Designing Quality Learning Spaces: Ventilation & Indoor Air Quality

Developed by BRANZ Ltd for the Ministry of Education
Introduction

The Ministry of Education has prepared a series of guidelines to help boards of trustees and principals to:

- assess the performance of existing teaching spaces
- be aware of the characteristics of quality learning spaces
- achieve the highest possible quality spaces.

This information is important because of the effect the teaching environment can have on student learning.

For this series, ‘environment’ refers to the quality of the learning environment which is affected by many physical factors, including:

- acoustics
- air quality and ventilation
- heating and insulation
- lighting
- interior design, function and aesthetics.

These factors interact with one another. Achieving good natural lighting must be balanced against possible uncomfortable heat gain from the sun, and the need for natural ventilation can clash with outside noise control efforts. No single factor should be altered without assessing its effect on all the others – a holistic approach is essential.

It is also important to spend the available money well (both the initial outlay and long-term running and maintenance costs).

This series gives practical advice, but it cannot provide definitive answers for all circumstances. What Designing Quality Learning Spaces can do is give advice which should improve teaching spaces for both students and teachers.

Although the main objective is to guide boards of trustees and principals, the series should also be available for teachers, to help them understand what makes a good learning environment and how they can contribute to this, such as by ensuring windows are opened for good ventilation. The guides can also be given to professional designers as part of their brief.

While the specific designs and solutions chosen will vary between schools, all quality learning spaces have certain features in common:

- there is always a fresh air supply, which helps to prevent the build up of carbon dioxide levels, clears away pollutants, odours and excessive moisture, and improves comfort in warm weather by increasing air movement and removing heat
- there is a comfortable temperature regardless of outdoor conditions
- there is good lighting, preferably natural, without glare
- students can hear and understand the teacher from all parts of the room (and vice versa), teachers don’t need to raise their voices to be heard, and noise from outside doesn’t interfere with teaching.

In their design and layout, learning spaces should:

- allow the teacher to move about easily
- allow for a variety of teaching methods
- allow enough personal space for students
- let all the students see visual aids clearly
- provide work space for specialised activities
- cater for students with special education needs
- be safe and comfortable.

A quality learning space will have furniture which:

- allows learning and tasks to be carried out efficiently without fatigue
- helps protect students from injury owing to bad posture
- reduces the risk of distraction or fidgeting owing to discomfort.
Editorial Note

This guideline for ventilation and indoor air quality is part of a series for boards of trustees, principals and teachers to help them understand the importance the internal environment plays in the design of quality learning spaces. It will also help boards of trustees brief consultants and tradespeople on their schools’ requirements when planning alterations or maintenance. Other topics in the series include acoustics, heating and insulation, lighting, and interior design.

The series is also designed to help boards assess the quality of their existing teaching spaces and includes practical steps to improve indoor air quality and ventilation.

Children are more susceptible to inhaling pollutants than adults because their breathing and metabolic rates are higher. Children inhale more pollutants per body weight than adults. Their breathing zone also tends to be closer than adults to some pollutant sources (such as new carpet or vinyl) and is less likely to be well ventilated. Their immune systems are immature so that exposure to pollutants can mean allergic reactions or ill health in later life. It is important to provide good indoor air quality in classrooms to help minimise these effects.

These guidelines cover indoor air quality, ventilation, humidity and dampness, all of which are closely linked to the health of students and teachers.

