# 8 Internal Environmental Quality

Much of the building stock currently in use in South Africa and indeed in Steve Tshwete have outdated or poor designs and systems, and offer building occupants a poor internal environmental quality (IEQ). This includes high noise levels, stuffiness, poor levels of ventilation, bad internal space design and poor thermal comfort (that is heating and cooling controls, air quality, air tightness, daylighting and artificial lighting, and a lack of privacy). Health problems relating to poor indoor air quality have a major impact on staff productivity, and in the late 1980s the term "sick building syndrome" was coined to describe this.

Modern materials used in buildings are constantly off-gassing, and so the average building occupant is impacted by not only their own carbon dioxide emissions, but also pollutants such as volatile organic compounds from fittings and furnishings, and emissions from the suite of IT equipment in offices and at homes.

Studies indicate that continued reliance on, and exposure to, artificial lighting has a detrimental effect on occupant health and well-being. Increased access to natural lighting assists with human circadian rhythms, which in turn affects productivity, happiness and overall health. At the same time, the provision of sufficient natural lighting can lead to glare or reflective problems, particularly at certain times of the day or year.

## 8.1 What changes do we need?

This set of green building guidelines looks to address this historic legacy, and improve the well-being of occupants in both newly built buildings as well as retrofitting older building stock. The guidelines offer suggestions to establish a good quality internal environment by describing how building designers and managers can eliminate, reduce, and manage the sources of indoor air pollutants, lighting, and maximise comfort factors such as external views, individual climate control and noise levels, provide for occupant connection to the outdoor environment, and prevent or reduce health issues (including the minimisation of indoor volatile organic compounds, asbestos and formaldehyde emissions as well as mould prevention). Small changes like increasing the amount of fresh air circulating in a building have been demonstrated to hold significant benefits to the health of occupants through the dilution and reduction of indoor pollutants.

### Fast Fact:

**Benefits from an improved IEQ**

**Small changes to the indoor environmental quality can have large impacts on users. For instance, daylighting is known to improve productivity in offices, improve test scores in schools, reduce recovery times in hospitals and increase sales in retail stores.**

## 8.2 How do we design our buildings?

### 8.2.1 Design for improved ventilation and fresh air provision

Good building design provides the opportunity to maximise the provision of fresh air within a building. Fresh outside air is used to dilute the build-up of indoor pollutants as experienced by building users.

There are three ways of providing this fresh air: via natural ventilation, mechanical ventilation or mixed mode ventilation, which is a combination of two. A design with natural ventilation capitalises on the local wind patterns and/or enhances air movement through the building's form. Some of the common design features used for natural ventilation include openable windows, thermal chimneys, atria and courtyards.

**Statutory requirement as per SANS 10400-O:**

Buildings require a minimum of 5% openable areas to qualify for natural ventilation.

Air movement creates a sense of comfort for building occupants, meaning a higher temperature setpoint can be used and less cooling is required from buildings that also use supplementary mechanical systems (mixed mode systems). It should be highlighted that the SANS regulations prescribe minimums which are considered required for liveable or useable space; green buildings would exceed these standards and seek to push that boundary.

The design of any HVAC (Heating, Ventilation and Air Conditioning) system should include systems which deliver sufficient quantities of fresh air to all occupants during the occupied time, and which monitor and trigger an audible alarm should pollutant levels (particularly Carbon Dioxide) rise above a designated safe level (normally assumed to be CO2 > 1,000ppm).

### 8.2.2 Provide sufficient fresh air

**Statutory requirement as per SANS 10400-O:**

Commercial Buildings are to be supplied with outside air at a rate not less than 5 litres/second/person).

In instances where mechanical ventilation is used, the HVAC system should be designed in such a way that the majority of the useable area of that building is supplied with fresh air at rates which comply with or exceed the five litres per person per second stipulated requirement of SANS 10400-O.

A carbon dioxide monitoring and control system should be included with a minimum of one $CO^2$ sensor at all return points on each floor so as to provide constant adjustment of outside air rates to each level.

