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Indoor air quality—is ventilation the answer?

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Background

The energy crisis and rapid escalation in oil costs in the 70's saw utility costs rapidly become a significant component in building operating budgets. Consequently, a need to conserve energy was instigated. The result was a changed approach to building design and building operation for industry professionals. The architectural response was to pursue passive energy conservation techniques, such as reducing the extent of glazing, introducing solar shading as well as greater thermal stability, insulation and sealed construction techniques.

At the same time there was also a move toward greater use of petroleum based products, such as synthetic fibres, plastics, wood laminates, paints, etc, for use in construction. Buildings tended to use more synthetic products in lieu of natural materials. Such products, which contain oil based residues, have now been proved to introduce, under certain conditions, gases and odours into the space at various concentration levels. This phenomenon is referred to as "off gassing" of volatile organic compounds.

The need for lower building energy costs also saw reductions in outdoor airflow rates. Air conditioning systems became more energy efficient by reducing their reliance on simultaneous heating and cooling, and also by reducing fluid handling power. The introduction of systems that varied the volume of air delivered to a space to control temperature, independent of other air quality issues saw further reductions in energy consumption.

All of these factors coincided to result in a deterioration of our indoor environment, in the quest for lower capital and running costs.

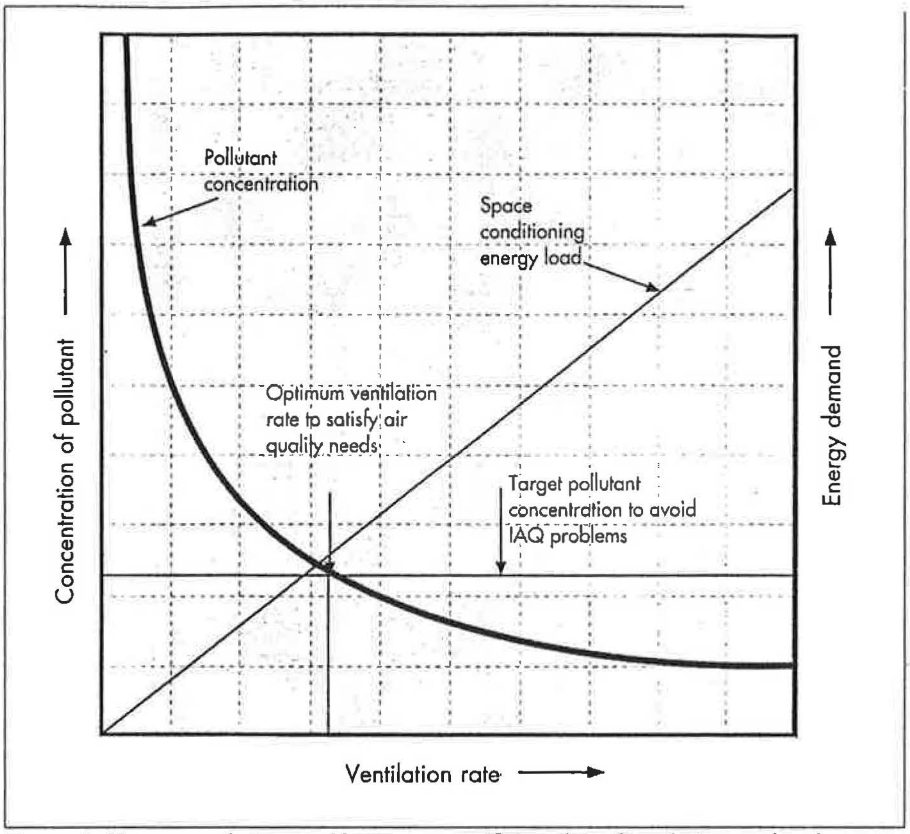

Figure 1: Using ventilation to dilute pollutant concentration

Taken from Ventilation and indoor air quality by Martin A Liddament, IEA Information Centre on Air Infiltration and Ventilation, CADDET Energy Efficiency Newsletter No.1, 1996.

The Sick Building Syndrome

In the mid to late 1980's a series of reports were commissioned and published by American authorities to investigate the reasons for increasing absenteeism in employees. The outcome of these studies was the emergence of maladies which were related to the place of work.

