

Mitigating IAQ Problems

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Over the years many types of mitigation (correction) strategies have been implemented to solve indoor air quality problems. The purpose of this section is to provide an understanding of basic approaches to mitigation and the various solutions that can be effective in treating commonly-encountered IAQ problems. It is not intended to provide detailed instructions for using each type of mitigation approach but rather to give guidance in selecting a mitigation strategy and in judging proposals from in-house staff or outside consultants.

Mitigation of indoor air quality problems may require the involvement of building management and staff representing such areas of responsibility as:

- n facility operation and maintenance
- n housekeeping
- n shipping and receiving
- n purchasing
- n policymaking
- n staff training

Successful mitigation of IAQ problems also requires the cooperation of other building occupants, including the employees of building tenants. Occupants must be educated about the cause(s) of the IAQ problems and about actions that must be taken or avoided to prevent a recurrence of the problems.

BACKGROUND: CONTROLLING INDOOR AIR PROBLEMS

Section 2 introduced the idea that indoor air quality problems result from interactions between contaminant source, building site, building structure, activities within the building, mechanical equipment, climate, and occupants. Efforts to control

indoor air contaminants change the relationships between these factors. There are many ways that people can intervene in these relationships to prevent or control indoor air contaminant problems. Control strategies can be categorized as:

- n source control
- n ventilation
- n air cleaning
- n exposure control

Successful mitigation often involves a combination of these strategies. Possible remedies for the other environmental stressors discussed in *Section 6* are discussed briefly below.

Source Control

All efforts to prevent or correct IAQ problems should include an effort to identify and control pollutant sources. Source control is generally the most cost effective approach to mitigating IAQ problems in which point sources of contaminants can be identified. In the case of a strong source, source control may be the only solution that will work.

The following are categories and examples of source control:

Remove or reduce the source

- n prohibit smoking indoors or limit smoking to areas from which air is exhausted, not recirculated (NIOSH regards smoking areas as an interim solution)
- n relocate contaminant-producing equipment to an unoccupied, better ventilated, or exhaust-only ventilated space
- n select products which produce fewer or less potent contaminants while maintaining adequate safety and efficacy

- n modify other occupant activities

Seal or cover the source

- n improve storage of materials that produce contaminants
- n seal surfaces of building materials that emit VOCs such as formaldehyde

Modify the environment

- n after cleaning and disinfecting an area that is contaminated by fungal or bacterial growth, control humidity to make conditions inhospitable for regrowth

Source removal or reduction can sometimes be accomplished by a one-time effort such as thorough cleaning of a spill. In other cases, it requires an ongoing process, such as establishing and enforcing a non-smoking policy.

Sealing or covering the source can be a solution in some cases; application of a barrier over formaldehyde-emitting building materials is an example. Sealing may also involve educating staff or building occupants about the contaminant-producing features of materials and supplies and inspecting storage areas to ensure that containers are properly covered.

In some cases, modification of the environment is necessary for effective mitigation. If the indoor air problem arises from microbiological contaminants, for example, disinfection of the affected area may not eliminate the problem. Regrowth of microbiologicals could occur unless humidity control or other steps, such as adding insulation to prevent surface condensation, are taken to make the environment inhospitable to microbiologicals.

Ventilation

Ventilation modification is often used to correct or prevent indoor air quality problems. This approach can be effective either where buildings are underventilated or where a specific contaminant source

cannot be identified. Ventilation can be used to control indoor air contaminants by:

Diluting contaminants with outdoor air

- n increase the total quantity of supply air (including outdoor air)
- n increase the proportion of outdoor air to total air
- n improve air distribution

Isolating or removing contaminants by controlling air pressure relationships

- n install effective local exhaust at the location of the source
- n avoid recirculation of air that contains contaminants
- n locate occupants near supply diffusers and sources near exhaust registers
- n use air-tightening techniques to maintain pressure differentials and eliminate pollutant pathways
- n make sure that doors are closed where necessary to separate zones

Diluting contaminants by increasing the flow of outdoor air can be accomplished by increasing the total supply airflow in the complaint area (e.g., opening supply diffusers, adjusting dampers) or at the air handling unit, (e.g., cleaning the filter on the supply fan). An alternative is to increase the proportion of outdoor air (e.g., adjusting the outdoor air intake damper, installing minimum stops on variable air volume (VAV) boxes so that they satisfy the outdoor air requirements of ASHRAE 62-1989).

Studies have shown that increasing ventilation rates to meet ASHRAE Standard 62-1989 (e.g., from 5 to 15 or 20 cfm/person) does not necessarily significantly increase the total annual energy consumption. The increase appears to be less than 5% in typical commercial buildings. The cost of ventilation is generally overshadowed by other operating costs, such as lighting. Further, improved maintenance can produce energy savings to balance the costs that might otherwise result from increased ventilation.

The cost of modifying an existing HVAC system to condition additional outdoor air can vary widely depending upon the specific situation. In some buildings, HVAC equipment may not have sufficient capacity to allow successful mitigation using this approach. Original equipment is often oversized so that it can be adjusted to handle the increased load, but in some cases additional capacity is required.

Most ventilation deficiencies appear to be linked to inadequate quantities of outdoor air. However, inadequate distribution of ventilation air can also produce IAQ problems. Diffusers should be properly selected, located, installed, and maintained so that supply air is evenly distributed and blends thoroughly with room air in the breathing zone. Short-circuiting occurs when clean supply air is drawn into the return air plenum before it has mixed with the dirtier room air and therefore fails to dilute contaminants. Mixing problems can be aggravated by temperature stratification. Stratification can occur, for example, in a space with high ceilings in which ceiling-mounted supply diffusers distribute heated air.