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## Fast Fact:

**SANS 10400-O**

**SANS 10400-O sets minimum permissible ventilation rates for buildings, giving consideration to health and ventilation amenity. However, these minimum rates are purely intended to maintain general contaminants at levels below those with the potential to cause harm, and tend to be far lower than international standards.**

In order to isolate, contain and allow maximum removal of noxious fumes from printers and other centralised office equipment, these should be located in a room next to the core that is serviced by an independent Tenant Exhaust Riser, which removes the fumes and exits these outside the building.

### 8.2.3 Design for good daylighting and electrical lighting

A well-designed building allows building users to capitalise on maximum access to natural daylight, whilst ensuring that glare is reduced and that the façade design does not encourage radiant heat build-up. The design of the building should promote a direct line of sight to the outdoors or large atria for as much of the office space as possible. This needs to be carried through in office space design, so as to locate cellular offices around the core and the open space areas on the periphery. The use of narrow floor plates in buildings increases the proportion of occupants near a glazed perimeter section who are thus able to benefit from natural light and views. A similar result can be obtained by the use of atria. In retail and residential buildings, additional natural lighting can be introduced into deep spaces using skylights.

It is necessary to be aware that maximising natural lighting and views risks increased glare and reflective stress from sunlight. This can be reduced by deploying fixed shading devices in the base build, or the addition of internal or external blinds. For years this meant losing the view, with heavy opaque blinds cutting out all the light – and views. Newer blinds tend to be almost transparent from the inside, so able to maintain views whilst significantly reducing glare.

A new trend is towards the use of automatic blinds or screens, which are controlled by a sun-sensitive monitor, and where the angle of the blind or screen changes accordingly at different times of the day or different seasons.

## Case Study

**My Green Home**
**Introduction of a Staircase Skylight**
**Pinelands**

A Pinelands family, chosen in 2014 by the Green Building Council SA to receive a full home retrofit and behavioural training as a showcase for the energy and water savings possible for an average suburban family, highlighted the significant impact that the installation of a skylight can have. As part of the installation process, a skylight was installed above the dark staircase of the double story home. The positive effect was dramatic, not only requiring no artificial lighting at times of the day (and during the full moon!) but also dramatically changing the feel of that part of the house.

For more information please see http://mygreenhome.org.za/

Electronic high frequency ballasts for fluorescent lighting systems have fast become the standard in the industry and should be specified over the old magnetic ballasts technology for numerous reasons. Electronic ballasts tend to be at least 15% more efficient than magnetic ballasts, run at lower temperatures, and thus have lower direct and indirect operating costs. Importantly, they do not create the visible flicker commonly associated with fluorescent lighting.

Project teams should specify light emitting diode (LED) lights, or as a second option compact fluorescent lamps (CFLs) where possible, as both are highly efficient fittings that are now commonly available. They provide a "better" quality of light to the user than standard tubular fluorescent lamps and save significantly more energy (and money) than standard incandescent lights.

## Fast Fact:

**The disposal of CFLs**

**CFLs contain mercury vapour and must absolutely be disposed of properly. All buildings should have a dedicated storage area (in the same area for storage of waste and recycling) for disposal of CFLs. If a CFL breaks it is advisable to ensure that the room is well ventilated to avoid inhalation of mercury vapour.**

### 8.2.4 Appropriate lighting levels and zones

Much of the existing building stock has lighting which has been overdesigned. Buildings should be designed with the lowest possible ambient lighting levels, and this should be supplemented with task lighting. Whilst the direct benefits of reduced lighting loads relate to lower electricity costs, reducing the amount of lighting also directly reduces heating loads and air conditioning requirements, therefore further reducing costs for the building operations.

Zoned lighting is considered a significant part of any demand reduction strategy and should be included in all new buildings. The most basic zoned lighting system allows users to switch off lights in areas that are not being used. More modern systems see zones linked to sensors that turn off lights automatically in unoccupied areas or in areas that are receiving enough daylight to not need lighting (these are termed "photometric sensors").

### 8.2.5 Design for improved thermal comfort – heating and cooling

Traditionally, buildings and HVAC systems have been designed to be able to maintain specific temperature ranges. Set points were selected during the commissioning of a building, and often never revisited or reviewed. There is a growing trend nationally and internationally to revisit this practice. With a growing awareness that occupant comfort is key, the focus has switched to thermal comfort as part of this. This means finding a balance between humidity, ambient temperature, draughts and radiant heat, and acknowledging the prevailing seasons. This is because such temperatures

should be set to reflect seasonal variations in what building occupants are likely to be wearing (warmer indoor ambient temperature in summer and cooler in winter).

