Monitoring indoor air quality

The concern with energy efficiency, paramount in the 1970s, have been overtaken by indoor air quality. In the USA, two ASHRAE standards dominate US directives on indoor air quality. This side of the Atlantic, an EC report 'Review of indoor air quality and its impact on the health and well-being of office workers' adds a European flavour of its own. Dr John Saffell charts a path through the confusion.

In the early 1970s, in response to the energy crisis, ventilation engineers turned down their ventilation systems and sealed buildings to improve energy efficiency. ASHRAE responded by producing a document which specified a low outdoor airflow rate per person in 'occupied zones' (space controlled by a single ventilation system). Over the next decade sick building syndrome (SBS) and building related illnesses (BRI) became a focus for studies and discussion in health and hygiene circles. ASHRAE rewrote ASHRAE 62-73 in 1981 and again in 1989, respecifying the minimum acceptable ventilation rate per occupant to a much higher level. This higher ventilation rate has a minimal effect on energy and greatly improves the air quality and, hence, the occupants' efficiency.

The increased use of photocopiers and new office materials, which release volatile organic contaminants (VOCs), as well as the increased awareness of the dangers of passive smoking, have led to tighter control of localised ventilation around these pollutant sources and pollutant pathways.

Good indoor air quality is defined as an environment where fewer than 20% of the occupants have any complaints, including rhinitis, dry skin, headaches, stuffiness etc. Two different approaches can be taken in an attempt to cure a building that has either SBS, BRI or generally poor air quality.

The first is to monitor all the possible pollutants — including carbon monoxide, radon, ozone, asbestos, particles, viruses and bacteria, VOCs etc. The ventilation system is then modified to include higher ventilation rates, scrubbers and filters for specific pollutants. This is called the indoor air quality procedure.

The second approach is to assume that an adequate ventilation rate will sweep clean these various airborne contaminants. Therefore the ventilation or hygiene engineer has only to ensure that the ventilation rates are adequate throughout the building to clean out the contaminants. This is especially important in areas near polluting sources, such as toilets, kitchens, newly-laid carpeting/furnishing, photocopy rooms and janitorial closets. This is called the ventilation rate procedure.

EC approach

Whereas ASHRAE has split the standard for IAQ and thermal comfort into separate standards, the EC is approaching these topics as a single topic which is being tasked to 10 different working groups. It is recommended that the EC sets guidelines rather than standards, apparently because of disagreements within the committees about the differences between northern and southern countries and the varying requirements due to the different climatic conditions (although the Americans have established a unified standard from Florida to Alaska).

The ASHRAE Standards use the principle that a standard should be workable, so, although they provide directions for both procedures (see above), the ventilation rate procedure is encouraged

Monitoring ventilation rate in an office atrium - ensuring an adequate ventilation rate to sweep away airborne contaminants is widely seen as more effective than monitoring indoor air quality.

and most widely practised because of its workability. The EC, through Cooperation Europenne dans la Domaine de al Recherche Scientific et Technique (COST project 613), is taking the more rigorous and laborious route of investigating which procedure to recommend and is also studying Professor Fanger's odour-tracing method as a third approach.

The two procedures require different technologies, with thermal environment having its own technical needs. In certain applications, a mixture of both specific pollutant detection and ventilation-rate monitoring is recommended.

Although it seems simple just to traverse the ventilation ducts to calculate total volume flow and hence ventilation rate, this approach has three shortcomings.

- Air enters and leaves buildings through opened windows, walls and local exhaust ventilation.
- Ventilation systems include both outside and recirculated air. Ventilation rates are calculated on outdoor air, not recirculated air.
- Ventilation rates vary within an occupied zone, due to poor mixing and ventilation short circuiting, whereby the inlet air flows directly into the exhaust grille in a stratified layer.

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Tracer gases can be used to follow the airflow, but the preferred method is to measure carbon dioxide, which is exhaled by all occupants. The use of carbon dioxide as a surrogate tracer gas has several advantages, but the building mechanical ventilating system must be in equilibrium to ensure accurate measurements.