A US National Centre for Health Statistics report in 1989 reported that 50% of absenteeism in workers in the period of 1983 to 1985 was due to upper respiratory infections. Of particular note was that an increasing number of afflicted persons were experiencing "flu like" symptoms which frequently disappeared when they left their place of work.

These reports were, in fact, some of the earliest diagnosed cases of the phenomenon we now refer to as the Sick Building Syndrome (SBS).

In contrast to SBS, Building Related Illnesses are specific illnesses which have clear and diagnosable causes related to the building environment. These maladies include hypersensitivity (allergic reactions), infections (such as Legionnaires Disease), and illnesses related to inhalation of fibres (such as Asbestos).

Sick building syndrome refers to a range of symptoms that affect a significant number of building occupants, that do not have clear causes, and are therefore often referred to as "non-specific" symptoms which abate when no longer in the building.

The most common symptoms experienced by individuals related to Sick Building Syndrome include:

- Irritation of eyes;
- Sore throat;
- Headache;
- Fatigue/lethargy;
- Dry or itchy skin;
- Difficulty breathing or chest tightness; and
- General malaise.

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There is no clear cut boundary between "sick" and "healthy" buildings, only that varying degrees of "sickness" could be applied to all buildings.

Studies within the United States and Europe have investigated buildings with reported high incidents of sick building syndrome among the occupants in an effort to identify a common source or link.

A 1984 NIOSH survey, in the United States of America, of 446 buildings identified the following causes:

• Contamination released inside the building	17%
• Contamination from outside the building	11%
• Building fabric construction	3%
• Microbial contamination	5%
• Inadequate ventilation	52%
• Unknown	12%
	100%

The results of this survey concluded that inadequate ventilation was a significant contributing factor in the incidence of the sick building syndrome.

The air pollution process

If we concur with the results of these surveys, and agree that a relationship exists between deteriorated air quality and increased occurrence of SBS, it then becomes relevant to consider the methodology by which an occupied space becomes polluted and how the quality of the air deteriorates.

The quality of air refers to a wide range of characteristics. Each characteristic has an impact and effect on how we perceive the quality of the environment. These characteristics include:

- Air purity;
- Air flow rate;
- The ratio of fresh air to recirculated air; and
- Humidity and temperature of air.

Items 2 to 4 are controllable, via mechanical means. The air however is dependent upon the level of source pollution contributed by the conditioned space.

A sealed occupied space suffers pollution from a variety of sources, which are related to the intended function and use of the space. Pollutants have been categorised as follows:

Occupants

Natural habitation of space results in a wide number of source pollutants, which are affected by the density of population and activity level of the occupants. Pollutants from occupants include:

- Respiration;
- Perspiration;
- Hair and skin; and
- Perfumes and body additives.

Internal processes

Internal processes within a space can give rise to added pollution. Such processes include:

- Cooking;
- Smoking;
- Photocopying, etc; and
- Cleaning agents.

Materials and finishes

This category covers a wide range of pollutants primarily associated with construction materials and fabrics. Significant amounts of research is ongoing at the present time into volatile organic compounds and the odours, or "off gassing", of various forms of building materials, furnishings and cleaning residues. Pollutants in this category include:

- "Off gassing" of volatile organic compounds;
- Negative ions;
- Electromagnetic radiation;
- PCB's; and
- Fibrous particles.

Micro-organisms

Bacteria, fungi, viruses and other micro-organisms inhabit all occupied spaces. Viruses are generally introduced into buildings by humans, however the stability and concentration of such organisms may be dependent upon internal conditions such as humidity, filtration and ventilation rate. Other pollutants in this category include:

- Moulds;
- Dust mites, etc; and
- Pollen.

In considering the sources of pollution within an occupied space, there are, unfortunately, an almost limitless number of contributors in each of the various categories, many of which are at virtually immeasurable low concentration and have a largely unknown toxicological affect. The task of identifying and assessing the risk of individual pollutants has therefore become a major research activity.

Ventilation and air distribution

Having discussed categories of sources for polluting a space, and the difficulty associated with measurably quantifying the effect of some of the more elaborate sources, it is appropriate, in terms of control, to classify sources as either avoidable or unavoidable.