The HVAC/ventilation system needs to allow for occupant control over ventilation rates. Building design should allow for individual thermal comfort control (either individually controllable ventilation openings in the case of naturally ventilated buildings or user control over air supply rate and air temperature in mechanically ventilated buildings). Office areas should be thermally zoned, with separate zones for core and perimeter areas.

Whilst the actual settings will differ from building to building, some of the norms recommended for a comfortable indoor environment are:

- a predicted mean vote of between -1 and +1 for commercial buildings and PMV levels between -1.5 and +1.5 inclusive for retail buildings
- a dry bulb temperature between 20 and 24°C
- mean radiant temperatures between 20 or 27 °C
- relative humidity within the range of 40-60%

### 8.2.6 Design for occupants comfort and satisfaction

Various other factors also impact on perceived occupant comfort in a building, which in turn has been demonstrated to have a direct effect on productivity levels (office and education) and recovery rates (hospitals). People are shown to thrive if they have some form of connection to nature, and hence buildings which are able to make this linkage are encouraged. This could include active planting, landscaped atriums, green walls, or even just maximising external views for all building occupants. The simplest way to maximise views is to work with relatively shallow floor plates, and to locate all cellular offices and meeting rooms along the core or within the deeper space, so allowing the movement and open plan areas to take place closest the perimeters.

People are very noise sensitive, and even though they may not consciously be frustrated by noise, the louder the ambient environment, the louder people have been demonstrated to talk, so increasing the ambient sound levels further. Green buildings are designed for lower ambient noise control, and have features in place to further control this in an occupied building.

**Statutory requirement for maximum internal noise levels as per SANS 10103:2004:**

**SANS 10103:2004** sets various statutory maximum design levels for noise in different buildings:

**1.1.1.1**

| COMMERCIAL BUILDING | Building Services noise | Overall ambient sound level |
|---|---|---|
| General office | 40dB(A)eq | 40dB(A)eq |
| Open plan space (>50m$^2$) | 45dB(A)eq | 45dB(A)eq |
| RETAIL SPACE | 55 dB(A) eq | 55 dB(A) eq |

Although there are currently no statutory requirements governing the residential market in South Africa, national good practice recommends the following maximum design levels:

| | Bedroom (night) | Other Habitable Rooms |
|---|---|---|
| RESIDENTIAL | 35 dB (A) eq | 40 dB (A) eq |

Modern offices often include the use of overhead baffle panels, carpeting, acoustically treated meeting rooms, floor to soffit dividers and plants as means of reducing and controlling ambient noise levels.

## Fast Fact:

**Health implications of Formaldehyde fumes**

**Formaldehyde is a widely used industrial chemical, present in almost all composite wood products, and is found by many people to be an irritant to mucous membranes and eyes, can increase the risk of cancer and have negative impacts on an unborn child.**

### 8.2.7 Reduction of internal pollutants and mould

All interior finishes should be specified to minimise the volatile organic compound (VOC) and formaldehyde levels or emissions. Over the past few years, paints, adhesives and sealants, and carpets and flooring with low or no total VOC levels have all become readily available to the market at no cost premium and should be specified for use.

Mould is a form of fungi, and the spores are floating through indoor and outdoor air and water at almost all times. Mould spores need three things in order to grow – moisture, nutrients and warm temperatures. The drier climate of Steve Tshwete Municipality acts as a natural mould retardant, which can be supported by the design of the HVAC system such as to maintain indoor relative humidity levels of between 30 and 60%.

It is recommended that building design avoids the use of evaporative cooling towers or other evaporative cooling systems as these may harbour Legionella. Other design features which can be used in HVAC systems to minimise Legionella growth include hot water delivery at 50°C or higher, cold water distribution at 20°C or lower, keeping pipe work as short and direct as possible, adequately insulating pipes and tanks, using materials that do not encourage the growth of Legionella, and preventing contamination (by fitting tanks with lids and insect screens).

