessment of Bioaerosols in the Indoor Environment. This is a comprehensive guide to the assessment and control of bioaerosols in the workplace.

AIHA – American Industrial Hygiene Association
www.aiha.org

The Industrial Hygienists Guide To Indoor Air Quality Investigations (1993)

This guide will help industrial hygienists carry out these studies in a quick and cost-effective manner. Changes affecting indoor air quality in recent years and their causes are discussed, and a thorough step-by-step outline for identifying and solving problems is presented. Several tables and appendices help break down critical information. There also is a helpful occupant health and comfort questionnaire suitable for in-the-field use.

Field Guide for the Determination of Biological Contaminants (1996)

This field guide addresses the sampling of various types of biocontaminants.

Report of Microbial Growth Task Force (2001)

This report offers a wealth of practical information about the proper assessment and remediation of microbial contamination in buildings. It is intended to help industrial hygienists make the tough decisions they face on this issue in the absence of complete data.

American Indoor Air Quality Council
http://www.iaqcouncil.org

The American Indoor Air Quality Council promotes awareness, education, and certification in the field of Indoor Air Quality through learning, sharing, and networking. It offers workshops, courses, a newsletter, and many links.

ASHRAE – American Society of Heating Refrigeration and Air-Conditioning Engineers **(now an international organization)**
www.ashrae.org

Standard 62-2001. "Ventilation for Acceptable Indoor Air Quality."

The purpose of the standard is to provide guidance for ventilation design and to specify indoor air quality "acceptable to human occupants." This standard is continually updated and addenda may be downloaded for free from the ASHRAE website. It has for several years been generally used as the industry standard for indoor air quality guidance. General recommendations include:

- Use of carbon dioxide (CO_2) as a surrogate indicator of air exchange, e.g., CO_2 should be less than 700 ppm over outdoor CO_2 levels.
- HVAC system design to provide a minimum volume of outdoor air based on use or occupancy, e.g., 15-20 CFM (8-10 L/s) per person for occupied zones in a building.

Standard 55-1992. "Thermal Environmental Conditions for Human Occupancy."

Provides guidance on environmental and personal factors that can be related directly to indoor air quality; addresses temperature, thermal radiation, humidity, air speed, activity, and clothing. Good IAQ is where 80% or more occupants find it acceptable. General recommendations include:

- Maximum Relative humidity = 60% (Range = 30% to 60%)
- Suggested temperature ranges = 68-75°F (winter) and 73-79°F (summer).
- ASHRAE has a number of other standards, including ones on aerosol filtration,

commissioning ventilation systems, and HVAC operations and maintenance.

ASTM International (formerly known as the American Society for Testing and Materials)
www.astm.org

ASTM International provides standards that are accepted and used in research and development, product testing, quality systems, and commercial transactions around the globe. Publications include test method for HEPA filter performance.

California Air Resources Board
http://www.arb.ca.gov/

The California Air Resources Board is a part of the California Environmental Protection Agency. Information found under the "Air Quality & Emissions" link includes air quality standards (summarized below), ambient air quality monitoring programs, emissions inventories, and air quality models. Specific air quality data from monitoring stations throughout California are available at http://www.arb.ca.gov/aqd/aqd.htm.

California Energy Code – California Energy Commission
2001 Energy Efficiency Standards for Residential and Nonresidential Buildings, (CCR Title 24 Part 6, .pdf document is available)
http://www.energy.ca.gov/title24/standards/index.html

- Ventilation requirements for nonresidential, high-rise residential, and hotel/motel facilities are outlined in Subchapter 3. Highlights are provided below as a quick reference. Refer to the subchapter for details.
- Design Requirements for Minimum Quantities of Outdoor Air
  - Natural ventilation may be provided for spaces that are within 20 feet of an operable wall or roof opening, which has a direct, unobstructed flow of outdoor air.
  - Mechanical ventilation shall be provided for spaces that are not naturally ventilated as above. The minimum amount of outdoor air provided by the mechanical system shall be at least the larger of:
    - Ventilation rate ranging from 0.15 – 1.5 cfm per square foot, depending on the type of use. Spaces with contaminant sources, such as bars, beauty shops, dry cleaners, auto repair shops, etc. will have higher rates.
    - Fifteen cfm per person times the expected number of occupants. (See Chapter 10 of the Uniform Building Code for occupancy determinations.)

Cal/OSHA, (General Industry Safety Orders, 8 CCR §5142.) Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation.
http://www.dir.ca.gov/Title8/5142.html

In general, this section requires:

- HVAC systems to be maintained and operated to provide at least the minimum quantity of outdoor air required by the State Building Standards Code in effect at the time the building permit was issued. Continuous operation during working hours (except for scheduled maintenance and emergency repairs).

- Annual inspections, problem correction within a reasonable time, and inspection/maintenance documentation.

ISIAQ (International Society of Indoor Air Quality and Climate)
http://www.ie.dtu.dk/isiaq/

ISIAQ is an international, multidisciplinary, non-profit organization whose purpose is to support the creation of healthy, comfortable and productive indoor environments. ISIAQ publishes a journal and newsletter, and sponsors conferences and seminars on indoor air.

Ambient Air Quality Standards

Source: California Air Resources Board www.arb.ca.gov/

Pollutant	Averaging Time	California	National
Ozone	1 hr.	0.09 ppm	0.12 ppm
	8 hr.	–	0.08 ppm
Respirable Particulate Matter (PM10)	24 hr.	50 µg/m^3	150 µg/m^3
	annual	20 µg/m^3	50 µg/m^3
Fine Particulate Matter (PM2.5)	24 hr.	none	65 µg/m^3
	annual	12 µg/m^3	15 µg/m^3
Carbon monoxide	8 hr.	9.0 ppm 6 ppm (Lake Tahoe)	9.0 ppm
	1 hr.	20 ppm	35 ppm
Nitrogen dioxide	1 hr.	0.25 ppm	0.053 ppm (annual average)
Sulfur dioxide	24 hr.	0.04 ppm	0.14 ppm (0.030 ppm annual ave.)
	1 hr.	0.25 ppm	
Lead	30 day	1.5 µg/m^3	1.5 µg/m^3 (calendar quarter)
Sulfates	24 hr.	25 µg/m^3	none
Hydrogen sulfide	1 hr.	0.03 ppm	none
Vinyl chloride	24 hr.	0.01 ppm	none

Jeff Burton Workbook Series

http://www.eburton.com/

Jeff Burton has a number of publications, self-study courses, and workshops that focus on ventilation, indoor air quality, and general industrial hygiene. These publications are also available through a variety of other sources, such as ACGIH. Some of the more popular workbooks include:

> **IAQ and HVAC Workbook, Fourth Edition (1993-2002)**
> This user-friendly workbook describes indoor air quality investigation techniques and building air handling systems in simple, understandable terms. Case studies, sample calculations, and exercises follow short sections of text. The new edition contains a number of charts, forms, and checklists, and is listed in the Federal Register as a "valuable data resource."
>
> **Indoor Air Quality Guidebook for Safety Professionals (1999)**
> New and written especially for the safety professional, the *IAQ Guidebook* is written in simple, understandable terms. This workbook covers investigation techniques, an overview of air contaminants, a description of building HVAC systems, and IAQ management control strategies. This workbook also has a number of charts, forms, and checklists, a glossary, and references.

The National Air Duct Cleaners Association (NADCA)

http://www.nadca.com/

NADCA offers several publications, including NADCA standards and guidelines, and a periodical. The latest standard is "Assessment, Cleaning and Restoration of HVAC Systems" (ACR-2002). It defines acceptable cleanliness levels after cleaning, provides two methods of verifying cleaning effectiveness, and specifies general requirements related to occupants health and safety, equipment, and other areas of cleaning.

NFPA – National Fire Protection Association

www.nfpa.org

NFPA is a worldwide leader in providing fire, electrical, and life safety to the public. It has a number of publications and standards, including NFPA 45, "Standard on Fire Protection for Laboratories Using Chemicals (2000)."

NIST (National Institute of Standards and Technology)

Building and Fire Research Laboratory – **http://www.bfrl.nist.gov/**
Indoor Air Quality and Ventilation Group Laboratory – **http://www.bfrl.nist.gov/863/iaq.html**

NIST is an organization that develops and promotes measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life. Publication topics include IAQ commissioning, ventilation evaluation, and green buildings. NIST has also developed an indoor air quality and ventilation analysis program computer program (CONTAMW). A number of these publications are available online.

OSHA – Occupational Safety and Health Administration
www.osha.gov

OSHA proposed to adopt standards addressing indoor air quality in 1994. While final rulemaking has not taken place, OSHA includes useful information on indoor air quality in the "Safety and Health Topics" section of their website. The indoor air quality link (http://www.osha-slc.gov/SLTC/indoorairquality/index.html) provides a good summary of recognition, evaluation, control, and compliance information.

