

BEDP ENVIRONMENT DESIGN GUIDE

Indoor Environment Quality, Design, and the Value of Facility Ecology

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Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- Poor office Indoor Environment Quality (IEQ) costs tenants in terms of occupant wellbeing, performance and productivity.
- Recent overseas research indicates the payback time for improved IEQ in the commercial sector is generally below two years.
- The release of new Australian guidelines and rating tools is expected in 2007/8 which will further increase the focus on IEQ in office and public facilities.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- Designers need to work closely with facilities managers to initiate a holistic and continuing view of IEQ.
- Building design must consider how facilities managers will control critical IEQ elements.

Cutting EDGe Strategies

- Conduct post-occupancy reviews, measurement and surveys to allow for assessment of the successful delivery of the design objectives.
- Promote and initiate productivity measurements to allow for assessment of the value and thus payback period of the design to the building owners and tenants.
- Include an experienced building scientist/s in the design team.
- Strive to educate and inform tenants.
- Take a holistic approach to building design.
- Compare the performance of new buildings to a tenant's previous facility, including pre and post occupancy surveys.

Synergies and References

- *BEDP Environment Design Guide*: GEN 15: Introduction to Indoor Environment and Health.
- *BEDP Environment Design Guide*: GEN 56: The National Australian Built Environment Rating System (NABERS)
- *BEDP Environment Design Guide*: GEN 64: Operating a Building for the Next 20 years.

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After 30 years of research into the health effects of Indoor Environment on occupants, there is now extensive research and assessment of the effects of Indoor Environment Quality (IEQ) on occupant performance and productivity. This article will discuss the latest findings and review techniques for assessing IEQ and productivity.

Keywords

building ecology, facility ecology, indoor ecology, Indoor Environment Quality (IEQ), Indoor Air Quality (IAQ), pollutants, productivity, rating tools, Volatile Organic Compounds (VOCs)

1.0 Introduction

The term **building ecology**, was first used by Levin (1981) in the journal *Progressive Architecture* and has been used for many years to represent the study of the interrelationship of buildings with their occupants, and their larger external environment.

In 2003, Cetec Pty Ltd introduced the term **facility ecology** as being the study of the functioning of a building, with respect to the measurable interaction of the occupants and the built facility, so as to optimise sustainable wellbeing and productivity of the occupants, and sustainable environmental performance of the building. Cetec's focus has primarily been on public and office buildings, where the occupants are typically office workers, or visitors to an office or public facility. Facility ecology creates a scientific framework based on measured data that shows if a building can, or is, delivering its primary function of improving the occupants' performance.

The elements of Facility Ecology include:

- building design and location
- occupant satisfaction and wellbeing
- facility and corporate management
- risk management
- Indoor Environment Quality (IEQ) as determined by measurement and assessment of:
 - Indoor Air Quality (IAQ)
 - light (natural and artificial) and outlook
 - acoustic comfort
 - radiation and
 - aspects of layout (i.e. location of partitions and workstations), interior design, and ergonomics.

Indoor Ecology focuses on the interaction of the occupants with the interior of the building, and studies the indoor components of facility ecology.

Indoor Environment Quality is the measurement of the key parameters affecting the comfort and wellbeing of occupants.

2.0 Indoor Environment

2.1 The Developmental Focus of Indoor Environment

Focus on the Indoor Environment has evolved over recent decades:

- 1970s: thermal environment
- 1980s: ventilation
- 1990s: IAQ, then IEQ and low emitting building materials; and
- 2000s: healthy buildings (and therefore the relationship between IAQ/IEQ with occupant productivity and wellbeing).

Figure 1 illustrates how research activities have progressed in the field of indoor pollutants during the last three or more decades. As these contaminants have been identified and more accurately measured in the indoor environment, they have been gradually reduced. This is generally as a result of increased awareness leading to more suitable ventilation, heating and air-conditioning systems, HVAC management in general, changes in building design and building materials, and improved selection criteria.

