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IAQ

Indoor Air Quality

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STRATEGIES: TODAY & TOMORROW

There are methods and guidelines now which should be applied by the engineer, and several areas that indicate promise with further research

Preston E. McNall, Jr., P.E., Ph.D.

Fellow ASHRAE

VENTILATION has long been known as an essential part in creating suitable indoor environments for human occupancy. The predecessor society to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) included "ventilation" in its title. Over the nearly 100 years since the formation of the society, it was assumed if the usual practices were used, the indoor air quality (IAQ) was not life-threatening to the occupants.

Since the "energy crisis" of the 1970's, several things have adversely impacted indoor air quality.

In brief, they are: (1) Purposely lower ventilation rates to conserve energy. General ventilation and outdoor air rates have been reduced, and variable air volume (VAV) systems of many types are employed, which further reduce air supply at part-load conditions and may reduce mixing in the space; (2) Better sealing of envelopes against infiltration; (3) New construction and maintenance materials and machines introduced into buildings; (4) Increased use of unvented combustion appliances; (5) Increased health research; and (6) New occupant behavior patterns which reduce ventilation.

These factors have increased concentrations of materials which were already in the air, introduced new materials into the air, and implicated some as being possible or real health threats.

The heating, ventilating and air-conditioning (HVAC) engineer must be knowledgeable of the indoor air quality issues. The engineer's skills must be used *now* as well as in the future to fulfill the obligations to the building occupants.

General control methods

Indoor air pollutants, as used here, are materials which can be dispersed in air and are unwanted because of their effects on comfort and/or health. Pollutants may also have deleterious effects on the structure or its furnishings.

General control options fall into four categories: (1) isolate contaminants from the air, (2) exclude contaminants from the building, (3) remove the contaminants from the air, and (4) exercise personal options to minimize human exposure. (The fourth option will not be covered further.)

The first option, preventing entry of contaminants, includes all barriers to entry from the sources: (1) Enclosing the source with solid materials impervious to the contaminant, (2) coating with special paints, etc., and (3) other measures of isolating the contaminants, for example, design, process control and choice of appliances.

The second category, excluding the contaminant, includes all possible material and process substitutions, whereby contaminants can be avoided, and other means to prevent contamination entry from the local environment.

The third option, removal from the air, includes: (1) General ventilation, or dilution with less contaminated air, (2) pollutant removal by mechanical measures such as air cleaners, and (3) special ventilation strategies, such as locally exhausting the air near the contaminant source, providing differential pressure control to isolate areas within buildings, the use of various air mixing strategies to control the effectiveness of ventilation air, etc. HVAC systems usually can deal with only this third option.

In a practical situation, it is unlikely that any single option will be optimum from a life-cycle cost point of view. Usually a number of options, each with different effectiveness, are needed to provide the desired IAQ at near-minimum cost. Because of the differences between buildings, climates, uses, etc. different combinations of options will usually be necessary to achieve practical results among different buildings.

Currently, considerable engineering judgment is needed to arrive at practical solutions.

Enough research has been done to indicate that following usual ventilation design practices will not always insure problem-free indoor air quality environments. Engineering judgment can be used to improve the environments heretofore thought to be adequate. The practitioner should determine, insofar as possible, the unusual pollutant sources expected in the spaces, even though he has no direct control over them. Continued research is necessary. Considerations which should be included *now* are several.

1. *Ventilation* - ASHRAE Standard 62-1981 is the latest approved document. It calls for a *minimum* of 5 cfm (2.5 L/s) per person, and specifies larger amounts of suitable outdoor air for many situations. It is recommended that this now be used as minimum requirements, modified as follows. The current revision, Standard 62-1981P, now underway, will specify a *minimum* of 15 cfm (7.5 L/s) per person, due to recent research. It is recommended that this minimum now be used.

Many building codes, modified with energy in mind, allow ventilation rates which are too low in the light of recent IAQ research. The practitioner should be as knowledgeable as possible about all the factors involved in IAQ and use the best judgment in the design of systems. This may mean that ventilation rates in excess of those required by applicable codes are necessary. It is further recommended that the outdoor air requirements given in Standard 62-1981 and 62-1981P be carefully consulted, and judgment be used on the quantities to use in designs until the revised standard is finally approved for release by ASHRAE.

2. *System Design, Installation and Maintenance* - The practitioner must also be concerned with, and avoid insofar as possible, deleterious effects which might be exacerbated by the HVAC system. These systems have been identified as possible causes of some building problems.

Systems can introduce: (1) Biological material, pathogens, and allergens. (2) other particles, and (3) gases. Systems should be designed to minimize these possibilities by material and equipment selection, location and arrangement, avoiding standing water, etc.