Glossary of Terms used for Ventilation and Indoor Air Quality

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active ventilation</td>
<td>ventilation where air is moved by a mechanical device such as a fan</td>
</tr>
<tr>
<td>Air pollutant</td>
<td>any substance, dust, chemical or gas that pollutes the air</td>
</tr>
<tr>
<td>Allergen</td>
<td>substance (usually a protein such as pollen) that induces reactions in people who are sensitive to it</td>
</tr>
<tr>
<td>Cross-ventilation</td>
<td>air is forced into the room on one side by positive wind pressure and sucked out the other side by negative pressure</td>
</tr>
<tr>
<td>Damp-proof membrane</td>
<td>underlay with low water vapour transmission (such as polythene sheeting) that stops moisture rising from the ground</td>
</tr>
<tr>
<td>Fresh air</td>
<td>used in this document to mean ‘outside air’</td>
</tr>
<tr>
<td>Heat pump</td>
<td>unit capable of gathering heat from air (or other sources such as the ground) and transferring it to a heating system or reversing the process and providing cooling</td>
</tr>
<tr>
<td>HEPA filter</td>
<td>high efficiency particulate air (HEPA) filter membrane that allows air to flow, but traps small particles</td>
</tr>
<tr>
<td>HRS</td>
<td>heat recovery system that heats ventilation air with heat recovered from exhaust air</td>
</tr>
<tr>
<td>HVAC</td>
<td>a generic term for a system that provides heating, ventilating or air conditioning (HVAC) in various combinations</td>
</tr>
<tr>
<td>Indoor air quality (IAQ)</td>
<td>degree of how polluted air is compared to a set standard</td>
</tr>
<tr>
<td>Passive ventilation</td>
<td>ventilation by natural means eg. opening a window or door</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Relative humidity (RH)</td>
<td>ratio of water vapour present in air compared to the amount the air could hold if totally saturated, expressed as a percentage</td>
</tr>
<tr>
<td>Solar gain</td>
<td>heat gain by passive collection of the sun’s heat through windows or the structure of the building</td>
</tr>
<tr>
<td>Stack effect</td>
<td>warm air rises, as it does in a chimney stack, and cooler air is drawn in at low level to replace it</td>
</tr>
<tr>
<td>Sub-floor space</td>
<td>the space between the ground and the floor in a building with a suspended ground floor</td>
</tr>
<tr>
<td>Thermal mass</td>
<td>solid part of the building (e.g., concrete blocks or concrete floor) in which heat energy can be stored and gradually released indoors</td>
</tr>
<tr>
<td>VOCs</td>
<td>volatile organic compounds (such as solvents)</td>
</tr>
<tr>
<td>Water table</td>
<td>the level below which ground is saturated with water</td>
</tr>
</tbody>
</table>
# Contents

Editorial Note 1

Glossary of terms used for Ventilation and Indoor Air Quality 1

**PART ONE: VENTILATION** 6

**> SECTION 1 – Ventilation Concepts** 6

* Overview 7
* Ventilation 8
* Fresh air 8
* Ventilation from wind 9
* Cross-ventilation 9
* Single-sided ventilation 9
* Natural convection 10

**> SECTION 2 – Active Ventilation** 11

* When active ventilation may be necessary 12
* Most active ventilation requires specialist input 12
* Mechanical ventilation 12
* What is air conditioning? 13
* Heat recovery systems 13
* Air extract fans 13
* Non-ventilating air movement devices 14

**> SECTION 3 – Passive Ventilation** 15

* Adequate passive ventilation 16
* Windows and doors 18

**> SECTION 4 – Providing Good Ventilation** 19
## PART TWO: INDOOR AIR QUALITY

> **SECTION 5 – Good Indoor Air Quality**

- Why is IAQ important? 22
- Is IAQ a problem in New Zealand schools? 23
- How to identify poor IAQ
- Causes of poor IAQ
- Providing good IAQ

> **SECTION 6 – Humidity And Moisture Effects**

- Moisture in the air 30
- What is relative humidity? 31
- Sources of moisture 31
- Reducing Humidity and Moisture 33

> **SECTION 7 – Specialist Teaching Spaces**

- Multi-purpose Halls 37
- Gyms 38
- Libraries 39
- Music Rooms 40
- Design, Art and Technology Rooms 41

> **SECTION 8 – Students with Special Education Needs**

- Schools for all people 43
- Planning ahead 44
- Creative problem-solving 44
- Practical suggestions 44
PART ONE: VENTILATION

> SECTION 1
– Ventilation Concepts
Overview

There is considerable research worldwide on the importance of good quality ventilation and the impact of poor indoor air quality. While this may not have been widely recognised as a major issue in New Zealand schools it is important that we acknowledge the potential for problems to exist. New Zealand schools are, in most cases, designed to provide ventilation through opening windows. However, if windows remain closed the air quality will deteriorate and this may or may not be recognised by the occupants. Someone coming into the room from a well-ventilated space will immediately recognise the difference. Stuffiness and a buildup of CO$_2$ may cause drowsiness.