Note the side effects of increased ventilation:

- n mitigation by increasing the circulation of outdoor air requires good outdoor air quality
- n increased supply air at the problem location might mean less supply air in other areas
- n increased total air in the system and increased outdoor air will both tend to increase energy consumption and may require increased equipment capacity
- n any approach which affects airflow in the building can change pressure differences between rooms (or zones) and between indoors and outdoors, and might lead to increased infiltration of unconditioned outdoor air
- n increasing air in a VAV system may overcool an area to the extent that terminal reheat units are needed

Ventilation equipment can be used **to isolate or contain contaminants by controlling pressure relationships**. If the contaminant source has been identified, this strategy can be more effective than dilution. Techniques for controlling air pressure relationships range from adjustment of dampers to installation of local exhaust.

Using local exhaust confines the spread of contaminants by capturing them near the source and exhausting them to the outdoors. It also dilutes the contaminant by drawing cleaner air from surrounding areas into the exhaust airstream. If there are return grilles in a room equipped with local exhaust, the local exhaust should exert enough suction to prevent recirculation of contaminants. Properly designed and installed local exhaust results in far lower contaminant levels in the building than could be accomplished by a general increase in dilution ventilation, with the added benefit of costing less.

Note that replacement air must be able to flow freely into the area from which the exhaust air is being drawn. It may be necessary to add door or wall louvers in order to provide a path for the make-up air. (Make sure that this action does not violate fire codes.)

Correct identification of the pollutant source and installation of the local exhaust is critically important. For example, an improperly designed local exhaust can draw other contaminants through the occupied space and make the problem worse.

The physical layout of grilles and diffusers relative to room occupants and pollutant sources can be important. If supply diffusers are all at one end of a room and returns are all at the other end, the people located near the supplies may be provided with relatively clean air while those located near the returns breathe air that has already picked up contaminants from all the sources in the room that are not served by local exhaust.

Elimination of pollutant pathways by air sealing (e.g., caulking cracks, closing holes) is an approach that can increase the effectiveness of other control techniques. It can be a difficult technique to implement because of hidden pathways (e.g., above drop ceilings, under raised flooring against brick or block walls). However, it can have other benefits such as energy savings and more effective pest control (by eliminating paths used by vermin).

Air Cleaning

The third IAQ control strategy is to clean the air. Air cleaning is usually most effective when used in conjunction with either source control or ventilation; however, it may be the only approach when the source of pollution is outside of the building. Most air cleaning in large buildings is aimed primarily at preventing contaminant buildup in HVAC equipment and enhancing equipment efficiency.

Air cleaning equipment intended to provide better indoor air quality for occupants must be properly selected and designed for the particular pollutants of interest (for example, gaseous contaminants can be removed only by gas sorption). Once installed, the equipment requires regular maintenance in order to ensure good performance; otherwise it may become a major pollutant source in itself. This maintenance requirement should be borne in mind if an air cleaning system involving a large number of units is under consideration for a large building. If room units are used, the installation should be designed for proper air recirculation.

There are four technologies that remove contaminants from the air:

- n particulate filtration
- n electrostatic precipitation
- n negative ion generation
- n gas sorption

The first three approaches are designed to remove particulates, while the fourth is designed to remove gases.

Particulate filtration removes suspended liquid or solid materials whose size, shape and mass allow them to remain airborne for the air velocity conditions present. Filters are available in a range of efficiencies, with higher efficiency indicating removal of a greater proportion of particles and of smaller particles. Moving to medium efficiency pleated filters is advisable to improve IAQ and increase protection for equipment. However, the higher the efficiency of the filter, the more it will increase the pressure drop within the air distribution system and reduce total airflow (unless other adjustments are made to compensate). It is important to select an appropriate filter for the specific application and to make sure that the HVAC system will continue to perform as designed. Filters are rated by different standards (e.g., arrestance and dust spot) which measure different aspects of performance.

Electrostatic precipitation is another type of particulate control. It uses the attraction of charged particles to oppositely charged surfaces to collect airborne particulates. In this process, the particles are charged by ionizing the air with an electric field. The charged particles are then collected by a strong electric field generated between oppositely-charged electrodes. This provides relatively high efficiency filtration of small respirable particles at low air pressure losses.

Electrostatic precipitators may be installed in air distribution equipment or in specific usage areas. As with other filters, they must be serviced regularly. Note, however, that electrostatic precipitators produce some ozone. Because ozone is harmful at elevated levels, EPA has set standards for ozone concentrations in outdoor air, and NIOSH and OSHA have

established guidelines and standards, respectively, for ozone in indoor air. The amount of ozone emitted from electrostatic precipitators varies from model to model.

Negative ion generators use static charges to remove particles from the indoor air. When the particles become charged, they are attracted to surfaces such as walls, floors, table tops, draperies, and occupants. Some designs include collectors to attract the charged particles back to the unit. Negative ion generators are not available for installation in ductwork, but are sold as portable or ceiling-mounted units. As with electrostatic precipitators, negative ion generators may produce ozone, either intentionally or as a by-product of use.