The system design must consider the effects, in the occupied zone, of several choices. The location, discharge velocities, and other parameters of supply air inlets and location of returns are critical to providing the most appropriate ventilation effectiveness (VE). The location of interior barriers, such as partitioned office modules, and the location and type of machine which may generate pollutants must be taken into account, if possible.

Attention should be paid to proper system commissioning. (ASHRAE is developing a new guideline.) Proper testing

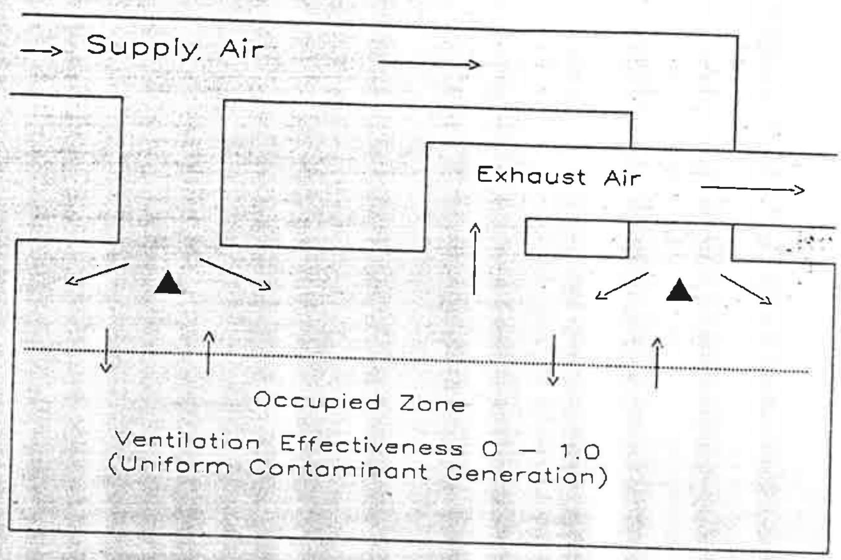


Figure 1—Common ventilation system

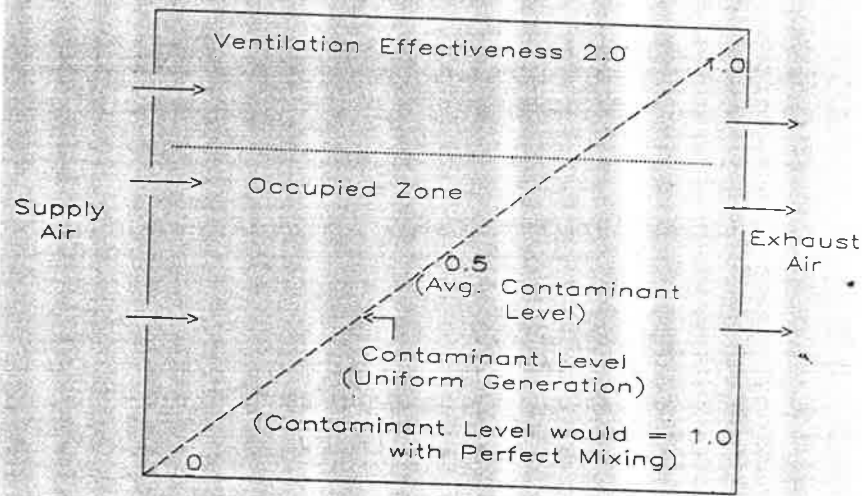


Figure 2—Plug flow

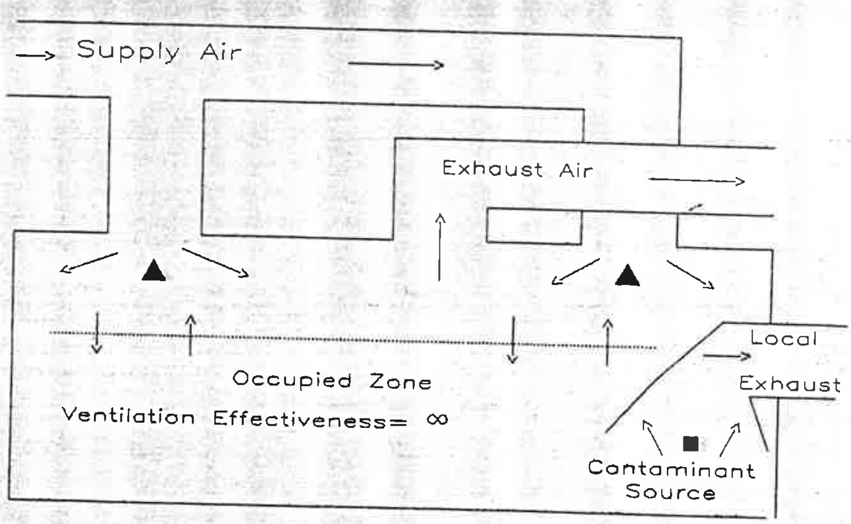


Figure 3—Local exhaust

and balancing is necessary. (ASHRAE is developing a new standard.)