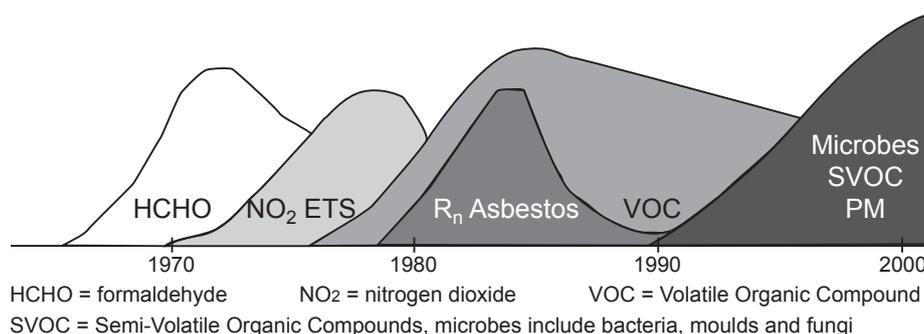


Figure 1. Research activities on various indoor pollutants over time

2.2 Influences on Office Indoor Environment

Many factors influence the measured, as well as the perceived, quality of indoor environments including:

- noise and vibration
- ventilation effectiveness
- draughts
- temperature and air humidity
- airborne pollutants
- personal control of environment
- natural light and outside view
- lighting and glare
- space and privacy
- decor and furnishings
- preexisting health and behavioural conditions
- job role
- worker and management relationships
- worker perceptions
- worker stress and
- business demands

2.3 Why Focus on the Indoor Environment?

Most working Australians now spend more than 70% of their working lives indoors (Environment Australia, 2001). Building design, use, and management, influence their comfort, wellbeing and productivity. Building problems, which go unrecognised or are neglected, can lead to building, staff, business and regulatory problems.

In addition, based on the author's experience, tenants are increasingly demanding and specifying improved environmental quality; significantly affecting the design, construction and ongoing management and maintenance of a facility. This is reflected in the incorporation of IEQ elements in various Australian rating tools and publications, as depicted in Figure 2.

2.4 How Designers Can Improve the Indoor Environment

It is essential for the architect to design an office building or public facility, so that a facility manager can effectively and efficiently control the critical IEQ elements that affect occupant wellbeing and productivity. These IEQ elements and their impact on occupants must be understood, recognised and managed (preferably during design, and construction), in a logical, factual and scientific manner. Due to the rapid introduction of new materials, information and rating tools, the inclusion of experienced building scientists in the design team can prevent expensive and embarrassing corrective measures, or deficiencies in the final facility delivery.

During and after construction, accurate measurement and reproducible information, properly interpreted, universally owned, and accounted for, is the key for delivery of

effective and efficient facility ecology management and hence design satisfaction. Post-occupancy facility ecology studies are the only way for rational and factual confirmation of the satisfactory delivery of the facility that allow for effective business improvement. Tenants can, and do at times, negatively influence the facility ecology of their own environment. The design and construction teams, as well as the facility managers, need to advise and educate tenants about how they can improve the performance of their occupied space.

Architects, working closely with facility managers, are well placed to initiate a holistic and continuing view of a building's indoor environment quality, and have a greater contribution to business performance financially, socially and environmentally. If the financial impact of facility ecology was more quantifiable, architects, constructors and facility managers would have the tools to demonstrate their critical role to building owners and managers, and to participate more meaningfully in cost planning.

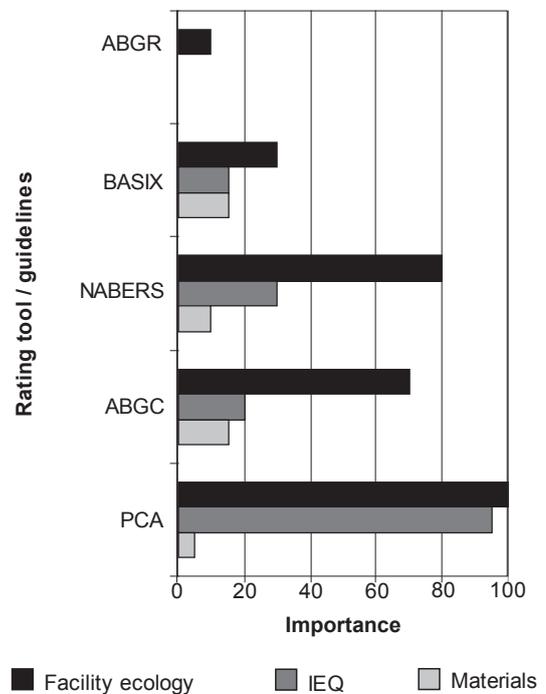


Figure 2. Relative importance of IEQ, facility ecology and materials in selected tools and publications

3.0 Justifying Improvements to IEQ

Research evidence in the current decade has increasingly confirmed strong links between the indoor environment, occupant wellbeing and comfort problems (proceedings from Healthy Buildings 2006). Some calculations reported show that the cost of deteriorated indoor environments is higher than both building maintenance and operational costs combined. With about 80% of the annual cost of an office building being its staff wages, benefits, and salaries, small changes in occupant productivity (caused by inadequate IEQ) can have a significant cost impact.