In a survey carried out for the Ministry of Education by AC Nielsen, designers, boards, principals, teachers and students considered that a well-ventilated classroom and the elimination of odours were essential elements of good design for learning. These included removing smells from dampness, chalk, poor student hygiene, old classrooms, accumulated odours in some specialist places and poorly maintained toilet facilities.

Teachers felt ventilation and air flow was critical overall, and that these were closely linked to their ability to maintain control over the temperature. Students also rated good ventilation, along with having rooms that were not too hot or too cold, as important in helping them learn.

Children are particularly vulnerable to all types of pollutants because their breathing and metabolic rates are high. In a school they also have much less floor space, by a factor of 10 allocated per person, than adults working in a typical office. Their breathing zone tends to be closer to pollutant sources, such as new carpet, and less likely to be well ventilated as it is below window level.

The immune system of young children is immature, and exposure to pollutants can mean allergic reactions or ill health. It is important to provide good indoor air quality (IAQ) in classrooms to help minimise these effects.

Ventilation and IAQ are closely linked. Inadequate ventilation may be a common problem in New Zealand schools, but it is an indicator and not the only cause of health problems. If the quality of indoor air is compromised by pollutants, ventilation may alleviate the situation, but may not cure it. Elimination of pollutants at their source is the most effective way to improve IAQ.

Ventilation must:

- supply fresh air for breathing
- clear away pollutants and odours to improve air quality
- help remove excessive moisture in the air
- improve thermal comfort in warm weather by increasing air movement and removing heat.

Classrooms require at least 10 times more fresh air than houses because of their high occupancy rate.
Ventilation

Ventilation is the supply and removal of air by either:
- passive means – where air movement is driven by wind and temperature differences through openings such as windows
- active means – where the air is supplied and/or extracted by mechanical methods such as ducts and fans.

Ventilation is required for two separate functions:
- in cold weather to provide:
  - air for breathing
  - fresh air to maintain IAQ
- in warm weather to provide:
  - air for breathing
  - air to maintain IAQ
  - air movement for thermal comfort.

Fresh air

Cold weather

In naturally ventilated classrooms in cold weather, uncontrolled natural ventilation rates can lead to large heat losses. This can result in coldness and draughts and increased heating costs, and a compromise is, therefore, necessary.

There is no escape from this compromise. Adequate passive ventilation rates for classrooms will require increased heat input in cold weather to maintain comfort levels and will increase heating costs. The alternative is to install an active ventilation system incorporating heat recovery (see Section 2).

Ventilation in cold weather requires well-controlled air movement to meet the minimum needs of IAQ and comfort. Excessive ventilation can unduly lower the temperature. Figure 1 shows the minimum volume of fresh air needed by each person for various purposes. We need 30 times the amount of fresh air to remove body odours and CO₂ than we need for breathing.

Adequate passive ventilation rates for classrooms will require increased heat input in cold weather.

The rate at which oxygen is consumed and CO₂ is produced rises rapidly with increased activity. The required rate of ventilation, therefore, rises with more vigorous activities. Table 1 shows recommended minimum ventilation for various teaching spaces.

### TABLE 1: MINIMUM VENTILATION FOR TEACHING SPACES (1)

<table>
<thead>
<tr>
<th>Type of space</th>
<th>Number of people</th>
<th>Fresh air requirement (litres per second per person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>Laboratories</td>
<td>30</td>
<td>10 [2]</td>
</tr>
<tr>
<td>Art, design, and technology rooms</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Libraries</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Multi-purpose halls</td>
<td>150</td>
<td>8</td>
</tr>
<tr>
<td>Gyms</td>
<td>30</td>
<td>10–13</td>
</tr>
</tbody>
</table>

Note: (1) This table has been adapted from Table 2 of NZS 4303:1990.

(2) Laboratories must comply with the Hazardous Substances (Exempt Laboratories) Regulations 2001.
For an average classroom, eight litres of air per second per person is about four complete changes of air every hour.