SMACNA – Sheet Metal and Air Conditioning Contractors' National Association, Inc.
www.smacna.org

An international association of union contractors who specialize in areas such as HVAC, sheet metal, and energy management. They develop voluntary technical standards and manuals, and are accredited by ANSI as a standards-setting organization. SMACNA standards and manuals address all facets of the sheet metal industry, from duct construction and installation to air pollution control, from energy recovery to roofing. Some of these publications (available for purchase) are summarized below:

Indoor Air Quality – A Systems Approach, 3rd Edition (1998)

This new manual is an update to the Indoor Air Quality (IAQ) manual. It provides for a system type approach to identifying and solving IAQ concerns, while introducing the fundamentals of IAQ. The manual also updates the technical aspects of IAQ with regard to typical contaminants found in today's facilities. Other topics covered are testing, identification and source mitigation. Also includes a standards and reference section, IAQ tracking forms, checklists, pollutant index, information on symptoms and illnesses, and resources.

IAQ Guidelines for Occupied Buildings Under Construction (1995)

IAQ Guidelines is a valuable resource for construction supervisors and management. This manual is a comprehensive guide on how to effectively manage indoor air quality during building renovation or when occupying a building during the final stages of new construction. It describes in a logical, easy-to-understand manner the source of pollutants, methods of control, and management techniques necessary to maintain acceptable indoor air quality during construction. It also addresses communicating with occupants and gives four example projects. Appendices include references, resources, and checklists.

The Texas Institute for Advancement of Chemical Technology, Inc. (TIACT)
http://www-chen.tamu.edu/TIACT/

TIACT offers a number of publications at no charge (some online) on topics such as handling odor problems, health effects of particulate matter, chemicals and cancer, and other workplace safety topics.

US EPA (US Environmental Protection Agency): Indoor Air Quality
http://www.epa.gov/iaq/

The US EPA's indoor air quality page contains a variety of information, including specific indoor air topics, a glossary, hotlines, publications and software, and links to other organizations. A number of the publications are available as free downloads online, such as:

Building Air Quality: A Guide for Building Owners and Facility Managers, December 1991
Developed by the EPA and the National Institute for Occupational Safety and Health (NIOSH), this document provides practical suggestions on preventing, identifying, and resolving indoor air quality (IAQ) problems in public and commercial buildings. This includes a large number of checklists and forms to use in IAQ investigations.

Mold Remediation in Schools and Commercial Buildings, March 2001
This document presents guidelines for the remediation/cleanup of mold and moisture problems in schools and commercial buildings; these guidelines include measures designed to protect the health of building occupants and remediators. It has been designed primarily for building managers, custodians, and others who are responsible for commercial building and school maintenance. It should serve as a reference for potential mold and moisture remediators.

IAQ Building Education and Assessment Model (I-BEAM) Computer Software
I-BEAM is computer software for use by building professionals and others interested in indoor air quality in commercial buildings. I-BEAM updates and expands EPA's existing Building Air Quality guidance and is designed to be comprehensive state-of-the-art guidance for managing IAQ in commercial buildings. I-BEAM contains text, animation/visual, and interactive/calculation components that can be used to perform a number of diverse tasks.

Additional Useful Links

American Lung Association
http://www.lungusa.org/air/air_indoor_index.html

Association of Energy Engineers
http://www.aeecenter.org/

California Department of Health Services – IAQ Program
http://www.cal-iaq.org/

Canadian Center for Occupational Health and Safety
http://www.ccohs.ca/

US Environmental Protection Agency – Indoor Air – Radon
http://www.epa.gov/radon/zonemap.html

Healthy Indoor Air for America's Homes (residential IAQ)
http://www.montana.edu:80/wwwcxair/

International Centre for Indoor Environment and Energy (Technical University of Denmark)
http://www.ie.dtu.dk/

www.legionella.org
http://www.legionella.org/

National Environmental Health Association (NEHA)
http://www.neha.org/index.html

New York Committee for Occupational Safety and Health (NYCOSH)
http://www.nycosh.org/onthejob.html

NIOSH (National Institute of Occupational Safety and Health) IAQ Page
http://www.cdc.gov/niosh/iaqpg.html

North American Insulation Manufacturers Association (NAIMA)
http://www.naima.org/

Appendices

IAQ GUIDANCE AND INFORMATION FACT SHEETS

The purpose of this section is to help the IAQ Practitioner with managing IAQ inquiries, complaints, and investigations.

Appendix A

AN ORGANIZATIONAL APPROACH TO ADDRESSING IAQ ISSUES

INDOOR AIR QUALITY IMPROVEMENT TEAM (IAQIT)

1. Objective

To develop a pro-active, organized and cost-effective method for addressing specific Indoor Air Quality (IAQ) needs of each University of California campus. This method for addressing IAQ promotes:

- A safe and healthy work environment
- Education and information regarding IAQ
- Quick and efficient response to IAQ problems

2. Assessing the Current Situation

An initial assessment of individuals and working groups currently addressing IAQ situations within the campus or facility should be made. Commonly, these individuals or groups can be found in both the Health and Safety department and at the Heating, Ventilation, and Air Conditioning (HVAC) maintenance shop. Individuals working within an affected facility may also serve as a valuable resource. It is important to identify all persons involved to eliminate duplication of efforts and prevent the spread of misinformation. Involved individuals typically consist of:

- Health and Safety Departments
- HVAC Maintenance Shop(s)
- On-Site Medical Facilities
- Facility Managers
- Building Coordinators
- Clients/Occupants

3. Developing the Team

Since there are many groups of people effected by IAQ, there should likewise be many groups represented on any Team assembled to address the “big picture”. Although the actual composition of an Indoor Air Quality Improvement Team (IAQIT) may vary from campus to campus, individuals representing the following groups should be considered:

- Health and Safety Department
  - Industrial Hygienists
  - Safety Engineers
- HVAC Maintenance Shop
- On-Site Medical Facility
- Facility Managers
- Building Coordinators

- Custodians
- Engineering and Construction
- Employee Representatives (including Union representatives)

4. IAQIT Responsibilities

Most campuses have many constituents involved in IAQ issues of one sort or another. Therefore, the effort to resolve these issues is already within a group's pre-existing responsibilities. Spending time and energy on a Team whose goal is prevention will eventually reduce the total amount of IAQ-related time already allotted to these individuals. All that is necessary is the creation of a framework that affords a coordinated approach to IAQ issues. A suggestion for that framework is as follows:

Health and Safety Department:

- Primary investigator = IAQ-related Health issues
- Secondary investigator = NO IAQ-related Health issues
- Identify single point contact for IAQ
- Developing campus-wide IAQ database of problem areas

HVAC Maintenance Shop:

- Primary investigator = NO IAQ-related Health issues
- Secondary investigator = IAQ-related Health issues
- Maintaining HVAC equipment and documenting action items
- Cooperate in developing the IAQ database (e-mail)
- Identify single point contact for IAQ

Facility Managers and Building Coordinators:

- Primary contact for initiating IAQ investigation
- Serve as a liaison between the occupants and IAQ investigator
- Ensuring all contacts are entered into the IAQ database (e-mail)

Custodians:

- Spotting potential IAQ-related situations
- General knowledge of basic IAQ
- Cognizant use of cleaning supplies

On-Site Medical Facility:

- Ensure all referrals are entered in IAQ database (e-mail)
- Contact H & S to initiate investigation with health problem(s)
- Source of current trend information on campus and nationally
- Supply training if equipped to do so

Engineering and Construction:

- Design remodeling and new construction with IAQ in mind
- Utilize H & S as well as HVAC during design phase
- Identify specific standards and codes

- Ensure compliance with standards and codes
- Relocation
- Design office space with IAQ in mind
- Office locations relative to HVAC systems
- Recognize HVAC system limitations and age
- Minimize partial occupancy during construction

Employee Representatives (including Union representatives):

- Ensure employee issues are addressed properly
- Ensure IAQ issues are brought to a satisfactory conclusion

5. Minimizing IAQIT Costs

- Meetings twice per month initially
- Meetings once per month after guidelines and framework completed
- Sharing each other's knowledge accomplishes cross-training
- Establish & Maintain IAQ database with e-mail notifications

6. Implementation

The role that each member of the IAQIT needs to implement is already within his or her existing job structure. Existing issues can therefore be addressed in a Team atmosphere that uses the synergy of joined minds. The end result is a reduction in the individual's amount of time spent addressing the IAQ issues while simultaneously ensuring a better "buy-in" for all parties involved. Although pro-active initiatives like the IAQIT do take some time and energy in their initiation and formation (as all pro-active endeavors do), the overall benefit to the campus will be well worth all the time spent. There is a potential for very large cost avoidance for the campus as a whole, while at the same time enhancing the health, safety and well-being of individuals directly affected by IAQ issues. Avoiding just one IAQ complaint can pay for all the time invested.

Appendix B

Indoor Air Quality and Some Things You Should Know About It

THE PROBLEM

Indoor air quality (IAQ) has become a matter of increased concern in the University of California (UC) campus community. This is not surprising since most of us spend 80 to 90 percent of our time indoors. The environmental health and safety professionals are routinely asked to address IAQ concerns, so we have put together this document to provide you with some background information on this persistent problem. The information was gathered from several sources including the federal register, publications from federal agencies, professional journals, and an indoor air quality workshop training manual. Described in this appendix is information covering:

- Background and regulatory perspectives of IAQ problems
- Specific complaints and symptoms associated with poor IAQ
- Sources and types of indoor air pollutants
- Campus issues and recommendations for acceptable air quality
- Approaches to investigating and resolving IAQ concerns

Acceptable Indoor Air Quality 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.