Unavoidable sources are directly associated with the essential functions and occupation of the space. As such, these are mainly associated with metabolism.

Essential activities, such as cooking, photocopying, etc, also fall into this category, however a certain level of control can be provided by local exhaust systems.

Avoidable sources include emissions from non-essential activities, eg smoking, poor quality building materials and furnishings and inadequately enclosed and vented appliances.

Ventilation

Mechanical ventilation rates are currently set by regulatory codes, in particular Australian Standard 1668.2, which was upgraded in 1991 and saw a significant increase in the amount of outdoor air to be introduced to an occupied space.

Unfortunately, this code relates the outdoor air flow rate directly to the density of people within an occupied space, thereby not giving consideration to the other

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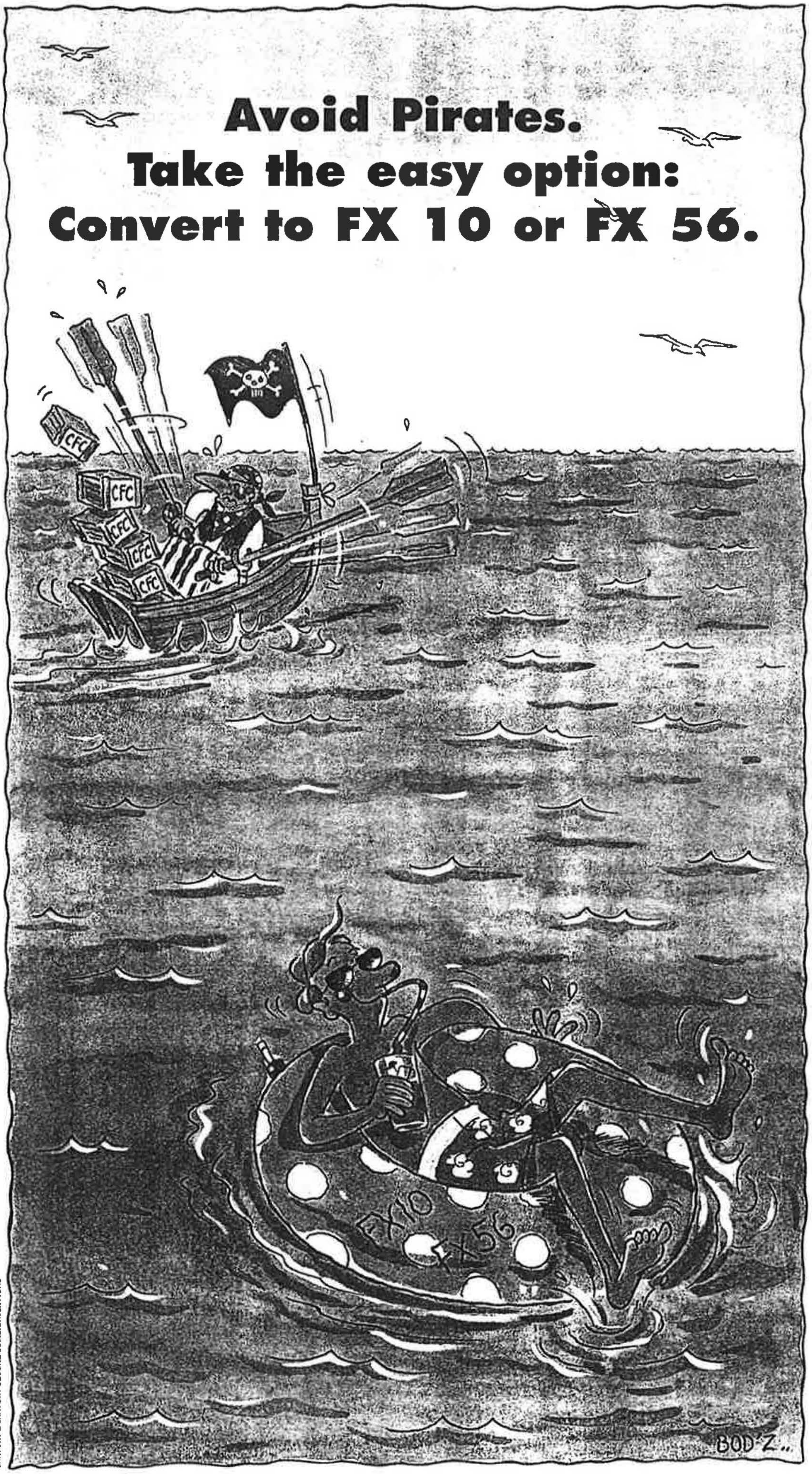

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sources of pollutants. It therefore follows that compliance to AS 1668 alone may not prevent a building from having poor quality air.