The dangers of cigarette and pipe smoke have long been documented, and the country has strong anti-tobacco legislation which must be adhered to. Taking this one step further, it is recommended that all buildings be declared smoke-free zones. This requires that the developer, landlord and tenants buy into the concept, and that in the design (and indeed operational phase) or the building, no provision should be made for smoking inside the building (via a smoking room, decks assigned for smoking areas or other special smoking areas).

### 8.2.8 Reduction and monitoring of building-related emissions

Another aspect of indoor quality relating to buildings is ensuring that hazardous fluids and gases used as refrigerants, insulants and for fire and leak suppression are well-managed. In essence, this entails the preferential specification of insulants, refrigerants and other gases that do not contribute to the long-term damage of the earth's stratospheric ozone layer theough the release of harmful gases. Building design should include the specification and installation of building systems which minimise the environmental damage from refrigerant leaks. Other building emissions that should, and can, be addressed through good building design are discussed elsewhere in these guidelines, but are highlighted here for clarity. These include:

- Building design should minimise stormwater run-off to, and pollution of, the natural watercourses.
- Building design should minimise discharge to the municipal sewerage system.
- Building design and lighting layout should be such as to minimise the light pollution into the night sky.

Where boilers or generators are specified, ensure that all gas boilers have NOx emissions of <100mg/kWh (at 0% excess O2) and generators comply with the Tier 3 emission standards as defined by the United Stated Environmental Protection Agency (USEPA) or similar.

### 8.2.9 Promote the use of stairs

Multi-story buildings should be designed with prominent trafficable staircases providing connectivity between floors. This reduces the demand on lifts and escalators, and also contributes positively to the health and well-being of building occupants.

In buildings where this is not possible, the fire escape stairs could be designed so as to allow them to be used by daily traffic, and should be afforded a higher level of finish to make them more user-friendly.

### 8.2.10 Universal access

All buildings should be designed to allow for universal access at all entrances to the site or building. Universal access allows for ease of entry to those who use wheelchairs, prams, walking sticks and other aids for mobility. The easiest available reference for this in South Africa is SANS 10400_S (Facilities for persons with disabilities). Architects are encouraged to design residential buildings which would allow for universal access to and within the individual dwelling units, so as to meet the needs of different occupants and the needs of existing occupants. All dwelling units and common properties should be designed to comply with this and have at least one toilet at the entry level of the unit which is accessible to wheelchairs.

### 8.2.11 Reduction and safe removal of hazardous materials (e.g. asbestos)

A hazardous materials survey should be conducted by a suitably qualified professional before any demolition works for existing structures commence or when an extension or alteration to an older building thought to contain such is planned. Should hazardous materials such as asbestos, lead or polychlorinated biphenyls (PCBs) be identified in the existing structure, they should be removed by a suitably qualified and experienced company in accordance with the relevant standards or legislation, in order to mitigate risks to contractors and future building occupants alike.

## 8.3 How do we construct our buildings?

Good construction practice calls for the establishment and adherence to an environmental management plan to guide construction activities. This has the advantage of providing a means to detail and monitor correct procedures so as to safeguard the health of construction workers during a project. Some of the areas where this links back to the indoor environmental quality are: adequate toilet facilities on site (accessible within a few minutes from anywhere on site); separate and designated eating areas; regular damping down of site to reduce excessive dust; enforced use of proper personal protective equipment (especially dust masks when chasing into walls or sweeping debris, and goggles for welding or skimming soffits), proper labelling and regular inspection of portable distribution boards and extension leads.

## 8.4 How do we manage our buildings?

Good building management is essential to ensure the maintenance of a quality indoor environment. This requires both the ongoing monitoring of the indoor air quality of a building and the systems which impact on this. Where necessary this also requires the implementation of appropriate remedial actions to ensure that the systems and quality of the indoor environment is retained. In addition, when tenant churn or the natural lifecycle of the building determines that a major overhaul or renovation is due, the building manager or owner should consider the introduction of green features and initiatives that can further improve the quality of the indoor environment of the building. The first step is to conduct a detailed audit of what is in place and the current practices, and then to develop a phased implementation plan based on that. Many of the initiatives can also be included in the annual operational and natural replacement cycle of the building.