Gas sorption is used to control compounds that behave as gases rather than as particles (e.g., gaseous contaminants such as formaldehyde, sulfur dioxide, ozone, and oxides of nitrogen). Gas sorption involves one or more of the following processes with the sorption material (e.g., activated carbon, chemically treated active clays): a chemical reaction between the pollutant and the sorbent, a binding of the pollutant and the sorbent, or diffusion of the contaminant from areas of higher concentration to areas of lower concentration. Gas sorption units are installed as part of the air distribution system. Each type of sorption material performs differently with different gases. Gas sorption is not effective for removing carbon monoxide. There are no standards for rating the performance of gaseous air cleaners, making the design and evaluation of such systems problematic. Operating expenses of these units can be quite high, and the units may not be effective if there is a strong source nearby.

Exposure Control

Exposure control is an administrative approach to mitigation that uses behavioral methods, such as:

Scheduling contaminant-producing activities to avoid complaints

- n schedule contaminant-producing activities to occur during unoccupied periods
- n notify susceptible individuals about upcoming events (e.g., roofing, pesticide application) so that they can avoid contact with the contaminants

Scheduling contaminant-producing activities for unoccupied periods whenever possible is simple common sense. It may be the best way to limit complaints about activities (such as roofing or demolition) which unavoidably produce odors or dust.

Relocating susceptible individuals

- n move susceptible individuals away from the area where they experience symptoms

Controlling exposure by relocating susceptible individuals may be the only practical approach in a limited number of cases, but it is probably the least desirable option and should be used only when all other strategies are ineffective in resolving complaints.

Remedies for Complaints Not Attributed to Poor Air Quality

Specific lighting deficiencies or localized sources of noise or vibration can sometimes be readily identified, and remedial action may be fairly straightforward (more or fewer lights on, adjustments for glare; relocating, replacing or acoustically insulating a noise or vibration source). Similarly, flagrant ergonomic stress or blatant psychosocial stress may be apparent even to an untrained observer.

In other cases, however, problems may be more subtle or solutions more complex. Since specialized knowledge, skills, and instrumentation are usually needed to evaluate lighting, noise, vibration, ergonomic stress, or psychosocial stress, such evaluations are generally best done by a qualified professional in that particular field.

Remedial actions for lighting, noise, and vibration problems might range from modifications of equipment or furnishings to renovation of the building. Ergonomic deficiencies may require furniture or equipment changes or different work practices. The solution to psychosocial problems may involve new management practices, job redesign, or resolution of underlying labor-management problems.

SAMPLE PROBLEMS AND SOLUTIONS

In the investigation section you were introduced to a variety of problems that are often found in buildings. This section presents fifteen categories of IAQ problems. Specific problem “examples” are given, followed by solutions” that have been used for that category of problem. Most of the problems presented here are common and do not have serious, life-threatening consequences. At the end of the section is a brief description of problems that can have severe health impacts. The basic correction principles that apply to these serious problems are similar to those used in less critical situations.

Reading these examples may help you to think about the best way to solve your indoor air quality problems. Remember that these are brief sketches, and apparent parallels to your building could be misleading. It is better to carry out a building investigation and learn the specific facts in your own case, rather than adopt a mitigation approach that might not be appropriate. Attempting to correct IAQ problems without understanding the cause of those problems can be both ineffective and expensive.

You will note that some solutions are simple and low-cost, while others are complex and expensive. Do not assume

that each solution listed would be an effective treatment for all of the problems in its category.

The example problems and solutions are presented in the following sequence:

- Problem #1:** Outdoor air ventilation rate is too low
- Problem #2:** Overall ventilation rate is high enough, but poorly distributed and not sufficient in some areas
- Problem #3:** Contaminant enters building from outdoors
- Problem #4:** Occupant activities contribute to air contaminants or to comfort problems
- Problem #5:** HVAC system is a source of biological contaminants
- Problem #6:** HVAC system distributes contaminants
- Problem #7:** Non-HVAC equipment is a source or distribution mechanism for contaminants
- Problem #8:** Surface contamination due to poor sanitation or accidents
- Problem #9:** Mold and mildew growth due to moisture from condensation
- Problem #10:** Building materials and furnishings produce contaminants
- Problem #11:** Housekeeping or maintenance activities contribute to problems
- Problem #12:** Specialized use areas as sources of contaminants
- Problem #13:** Remodeling or repair activities produce problems
- Problem #14:** Combustion gases
- Problem #15:** Serious building-related illness

Problem #1: Outdoor Air Ventilation Rate is Too Low

Examples

Routine odors from occupants and normal office activities result in problems
(e.g., drowsiness, headaches, discomfort)

Measured outdoor air ventilation rates do not meet guidelines for outdoor air supply
(e.g., design specifications, applicable codes, or ASHRAE 62-1989)

Peak CO₂ concentrations above 1000 ppm indicate inadequate ventilation

Corrosion of fan casing causes air bypassing and reduces airflow in system

Solutions

Open, adjust or repair air distribution system

- n outdoor air intakes
- n mixing and relief dampers
- n supply diffusers
- n fan casings

Increase outdoor air within the design capacity of

- n air handler
- n heating and air conditioning equipment
- n distribution system

Modify components of the HVAC system as needed to allow increased outdoor air

(e.g., increase capacity of heating and cooling coils)

Design and install an updated ventilation system

Reduce the pollutant and/or thermal load on the HVAC system

- n reduce the occupant density: relocate some occupants to other spaces to redistribute the load on the ventilation system
- n relocate or reduce usage of heat-generating equipment

Malfunctioning controls such as this broken damper linkage can virtually eliminate intake of outdoor air. Such problems may go undetected for years without a careful investigation of the HVAC system components.