The air quality of teaching spaces can be adversely affected by the poor ventilation of other parts of the school because odours and contaminated air are easily transferred. It is important that areas such as corridors (particularly when used for hanging outdoor clothes and storing shoes), toilets and cloakrooms are well ventilated. Table 2 shows some appropriate rates of ventilation taken from NZS 4303:1990, and improved rates recommended by the Ministry of Education.

### TABLE 2. MINIMUM VENTILATION FOR ANCILLARY SPACES

<table>
<thead>
<tr>
<th>Type of space</th>
<th>Rate of ventilation ( \text{l/m}^2 ) (litres per square metre of floor area)</th>
<th>Improved minimum ventilation rate recommended by the Ministry of Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloakrooms</td>
<td>2.5</td>
<td>4 ( \text{l/m}^2 )</td>
</tr>
<tr>
<td>Toilets</td>
<td>4.0</td>
<td>10 ( \text{l/m}^2 ) or 25 ( \text{l/ per fixture} )</td>
</tr>
<tr>
<td>Corridors</td>
<td>0.5</td>
<td>1 ( \text{l/m}^2 )</td>
</tr>
<tr>
<td>Showers</td>
<td>50 ( \text{l/ per fixture} )</td>
<td></td>
</tr>
</tbody>
</table>

*(Note) This part of the table has been adapted from Table 2 of NZS 4303:1990.*

cooling us by evaporating our sweat. In warm weather we need to maintain a steady flow of air for comfort.

Air movement can be caused by:
- wind
- natural convection – hot air rises
- active (mechanical) means eg. fans.

### Ventilation from wind

New Zealand is a windy country and most places can rely on wind for ventilation most of the time. The worst situation is hot, still, humid days in summer. Too much wind can be a nuisance. For example, on sunny, windy days classrooms can become overheated when windows are closed to avoid draughts, noise and papers being blown about (see Figure 2).

**Cross-ventilation**

Wind pressures are positive (push) on the windward side of the building and negative (suck) on the leeward side. This encourages good cross-ventilation in rooms with windows on opposite sides. Cross-ventilation must be carefully controlled to prevent too much air movement in windy conditions.

**Single-sided ventilation**

Wind cannot move the air through a room when there are only windows on one side. Winds can have an

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**Figure 2** Natural ventilation on a windy day

Even with the windows partly open the draught causes a problem

Papers scattered

Heat lost rapidly through the window
effect on air changes in rooms up to eight metres deep, depending on wind strength (see Figure 3). However, effective ventilation may only be possible in shallower rooms, i.e., no deeper than 2.5 times the ceiling height (see Figure 4).

Natural convection

Stack effect

Warm air rises, pushing air upwards. This is sometimes referred to as the 'stack effect' (like movement of hot air up a chimney). Cooler outside air is drawn in to replace the air going out the top, which supplies fresh air and air movement, improving thermal comfort and heat removal. Air movement from the stack effect is significant only in rooms with very high ceilings, such as large, multi-purpose rooms or two-storey spaces and atriums (see Figure 5). Its effect in most spaces is minor compared to the effect of wind.

Stratification

If warm air rises and is not vented outside, it is trapped at ceiling level causing a temperature difference between floor and ceiling (stratification). Students sitting on

In winter the temperature at the ceiling can be 3–5°C warmer than at the floor.

or near the floor may feel cold, and the heads of adults standing may be 3°C warmer than their feet (see Figure 6). A ceiling fan can redistribute the air, which is useful in cold weather, but in hot weather may cause overheating in the lower zones.
SECTION 2
– Active Ventilation
This section discusses systems only with regard to ventilation requirements. Heating systems are covered in *Designing Quality Learning Spaces – Heating and Insulation*.

**When active ventilation may be necessary**

Satisfactory passive ventilation of teaching spaces should be achievable in most situations in New Zealand, particularly in new buildings, provided it is properly integrated with other design aspects such as:

- heating
- insulation
- control of solar gain
- lighting.