### 8.4.1 Opportunities for improved IEQ through good operational practices

In recent years, there has been an increase in operational practices which support good indoor environmental quality. Firstly, by understanding the activities taking place in the building, one can begin with implementing monitoring and control procedures to constantly asses and adjust systems to prevent and minimise the build-up of indoor pollutants in the building. Secondly, a building manager or owner needs to establish a set of performance metrics for minimum indoor quality for the building based on green building best practice principles. Some common metrics are:

- Carbon monoxide levels in covered parking areas should not exceed 26ppm.
- Carbon dioxide levels in regularly occupied areas should not exceed 1000ppm.
- Green Building Measurements:

Given the focus on occupant comfort and necessary adjustments, regular occupant surveys of both staff and visitors to the building should be conducted to inform these adjustments. In larger buildings or portfolios, it is proposed that a dedicated and suitably qualified Indoor air quality manager be appointed.

Building managers should ensure that a good maintenance schedule is compiled and adhered to, that air filters are regularly inspected and replaced, and fresh air ducting cleaned. A quarterly schedule is recommended, but at a minimum annually.

Indoor Air Qulaity (IAQ) best practice should include an environmental tobacco smoke policy for the building (to prevent and minimise exposure to environmental tobacco smoke; prohibit smoking in the building, locate exterior designated smoking areas as least eight metres away from all building entries, outdoor air intakes, and operable windows. This area needs to have a visible butt disposal area to prevent cigarette butts landing up on the streets).

*Figure 16: Performance Measures for Buildings*

| Performance Measure | Excellent | Good |
|---|---|---|
| Thermal Comfort (AC) | -0.5<PMV<+0.5 | -1<PMV<+1 |
| Thermal Comfort (natural ventilation) | <1% operating hours exceed 28 °C | <2% operating hours exceed 28 °C |
| % Usable Area >2% Daylight Factor | >60% | 30-60% |

### 8.4.2 Encourage the use of green cleaning materials

The building manager can use green cleaning techniques and materials to assist in reducing exposure by cleaning teams and building occupants alike to potentially hazardous chemical, biological and particulate contaminants. As with most interventions, the first step should be a review of the current practices, including the building, tenant or corporate cleaning policy, purchasing and procurement decisions, cleaning equipment, indoor pest management protocols. It is deemed desirable that all of these are "greened". A holistic implementation program should be implemented including:

- Green cleaning policy – cleaning products, cleaning equipment, standard operating procedures, hand hygiene, handling and storage of hazardous materials, feedback mechanisms, move to environmentally friendly products.
- Indoor integrated pest management system (manage indoor pests with the most effective, least risk and environmentally friendly option).
- Green purchasing and procurement.
- The specification and use of low irritant or non-chemical cleaning products.

### 8.4.3 Monitor outdoor air delivery

Buildings may be retrofitted with ventilation system monitoring in order to help sustain building occupants comfort and well-being. This should include the provision of carbon dioxide ($CO^2$) sensors in densely occupied spaces (particularly relevant to commercial buildings). It is desirable to keep $CO^2$ levels at under 700ppm at any given time. As discussed in the design section, there are significant benefits for building occupants from increased fresh air, and the levels of fresh outdoor air supplied can be increased fairly easily.

### 8.4.4 Give preference to natural ventilation

The IEQ management strategy for a building may include the desire to increase rates of natural ventilation. This can be done in part through the installation of openable windows for cross ventilation where these do not already exist. Another strategy used by some building managers is the supplementation of the mechanical ventilation systems with natural ventilation. It has been observed that significant energy savings can be achieved from night purging of the building space using natural ventilation.

## Fast Fact:

**Indoor Planting**

**Mother-in-law's tongue, or Sansevieria trifasciata, is a popular indoor plant as it is tolerant of low light levels and irregular watering; and is commonly regarded as one of the best plants for improving indoor air quality by passively absorbing toxins such as nitrogen oxides and formaldehyde.**

*Figure 17 : Mother-in-law's tongue in an office*

### 8.4.5 Opportunities for improved IEQ within the maintenance cycle

#### 8.4.5.1 Promote health and wellbeing of building occupants

Good office space planning and the procurement of suitable furniture is also important. The use of ergonomic equipment (such as standing desks or laptop stands) and the clever design of tenant space can promote occupant well-being, efficiency and effectiveness.