Problem #2:
Overall Ventilation Rate Is High Enough, But Poorly Distributed and Not Sufficient in Some Areas

Examples

Measured outdoor air meets guidelines at building air inlet, but there are zones where heat, routine odors from occupants, and normal office activities result in complaints

(e.g., drowsiness, headaches, comfort complaints)

Solutions

Open, adjust, or repair air distribution system

- n supply diffusers
- n return registers

Ensure proper air distribution

- n balance the air handling system
- n make sure that there is an air gap at tops and bottoms of partitions to prevent dead air space
- n relocate supply and/or return diffusers to improve air distribution

Seal leaky ductwork

Remove obstructions from return air plenum

Control pressure relationships

- n install local exhaust in problem areas and adjust HVAC system to provide adequate make-up air
- n move occupants so that they are closer to supply diffusers
- n relocate identified contaminant sources closer to exhaust intakes

Reduce source by limiting activities or equipment use that produce heat, odors, or contaminants

Design and install an appropriate ventilation system

Complaining of discomfort, building occupants blocked air supply diffusers in their work areas. The HVAC system in this building was in poor condition and was not balanced.

Problem #3: Contaminant Entering Building From Outdoors

Examples

Soil gases

(e.g., radon, gasoline from tanks, methane from landfills)

Contaminants from nearby activities

(e.g., roofing, dumpster, construction)

Outdoor air intake near source

(e.g., parking, loading dock, building exhaust)

Outdoor air contains pollutants or excess moisture

(e.g., cooling tower mist entrained in outdoor air intake)

Solutions

Remove the source, if it can be moved easily

- n remove debris around outdoor air intake
- n relocate dumpster

Reduce source (for example, shift time of activity to avoid occupied periods)

- n painting, roofing, demolition
- n housekeeping, pest control

Relocate elements of the ventilation system that contribute to entry of outdoor air contaminants

- n separate outdoor air intakes from sources of odors, contaminants
- n separate exhaust fan outlets from operable windows, doors, air intakes
- n make rooftop exhaust outlets taller than intakes

Change air pressure relationships to control pollutant pathways

- n install subslab depressurization to prevent entry of soil gas contaminants (radon, gases from landfills and underground tanks)
- n pressurize the building interior relative to outdoors (this will not prevent contaminant entry at outdoor air intakes)
- n close pollutant pathways (e.g., seal cracks and holes)

Add special equipment to HVAC system

- n filtration equipment to remove pollutants (select to fit the situation)

For cosmetic reasons, air intakes are frequently located on rooftops or near the ground. This air intake could become a means of drawing lawn cuttings, vehicle exhaust, and pesticides into the building.

Problem #4:
**Occupant Activities
Contribute to Air
Contaminants or to
Comfort Problems**

Examples

Smoking

Special activities such as print shops, laboratories, kitchens

Interference with HVAC system operation:

- n blockage of supply diffusers to eliminate drafts
- n turning off exhaust fans to eliminate noise
- n use of space heaters, desktop humidifiers to remedy local discomfort

(*Note: While such interference can cause IAQ problems, it is often initiated in response to unresolved ventilation or temperature control problems.*)

Solutions

Remove the source by eliminating the activity

(*Note: This may require a combination of policy-setting and educational outreach.*)

- n smoking
- n use of desktop humidifiers and other personal HVAC equipment
- n unsupervised manipulation of HVAC system

Reduce the source

- n select materials and processes which minimize release of contaminants while maintaining adequate safety and efficacy (e.g., solvents, art materials)

Install new or improved local exhaust to accommodate the activity, adjust HVAC system to ensure adequate make-up air, and verify effectiveness

- n smoking lounge, storage areas which contain contaminant sources
- n laboratory hoods, kitchen range hoods (venting to outdoors, not recirculating)

Personal equipment such as humidifiers brought in by building occupants can become a source of contaminants if not properly maintained. An effective communication strategy can help occupants to understand their role in causing indoor air quality problems and in correcting those problems.

Problem #5:

HVAC System is a Source of Biological Contaminants

The HVAC system can act as a source of contaminants by providing a hospitable environment for the growth of microorganisms and by then distributing biologically-contaminated air within the building.

Examples

Surface contamination by molds (fungi), bacteria

- n drain pans
- n interior of ductwork
- n air filters and filter media (collected debris).

Solutions

Remove source by improving maintenance procedures

- n inspect equipment for signs of corrosion, high humidity
- n replace corroded parts
- n clean drip pans, outdoor air intakes, other affected locations
- n use biocides, disinfectants, and sanitizers with extreme caution and ensure that occupant exposure is minimized

(Note: See discussion of duct cleaning in Appendix B.)

Provide access to all the items that must be cleaned, drained, or replaced periodically

This blackish deposit was scraped from a poorly-maintained air handling unit drain pan. The pan contained nutrients caused by poor upstream filtration and stagnant water that fostered the growth of microbiological contaminants.

Problem #6: HVAC System Distributes Contaminants

Standing water on a roof can cause water damage and potential mold growth sites inside the building as well as providing a breeding area for insects and microbiologicals such as Legionella. The outside air intake (near the far left of this photograph) is located close to the standing water and could be drawing in insects and microbiological contaminants.