3.1 Productivity vs Staff Costs

The Chartered Institution of Building Services Engineers (CIBSE, 1999) has shown that in an office building, staff costs are 100 to 200 times the energy cost for the building, and can therefore be offset by a corresponding 0.5 - 1% increase in staff productivity. Staff costs are also 20-44 times the HVAC running cost, and so a productivity increase of 2-5% can offset this entire cost.

To assess a poorly performing building (which is often measured by a high number of occupant complaints) an evaluation is required to confirm its actual performance. This would include measurements of the IEQ, building and HVAC assessments, and occupant surveys. These surveys would collect occupant perceptions of IEQ and their productivity, as well as their health symptoms, and will give productivity measurements via a structured process. The costs from the additional capital expenditure involved to improve IEQ may at times seem high; however the productivity gains are larger, and easily justify the investment (Proceedings from Healthy Buildings 2006).

3.2 The Right Temperature

The link between occupant comfort and temperature is well understood. There have been numerous studies reporting a relative performance improvement of as much as 15% for a 7°C reduction in temperature from above 30°C. As a guide, the rule of thumb is that there is a reduction of performance of 1%, for every 1°C change in temperature above and below 22°C (Proceedings from Healthy Buildings 2006). This performance drop is most evident as the temperatures move to high 20's and beyond.

3.3 Ventilation

The ventilation rate has also been found to affect performance as reported in a review study by Seppänen et al (2006a). The performance increase, per unit increase in ventilation, was the largest with ventilation rates below 20 litres per second per person. A doubling of the air supply rate (from a 8l/s ventilation base rate) resulted in typically a 1.5% increase in performance (see Figure 3 below). These findings may not be appropriate for all facilities; as other factors may influence the relationship.

Wargocki reported at the Healthy Buildings 2006 conference in Lisbon that the research conducted has culminated in a consensus European protocol representing 31 countries, for methods of measuring the financial benefit to organisations of their improved IEQ (some of which have been highlighted above). Their work has shown that a 2% office productivity gain can be worth as much as \$270/m², over the lifetime of the building. This work involves integrating productivity into the life cycle cost analysis of building services.

It is unlikely that facility ecology problems will ever be totally eliminated, due to the complex interacting needs of regulators, owners, designers, occupiers, the public and the environment. However, occupant dissatisfaction with the indoor environment can be minimised by monitoring and understanding the symptoms, causes, and sources of complaints, and implementing effective, measured management strategies.

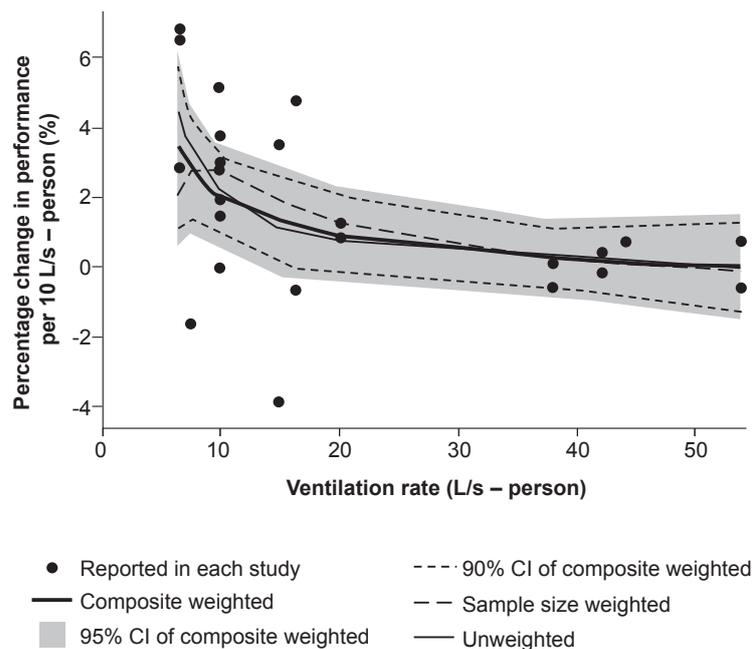


Figure 3. The change in performance per person vs ventilation rate

Techniques now exist to estimate the effect that the indoor environment has on occupant wellbeing and productivity, and to rate or benchmark relative performance. This is a very active area of research internationally. Australia is leading the way in rating the built environment and has the opportunity to contribute with benchmarking.