Active ventilation may be necessary in:

- regions with a significant number of hot, windless days during the school term
- existing buildings where it is physically impractical, because of the building configuration, to obtain adequate passive ventilation
- specialist rooms such as:
  - recording studios
  - music practice rooms
  - rooms that contain significant numbers of heat-producing equipment such as computers
  - multi-purpose halls and gyms
- spaces with sources of contaminants which must be extracted at source such as:
  - cooking facilities
  - workshops
  - science rooms.

**Most active ventilation requires specialist input**

Active ventilation systems must be designed by an experienced heating and ventilating engineer to ensure:

- correct air distribution
- appropriate temperature and humidity
- satisfactory air filtration
- low noise
- economical operation.

**If you consider that mechanical ventilation may be needed, seek advice from an expert.**

**Mechanical ventilation**

Mechanical ventilation is basically a method of delivering fresh air to the space using fans and ducts. The aim is for a system that will:

- give sufficient outside air ventilation to maintain good IAQ while minimising heat lost in exhaust air in cold weather
- heat the air sufficiently to maintain thermal comfort conditions in cold weather
- provide sufficient air movement to give thermal comfort conditions without draughts in warm weather
- be economical to run and easy to maintain.

There are many variations and methods by which these goals can be achieved. An engineer will be able to give advice on the most practical solution for your situation.

If comfort conditions in hot humid weather cannot be achieved by air movement, consideration may be given to cooling the air. However, the introduction of air cooling should be treated with
Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

caution because of associated higher running costs and expensive maintenance.

What is air conditioning?
The term ‘air conditioning’ refers to a mechanical process which controls the temperature, humidity, cleanliness and circulation of air. Air conditioning systems use more energy to provide temperature control within a tighter comfort range than mechanical ventilation. Originally conceived for use in office buildings, these systems typically rely on recycling indoor air to retain heat or cold. This can lead to reduced IAQ through the recirculation of contaminants. If a higher rate of outdoor air is introduced, as needed in classrooms, running costs will increase substantially.

Heat recovery systems
Heat recovery systems are basically mechanical ventilation systems with added refinements. They supply fresh (outside) air, but warm it with heat recovered from the exhaust air by an indirect heat exchanger without the exhaust air and the fresh air coming into contact (see Figure 7). This means a considerable portion (60 to 90%) of heat can be recovered.

Heat recovery systems:
- are economic to run
- can be retrofitted to existing buildings
- can work in parallel with existing heating systems such as radiators
- maintain good ventilation by supplying 100% fresh air to keep CO₂ levels below 1,000 parts per million (ppm)

Air extract fans
Because sufficient natural ventilation cannot always be provided to toilets or classrooms, a fan-assisted extract system will help to reduce odours and remove heat. The air is exhausted directly to the outside and make-up air is either drawn from other parts of the building or through vents or windows.

Air extract fans:
- are inexpensive
- may not introduce fresh air
- do not recover heat
- may be noisy if not properly designed.

The introduction of air conditioning into classrooms should be treated with caution.

Equipment that only cools the air, such as split system heat pumps and cassette type ‘air conditioners’, only recirculate the air. While they may be useful when used in association with other ventilation systems, they do not in themselves provide any ventilation and are not air conditioning systems.

- can incorporate filters to reduce pollutants such as dust and pollen.

FIGURE 7  Diagram of a mechanical ventilation system
Non-ventilating air movement devices

Pedestal fans
Using a pedestal or desk-top fan to circulate air has the same effect as natural air movement and improves thermal comfort locally. The air speed and direction can also be controlled.

Pedestal fans:
- create air movement which makes people feel cooler
- do not introduce fresh air into the room so do not ventilate
- make some noise
- produce a small amount of heat from the motor.

Ceiling fans
Ceiling fans, which are running very slowly, will redistribute warm air more evenly in a space and restore comfort levels if stratification occurs in winter. In summer, ceiling fans running faster will create air movement lowering the perceived temperature.

Ceiling fans:
- create air movement which makes people feel cooler
- do not introduce fresh air into the room
- make some noise, but are quieter at lower speeds
- produce a small amount of heat
- may blow hot air down from upper levels in summer and increase the temperature at lower levels.