Building Related Illness Specific medical conditions of known etiology which can often be documented by physical signs and laboratory findings. -- Federal Register Vol. 56, No. 183

Sick Building Syndrome Refers to a class of complaints or symptoms generally not traceable to a specific substance, but are sometimes attributable to exposure to a combination of substances or to individual susceptibility to low concentrations of contaminants. -- Federal Register Vol. 56, No. 183

BACKGROUND ON THE IAQ PROBLEM

Complaints related to indoor air quality increased significantly following energy conservation measures instituted in the early seventies. A move was made to "tighten" buildings by reducing air leakage and minimizing the volume of outside air brought in. These actions allowed contaminants to build-up and re-circulate inside.

Numerous studies have documented a wide range of different chemical and biological contaminants present in indoor environments. Unfortunately, the extent to which these contaminants may affect your health is difficult to determine. Indoor air contaminants are typically present in very low concentrations making it extremely difficult to accurately measure and identify specific pollutants or to establish any kind of defensible cause and effect relationship from exposure.

Comfort Issues

Historically, office environmental concerns focused only on comfort issues such as temperature, humidity, draftiness, stuffiness, and odor control. Building designers worried about oxygen depletion and carbon dioxide buildup but found that simple odor control measures provided enough ventilation to offset these concerns.

Health Issues

More recently, attention has concentrated on possible health effects associated with exposure to low concentrations of indoor air contaminants. Investigations have shown that many physical or psychological symptoms have resulted from these types of exposures particularly among sensitive individuals. To complicate the issue, workers in an office environment are typically much more sensitive to slight environmental changes such as temperature, odor, and light than other workers in general industry. These sensitivities make it difficult to separate factors that affect comfort from those that may affect health.

Regulations

Currently the primary *legal* standards available for indoor air exposures are the same ones that protect workers in general industrial environments. These standards are enforced by the California Occupational Safety and Health Administration (Cal/OSHA) and are based on Permissible Exposure Limits. On a national level, Federal OSHA has looked into developing a specific standard on "Occupational Exposure to Indoor Air Pollutants" but thus far, this effort has been unsuccessful.

Guidelines

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE Standard 62-2001) developed a consensus standard for IAQ titled "Ventilation for Acceptable Indoor Air Quality." ASHRAE 62-2001 This consensus standard is only a ***recommended guideline***, but it has been widely used by industrial hygienists and engineers. UC adheres to these guidelines where possible and initiates corrective actions in locations where these guidelines are not met. The ASHRAE consensus standard recommends carbon dioxide levels to be kept to no more than 700 parts per million (ppm) above the outdoor concentration. This equates to approximately 1000 ppm indoors. Although this level is commonly used as a limit for acceptable IAQ, it is more appropriately applied as a guide for elimination the presence of bioeffluents (e.g., body odor from occupants). Therefore, it is one indicator of the performance of the ventilation system for dilution and removal of bioeffluents. Occupant complaints, esapecially odors, may still occur with carbon dioxide levels between 700 and 1000 ppm. Corrective action may be warranted (based on EH&S recommendation) to improve ventilation flow which results in a lower carbon dioxide level. Occupational exposure limits for carbon dioxide (Cal/OSHA PEL = 5000 ppm) relate to the adverse health effects of high exposures not typically encountered in non-industrial environments.

COMPLAINTS AND SYMPTOMS

Typical IAQ complaints

At one end of the spectrum are the transient or non-specific symptoms and complaints such as common colds that may simply be brought from home or passed around the building from person to person. At the other end is a problem known as "mass psychogenic disease" caused by *suggestions* that the air is bad and people should be feeling sick. In between are a number of conditions that may be the result of poor ventilation and/or causative agents (chemical or biological contaminants) which genuinely cause "sick building syndrome" (SBS) and "building related illnesses" (BRI). IAQ problems, real or imagined, seem to always affect morale, efficiency, and attendance. A difficulty in solving IAQ problems is that symptoms and complaints are typically non-specific and episodic. Often, only a select number of people are affected by a problem and their complaints may come and go. Many persons report their symptoms subside after they vacate a building and reappear upon entry. Medical diagnosis can also be inconclusive.

The most common symptoms and complaints attributed to poor IAQ include:

- Upper respiratory irritation, coughing, congestion
- Itching, watering eyes
- Sinus irritation, sneezing
- Headache, dizziness, nausea
- Fatigue, listlessness, inability to concentrate
- Shortness of breath
- Discomfort of a non-specific nature

This list of complaints is typically associated with the phenomenon known as sick building syndrome. A difficulty in resolving sick building syndrome is that these same symptoms can also originate from any number of possible sources including common colds, allergies, smoking, poor lighting, poor ergonomics, or stressful work loads.

Specific IAQ Illnesses

On the other hand, there are some very specific illnesses directly associated with indoor air contamination. Each of the diseases listed below with the exception of asthma is typically associated with building-related illnesses. These include:

- Humidifier fever – (mild flu-like symptoms, no deaths);
- Pontiac fever – (similar to humidifier fever, non-pneumonia, no deaths);
- Legionnaires' disease – (pneumonia, high fever, 10-20% mortality; *incidence is low*);
- Hypersensitivity pneumonitis – (flu-like symptoms, recurrent pneumonia, chest tightness, immunological sensitization to microorganisms in building environment);
- Asthma – (normally affects 3 - 4% of population and can be exacerbated by poor air quality).

SOURCES AND TYPES OF INDOOR AIR POLLUTANTS

The National Institute for Occupational Safety and Health (NIOSH), in studies of over 500 IAQ Health Hazard Evaluations, categorized the major sources or factors involved with IAQ problems as follows:

Problem Origin		Typical Sources
Inadequate Building Ventilation Systems	52%	Lack of outside air, poor air distribution, uncomfortable temperature and humidity, contaminant sources inside the system
Contaminants Originating Inside Building	20%	Solvent vapors, dusts, formaldehyde, building materials, furnishings
Unknown Causes	12%	Unidentified sources
Outdoor Contaminants Entering Building	11%	Motor vehicle exhaust, pollen, fungi, smoke, construction activities
Microbiological Agents	5%	Bioaerosols, Legionella

Chemicals and Carbon Dioxide

People give off body odors and exhale carbon dioxide. Over the course of a day, the background levels of carbon dioxide may rise, often reaching concentrations exceeding 1,000 ppm. Carbon dioxide itself is not harmful at this concentration but is a good indicator that other contaminants of greater concern (e.g., carbon monoxide, hydrocarbon vapors, aerosols, tobacco smoke, and microorganisms) may also build up. In the absence of specific pollutant sources, carbon dioxide is used simply to indicate the adequacy of outside air supply.

Two major IAQ sources extensively referenced as contaminants of particular concern are environmental tobacco smoke (ETS) and radon gas. We are fortunate that California's *No Smoking* policy has virtually eliminated ETS as a problem and radon gas has not been identified as an area of concern in campus buildings. However, smoking occurring just outside the entrance to a building or near fresh air intakes should not be overlooked as a potential problem source.

Biological Contamination

Bioaerosols are particles of biological origin including fungi, bacteria, viruses, algae, amoebae, pollen grains, and the dead particles they produce. They may also include parts of plants, insects, animals and their wastes such as saliva, urine, feces, and dander. Exposure to bioaerosols may cause some individuals to develop allergies, sensitization, or disease.

Microorganisms are always present in indoor environments. It is the excess quantity of microbes that generate concern. IAQ problems are rarely caused by biological contaminants unless a combination of four conditions exists. These conditions include:

1. There must be a reservoir or suitable environment for bioaerosols to accumulate (water settled in a cooling coil drain pan is a typical example.)
2. There must be a source of nourishment such as organic debris settled or suspended in the reservoir.

3. There must be proper conditions for amplification, or the growth of the microorganism (i.e. temperature, moisture.)
4. There must be a mechanism or pathway for dispersing the biological material.

DEALING WITH INDOOR AIR QUALITY AT UC

Campus Problems

The campus community generates a substantial number of IAQ complaints. The vast majority of these involve concerns about "stale air," odors, asbestos, or various transient pollutants that can usually be identified through simple investigations. Summarized below are items EH&S finds to be the most common campus-wide IAQ concerns.

1. **Outside contaminants entering building from air intakes, windows, and doors**
    - asphalt roofing operations
    - motor vehicle exhaust
    - grounds maintenance activities
    - power plant operations
2. **Deficiencies in the ventilation systems**
    - too much or too little air
    - sewer vents, dry floor and sink drains
    - maintenance or mechanical problems, i.e. fan motors, fan belts, dirty air filters, leaking drip pans, plenums
3. **Materials used during new construction or renovation activities**
    - glues, paints, sealants, primers
    - construction dusts, fumes, and vapors
4. **Equipment, furnishing and space specific to the worksite**
    - copy machines, inks, photochemicals
    - chemicals used for cleaning and repair activities
    - space use changes which significantly differ from design
    - laboratory chemicals and operations
5. **Personal habits and hygiene**
    - forgotten food that rots in desks
    - Using strong-smelling laundry products or colognes
    - wearing strong perfumes
    - different cultural concepts of personal hygiene

Campus Standards

The table below summarizes in-house standards UC tries to follow for outside air and acceptable comfort criteria.