4.0 The Effect of IEQ Guidelines and Rating Tools

The National Australian Built Environment Rating Scheme (NABERS) rates a building on the basis of its measured operational impacts. NABERS was developed by the Australian Government Department of Environment and Heritage, and is now being commercialised by the New South Wales Government: Department of Energy, Utilities and Sustainability (DEUS). NABERS is a scheme for rating the performance of existing buildings (including homes or commercial offices) that is designed to provide an indication of how well a building is managing its environmental impacts.

NABERS Office is intended to rate buildings on a full range of measured operational impacts. The environmental indicators, such as energy, water, waste and indoor environment quality, forming NABERS are being developed and launched. The most established component is the Australian Building Greenhouse Rating (ABGR) for energy.

The Green Building Council of Australia (GBCA) in its Green Star range of building rating tools focuses on environmental stewardship, and also awards a large proportion of its rating credits for IEQ, low polluting materials and good facility environmental management. Since the launch of this tool in 2003, its effect has started to be seen on building design, manufacturing standards, leases, regulations and business expectations. For example, architects are starting to design in ways that maximise energy savings and minimise chemical emissions. The Carpet Institute of Australia has developed stringent environmental and emission standards, and numerous other suppliers have sought and gained GBCA accreditation for their products.

Private development companies are also being involved in encouraging better IEQ. For example, Investa, in partnership with the Department of Environment and Conservation (NSW), the Cities of Melbourne and Sydney, and the Institute for Sustainable Futures, has publicly released its *Green Lease Guide*. This document includes a checklist for managing IEQ in its section 'Comfortable, productive & healthy indoor environments'. In general, this document aims to assist office building tenants to secure highly productive and environmentally friendly workplaces. Other local, state and federal government bodies and departments are also including 'green' clauses that include IEQ elements, into their leases and incentive schemes.

5.0 Measurement of Pollutants

It is difficult to manage what you can't measure.

An individual's performance can be affected by a number of interacting, interdependent and cumulative factors including the working environment, personal motivation and the ability to perform a job.

The working environment comprises:

- indoor climate (temperature, ventilation, noise, lighting etc)
- the facilities (cafeteria, mail service, etc) and
- infrastructure (workstation layout, landscaping etc).

Weakness in any one of these elements can render the business less effective/efficient.

The ideal office environment requires comfortable temperature and humidity, an adequate supply of clean outdoor air, appropriate air distribution within the space, low levels of contaminants, and good communication between building occupants and building operators. Some of these indoor environment parameters can be quantitatively measured, while others require careful evaluation of occupant perception or satisfaction. For example, quantifiable facility ecology and its links to occupant productivity provide the basis for informed design and management decision-making.

The overall quality of indoor air is influenced by thermal acceptability, ventilation and air contaminants. This section provides a description of the more common pollutants found in indoor air. Pollutants can originate from outside the building (e.g. atmospheric pollution), inside the building (mechanical ventilation system or construction materials), or from the occupants and their appliances.

The pollutants that affect occupant wellbeing and productivity can be classified as chemical, particulate and biological.

5.1 Chemical

The World Health Organization defines volatile organic compounds (VOCs) as organic compounds with boiling points between 50°C and 260°C, excluding pesticides. The term encompasses a very large and diverse group of carbon-containing compounds. There are literally thousands of organic compounds, synthetic and natural, emitted into the atmosphere at room temperature from products used in buildings. According to *Air Toxics and indoor air quality in Australia: State of knowledge report* (Environment Australia, 2001), 50-150 different VOCs can be detected using sensitive analytical methods in any one building, at any one time.

As VOCs have widely varying toxicities, irritant and odour properties, it is important to characterise them if a raised VOC level is detected. VOCs may cause irritation of mucous membranes and are associated with headaches, dizziness and nausea. (Health Canada, 1995). It is widely recognised that some VOCs are confirmed or suspected carcinogens and mutagens.