Examples

Unfiltered air bypasses filters due to problems

- n filter tracks are loose
- n poorly-maintained filters sag when they become overloaded with dirt
- n filters are the wrong size

Recirculation of air that contains dust or other contaminants

- n system recirculates air from rooms containing pollutant sources
- n return air plenum draws air from rooms that should be exhausted (e.g. janitor's closets)
- n return air plenums draw soil gases from interiors of block corridor walls that terminate above ceilings

Solutions

Modify air distribution system to minimize recirculation of contaminants

- n provide local exhaust at point sources of contaminants, adjust HVAC system to provide adequate make-up air, and test to verify performance
- n increase proportion of outdoor air
- n seal unplanned openings into return air plenums and provide alternative local ventilation (adjust HVAC system to provide adequate make-up air and test to verify performance)

Improve housekeeping, pest control, occupant activities, and equipment use to minimize release of contaminants from all sources

Install improved filtration equipment to remove contaminants

Check filter tracks for any gaps

Problem #7:

Non-HVAC Equipment is a Source or Distribution Mechanism for Contaminants

This discussion pertains to medium- to large-scale pieces of equipment.

Examples

Non-HVAC equipment can produce contaminants, as in the case of:

- n wet process copiers
- n large dry process copiers
- n engineering drawing reproduction machines

It can also distribute contaminants, as in the case of:

- n elevators, which can act as pistons and draw contaminants from one floor to another

Solutions

Install local exhaust near machines

(Note: Adjust HVAC system to provide adequate make-up air, and test to verify performance.)

Reschedule use to occur during periods of low occupancy

Remove source

- n relocate occupants out of rooms that contain contaminant-generating equipment
- n relocate equipment into special use areas equipped with effective exhaust ventilation (test to verify control of air pressure relationships)

Change air pressure relationships to prevent contaminants from entering elevator shaft

Sometimes there are unusual sources of indoor air quality problems. An inspection of the HVAC system revealed air filters covered with a graphite dust deposit from a broken elevator motor generator. The motor generator was repaired and corrections were made to prevent the crossover of ventilation air from the motor generator into the HVAC mechanical room.

Problem #8:
**Surface Contamination
Due to Poor Sanitation or
Accidents**

Examples

Biological contaminants result in allergies or other diseases

- n fungal, viral, bacterial (whole organisms or spores)
- n bird, insect, or rodent parts or droppings, hair, dander (in HVAC, crawlspace, building shell, or near outdoor air intakes)

Accidents

- n spills of water, beverages, cleansers, paints, varnishes, mastics or specialized products (printing, chemical art supplies)
- n fire damage: soot, odors, chemicals

Solutions

Clean

- n HVAC system components
- n some materials and furnishings (others may have to be discarded)

(Note: Use biocides, disinfectants, and sanitizers with caution and ensure that occupant exposure is minimized.)

Remove sources of microbiological contamination

- n water-damaged carpet, furnishings, or building materials

Modify environment to prevent recurrence of microbiological growth

- n improve HVAC system maintenance
- n control humidity or surface temperatures to prevent condensation

Provide access to all items that require periodic maintenance

Use local exhaust where corrosive materials are stored

Adjust HVAC system to provide adequate make-up air, and test to verify performance

The carpet on this floor was flooded and an outbreak of humidifier fever occurred. To eliminate microbiologicals, the contaminated carpet was removed and new carpet was installed.

Problem #9: **Mold and Mildew Growth Due to Moisture from Condensation**

Examples

Interior surfaces of walls near thermal bridges

(e.g., uninsulated locations around structural members)

Carpeting on cold floors

Locations where high surface humidity promotes condensation

Solutions

Clean and disinfect to remove mold and mildew.

(Note: Follow up by taking actions to prevent recurrence of microbiological contamination. Use biocides, disinfectants, and sanitizers with caution and ensure that occupant exposure is minimized.)

Increase surface temperatures to treat locations that are subject to condensation

- n insulate thermal bridges
- n improve air distribution

Reduce moisture levels in locations that are subject to condensation

- n repair leaks
- n increase ventilation (in cases where outdoor air is cold and dry)
- n dehumidify (in cases where outdoor air is warm and humid)

Dry carpet or other textiles promptly after steam cleaning

(Note: Increase ventilation to accelerate drying.)

Discard contaminated materials

This is a school crawlspace in which moisture should be controlled. The fungus is Fusarium, some species of which are toxigenic and should not be inside. The spores were distributed by the air handler because the return plenum was open to the crawlspace.

Problem #10:
**Building Materials and
Furnishings Produce
Contaminants**

Examples

*Odors from newly installed carpets,
furniture, wall coverings*

Newly drycleaned drapes or other textiles

Solutions

***Remove source with appropriate cleaning
methods***

- n steam clean carpeting and upholstery,
then dry quickly, ventilating to acceler-
ate the drying process
- n accept only fully dried, odorless
drycleaned products

Encapsulate source

- n seal surfaces of building materials that
emit formaldehyde

Reduce source

- n schedule installation of carpet, furniture,
and wall coverings to occur during
periods when the building is unoccupied
- n have supplier store new furnishings in a
clean, dry, well-ventilated area until
VOC outgassing has diminished

Increase outdoor air ventilation

- n total air supplied
- n proportion of fresh air

***Remove the materials that are producing
the emissions and replace with lower
emission alternatives***

(Note: Only limited information on
emissions from materials is available at
this time. Purchasers can request that
suppliers provide emissions test data, but
should use caution in interpreting the test
results.)