Heat pumps
Heat pump units used to cool and to heat teaching spaces have become very popular in schools. Heat pumps are very efficient and cost-effective and they:
- can cool or heat the air
- may make a low level of noise
- are not as effective when outside air temperatures fall (output drops by approximately one-third when the outside temperature falls from 15°C to 0°C, depending on the make)
- do not introduce fresh air into the room.
SECTION 3
– Passive Ventilation
Adequate passive ventilation

The concentration of CO₂ in a room is often used as a guide to the quality of indoor air. Indoor concentrations above about 1,000 parts per million (ppm) CO₂ indicate that IAQ is unacceptable (see Figure 9).

There is currently no clear picture of the adequacy of passive ventilation in New Zealand schools. Indications from overseas, New Zealand studies and anecdotal evidence suggest passive ventilation fails to meet recommended standards in many classrooms for some of the time.

A study carried out in 18 classrooms in New Zealand showed that CO₂ levels often exceeded recommendations.

In the study, levels climbed steadily until temperatures reached about 20°C at which point windows were opened and CO₂ levels reduced (see Figure 10). Measurements were made at regular intervals throughout the day using sensing and recording devices.
For much of the time passive ventilation can provide satisfactory results (see Figure 11). However, passive ventilation often fails to provide ventilation to the required standard in the following situations:

• on windy days when windows are closed to prevent draughts
• on cold days when windows are closed to keep the heat in (see Figure 12)
• on still, hot days when there is insufficient air movement, a situation often made worse by solar heat build-up (see Figure 13)
• when there are insufficient opening windows
• when the room is too deep
• if there are too many people in the room
• if there is heat-generating equipment, such as computers, in the room.

FIGURE 11 Natural ventilation on an ideal summer day

FIGURE 12 Natural ventilation on a very cold day

FIGURE 13 Natural ventilation on a hot, still day
Windows and doors

Providing window ventilation

You can get ventilation from:

- windows fitted with stays that hold them in place and which may open outwards from the:
  - bottom (top hung awning windows – see Figure 14)
  - side (side hung windows)
- vertically or horizontally sliding windows
- a door held open by a catch.

Supplementary ventilation can be provided by:

- trickle ventilators built into the frame to let in continuous fresh air when windows are closed
- window catches that maintain security by only opening a small amount (double catches).

Trickle ventilators and double catches can be fitted to new or existing aluminium windows. Opening windows can be retrofitted to most types of aluminium windows. Awning window stays must be installed so that they allow effective free ventilation opening (Figure 14).

Design of opening windows

To allow for different weather conditions, classrooms should have ventilation options that include all of the following (see Figure 15):

- trickle ventilators for cold weather, high winds and when other windows are closed for security
- small, high-level windows, which allow small amounts of ventilation in high winds
- small windows at bench height for all-round ventilation – may have to be closed in high winds to prevent papers flying
- large, main central windows for still, hot, summer weather.

Where to put windows

When putting in opening windows ensure:

- they are not a danger to people walking past
- catches are not out of reach
- maximum advantage is taken of cross-ventilation
- they do not open onto noisy areas (see Designing Quality Learning Spaces – Acoustics)
- they are secured and not a security risk.

Remote window opening gear

Windows out of normal reach can be operated by electrical or hand-wound remote window opening gear. Such fittings are expensive, and often designers have too many windows on each set of gear to save costs. This makes them difficult to operate and liable to break down.

Doors

Outside opening doors from classrooms must not be relied on for ventilation because too often they must be kept closed because of the weather.
> SECTION 4

– Providing Good Ventilation
Steps to achieving good ventilation include:

- developing a property health and safety IAQ policy for the school (see Appendices)
- using good passive ventilation options
- using good active ventilation options where appropriate.