Another design option involves attention to outdoor air inlets and exhaust outlets to minimize reentry of pollutants, and positioning air inlets to minimize entry of pollutants from local sources.

In summary, currently available information which can help minimize IAQ problems caused by ventilating systems should be applied.

In the interest of energy conservation, one of a number of air-to-air heat recovery systems can be used (ASHRAE does have a test standard, 84-78, for methods of measurement of heat recovery systems, and a revision is underway). Practical procedures are also available to guide the practitioner in selection and operation of such equipment in the ASHRAE Handbook and elsewhere.

ASHRAE Standard 62-1981 and 62-1981P also include options for variable occupancy ventilation control, and start-stop procedures, taking into account the pollutant capacity of the space for additional energy savings.

3. *Contaminant removal from air for recirculation.* There are two primary categories of filters.

a. **Particulate filters.** ASHRAE Standard 52-76 specifies test procedures for atmospheric dust removal (dust spot method), and coarse particle removal (weight arrestance method). While the arrestance method is necessary to measure the performance of filters designed to keep the system from fouling, it does not measure the removal of the "respirable fraction", (0.1 - 10 μm) which is more associated with health and comfort effects.

The dust spot method is appropriate for the "respirable fraction". Efficiencies above 90 percent can be evaluated. The DOP test is used for so-called "absolute" filters (HEPA) approaching 100 percent efficiency. However, examination of the ventilation system equations shows a diminishing return in performance in practical spaces, so that efficiencies above 90 percent are not usually cost-effective for general ventilating system use. Both electronic and media filters are available with high dust spot efficiencies.

Some unpublished works suggest that the dust spot efficiency test is also practically appropriate as an estimate of removal of viable particles and allergens. Standard 52-76 is currently being revised, (52.1-76P) and a particle size-efficiency test method is planned to be added, (52.2-76P), which may include new evaluation methods, such as particle counting techniques.

b. **Gaseous removal filters.** These present more complex problems. No good standards evaluating the efficiency or loading exist for general ventilation use. The wide variety of gaseous pollutants encountered and their different characteristics complicates the problem. The known methods seem to be selective in their ability to remove the various contaminants. The practitioner must rely on the supplier's information, which may employ different evaluation methods on removal efficiencies and loading capacities for competitive equipment.

Activated charcoal. Many configurations of these filters are available. In general, they adsorb higher molecular weight materials in preference to lower molecular weight materials, and attention must be paid to off-gassing of previously-adsorbed materials as the filters become loaded. Maintenance is necessary, by regeneration or replacement, as recommended by the manufacturers.

Porous pellets. Impregnated with active chemicals, such as potassium permanganate, these materials chemically react with many contaminants, removing or rendering them less annoying or harmful. Again, maintenance is required, either by replacement or regeneration.

Air washers. These have been used primarily for special applications and humidity control. Additives in the water are used for specific cases, such as bacterial control. Air washers can adsorb many gases. However, there are no accepted standards for general ventilation system performance, and maintenance is necessary. Inadequately treated water sumps may be "environmental niches" where biomatter can multiply.

4. *Specific ventilation strategies.* These include the use of airflow principles to minimize pollution levels in specific cases.

a. **Local exhaust.** The extensive development of systems for restrooms, fume hoods, etc. can be applied to other areas to reduce pollutant levels.

b. **Differential pressure control systems.** These are well-developed for clean rooms, hospitals, etc. and the principles can be used in general ventilating systems where appropriate.

c. **Ventilation effectiveness.** This relates to the effectiveness with which general ventilation mixes or does not mix with air in the occupied zone. Ventilation effectiveness (and ventilation efficiency) has no standard definition yet, and researchers have proposed several definitions for their individual purposes. ASHRAE currently has a standards project committee working on methods to measure ventilation effectiveness. For discussion here a general definition is:

The measure of the effectiveness of the ventilation air to provide a contaminant level in the occupied zone of a space divided into the contaminant level produced by a similar amount of ventilation air with perfect mixing in the space.

Using this definition, *Figures 1-3* show a range of stylized cases in which the ventilation effectiveness (VE) can vary from zero to infinity!

In *Figure 1,* mixing between the occupied zone and upper zone is shown. If this mixing is complete, the perfect mixing cases exists, and VE equals 1. As the mixing becomes less than complete, VE is less than 1. If the supply air totally bypasses the occupied zone, VE equals 0. (Contaminants generated in the occupied area would continually increase with time.)