*Low levels of contaminants are emitted
from many of the building materials
and furnishings in an office. Dust can
accumulate on stacks of papers and
open shelves. Depending on how
they are cared for, plants potentially
add moisture, soil microbiologicals,
and pesticides.*

Problem #11: Housekeeping or Maintenance Activities Contribute to Problems

Examples

Cleaning products emit chemicals, odors

Particulates become airborne during cleaning (e.g., sweeping, vacuuming)

Contaminants are released from painting, caulking, lubricating

Frequency of maintenance is insufficient to eliminate contaminants

Solutions

Remove source by modifying standard procedures or frequency of maintenance
(Note: Changing procedures may require a combination of policy-setting and training in IAQ impacts of staff activities.)

- n improve storage practices
- n shift time of painting, cleaning, pest control, other contaminant-producing activities to avoid occupied periods
- n make maintenance easier by improving access to filters, coils, and other components

Reduce source

- n select materials to minimize emissions of contaminants while maintaining adequate safety and efficacy
- n use portable HEPA (high efficiency particulate arrestance”) vacuums vs. low-efficiency paper-bag collectors

Use local exhaust

- n on a temporary basis to remove contaminants from work areas
- n as a permanent installation where contaminants are stored

Indoor air quality problems can be caused by lack of adequate house-keeping practices. On the other hand, deodorizers, cleansers and other products can also produce odors and contaminants.

Problem #12:
**Specialized Use Areas as
Sources of Contaminants**

Examples

*Food preparation
Art or print rooms
Laboratories*

Solutions

Change pollutant pathway relationships

- n run specialized use area under negative pressure relative to surrounding areas
- n install local exhaust, adjust HVAC system to provide make-up air, and test to verify performance

Remove source by ceasing, relocating, or rescheduling incompatible activities

Reduce source by selecting materials to minimize emissions of contaminants while maintaining adequate safety and efficacy

Reduce source by using proper sealing and storage for materials that emit contaminants

This chemical storage room should be maintained under negative pressure. Properly designed and maintained local exhaust will achieve the proper air pressure relationship with surrounding areas. Otherwise, such storage areas can be a source of occupant exposure to many airborne contaminants.

Problem #13: Remodeling or Repair Activities Produce Problems

Examples

Temporary activities produce odors and contaminants

- n installation of new particleboard, partitions, carpet, or furnishings
- n painting
- n reroofing
- n demolition

Existing HVAC system does not provide adequate ventilation for new occupancy or arrangement of space

Solutions

Modify ventilation to prevent recirculation of contaminants

- n install temporary local exhaust in work area, adjust HVAC system to provide make-up air, and test to verify performance
- n seal off returns in work area
- n close outdoor air damper during re-roofing

Reduce source by scheduling work for unoccupied periods and keeping ventilation system in operation to remove odors and contaminants

Reduce source by careful materials selection and installation

- n select materials to minimize emissions of contaminants while maintaining adequate safety and efficacy
- n have supplier store new furnishings in a clean, dry, well-ventilated area until VOC outgassing has diminished
- n request installation procedures (e.g., adhesives) that limit emissions of contaminants

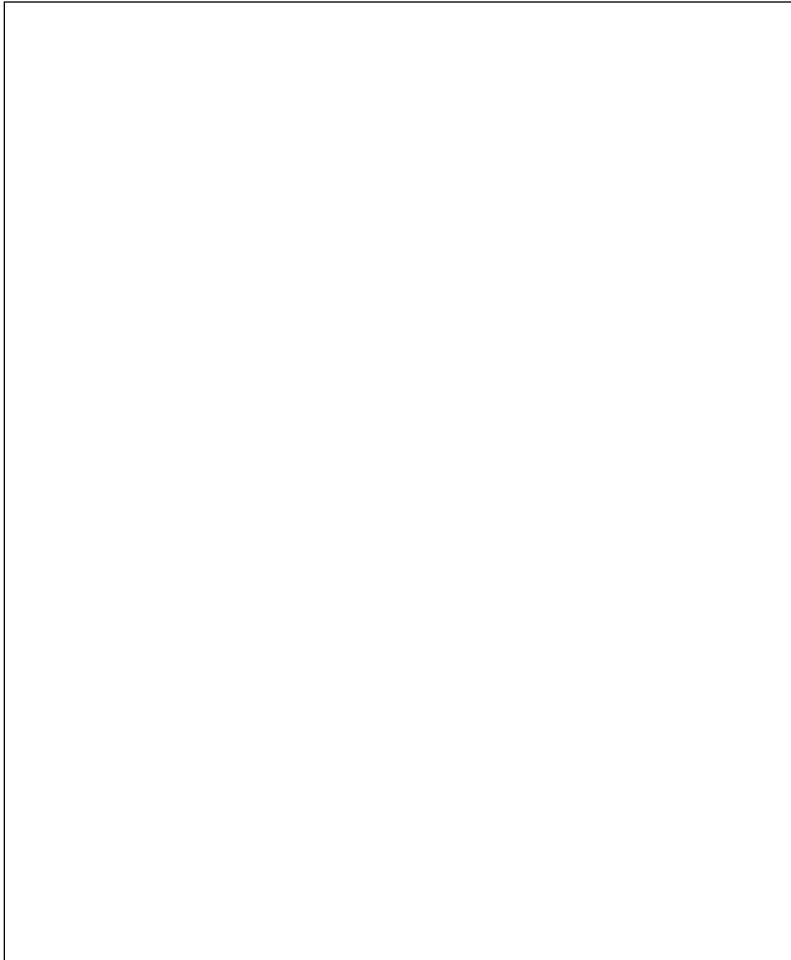
Modify HVAC or wall partition layout if necessary

- n partitions should not interrupt airflow
- n relocate supply and return diffusers
- n adjust supply and return air quantities
- n adjust total air and/or outdoor air supply to serve new occupancy

Remodeling may involve many activities that can cause IAQ problems. Ventilation modifications can be used to isolate the work area and prevent pollutant build-up in occupied spaces. Proper storage practices can minimize the release of contaminants.