## Practical steps to improve ventilation

<table>
<thead>
<tr>
<th>Step</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make ventilation part of the school’s property health and safety IAQ policy</td>
<td>helps to identify unsatisfactory situations and practices</td>
</tr>
<tr>
<td>Encourage teachers and students to participate in its development</td>
<td>encourages knowledge about when windows should be open</td>
</tr>
<tr>
<td>Do spot checks on CO&lt;sub&gt;2&lt;/sub&gt; levels in occupied classrooms</td>
<td>raises awareness</td>
</tr>
<tr>
<td>Consider sharing the cost of a CO&lt;sub&gt;2&lt;/sub&gt; data logger with other schools</td>
<td>gives guidance on potential problems</td>
</tr>
<tr>
<td>Turn heating on early on cold mornings or have a low level of heat on all night during the week</td>
<td>makes rooms warm enough to allow windows to be opened from the start of the day, may be cost-effective, reduces condensation</td>
</tr>
<tr>
<td>Keep window catches, hinges, stays and opening gear in good working order</td>
<td>windows that don’t work are not opened</td>
</tr>
<tr>
<td>Free up and repair painted wooden windows and replace broken sash cords</td>
<td>ventilation in many older buildings is restricted by the number of windows that can be opened because of poor maintenance</td>
</tr>
</tbody>
</table>

## Passive ventilation options

<table>
<thead>
<tr>
<th>Option</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening window systems</td>
<td>must provide the right options, teachers must understand how to use the options provided, the cost of lost heat in winter is an unavoidable expense resulting from good ventilation</td>
</tr>
<tr>
<td>Provide some small well-placed high and low-level opening windows in every classroom in addition to larger windows</td>
<td>allows windows to be opened in windy weather, allows the right amount of ventilation in cold weather, can be retrofitted to existing windows, essential for good ventilation in most situations, moderately expensive but may be the best solution</td>
</tr>
<tr>
<td>Have opening windows on opposite sides of the room</td>
<td>allows for cross-ventilation in warm weather, windows on the negative pressure (suck) side can be opened in windy weather, will give ventilation options in adverse weather, can be retrofitted to existing windows, may be expensive but may provide a cost-effective solution</td>
</tr>
</tbody>
</table>
Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

Fit trickle ventilators
- reduces odours and stuffiness when the building is closed up
- gives some continuous ventilation, even in windy or cold weather
- they are in addition to, not instead of, suitable opening windows
- can be retrofitted to aluminium windows
- moderate cost and effective for the purpose

Active ventilation options
Fit extract units in toilets, changing rooms, classrooms and at sources of pollutants
- prevents odours and pollutants drifting to occupied rooms and maintains the recommended ventilation rates
- installation and running are the cost of good ventilation

Install mechanical ventilation
- suitable where adequate ventilation cannot be achieved passively
- suitable where external noise cannot be controlled because windows can be sound-rated and kept closed (see Designing Quality Learning Spaces – Acoustics)
- ensures good ventilation
- can be retrofitted to existing rooms
- must be designed by an expert
- expensive to install
- increases running costs

Install heat recovery ventilation system
- suitable where adequate ventilation rates cannot be achieved by passive means (see also Section 3)
- suitable where external noise cannot be controlled because windows can be sound-rated and kept closed (see Designing Quality Learning Spaces – Acoustics)
- ensures good ventilation
- can be retrofitted to existing rooms
- must be designed by an expert
- expensive to install
- heat recovery reduces heat loss
- increases running costs
- effective

Install ceiling fans
- low-cost option
- gives air movement for thermal comfort in still, hot conditions
- prevents stratification in winter by spreading room heat more evenly
PART TWO: INDOOR AIR QUALITY

> SECTION 5

– Good Indoor Air Quality
Indoor air quality and ventilation are linked because good ventilation is one of the main methods of controlling IAQ. Removal of pollutants at source is the most effective way of improving IAQ.

**Why is IAQ important?**

Poor IAQ can cause non-specific illnesses with symptoms including:

- headaches, fatigue, shortness of breath
- sinus congestion, coughing and sneezing
- eye, nose, throat or skin irritations
- dizziness and nausea.

**The quality of indoor air has been recognised as a crucial health factor.**

**Is IAQ a problem in New Zealand schools?**

A BRANZ study of 12 naturally ventilated New Zealand classrooms concluded that:

- air contaminants showed concentrations of fungi and bacteria associated with damp conditions in some classrooms
- CO₂ levels measured throughout the school day often exceeded the recommended standard
- modern, stand-alone classrooms are more airtight than older ones
- ventilation rates are generally below the targets set for mechanically ventilated buildings (see Section 9: Statutory Requirements for Ventilation of Teaching Spaces)

- Volatile Organic Components (VOCs) were at an acceptable level.