In *Figure 2,* plug flow, with uniform contaminant generation in the occupied zone, the contaminant level would be 0 at the left and increase linearly to the right, where the contaminants would be removed at the same rate as if uniform mixing had occurred. (Contaminant level equals 1.0.) However, the average contaminant level in the occupied zone would be 0.5, hence VE equals 2.

In *Figure 3,* if the local exhaust system removes all the contaminants from the point source shown, the concentration in the balance of the occupied zone would be 0. resulting in VE equals infinity.

Some field tests have measured effectiveness as low as 50 percent for the ventilation air to remove contaminants in the common ceiling supply/ceiling return systems, *Figure 1.* The engineer should consider the space distribution systems, and should supply *additional* ventilation in cases where mixing is desired and may be inadequate, inversely with the expected ventilation effectiveness, or change the outlet locations, types, etc., to improve VE. Office partitions 60-inches high, for example, may make mixing in the breathing (occupied) zone worse than in an open office environment.

d. **Occupancy control.** Strategies to conserve energy by providing ventilation in proportion to occupancy have been developed. They can be employed in some cases as suggested in ASHRAE Standards 62-1981 and 62-1981P.

e. **Lead-lag ventilation startup.** Standard 62-1981 and 62-1981P also provides acceptable methods to conserve energy by employing the capacity of the space to accept pollutants.

1. *Ventilation Standards:* These require continuous review and revision as parts of the increased research efforts are completed. They may require delivery of the air of specified quality to the occupant, by new means, for example, and require reevaluation if the use of the space changes.

2. *Ventilation Effectiveness:* With the large range of effectiveness possible, development and application of different

supply and return systems in spaces can be valuable in future IAQ control systems. When standards for the measurement of ventilation effectiveness are in use, research on distribution systems may suggest methods to predict the performance of, and design systems which employ effectiveness to mitigate pollution problems.

3. *Differential pressure control:* Applied to general ventilation systems, further development is needed to aid effectiveness. It could be useful in many cases where contaminant sources are not uniformly distributed in buildings, or when different contamination levels in different zones may be practical. (Segregated smoking areas, for example.)

4. *Gaseous removal:* Better test methods for the equipment are needed.

5. *Air Ionization:* Air ionization, usually negative, has been experimented with extensively over the past two decades. It was first proposed to add perceived "freshness" to inside environments, and also as a possible thermal comfort modifier. ASHRAE's conclusion was, after the cognizant technical committee finished its consideration, "if ionization has an effect, it is too small to be of engineering importance for freshness, well-being or thermal comfort effects."

It has also been known that air ionization, either positive or negative, can be an effective method to clean the air. The charged particles will be accelerated to the surfaces of opposite charge in the space.

Conclusions

These control strategies are recommended for consideration *now* by HVAC practitioners in designing new systems or retrofitting existing systems:

1. Use ASHRAE Standard 62-1981 and Standard 62-1981P to determine the most appropriate outdoor air quantities fo dilution of contaminants, employing engineering judgment as appropriate. (Loca building codes should be consulted, bu larger outdoor air quantities will often b appropriate.)

2. Use the minimum outdoor ai quantity now in the Standard 62-1981P draft of 15 cfm/person (7.5 L/s/person).

3. Use engineering judgment on increasing outdoor air if ventilation effectiveness is thought to be much less thar 1.0.

4. Provide system designs which eliminate or minimize standing water, anc allow easy access for system maintenance.

5. Provide for cleaning ducts and fo easy system commissioning.

6. Provide easy access for testing and balancing instruments to ensure proper adjustments for system operatior as designed.

7. Employ system designs to eliminate or minimize exhaust recycle intc intakes.

8. Position intakes to minimize entrance of pollutants from traffic and other possible local outside sources.

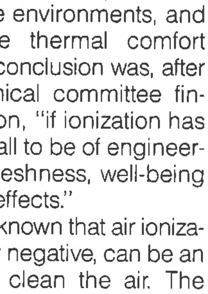
9. Use ASHRAE Standard 52-76 tc evaluate particulate removal, and carefully evaluate information on gaseous remova equipment where recirculation is desired.

10. Consider heat reclaim equipment and other strategies to conserve energy.

11. Consider local exhaust and differential pressure control as appropriate.

Further research and development is necessary to suggest other verifiec strategies, as well as to better quantify those listed above. ■

About the author



Preston E. McNall, Jr., P.E., is a senior research engineer with the National Bureau of Standards in Gaithersburg, Maryland. From 1977 to 1983, he was chief of the NBS Building Physics Division. Prior to his service at NBS, McNall held various development, research and engineering positions with Johnson Controls, Inc., Kansas State University, and Honeywell, Inc. He holds a B.S. in mechanical engineering from the University of Wisconsin, and an M.S. and Ph.D. from Purdue University.

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