Comfort		
Temperature	68 to 78 degrees F	Upper temperature maintained in air conditioned spaces only
Humidity Range	30% to 60 %	Where controllable
Carbon Dioxide	1000 parts per million (ppm)	Cal/OSHA PEL = 5000 ppm

Outdoor Air Requirements	
Air dampers are set to allow at least 20% outside air into buildings	
Type of Location	**cfm/person***
Office Space	20
Classroom	15
Reception Areas	15
Conference Rooms	20
Laboratory	20
Auditoriums and Stages	15
Telecommunication center & data entry	20
Libraries	15
Music Rooms	15
Smoking Lounges (no longer applicable)	60

* Cubic Feet Per Minute (cfm) Outside Air Per Person

INVESTIGATING AND RESOLVING IAQ PROBLEMS

Strategies for investigating indoor air quality problems are often very straightforward in that information is gathered and conclusions are drawn based on findings. In the absence of specific contaminant sources or obvious ventilation problems, EH&S will try to characterize the scope of the problem and systematically identify or eliminate elements which are specifically associated with IAQ episodes. Outlined below are typical response actions taken by EH&S during a campus IAQ investigation. In Chapter 1 of this document, IAQ investigation is discussed in detail. The scope of each investigation may vary depending on findings.

IAQ Investigation Criteria	
Meeting	An EH&S staff person will meet with someone familiar with the problem, usually the affected person(s), or their supervisor to identify specific concerns (i.e. comfort, odors, health, ventilation)
Walk Through Investigation	An initial, walk-through investigation is conducted by EH&S to identify immediately correctable causes or to develop a plan for conducting a more thorough investigation.
Define Scope	Strategies are developed to evaluate suspected problems (e.g., ventilation system, chemical sources, microorganisms, or circulate questionnaires to better define the nature, scope, extent, and location of the problem).
Initial Monitoring	Preliminary air sampling may be conducted. Normally it will involve the use of real time analyzers for carbon dioxide and other easy-to-measure air contaminants, or cursory testing with smoke tubes and velometers.
Involve Other Departments	Physical Plant -- Ventilation system evaluation, Preventive maintenance Physical Planning and Construction—Ventilation system planning/design Occupational Physician—Medical concerns Office of Risk Management—Workers' Compensation concerns
Detailed Monitoring	Ventilation system testing and/or sampling for chemical and biological contaminants may be conducted as warranted or outsourced.
Evaluate Findings	Conditions and monitoring results are compared to criteria established through standards, codes, guidelines and good practice.
Identify Solutions	The need for corrective actions and controls is identified, and solutions are recommended.
Correction	Controls and recommendations are implemented as necessary.
Follow-up	Findings and results are communicated to concerned parties.

Even in the absence of clinical illness or obvious contamination sources, EH&S recognizes IAQ concerns are very real and potentially serious. We will make every effort to effectively evaluate IAQ complaints and inform concerned persons of the results of our investigation. Our objectives are:

- help employees, supervisors and building coordinators resolve short term or easily corrected IAQ problems;
- initiate corrective actions for the more difficult problems by involving other campus units and identifying special needs or controls; and
- help ensure building occupants maintain a level of confidence in their building's air quality.

For more information about IAQ or campus procedures please contact EH&S.

Appendix C

OCCUPANT INFORMATION SHEET ON INDOOR AIR QUALITY

We spend up to 90 percent of our time indoors. The quality of indoor air has an impact on our health, comfort, well being, and productivity. While most buildings do not have severe indoor air quality problems, even well maintained buildings with good ventilation systems can experience episodes of poor air quality. Occupants can have a positive influence on the indoor environment by practicing the following:

Building Occupants— Influence Your IAQ

1. Do not water indoor plants more than once a week, and do not allow water to accumulate in the bottom of the pot. Excess moisture contributes mold and mildew growth and attracts pests.
2. If there are floor drains or infrequently used sinks, pour water down the drains periodically. Mineral oil (not vegetable oil) can be added to the water to create a sealant that will prevent the water from evaporating too quickly. When a drain is not used for a while, the liquid in the trap may evaporate, allowing sewer gases to rise through the plumbing.
3. Keep your work area clean and neat by minimizing paper accumulation and by washing cups and utensils. Remove food crumbs and avoid storage of perishable food (i.e., oranges in a desk drawer) that may attract pests or cause odors.
4. Store food properly. Remove old food containers and perishable items from the refrigerator periodically.
5. Wipe down your desk, phone receiver, and key pads periodically. Use Lysol or other disinfectant products to clean items that you commonly use, especially phone receivers that may be used by several persons.
6. Check areas where water may intrude (i.e., water cooler, refrigerator, plants, coffee maker, windows, ceiling tiles) and look for stain marks. Make sure that those areas are cleaned and dried as soon as possible.
7. Report water leaks and floods to your facility management department.
8. Clean out the water collection container of your water cooler. Using diluted bleach solution (1 part bleach to 10 parts water) will help minimize mold growth.
9. Ensure that all appliances including the photocopy machines, computers, and printers are in good condition.
10. If odiferous products are used, make sure that there is adequate ventilation. Avoid using products that contain volatile organic compounds; substitute water-based products for them.
11. Do not smoke indoors, and avoid smoking near the building ventilation intakes or doorways.

12. Use perfume or cologne sparingly.
13. Do not block air vents or grills with equipment, furniture, decorations, or other materials. Keep supply vents and return air grilles unblocked, so you won't unbalance the HVAC system or affect the ventilation of a neighboring office.
14. Make sure that the carpet is vacuumed weekly and deep cleaned at least annually.
15. Do not allow dust to collect. Periodically wet-wipe or vacuum surfaces to minimize dust accumulation.
16. Make sure that garbage containers are emptied daily to prevent odors and biological contamination.
17. Wash your hands frequently with soap and water to curtail the spread of colds, flu, and other infectious illnesses. Don't come to work during the infectious phase of a cold or flu.

Factors that Affect Occupant Comfort and Productivity

According the Environmental Protection Agency, a number of environmental and personal factors affect how people perceive air quality. Below are some common ones:

- Odors
- Temperature—too hot or cold,
- Air velocity and movement— too drafty or stuffy
- Heat or glare from sunlight
- Glare from ceiling lights, especially on monitor screens
- Furniture crowding
- Stress in the workplace or home
- Comfort with the physical aspects of the workplace: location, work environment, availability of natural light, and the aesthetics of office design
- Work space ergonomics, including the height and location of the computer and the availability of adjustable keyboards and chairs
- Noise and vibration levels
- Selection and location of office equipment

Occupants should consult their supervisor or office manager if there are any concerns about these factors.

Appendix D

IAQ Management During Construction Projects

Construction projects can have a significant impact on indoor air quality through the introduction of pollutants such as particulates, diesel exhaust, offensive odors, toxic chemical vapors, microbials, and combustion products. Pre-planning efforts that anticipate these issues and specify adequate pollutant control methods prior to commencing work can be an essential step to "on-time", "within budget", project completion. Planning efforts should also include a commissioning procedure that specifies re-occupancy criteria at project completion. Outlined below are components of project management that should be considered to minimize negative IAQ impacts:

Pre-Planning

During pre-planning, some key factors to assess include:

- Types of dusts or odors produced from:
  - Demolition activities;
  - Construction products;
  - Construction equipment.
- Presence of pollutants which are a recognized hazard, as described in the Material Safety Data Sheet (MSDS).
- Times and locations where occupants are most likely to encounter airborne pollutants.
- The expected amount and duration of exposure occupants may have to pollutants.

The following "Assessment Checklist" may assist in pre-planning the project.

ASSESSMENT CHECKLIST
Identify chemical and physical sources of odor and dust.
Clearly identify occupied areas potentially affected by the project.
Identify specific construction activities likely to produce dust/odors.
Identify control options and assess available control measures.

As specific details of the project become clear, pollutant control methods can be tailored to the project. Specific control measures may involve:

- Protection of the heating, ventilating, and air conditioning (HVAC) system;
- Install carbon filters at the air intakes to prevent diesel exhaust infiltration;
- Control of the pollutant source;
- Interruption of the pollutant pathway;
- Housekeeping;
- Scheduling considerations.

Occupant Notification

Notifying area occupants of the proposed work, work schedule, and a description of the type of inconvenience it may cause is critical to the success of most projects. Specifically, occupants should be advised of potential odors, noise, dust generation, etc., well in advance of work so that individuals with pre-existing medical conditions that could be aggravated by construction activities can make alternate arrangements.

Contractor Notification

Prior to start of work, contractors and their employees should be made familiar with locations of all posted regulations, personal protection requirements (including workplace entry and exit procedures), and emergency procedures.

Contractor should wear appropriate personal protective equipment if they will be working in potentially hazardous areas; specifically, contractors and their employees should be advised of any hazards that may already exist in the project area.

HVAC Protection

- Where feasible, HVAC system for the project area should be shut down for the duration of the demolition project.
- All openings, including but not limited to ducts, grilles, grates, diffusers, pipe chases, or other openings within the designated work area should be sealed with 6-mil polyethylene sheeting and secured with duct tape.
- When total HVAC isolation is not feasible, consider the use of temporary filters on grilles, diffusers, etc. These filters should be frequently inspected during the course of the project and replaced as needed.
- The mechanical room should not be used to store construction or waste materials.