Problem #14: Combustion Gases

Combustion odors can indicate the existence of a serious problem. One combustion product, carbon monoxide, is an odorless gas. Carbon monoxide poisoning can be life-threatening.



Air intakes are frequently located near the loading dock for aesthetic reasons. Unfortunately, this air intake placement can draw car and truck exhaust into the building, causing a variety of indoor air quality complaints.

Examples

Vehicle exhaust

- n offices above (or connected to) an underground parking garage
- n rooms near (or connected by pathways to) a loading dock or service garage

Combustion gases from equipment

(e.g., spillage from inadequately vented appliances, cracked heat exchanger, re-entrainment because local chimney is too low)

- n areas near a mechanical room
- n distributed throughout zone or entire building

Solutions

Seal to remove pollutant pathway

- n close openings between the contaminant source and the occupied space
- n install well-sealed doors with automatic closers between the contaminant source and the occupied space

Remove source

- n improve maintenance of combustion equipment
- n modify venting or HVAC system to prevent backdrafting
- n relocate holding area for vehicles at loading dock, parking area
- n turn off engines of vehicles that are waiting to be unloaded

Modify ventilation system

- n install local exhaust in underground parking garage (adjust HVAC system to provide make-up air and test to verify performance)
- n relocate fresh air intake (move away from source of contaminants)

Modify pressure relationships

- n pressurize spaces around area containing source of combustion gases

Problem #15: Serious Building-Related Illness

Some building-related illnesses can be life-threatening. Even a single confirmed diagnosis (which involves results from specific medical tests) should provoke an immediate and vigorous response.

Examples

Legionnaire's disease

(*Note:* If you suspect Legionnaire's disease, call the local public health department, check for obvious problem sites, and take corrective action. There is no way to be certain that a single case of this disease is associated with building occupancy; therefore, public health agencies usually do not investigate single cases. Watch for new cases.)

Hypersensitivity pneumonitis

(*Note:* Affected occupant(s) should be removed and may not be able to return unless the causative agent is removed from the affected person's environment.)

Solutions

Work with public health authorities

- evacuation may be recommended or required

Remove source

- drain, clean, and decontaminate drip pans, cooling towers, room unit air conditioners, humidifiers, dehumidifiers, and other habitats of *Legionella*, fungi, and other organisms using appropriate protective equipment

- install drip pans that drain properly
- provide access to all the items that must be cleaned, drained, or replaced periodically
- modify schedule and procedures for improved maintenance

Discontinue processes that deposit potentially contaminated moisture in air distribution system

- air washing
- humidification
- cease nighttime shutdown of air handlers

This air intake is located between the cooling towers. If the water in the cooling towers becomes contaminated with Legionella, there is potential for Legionnaire's disease in the building.

The most economical and successful solutions to IAQ problems are those in which the operating principle of the correction strategy makes sense and is suited to the problem.

JUDGING PROPOSED MITIGATION DESIGNS AND THEIR SUCCESS

Mitigation efforts should be evaluated at the planning stage by considering the following criteria:

- n permanence
- n operating principle
- n degree to which the strategy fits the job
- n ability to institutionalize the solution
- n durability
- n installation and operating costs
- n conformity with codes

Permanence

Mitigation efforts that create permanent solutions to indoor air problems are clearly superior to those that provide temporary solutions (unless the problems are also temporary). Opening windows or running air handlers on full outdoor air may be suitable mitigation strategies for a temporary problem such as outgassing of volatile compounds from new furnishings, but would not be good ways to deal with emissions from a print shop. A permanent solution to microbiological contamination involves not only cleaning and disinfection, but also modification of the environment to prevent regrowth.

Operating Principle

The most economical and successful solutions to IAQ problems are those in which the operating principle of the correction strategy makes sense and is suited to the problem. If a specific point source of contaminants has been identified, treatment at the source (e.g., by removal, sealing, or local exhaust) is almost always a more appropriate correction strategy than dilution of the contaminant by increased general ventilation. If the IAQ problem is caused by the introduction of outdoor air that contains contaminants, increased general ventilation will only make the

situation worse (unless the outdoor air is cleaned).

Degree to Which the Strategy Fits the Job

It is important to make sure that you understand the IAQ problem well enough to select a correction strategy whose size and scope fit the job. If odors from a special use area such as a kitchen are causing complaints in a nearby office, increasing the ventilation rate in the office may not be a successful approach. The mitigation strategy should address the entire area affected.

If mechanical equipment is needed to correct the IAQ problem, it must be powerful enough to accomplish the task. For example, a local exhaust system should be strong enough and close enough to the source so that none of the contaminant is drawn into nearby returns and recirculated.