Carbon dioxide is exhaled by all occupants, so it is also representative of the ventilation needs for the occupied zone. The concentration of carbon dioxide outdoors is relatively constant worldwide, at 320 p.p.m. (except in some urban centres), giving a repeatable reference point when calculating outside/recirculated air-mixing ratios. Sulphur hexafluoride tracer gases are expensive, and their odour can be offensive to the occupants, while carbon dioxide is odourless and free.

Ventilation rate can be reported as ventilation rate per person (volume/person), building ventilation rate (air changes per hour) or ventilation efficiency (per cent outdoor air in the ventilation system). To calculate ventilation rates per person using carbon dioxide, the engineer first measures the outside carbon dioxide, then measures the carbon dioxide in the occupied zone (as explained in ASHRAE 62-89). Referring to a table that lists the volume of carbon dioxide exhaled for different activities (e.g. in offices, loading bays or auditorium), this ratio of exhaled carbon dioxide and the inside-outside concentration difference is the ventilation rate: the recommended office ventilation rate is at least 7 l/s per person.

To measure carbon dioxide, infra-red absorption has traditionally been used. However, this technique drifts with barometric pressure and is either expensive (if full temperature compensation has been used) or drifts with ambient temperature for inexpensive units. Also, due to the power requirements of the infra-red light source, these units can operate for only a few hours from batteries — not enough time to monitor the diurnal patterns of the zone without connecting to the mains..

Although detector tubes are available to measure carbon dioxide, the USA National Institute of Standards & Technology has unequivocably found them unreliable..

An alternative technology is electro-chemical cells. They require no power, respond quickly, and are inexpensive. However, the traditional carbon dioxide cell is not sensitive and drifts with time. The Neotronics/Solomat patented CO_2 cell has eliminated these problems and has finished successful trials with NIOSH, the research branch of the OSHA in the USA.

VOCs, especially formaldehyde, are present in very low concentrations, so they are hard to detect accurately. Photo-ionisation and detector tubes (with lab analysis) are frequently used. Solid state (tin oxide) sensors can identify the existence of VOCs, but cannot accurately tell type or concentration, so they have limited use.

For the measurement of thermal comfort, polymer sensors are rapidly replacing whirling hygrometers and psychrometers as their accuracy improves, especially at high humidities. This is especially important in ventilation systems where cooling units produce localised high humidity, which is necesary for breeding pathogens such as viruses and legionella. Temperature is readily monitored, but caution is necessary when measuring radiant temperature — important for workers near outside windows.

At present the only way to accurately measure airborne bacteria, viruses and other pathogens is to collect samples using impact tubes for later laboratory analysis.

Radon is an invisible, odourless gas that can be measured by electrostatic discharge techniques, which are expensive, but accurate. Most hygienists assume that adequate ventilation rates avoid radon build-up.

Certain undetectable but dangerous gases such as carbon monoxide and nitrogen dioxide can be accurately measured with electrochemical cells. Studies have also shown that carbon monoxide is a good tracer gas for monitoring the routes of tobacco smoke. Carbon monoxide is a natural byproduct of tobacco smoke.

Each of the two procedures for monitoring indoor air quality has its advantages.

The indoor air quality procedure thoroughly evaluates each pollutant, leading to accurate assessment of the problems in the occupied zone. On the other hand, it is very expensive, time-consuming and technically very difficult, demanding a great amount of capital expenditure in instruments and laboratory equipment.

The ventilation rate procedure assumes that adequate ventilation solves pollutant problems, but generally overestimates the required ventilation rate for adequate IAQ (by 5 to 20% in most cases). On the other hand, this procedure is quick, allows real-time monitoring, and can be performed by engineers with minimum training and much less capital investment.

Indoor air quality is coming of age, and it is coming to Europe. Let us hope that Brussels stays focused on the practicalities of monitoring IAQs — not the theoretical possibilities. □

Airflow can be effectively measured by monitoring carbon dioxide. This gas is exhaled by all occupants, making it representative of the ventilation needs of an occupied zone.

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