When considering internal areas of a building, use should be made of plants and greenery to further improve the indoor air quality. Indoor plants have the ability to reduce airborne concentrations of VOCs, as well as assist in reducing $CO^2$ and dust levels, baffling noise, and stabilising humidity and temperature in the space. Furthermore, research has shown that the presence of indoor plants in an office space tends to lead to healthier and happier staff.

#### 8.4.5.2 Reduction of internal pollutants and mould

Only no or low VOC and no or low formaldehyde products should be used in the internal spaces of a building. This includes but is not restricted to paints, adhesives and sealants, carpets and flooring, engineered wood products.

Where possible all photocopy and print equipment should be located in a dedicated room close to the core and connected to a dedicated exhaust riser or ducted exhaust system. It is further recommended that a service level agreement be signed with a supplier of photocopy and print equipment who has low emission certified equipment available.

Another action which can be taken relatively easily is to check that the HVAC system maintains a humidity level of no more than 60% relative humidity in the space and no more than 80% relative humidity in the supply ductwork.

#### 8.4.5.3 Reduction and monitoring of building-related emissions

There are various actions which can be taken to assist in the reduction of building-related emissions. Once again adequate planning and monitoring is key. It is highly recommended that building managers implement a replacement policy for refrigerants and insulants, and in the medium term work to replace all non-zero ozone depletion potential (ODP) refrigerants (or equipment) and insulants with less harmful modern ones. Associated with this would be the implementation of a plan to convert the refrigerant mass serving the building to low (<10) global warming potential (GWP) refrigerants.

Regular leak testing should take place on all refrigerant mass which is not composed of zero ozone depletion potential (ODP) refrigerants, and if possible a leak detection system connected to the building management system should be installed for all non-zero ODP refrigerant equipment with mass more than 3kg refrigerant (unless 100% zero ODP).

#### 8.4.5.4 Generator / boiler maintenance programme

Whilst few South African buildings make use of boilers, an increasing number are installing emergency generators to run critical systems and ensure business continuity during electrical load shedding. A regular generator and/or boiler maintenance program should be implemented in order to minimise excessive NOx, CO and $CO^2$ emissions.

### 8.4.6 Opportunities for improved IEQ when retrofitting or refurbishing

A major building retrofit or refurbishment presents an ideal opportunity to make more significant changes which may have a marked positive impact on the indoor environmental quality. It allows for several measures to take place simultaneously, instead of having to wait for the maintenance cycle or obsolescence, and often comes with a capital budget of its own.

Through reconfiguration of the internal spaces and a few changes to the external envelope and systems, dramatic improvements can be achieved. The opportunity for the identification and removal of hazardous materials such as asbestos (many old ceiling tiles are asbestos, and it was painted onto soffits as a fire retardant) should be embraced as a first step in any retrofit. Thereafter, the installation of proper zoned systems for lighting and HVAC should be considered, along with the introduction of opening windows where appropriate, and the introduction of internal or external screening and blinds to maximise daylight but minimise glare and radiant heat. Light fittings are another easy target, and all magnetic ballasts should be replaced with the high frequency electronic ones. A move to LED lighting should also be considered.

The layout of the interior fit-out will also impact how much light reaches the core of the building. In office buildings, any cellular offices should be in the middle of the floor, with transparent glass, and open desk areas should be at the perimeter. Open plan fit-outs provide the most daylight to the greatest proportion of floor area. In multi-unit residential buildings, living areas and bedrooms should be at the perimeter with kitchens, bathrooms and utility areas in the core.

Internal layouts should be designed so as to maximise views to the outside for the majority of building users, and to cluster printers and photocopiers in an area which can be ducted. In buildings where a single tenant may occupy multiple floors, or where there are many tenants

on a floor and hence a common shared passage, the introduction of useable staircases between the floors can be considered (in many cases structural engineers will approve the punching of a hole into the slab to allow this).

In larger buildings the opportunity may exist for the introduction of an atrium within the building, which will assist in improving natural daylight and ventilation.