Recent studies conducted as part of the American State of Washington's East Campus Plus Program (www.aerias.org) showed that 96 percent of the VOCs found in a large office building following construction, resulted from the materials used to construct and furnish the building. Contributors included hard surface and carpet flooring materials, paints, adhesives and sealants, office furniture, computers, insulations, vinyl wall coverings, ceiling tiles, cabinetry, fireproofing, and textile furnishings.

5.2 Particulate

In the office environment, particulates can be generated from external dust, wear particles and cleaning activities. Of greatest concern are the smaller respirable particles below 10 micron in diameter (PM_{10}). Very fine particles can remain suspended for up to 72 hours and hence effective ventilation and filtration is required in office environments. Cleaning activities and poorly maintained flooring are major contributors to the remobilisation of indoor particulates. High quality filtration in the air-conditioning systems is able to minimise this particulate matter. Filters come in a range of efficiencies, and are detailed in the Australian Standards (AS 1668.2-2002).

5.3 Biological

There are numerous biological pollutants in the indoor environment. They may originate from within or outside a building. Many biological substances are benign and do not necessarily indicate the existence of a hazardous work environment. However, some viruses, bacteria and fungi are capable of causing infections, while fungi, protozoa and dust mites may cause allergic conditions such as asthma (Environment Australia, 2001).

Some fungal species are known to produce direct toxic effects when ingested, as well as causing typical sub-clinical symptoms. Micro-organisms such as bacteria and fungi tend to become established and proliferate on wet surfaces and in humid conditions. (USEPA and US Department of Health and Human Services, 1991). For example, carpets damaged by local flooding often become the site of fungal growth (MDH, 2007).

Non-living biological pollutants are associated with allergic conditions in susceptible people. They originate both inside and outside buildings. Those from outside, such as pollen, enter the air stream because of inadequate or damaged fresh air filtration systems. Many of those generated inside buildings, such as dead skin cells and other dander, may remain in circulation for some time, especially where filtration of recycled air is inadequate.

6.0 Conclusion

With the knowledge accumulated from IEQ studies worldwide, there is a desperate need to consolidate findings into a methodology that demonstrates tangible occupant wellbeing, and productivity gains from facility ecology expenditure, effort and rating.

With its advances in rating tools, Australia is well placed to benchmark the performance of indoor environment quality. Australia needs to participate in leadership by establishing international protocols to measure facility, and office productivity, as well as gains in wellbeing that relate to our national expectations.

In 2005 the Department of Industry, Tourism and Resources recognised the need to improve the productivity of Australian Industry and launched the Facility Management Action Agenda (FMAA) (<http://www.fmactionagenda.org>). The FMAA platforms include subgroups such as education, sustainability and innovation.

In acting on this acknowledged need for improved facilities ecology, many organizations are leading the way, including the Facility Management Association of Australia (FMA), The Property Council of Australia (PCA), Green Building Council of Australia (GBCA), the NSW Department of Water and Energy (DWE), the Federal Department of Environment and Water Resources (DEWR), and the Standards Association of Australia (SAA). These organisations are working with key specialists to develop and release design and operations tools, guidelines to measure and manage the performance of IEQ, and ratings to measure the performance in IEQ and related factors. Most of the above groups are strongly represented by architects, designers and constructors.

In order to avoid the type of action taken by governments on asbestos and legionella (i.e. issues that relate to human health), architects, designers and facility managers should be proactive, and follow the lead of their industry bodies, including the lead shown by NABERS, PCA and the GBCA to action the measurement and management of facility ecology issues.

A conference in Australia to discuss international protocols and then to unify Australian practice on IEQ measurement is required as a matter of great urgency and the FMA Indoor Ecology Special Interest Group is working towards this.

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Biography

Dr Garnys PhD (BSc (Hons), ARACI, AIMM, ACA, FMA, AIRAH, ISIAQ) graduated in Chemistry in 1970 from the University of WA, and has a doctorate from UNSW (1980). In his 30 years of professional experience he has solved technical problems and conducted investigations over a diverse range of issues and industries. He formed his own technical consultancy, Cetec P/L in 1987. In the 1980's he started research into indoor air which has now broadened into facility ecology. Dr Garnys is the Chairman of Standards Australia Committee for IAQ Measurement, and FMA's Special Interest Group on Indoor Ecology. Dr Garnys is a NATA signatory, a NATA Laboratory Registration Assessor, chairs the NATA Inorganic Chemical Committee, and is an Independent Chair of Green Star Assessors.

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