In theory if the emission characteristic of each pollutant were known, then it would be possible to calculate a ventilation rate, that would be needed to prevent each pollutant exceeding a predetermined threshold value.

This theory would be simplified by determining a dominant pollutant that would be satisfied by a calculated ventilation rate, thereafter the remaining pollutants would remain below their respective concentration thresholds.

Indeed our current codes have commenced this process with the more identifiable pollutants, such as carbon monoxide and carbon dioxide. Ventilation calculations are now applied to enclosed carparks based on the number of cars and therefore amount of carbon monoxide produced. In addition, fresh air modulation in office buildings can now be based on carbon dioxide sensors in exhaust air.

What should not be overlooked, is the quality of the outdoor air itself. Factors such as vehicle exhausts, stack emissions, pollens, microbial aerosols degrade the quality of the outdoor air that is being introduced.

As such careful siting and locating of outdoor air intakes becomes relevant along with the need for filtration of outdoor air.

Air distribution

Corruption of the air source commonly occurs in the air distribution system from dirt build-up, moulds, moisture carry over and duct degradation. Consequently house keeping and high levels of maintenance becomes an essential activity in achieving high IAQ.

The type of air distribution system employed also has an effect on air quality. Air distribution systems common in Australia, which employ ceiling mounted registers designed to promote mixing and induction of supply air with room air, result in pollutants being distributed with relative uniformity throughout the workspace.

In contrast to this technique, displacement style air conditioning has gained popularity in Europe with significantly improved indoor air quality results. This method introduces conditioned air at low level into the occupied space, at 2-3°C below space temperature set point, which is then removed at ceiling level. As the supply air absorbs heat loads, convection currents cause the air to rise naturally with decreases in density. Features of this system are that air change rates in the ventilated space are increased, natural heat emitting loads are allowed to rise naturally with decreases in density. Features of this system are that air change rates in the ventilated space are increased, natural heat emitting loads are allowed to rise and pollutants are less concentrated in the breathing zone due to minimal mixing.

The integrated approach

The need for high indoor air quality should be established as a design objective of the project. Design principals which provide inherent benefits should be investigated by the engineers in conjunction with the architect and building owner and manager.

These principles include:

Engineers

- Detailed reviews of the air conditioning options available and selection of systems which inherently provide higher circulation sites and air quality.
- Locating of outdoor air intakes and exhausts. Particular relevance to surrounding contamination sources and prevailing winds.
- Design for humidity in the range of 40 to 70%rH.
- Selection of materials which are cleanable and resistant to micro-organism proliferation.
- Local exhaust from internal processes.

Architects

- Adequate allowances made in conjunction with the engineers, for equitable cleaning and maintaining of plant.
- Detailed review of materials and finishes for toxicological impart.
- Segregation between dirty and clean areas in planning design.

Of particular importance in the quest for higher IAQ standards is the role and activities of the building engineer.

The building engineer is responsible for keeping the building running, in top condition, within the constraints presented by limited resources, time and money.

Problems too often only surface after the building has been operational for some time.

As such, the following involvement is recommended from building engineers:

- Being involved in the design briefing and design review process. Maintaining this involvement in all tenancy changes and fitouts.
- Ensure controls systems are regularly calibrated and systems are rebalanced.
- Routine maintenance procedures are imperative, and must incorporate filtration management, internal plant cleaning, housekeeping etc. Log books to be maintained.
- Periodic evaluation of external influences on the building.
- Maintain a log book of complaints and building health audits.

It is our opinion that a collaborative approach in design and operation; and an objective balance of energy conservation and indoor air quality is the most successful method of optimising indoor air quality without unduly compromising capital or recurrent cost issues.

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