Ability to Institutionalize the Solution

A mitigation strategy will be most successful when it is institutionalized as part of normal building operations. Solutions that do not require exotic equipment are more likely to be successful in the long run than approaches that involve unfamiliar concepts or delicately maintained systems. If maintenance or housekeeping procedures or supplies must change as part of the mitigation, it may be necessary to plan for additional staff training, new inspection checklists, or modified purchasing practices. Operating schedules for HVAC equipment may also require modification.

Durability

IAQ mitigation strategies that are durable and low-maintenance are more attractive to owners and building staff than approaches that require frequent adjustment or

specialized maintenance skills. New items of equipment should be quiet, energy-efficient, and durable, so that the operators are encouraged to keep them running.

Installation and Operating Costs

The approach with the lowest initial cost may not be the least expensive over the long run. Other economic considerations include: energy costs for equipment operation, increased staff time for maintenance; differential cost of alternative materials and supplies; and higher hourly rates if odor-producing activities (e.g., cleaning) must be scheduled for unoccupied periods. Although these costs will almost certainly be less than the cost of letting the problem continue, they are more readily identifiable, so an appropriate presentation to management may be required.

Conformity with Codes

Any modification to building components or mechanical systems should be designed and installed in keeping with applicable fire, electrical, and other building codes.

Judging the Success of a Mitigation Effort

Two kinds of criteria can be used to judge the success of an effort to correct an indoor air problem:

- n reduced complaints
- n measurement of properties of the indoor air (often only of limited usefulness)

Reduction or elimination of complaints appears to be a clear indication of success, but that is not necessarily the case. Occupants who see that their concerns are being heard may temporarily stop reporting discomfort or health symptoms, even if the actual cause of their complaints has not been addressed. Lingering complaints may also continue after successful mitigation if people have become upset over the

MANAGING MITIGATION PROJECTS INVOLVING SEVERE CONTAMINATION	
Elements	Cautions
Identify the extent of contamination	Locating the original source of a chemical release or microbiological growth may only be the tip of the iceberg. Pollutants often tend to migrate through a building and collect in “sinks”, from which they can be resuspended into the air. For example, particles accumulate on horizontal surfaces that are not subject to regular housekeeping; odors may adsorb (stick) to porous materials. Detailed surface and/or bulk sampling may be needed to locate such “secondary” sources in order to solve an air quality problem.
Develop a precise scope of work specifying exactly how remediation will be performed	Depending on the problem, a detailed knowledge of chemistry, microbiology, building science, and health and safety may be required.
Monitor remediation to ensure work practices are followed	Include air sampling along with regular inspections if needed. Decontamination of areas within an occupied building is especially critical.
Conduct clearance sampling	In the event of severe contamination, representative air samples should be collected to ensure that key indicators have returned to background levels and that the space can be safely reoccupied.

Many routine IAQ problems can be corrected by a common sense approach not requiring special expertise. However, when complex exposure or contamination issues are involved, more detailed technical assistance may be needed for successful remediation. Efforts such as those outlined above are sometimes needed to deal with severe contamination.

If you have made several unsuccessful efforts to control a problem, then it may be advisable to seek outside assistance.

handling of the problem. Ongoing (but reduced) complaints could also indicate that there were multiple IAQ problems and that one or more problems are still unresolved.

However, it can be very difficult to use measurements of contaminant levels as a means of determining whether air quality has improved. Concentrations of indoor air pollutants typically vary greatly over time; further, the specific contaminant measured may not be causing the problem. If air samples are taken, readings taken before and after mitigation should be interpreted cautiously. It is important to keep the “before” and “after” conditions as identical as possible, except for the operation of the control strategy. For example, the same HVAC operation, building occupancy and climatic conditions should apply during both measurement periods. “Worst-case” conditions identified during the investigation should be used.

Measurements of airflows, ventilation rates, and air distribution patterns are the more reliable methods of assessing the results of control efforts. Airflow measurements taken during the building investigation can identify areas with poor ventilation; later they can be used to evaluate attempts to improve the ventilation rate, distribution, or direction of flow. Studying air distribution patterns will show whether a mitigation strategy has successfully prevented a contaminant from being transported by airflow.

Persistent Problems

Solving an indoor air quality problem is a cyclical process of data collection and

hypothesis testing. Deeper and more detailed investigation is needed to suggest new hypotheses after any unsuccessful or partially-successful control attempt.

Even the best-planned investigations and mitigation actions may not produce a resolution to the problem. You may have made a careful investigation, found one or more apparent causes for the problem, and implemented a control system. Nonetheless, your correction strategy may not have caused a noticeable reduction in the concentration of the contaminant or improvement in ventilation rates or efficiency. Worse, the complaints may persist even though you have been successful at improving ventilation and controlling all of the contaminants you could identify. When you have pursued source control options and have increased ventilation rates and efficiency to the limits of your expertise, you must decide how important it is to pursue the problem further.

If you have made several unsuccessful efforts to control a problem, then it may be advisable to seek outside assistance. The problem is probably fairly complex, and it may occur only intermittently or cross the borders that divide traditional fields of knowledge. It is even possible that poor indoor air quality is not the actual cause of the complaints. Bringing in a new perspective at this point can be very effective.

The next section provides guidance on hiring professional indoor air quality assistance. An interdisciplinary team (such as people with engineering and medical or health backgrounds) may be needed to solve particularly difficult problems.