Source Control

- All surfaces to be disturbed should be misted with water to minimize airborne dust.
- When possible, only products emitting lower amounts of odor or volatile organic compounds (VOC's) should be used.
- If feasible, electric powered equipment should be used in lieu of diesel or gasoline-powered equipment.
- Diesel or gasoline-powered equipment should not be used inside a building.

Pollutant Pathway Interruption

- All openings, including but not limited to windows, doorways, drains, ducts, grilles, grates, diffusers, pipe chases, access panels, or other openings within the designated work area should be sealed with 6-mil fire resistant polyethylene sheeting and duct tape.

- Temporary isolation wall enclosures should be constructed. The temporary wall enclosures should be assembled with one layer of 4-mil polyethylene sheeting overlapping in alternate layers. Affix 4-mil polyethylene sheeting to the ceiling grid or a temporary framework to form the walls of the enclosure.
- The floor within the enclosure should be covered with one layer of 6-mil polyethylene sheeting. Each layer should be taped at all edges. All carpeting should be protected from contamination during construction, unless new carpeting will be installed.
- Adequate exhaust ventilation equipment should be installed to maintain a negative pressure differential between the work area and adjacent areas of the building. (Note: It is good practice to smoke test the enclosure to ensure it is under negative pressure.)
- As far as practicable, negative pressure ventilation units should be exhausted to the outside of the building. Careful installation and daily inspections should be performed to ensure ducting does not release construction debris into uncontaminated areas of the building.
- The negative pressure systems should continuously operate while work is in progress. Damage and defects in the enclosure system are to be repaired immediately upon discovery.

Housekeeping

After completion of the work, the entire work area (including walls, ceilings, floors, and other work surfaces) should be cleaned and vacuumed. All surfaces should be free from visible construction debris.

Scheduling

Depending on the expected impact, some projects should be scheduled off-hours. If this is not feasible, a buffer zone should be established around the work area where no building occupants are permitted. Building occupants should never be allowed to remain in the area where construction activities are in progress.

At times, the industrial hygienist may deem it necessary to conduct various types of sampling (i.e., chemicals or dust). When this is the case, the time it takes to perform the sampling and analysis should be taken into account when scheduling work hours, shifts, closures, or relocation of employees.

Re-occupancy Criteria/Commissioning

- Prior to reoccupation of the project area, the worksite should be cleaned until there is no visible haze in the air and no settled dust is found on surfaces.
- There should be low to no detectable odors upon re-occupancy.
- The HVAC system should be restored to good operating conditions when odors and visible emissions have dissipated or otherwise been eliminated.

Appendix E

Sample - Occupant Notification of Construction Project

To: Unit Managers [Note: Appropriate department or office management that may or may not be building occupants, but who are responsible for the occupational health and safety of the impacted building occupants.]

Occupants

From: Frank Lloyd Wright
Project Manager

Subject: Possible Indoor Air Quality Impact
Painting and Carpet Installation at My Favorite Campus Building [Note: Other types of construction activities may be noted here and in body of notification memo.)

Please be advised that on July 24-26, my favorite campus building will be painted and re-carpeted. The work will take place from 7:00 a.m. to 4:30 p.m. all three days. This process involves activities that may generate strong, unpleasant odors, noise, or dust in your workspace. Specifically, we anticipate dust from surface preparation and odors from both the paint application and the carpet installation. [Note: This paragraph should include date(s)/time(s), specific location(s) in building, type of work, and potential hazard(s).]

We will take steps to ensure the work is done in accordance with occupational safety and health standards and use controls where feasible to minimize the impact this project will have on your workspace. Even with these precautions, we cannot guarantee that fugitive emissions will not have a negative effect on some employees, especially persons with preexisting medical conditions or sensitivities. Therefore I encourage you to take whatever measures you feel are necessary to deal with this temporary inconvenience. [Note: This paragraph should include steps that will be taken by contractor to eliminate/minimize hazard(s) or steps that should be taken by occupants to eliminate/minimize their exposure.]

If you have any questions about the project or the materials involved please feel free to contact me. Thank you very much for your cooperation.

cc:

[Note: This letter can also be used to notify occupants of impending asbestos abatement as required under CCR Title 8, 1529. Asbestos. (k) Communication of Hazards, (2) Duties of Building and Facility Owners.]

Appendix F

Procedures for Handling Water Damaged Materials

Water damage occurring inside a building can be very disruptive and costly to occupants and/or building owners. Failing to deal with the issue quickly and correctly can result in negative consequences such as mold growth, mold discolored surfaces and odor problems. Molds and fungi can cause allergic reactions in susceptible individuals as well as other potential health problems.

Molds and fungi require moisture for growth so it is very important to completely remove or thoroughly dry all materials damaged by a flood or other water intrusion. In general, if carpets, walls, and ceilings are not dried within 24 to 48 hours, fungi will start to grow. Once the microorganisms proliferate it becomes difficult to prevent odor problems and near impossible to adequately clean the furnishing. Application of biocides may not resolve the problem because molds and fungi may still cause an allergic reaction even when nonviable (dead).

Following a flood, water leak or sewer system back up, immediate action is required to prevent microbial growth. The following list of considerations (if carried out quickly and carefully) should prevent or greatly limit microbial growth.

Carpets

1. Carpets which are contaminated due to sewer back up, shall be removed and discarded. The bare floor shall be entirely treated with 5% bleach solution and dried completely before installation of new carpet.
2. Where applicable, shovel out gross accumulations of mud and silt before it dries.
3. Before the area has dried, scrub the floors and woodwork with a stiff brush, water, a detergent, and a disinfectant. A 5% bleach solution or quaternary ammonium compound may serve as an adequate disinfectant. Test a small area for colorfastness. Remove the mud and silt from corners, cracks, and crevices.
4. Clean glued-down carpet in place before attempting to pull it up. Use a wet/dry vacuum to extract the water and then shampoo the carpet with detergent. If the carpet is not glued down, roll up the carpet and move it to another location for cleaning. Remove and discard the spongy carpet padding. After the carpets are rinsed, quickly dry them by turning on the heat and using dehumidifiers. Wet carpet should be thoroughly dried within 48 hours; if this is not possible, discard the carpet. **Materials contaminated with sewage or gray water must be completely discarded.**
5. If a professional carpet cleaner is retained, a steam cleaning method (hot-water extraction) is preferred.
6. After the carpet is thoroughly dried, vacuum the area.
7. Give floors a thorough final washing with a non-sudsing cleaning product. Repeat

the drying process. Vacuum again. Until the floors are thoroughly dried, runners should be placed on tile, or other slippery floors to help prevent slips and falls. The musty smell can be reduced by following these procedures:

   a. Sprinkle baking soda over the carpet, working it in with a broom or sponge mop.
   b. Leave the baking soda treatment on overnight.
   c. Vacuum the baking soda out. Vacuum twice, moving back and forth in a different direction the second time.

8. Consideration should be made for the presence of asbestos floor tiles when removing glued carpets.

Walls/Ceiling tiles Furnishing

1. Walls may wick up and retain water. Water may also accumulate in the interstitial spaces between walls. Remove all wet baseboards and drill holes between studs a few inches above the floor to drain these areas. Inspect the drywall and the interstitial spaces to determine if it is wet. Use a moisture meter to determine the extent of penetration.
2. Wet walls should be removed to at least the flood level, or dried by cutting holes at strategic location to increase air circulation. Serious fungal contamination can occur on the back of the drywall if left wet. Cut several inspection holes in the walls to determine if wall interiors are wet.
3. Wet walls that contain fiberglass insulation should have the insulation removed. Check the metal track for water accumulation.
4. Wet ceiling tiles should be dried or discarded.
5. Water can flow a considerable distance on hard ceilings. Thoroughly inspect hard ceilings that may be wet. Dry or remove all wet ceiling gypsum board.
6. The area under floor-mounted cabinets is difficult to dry out. The cabinets should either be lifted or panels removed from the cabinet to allow for water removal and drying.
7. Paper products and boxes should be completely dried or discarded.
8. Electrical circuits in the walls under the floors and in ceilings may be wet. A qualified electrician should inspect these prior to use.
9. A qualified technician should inspect computers and other electronic equipment before they are re-energized.

Good ventilation is essential to rapidly remove water vapor. Open windows and doors and/or adjust the ventilation equipment to provide as much air exchange to the outside as possible <u>or</u> use blowers and dehumidifiers until the carpet is dry. Use a dehumidifier to extract water from the air and maintain relative humidity to less than 70 percent (less than 60% is desirable).

Precautions should be taken to protect the employees against microbial and fungal contamination during removal and handling of water damaged items.

Resources:

Moisture Meter – This is an essential investigative tool in determining the moisture content of water damaged materials. Some meter manufacturers are: Delmhorst Instruments Co. (www.delmhorst.com), Tramex Ltd. (uses electrical signals) (www.tramexltd.com), and Professional Equipment (www.professionalequipment.com)

Additional Reference - Institute of Inspection, Cleaning and Restoration Certification, Standard and Reference Guide for Professional Water Damage Restoration S500, Second Edition, 1999, (360) 693-675, www.iicrc.org

Appendix G

Cleaning HVAC Systems

Periodic cleaning of HVAC systems may be necessary to ensure delivery of acceptable air to the indoor environment. Cleaning may be required on older systems that have not been properly maintained, damaged systems, or in special cases such as following extensive indoor or outdoor construction activities. HVAC system cleaning is expensive and potentially disruptive to normal operations so all possible sources of IAQ problems should be investigated and corrected prior to determining the need for system cleaning. Frequent cleaning of HVAC systems should not be required if the system is properly maintained as outlined in Chapter 3 of this document.

Resources and Guidelines

Included with this fact sheet is the National Air Duct Cleaners Association General Specification for the Cleaning of Commercial HVAC Systems. This specification represents the minimum requirements for cleaning commercial HVAC systems and can be used as a guideline for building owners developing their own specification.

For complete and detailed publications and standards regarding HVAC system design, maintenance, cleaning and restoration refer to applicable publications from:

1. American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE); http://www.ashrae.org/
2. Association of Specialists in Cleaning & Restoration (ASCR); http://www.ascr.org/
3. National Air Duct Cleaners Association (NADCA); http://www.nadca.com/
4. North American Insulation Manufacturers Association (NAIMA); http://www.naima.org/
5. Sheet Metal and Air Conditioning Contractors National Association (SMACNA); http://www.smacna.org/

Contractor Qualifications

The UCIAQ Work Group recommends hiring a certified and trained contractor to perform HVAC system cleaning. Contractors should use accepted industry standards such as those outlined by the Association of Specialists in Cleaning and Restoration (ASCR), the National Air Duct Cleaners Association (NADCA), and the North American Insulation Manufacturers Association (NAIMA). Although in-house facilities or custodial services may perform limited HVAC system cleaning activities (ie. removal of particulate debris from diffusers, cleaning and repairing small localized duct damage), specialized expertise, skill and experience are required to properly clean and restore an entire HVAC system to optimal performance.

Determining the Need for Cleaning

HVAC systems should be cleaned when a visual inspection indicates excessive particulate debris or microbiological growth on any interior surfaces. A fiber optic system or video inspection system is recommended to document the condition of the system both before and after any cleaning. A limited amount of adhered dust is expected on the inside surfaces of HVAC systems and may not indicate a problem. Obvious problems that require cleaning and restoration would include visible microbiological contamination, significant amounts of particulate debris coming out of supply ducts, or deteriorated fiberglass insulation that was contaminating the supply air. In all cases, the source or cause of particulate contamination or microbiological proliferation must be determined and corrected prior to system cleaning.

Visual inspection for cleanliness as outlined in Chapter 3 should be incorporated as part of the HVAC preventive maintenance schedule and should include all components of the system. The required frequency of inspection will vary depending on building use, occupant load, geographical location, and surrounding environment. In general, most HVAC systems should be inspected annually or biannually for cleanliness.

HVAC System Cleaning

For cleaning purposes, the HVAC system includes any interior surface of the air distribution system. This includes all components from where the air enters the system to all points of discharge in the facility. Methods to clean HVAC systems involve both mechanical techniques and chemical sanitizers or biocides. The preferred method of cleaning depends on the system component, type of debris or contamination, and access to the area. In no case should encapsulants or coatings be used prior to or instead of appropriate cleaning.

Mechanical Cleaning Techniques

Mechanical techniques are useful to clean certain HVAC components including duct work, fan components, diffusers, dampers, and internal surfaces of the air handling unit. When using mechanical cleaning methods, strict controls such as physical barriers, devices equipped with HEPA filtered exhaust, and system negative pressure must be used to contain and collect debris. Mechanical cleaning methods incorporate techniques to agitate and dislodge material as well as contain and remove it. Agitation devices may include power brushes, pressurized air and water systems, as well as hand tools such as brushes. Collection of dislodged particulate debris is achieved by vacuums. A vacuum collection device with an appropriate capture velocity should be connected to a service opening and operated continuously to collect material as it is dislodged. In certain areas of the HVAC system, direct contact vacuuming with a brush may be used to remove material from contaminated surfaces.

When using mechanical cleaning techniques, care must be taken to avoid damaging insulated or lined duct work. Fiberglass insulated components should be cleaned using HEPA filtered exhaust equipment while the system is maintained under negative pressure. Fibrous glass insulated materials identified as damaged prior to or following system cleaning should be identified and replaced. Potential damage to fibrous glass insulation materials includes delaminating, friable material, as well as fungal growth on damp, wet material. If fiberglass insulation material must be replaced, all replacement materials and repair work must conform to applicable industry standards and codes.

Chemical Sanitizers and Biocides

The use of chemical sanitizers or biocides may be necessary to clean certain HVAC system components such as heating or cooling coils. Following the use of chemical cleaners, all residues should be completely rinsed from the coil surfaces and removed from the HVAC system. Chapter 3 of this document, HVAC Operation and Maintenance, discusses the importance of routine sanitizing and use of biocides in cooling towers to reduce the number of microorganisms including *Legionella spp.*

The UCIAQ Work Group discourages the use of chemical sanitizers or biocides to treat the interior surfaces of building supply and return duct work. Although many antimicrobial products are EPA approved for use on hard, non-porous surfaces, these products were not specifically designed for use in HVAC systems and have not been evaluated for potential occupant health exposure issues. Any use of chemical sanitizers or biocides in duct work should be carefully reviewed by a health and safety professional prior to treatment. Problems involving visible fungal growth inside duct work must be addressed by first determining the source of moisture and correcting this problem. Following correction of the moisture problem, the system can be cleaned using mechanical techniques and detergents. Porous HVAC system materials such as insulation or fabric filters contaminated with visible fungal growth should be discarded and replaced.

Determining HVAC System Cleanliness

HVAC system cleanliness should be evaluated by visual inspection or an approved test method as outlined in appropriate NADCA standards. An HVAC interior surface is considered visibly clean when it is free of non-adhered debris. Surface comparison testing can also be used to verify cleanliness by visually inspecting HVAC system components before and after vacuuming a test area. If these methods are inconclusive, the NADCA vacuum test may be useful. This test relies on sampling a known surface area to determine the net weight of debris per area sampled and compares this value to an acceptable NADCA level.

Appendix H

ISSUES WITH FIBERGLASS DUCT LINER

Background

Fiberglass (fibrous glass or glass wool) internal duct liner has been used as acoustical and thermal insulation in many heating, ventilation and air conditioning systems. Indoor Air Quality (IAQ) complaints may arise when the fiberglass internal duct liner deteriorates over time. Deteriorating fiberglass duct liner, which is typically black in color, can migrate through supply diffusers. The liner bits can deposit in occupied spaces and onto flat surfaces, where it can cause complaints and adverse health effects.

Due to ongoing concerns about exposure to deteriorating fiberglass duct liner, the Indoor Air Quality Work Group of the UC Industrial Hygienists/Safety Committee has decided to address this issue and develop guidance for the UC campuses.

Adverse Health Effects

1. Fiberglass carcinogenicity has been studied and classified by the following organizations:

- International Agency for Research on Cancer (IARC) has classified it as a possible human carcinogen;
- National Toxicology Program (NTP) has classified it as an animal carcinogen;
- American Conference of Governmental Industrial Hygienists (ACGIH) has classified it as not classifiable as a human carcinogen (A4)
- Environmental Protection Agency (EPA) has classified it as an animal carcinogen.

Fiberglass, at a minimum, is an acute physical irritant to the skin, eyes and upper respiratory tract. The following are occupational exposure limits for fibrous glass or glass wool fibers, developed by US and international agencies:

Agency/Organization	Exposure limit
National Institute for Occupational Safety & Health (NIOSH)	3 f/cc
ACGIH, 2003	1.0 f/cc
Safety & Health Committee, Bldg. & Construction Trades Department of the AFL-CIO (1991)	1.0 f/cc
Cal/OSHA PEL (as an 8 hr TWA)	1.0 f/cc
Fed/OSHA PEL	15 mg/m3, total dust 5 mg/m3, respirable
Sweden	1.0 f/cc
Norway	1.0 f/cc

2. Microbial Contamination

Numerous IAQ case studies have shown that fiberglass duct liner, combined with dust, dirt and moisture, is a very good medium for microbial growth (examples: mold, fungus, Legionella bacteria). Microbial contamination in the HVAC system can cause serious long term health effects for building occupants. Internally lined ductwork is difficult to maintain and clean. A clean HVAC system is crucial to building occupant health and well-being.

Economic impact

Prefabricated ducts with interior fiberglass liners are less expensive, resulting in a lower "up-front" construction cost. However, internal linings create a resistance to airflow, causes static pressure drop, and are difficult to clean and maintain. It also reduces the capacity of the ductwork. Thus, the system requires more energy and has a higher long term cost.

Exterior insulation on the other hand, is initially more labor intensive and has higher "up-front" cost. However, the HVAC system requires less energy to operate, is cheaper to maintain, and has lower long term cost when compared to internal duct lining.

Alternatives for Insulating New Ductwork

1. Exterior Insulation

Insulating ducts on the exterior with bare metal on the interior is the ideal solution. Such a condition would eliminate dispersion of deteriorated fiberglass into the occupied space. It minimizes accumulation of dust and makes routine duct cleaning possible. Restrictions to air flow are minimized and overall, the system uses less energy to operate.

2. Other Types of Internal Liners

Another alternative would be a new type of duct liner, which does not deteriorate, does not absorb moisture, and has a smooth and cleanable surface. We located four new duct/AHU liner products, all of which are various polymer types. However, these new products were not approved by the UC Mechanical Engineers, as they do not attenuate elevated sound levels adequately.

Recommendations

The UC IAQ Work Group makes the following recommendations:

- **a)** Large HVAC systems should not need internal duct lining, as noise is controlled by sound baffles or external acoustical insulation at the source in the mechanical room.
- **b)** Rooftop HVAC units with long horizontal duct runs can be wrapped externally with fiberglass for thermal insulation and sound baffles can be used for noise attenuation.
- **c)** Rooftop package units with short vertical duct runs should be installed with sound baffles for noise attenuation.
- **d)** Laboratory buildings should not have any internally lined ductwork.

REFERENCES

(1) Occupational Exposure, Toxic Properties And Work Practices Guidelines for Fiber Glass
American Industrial Hygiene Association (AIHA), 1991 edition

(2) Threshold Limit Values (TLV) For Chemical Substances & Physical Agents
American Conference of Governmental Industrial Hygienists (ACGIH); 2003

(3) Permissible Exposure Limits for Fibrous Glass
California Code of Regulations, Title 8, Section 5155

(4) Permissible Exposure Limits for Nuisance Dust (includes fiberglass) Code of Federal Regulations, Part 1910.1000, Table Z-3

Appendix I

Prevention and Control of Legionnaires' Disease

OSHA-CDC (Legionnaires' Disease) - Maintenance Docs

BACKGROUND

Although *Legionella* bacteria are found naturally in the environment, it can and should be controlled in man-made water systems through maintenance and testing programs. Properly planned and conducted maintenance and testing programs will reduce the risk of exposure, infection, and disease.
Cases of Legionellosis (Legionella infection) continue to occur throughout the world (see "Recent Outbreaks of Legionnaires' Disease" at http://www.hcinfo.com/outbreaks-news.htm). Identified sources include:

- cooling towers, evaporative condensers, and fluid coolers that use evaporation to transfer heat;
- domestic hot-water and cold water systems;
- spas and whirlpools;
- dental water lines; and
- stagnant water in fire sprinkler systems, safety eyewashes and showers.

The following guidance has been excerpted from OSHA (www.osha.gov) and CDC (www.cdc.gov) publications which are widely available on the internet and should be consulted for new and additional information.

OSHA Technical Manual (TED 1-0.15A, 01-20-99) Sec. II – Chap. 7, LEGIONNAIRES' DISEASE

BIOCIDE

Unfortunately, measurements of water quality such as total bacterial counts, total dissolved solids, and pH have not proven to be good indicators of *Legionella* levels in cooling towers. Periodic use of biocides is needed to ensure control of *Legionella* growth.

Little information exists on the demonstrated effectiveness of many commercial biocides for preventing *Legionella* growth in actual operations. Recent Australian studies indicate that Fentichlor [2,2'-thiobis (4-chlorophenol) used weekly for 4 hours at 200 ppm, or bromo-chloro-dimethyl-hydantoin (BCD) in a slow-release cartridge at an initial concentration of 300 ppm are effective in controlling the growth of *Legionella*. There are no U.S. suppliers of Fentichlor, although the chemical is licensed by the EPA for water treatment in cooling towers. Towerbrom 60M™, a chlorotriazine and sodium bromide salt mixture, has been reported to be effective when alternated with BCD for control of *Legionella* in U.S. studies of *Legionella* contamination of cooling towers. The Australian study also indicates that quaternary ammonium compounds, widely used for control of bio-fouling in cooling towers, are not effective in controlling *Legionella*.

Traditional oxidizing agents such as chlorine and bromine have been proven effective in controlling *Legionella* in cooling towers. Continuous chlorination at low free residual levels can be effective in controlling *Legionella* growth. It is important, however, that the proper oxidant level be established and maintained because free residual chlorine above 1 ppm may be corrosive to metals in the system and may damage wood used in cooling towers; free residual levels below 1 ppm may not adequately control *Legionella* growth. Chlorine also combines with organic substances in water to form toxic by-products that are of environmental concern. Frequent monitoring and control of pH is essential for maintaining adequate levels of free residual chlorine. Above a pH of 8.0, chlorine effectiveness is greatly reduced. Proper control of pH will maintain the effectiveness of chlorination and minimize corrosion.

Bromine is an effective oxidizing biocide. It is frequently added as a bromide salt and generated by reaction with chlorine. Bromine's effectiveness is less dependent than chlorine on the pH of the water; it is less corrosive; and it also produces less toxic environmental by-products.

The effectiveness of any water-treatment regimen depends on the use of clean water. High concentrations of organic matter and dissolved solids in the water will reduce the effectiveness of any biocidal agent. Each sump should be equipped with a "bleed," and make-up water should be supplied to reduce the concentration of dissolved solids.

DESIGN

One of the most effective means of controlling the growth of *Legionella* is to maintain sump water at a low temperature. Sump-water temperatures depend on tower design, heat load, flow rate, and ambient dry-bulb and wet-bulb temperatures. Under ideal conditions, sump-water temperatures in evaporative devices approach the ambient wet-bulb temperature, and that may be low enough to limit *Legionella* amplification. System design should recognize the value of operating with low sump-water temperatures.

High-efficiency drift eliminators are essential for all cooling towers. Older systems can usually be retrofitted with high-efficiency models. A well-designed and well-fitted drift eliminator can greatly reduce water loss and potential for exposure.

Other important design features include easy access or easily disassembled components to allow cleaning of internal components including the packing (fill). Enclosure of the system will prevent unnecessary drift of water vapor, and other design features to minimize the spray generated by these systems are also desirable.

FREQUENCY OF CLEANING

Cooling towers should be cleaned and disinfected at least twice a year. Normally this maintenance will be performed before initial start-up at the beginning of the cooling season and after shut-down in the fall. Systems with heavy bio-fouling or high levels of *Legionella* may require additional cleaning. Any system that has been out of service for an extended period should be cleaned and disinfected. New systems require cleaning and disinfecting because construction material residue can contribute to *Legionella* growth.

WISCONSIN PROTOCOL

Acceptable cleaning procedures include those described in the Wisconsin Protocol. This procedure calls for an initial shock treatment with 50 ppm free residual (total) chlorine, addition of detergent to disperse bio-fouling, maintenance of 10 ppm chlorine for 24 hours, and a repeat of the cycle until there is no visual evidence of biofilms. To prevent exposure during cleaning and maintenance, wear proper personal protective equipment: a Tyvek-type suit with a hood, protective gloves, and a properly fitted respirator with a high-efficiency particulate (HEPA) filter or a filter effective at removing one-micron particles.

DOMESTIC HOT-WATER SYSTEMS

BACKGROUND

Domestic hot-water systems are frequently linked to Legionnaires' outbreaks. The term "domestic" applies to all nonprocess water used for lavatories, showers, drinking fountains, etc., in commercial, residential, and industrial settings. Disease transmission from domestic hot water may be by inhalation or aspiration of *Legionella*-contaminated aerosolized water. Water heaters that are maintained below 60 degrees C (140 degrees F) and contain scale and sediment tend to harbor the bacteria and provide essential nutrients for commensal micro-organisms that foster growth of L. pneumophila. Large water heaters like those used in hospitals or industrial settings frequently contain cool zones near the base where cold water enters and scale and sediment accumulate. The temperature and sediment in these zones can provide ideal conditions for amplification of the organism. Dead legs and nonrecirulated plumbing lines that allow hot water to stagnate also provide areas for growth of the organism.

DESIGN

Water systems designed to recirculate water and minimize dead legs will reduce stagnation. If potential for scalding exists, appropriate, fail-safe scald-protection equipment should be employed. For example, pressure-independent, thermostatic mixing valves at delivery points can reduce delivery temperatures. Point-of-use water heaters can eliminate stagnation of hot water in infrequently used lines. Proper insulation of hot-water lines and heat tracing of specific lines can help maintain distribution and delivery temperatures.

MAINTENANCE

To minimize the growth of *Legionella* in the system, domestic hot water should be stored at a minimum of 60 degrees C (140 degrees F) and delivered at a minimum of 50 degrees C (122 degrees F) to all outlets. The hot-water tank should be drained periodically to remove scale and sediment and cleaned with chlorine solution if possible. The tank should be thoroughly rinsed to remove excess chlorine before reuse.

Eliminate dead legs when possible, or install heat tracing to maintain 50 degrees C (122 degrees F) in the lines. Rubber or silicone gaskets provide nutrients for the bacteria, and removing them will help control growth of the organism. Frequent flushing of these lines should also reduce growth.

Domestic hot-water recirculation pumps should run continuously. They should be excluded from energy conservation measures.

CONTROL

Raising the water-heater temperature can control or eliminate *Legionella* growth. Pasteurize the hot water system by raising the water-heater temperature to a minimum of 70 degrees C (158 degrees F) for 24 hours and then flushing each outlet for 20 minutes. It is important to flush all taps with the hot water because stagnant areas can "re-seed" the system. Exercise caution to avoid serious burns from the high water temperatures used in Pasteurization.

Periodic chlorination of the system at the tank to produce 10 ppm free residual chlorine and flushing of all taps until a distinct odor of chlorine is evident is another means of control. In-line chlorinators can be installed in the hot water line; however, chlorine is quite corrosive and will shorten the service life of metal plumbing. Control of the pH is extremely important to ensure that there is adequate residual chlorine in the system.

Alternative means to control *Legionella* growth include the use of metal ions such as copper or silver (which have a biocidal effect) in solution. Ozonization injects ozone into the water. Ultraviolet (UV) radiation also kills microorganisms. Commercial, in-line UV systems are effective and can be installed on incoming water lines or on recirculating systems, but stagnant zones may diminish the effectiveness of this treatment. Scale buildup on the UV lamp surface can rapidly reduce light intensity and requires frequent maintenance to ensure effective operation.

DOMESTIC COLD-WATER SYSTEMS

Domestic cold water systems are not a major problem for *Legionella* growth. Maintaining cold-water lines below 20 degrees C will limit the potential for amplification of the bacteria. It is surprising, however, that elevated levels of *Legionella* have been measured in ice machines in hospitals. Cold-water lines near heat sources in the units are believed to have caused the amplification.

Dental water lines have recently been recognized as common sources of water contaminated with high concentrations of microorganisms including *Legionella*. However, to date an increased risk of disease among dental staff or patients has not been demonstrated. Dental water line operating conditions are especially appropriate for *Legionella* proliferation because the water is stagnant a majority of the time, the narrow plastic tubing encourages biofilm formation, and the water temperature is usually 20 degrees C (68 degrees F) or higher-some systems maintain water at 37 degrees C (98.6 degrees F). Filtration of water at the point of use with replaceable, in-line, 1-micron filters is a FDA approved method of minimizing risk to patients and staff in a dental facility.

Water tanks that allow water to remain uncirculated for long periods can also promote growth of bacteria. Such tanks should be eliminated or designed to reduce storage time to a day or less. They should also be covered to prevent contamination and protected from temperature extremes.

Cross-contaminations of the domestic cold-water system with other systems should always be suspected. All connections to process water should be protected by a plumbing code-approved device (e.g., back-flow preventer, air gap, etc.).

If significant contamination of the domestic cold water system occurs, the source of contamination should be determined. Inspect the system for "dead legs" and areas where water may stagnate. Elimination of these sections or frequent flushing of taps to drain the stagnant areas may be necessary to limit growth of the organism. Insulate cold-water lines that are close to hot-water lines to reduce the temperature in the line.

If the cold-water lines have significant contamination, hyperchlorination can eradicate *Legionella*. Free chlorine levels of 20 to 50 ppm are allowed to remain for one hour at 50 ppm, or two hours at 20 ppm. Faucets are then allowed to run until the odor of chlorine is present, and the water is allowed to remain for approximately two hours.

CDC - APPENDIX B Maintenance

MAINTENANCE PROCEDURES TO DECREASE SURVIVAL AND MULTIPLICATION OF LEGIONELLA SPP. IN POTABLE-WATER DISTRIBUTION SYSTEMS

I. Providing Water at > or = 50ºC at All Points in the Heated Water System, Including the Taps

   This requires that water in calorifiers (water heaters) be maintained at > or = 60ºC. In the United Kingdom, where maintenance of water temperatures at > or = 50ºC in hospitals has been mandated, installation of blending or mixing valves at or near taps to reduce the water temperature to *Legionella spp*. can multiply even in short segments of pipe containing water at this temperature. Increasing the flow rate from the hot-water-circulation system may help lessen the likelihood of water stagnation and cooling. Insulation of plumbing to ensure delivery of cold (<20ºc) water to water heaters (and to cold-water outlets) may diminish the opportunity for bacterial multiplication. "Dead legs" or capped spurs within the plumbing system provide areas of stagnation and cooling to <50ºC regardless of the circulating-water temperature; these segments may need to be removed to prevent colonization.] Rubber fittings within plumbing systems have been associated with persistent colonization, and replacement of these fittings may be required for *Legionella spp*. eradication.

II. Continuous Chlorination to Maintain Concentrations of Free Residual Chlorine at 1-2 mg/L at the Tap

This requires the placement of flow-adjusted, continuous injectors of chlorine throughout the water distribution system. Adverse effects of continuous chlorination include accelerated corrosion of plumbing resulting in system leaks and production of potentially carcinogenic trihalomethanes. However, when levels of free residual chlorine are below 3 mg/L, trihalomethane levels are kept below the maximum "safety level" recommended by the Environmental Protection Agency.

CDC - APPENDIX D CLEANING TOWERS

PROCEDURE FOR CLEANING COOLING TOWERS AND RELATED EQUIPMENT (Adapted from the Emergency Protocol in Control of *Legionella spp*. in Cooling Towers: Summary Guidelines.)

I. Preparatory to Chemical Disinfection and Mechanical Cleaning

A. Provide protective equipment to workers who would perform the disinfection, to prevent their exposure to (a) chemicals used for disinfection and (b) aerosolized water containing *Legionella spp*. Protective equipment may include full-length protective clothing, boots, gloves, goggles, and a full- or half-face mask that combines high efficiency particulate air filter and chemical cartridges to protect against airborne chlorine levels of up to 10 mg/L.

B. Shut off cooling-tower.

1. If possible, shut off heat source.
2. Shut off fans, if present, on the cooling tower/evaporative condenser (CT/EC).
3. Shut off the system blowdown (purge) valve. Shut off automated blowdown controller, if present, and set system controller to manual.
4. Keep make-up water valves open.
5. Close building air-intake vents within at least 30 meters of the CT/EC until after the cleaning procedure is complete.
6. Continue operating pumps for water circulation through the CT/EC.

II. Chemical Disinfection

A. Add fast-release, chlorine-containing disinfectant in pellet, granular, or liquid form, and follow safety instructions on the product label. Examples of disinfectants include sodium hypochlorite (NaOCl) or calcium hypochlorite (Ca[OCl]2), calculated to achieve initial free residual chlorine (FRC) of 50 mg/L, i.e., 3.0 lbs (1.4 kg) industrial grade NaOCl (12-15% available Cl) per 1,000 gallons of CT/EC water; 10.5 lbs (4.8 kg) domestic grade NaOCl (3-5% available Cl) per 1,000 gallons of CT/EC water; or 0.6 lb (0.3 kg) Ca(OCl)2 per 1,000 gallons of CT/EC water. If significant biodeposits are present, additional chlorine may be required. If the volume of water in CT/EC is not known, it can be estimated (in gallons) by multiplying the recirculation rate in gallons/minute by 10, or the refrigeration capacity in tons by 30. Other appropriate compounds may be suggested by a water-treatment specialist.

B. Record the type and quality of all chemicals used for disinfection, exact time the chemicals are added to the system, and time and results of measurements of (FRC) and pH.

C. Add dispersant simultaneously with or within 15 minutes of adding disinfectant. The dispersant is best added by first dissolving it in water and adding the solution to a turbulent zone in the water system. Examples of low or non-foaming, silicate-based dispersants are: automatic-dishwasher compounds, such as Cascade* or Calgonite* or an equivalent product. Dispersants are added at 10-25 lbs. (4.5-11.25 kg) per 1,000 gallons of CT/EC water.

D. After adding disinfectant and dispersant, continue circulating the water through the system. Monitor FRC by using an FRC-measuring device, such as a swimming pool test kit, and measure the pH with a pH meter every 15 minutes for 2 hours. Add chlorine as needed to maintain FRC at > or = 10 mg/L. Since the biocidal effect of chlorine is reduced at higher pH, adjust pH to 7.5-8.0. The pH may be lowered by using any acid (eg, muriatic acid or sulfuric acid used for maintenance of swimming pools) that is compatible with the treatment chemicals.

E. Two hours after adding disinfectant and dispersant or after FRC level is stable at 10 mg/L, monitor at 2-hour intervals and maintain FRC at 10 mg/L for 24 hours.

F. After FRC level has been maintained at 10 mg/L for 24 hours, drain the system. CT/EC water may be safely drained to the sanitary sewer. Municipal water and sewerage authorities should be contacted regarding local regulations. If a sanitary sewer is not available, consult local or state authorities (eg, Department of Natural Resources) regarding disposal of water. If necessary, the drain-off may be dechlorinated by dissipation or chemical neutralization with sodium bisulfite.

G. Refill system with water and repeat procedure outlined in steps 2-6 in I-B above.

III. Mechanical Cleaning

A. After water from the second chemical disinfection has been drained, shut down the CT/EC.

B. Inspect all water contact areas for sediment, sludge, and scale. Using brushes and/or a low-pressure water hose, thoroughly clean all CT/EC water contact areas including basin, sump, fill, spray nozzles, and fittings. Replace components as needed.

C. If possible, clean CT/EC water contact areas within the chillers.

IV. After Mechanical Cleaning

A. Fill the system with water, and add chlorine to achieve FRC level of 10 mg/L.
B. Circulate water for one hour, then open blowdown valve and flush the entire system until the water is free of turbidity.
C. Drain the system.
D. Open any air intake vents that were closed prior to cleaning.
E. Fill the system with water. CT/EC may be put back into service using an effective water-treatment program.

* Use of product names is for identification only and does not imply endorsement by the Public Health Service or the U.S. Department of Health and Human Services.