While the sample is too small to indicate the general standard of air quality in New Zealand classrooms, it provides information on the effectiveness of natural ventilation.

**How to identify poor IAQ**

The main indicator of poor IAQ is smells that may be caused by:

- body odours
- musty odours from mould and dust
- formaldehyde off-gassing (see later in this Section)
- gases from printers, paint or cleaning products
- gases from unflued gas heaters
- smells from faulty drains.

Smells are detectable and offensive to varying degrees by different people. Some people have allergic reactions to contaminants whether they can smell them or not. There are many toxic gases that don’t have an odour. After a short exposure to odours, our sense of smell becomes desensitised and the problem can go unnoticed. Smells are best investigated by someone who visits a suspect room for short lengths of time.

Concentrations of pollutants (such as dust, bacteria, fungal spores and gases) can be measured by scientific equipment, but again some cannot be smelt. If problems persist, call in a specialist.

**Causes of poor IAQ**

Poor IAQ is caused by pollutants or contaminants from a variety of sources, including outside air.

A pollutant is any factor which reduces the comfort and health standard of the internal air, including overheating through solar gain (see Section 3 – Passive Ventilation) and humidity (see Section 6), dust and microbes.

**Air from external sources**

The outside air used to ventilate the inside of the building must be of a suitable standard. Although New Zealand has very low industrial pollution, there are some external pollutants we need to be aware of:

- discharges from solid fuel burners, emissions from motor vehicle exhausts and generators
- dust and pollen
- gases and smells from foul and waste water systems
- top-dressing and pesticide sprays
- smells from toilet windows, which can be drawn into nearby rooms
- dust from extract system discharges
- fume cupboard discharges
- kitchen and incinerator discharges.

National Environmental Standards set down a minimum requirement for outdoor air quality that regional councils must meet. Many pollutants are contained in discharges from school boilers and incinerators. The Ministry of Education recommends that schools have an Energy Efficiency Report carried out (see Designing Quality Learning Spaces – Heating and Insulation). Such a report should include an assessment of how discharges from heating systems and incinerators comply with legislative requirements.
Note: On 1 October 2006 National Environmental Standards for air quality came into effect and schools now need resource consents to use incinerators or bury waste on school grounds.

Moisture

Moisture contributes indirectly to pollution by providing conditions in which moulds and bacteria flourish. Sources include:

- occupants
- leaks
- ground water under the building
- condensation
- moisture built into new buildings
- moisture brought into the building.

The causes, effects and control of moisture are discussed in more detail in Section 6.

Fungi and bacteria

Moulds grow on surfaces where there is:

- material they can live off, eg, paper on plasterboard and dust
- moisture from condensation or leaks
- high humidity (most moulds do not survive in humidities less than 70%)
- a suitable temperature (see Section 6).

Most moulds are not a health risk in themselves, but others are allergenic or toxic. One type of mould, stachybotrys, exists in wall cavities and produces toxins (see Section 6).

Bacteria thrive in similar conditions to mould, especially damp or wet carpets. Carpet that has been wet for more than 24 hours will support increased bacteria growth and should be replaced.

Airborne viruses and bacteria can cause infectious diseases such as colds, flu and tuberculosis. The main source of these is the occupants of the room.

Dust mites

Dust mites are tiny creatures not visible to the naked eye. They live in large numbers in clothing and soft furnishings (particularly carpet). The mites eat scales of human skin and their faeces contain allergens which can cause asthma. They absorb the moisture they require from the air and need high humidity to survive (65–70%).

Vacuum cleaning stirs up and pollutes the air with dust mite allergens unless machines have very fine tight-fitting filters (HEPA filters).

Building materials, furnishings and fittings

Many materials such as particleboard, textiles and carpets contain urea-formaldehyde resins which give off formaldehyde when new. Some people can detect its smell even in small concentrations.

Other volatile organic compounds (VOCs) can vaporise from building materials and furnishings including:

- cleaning products
- pesticides
- paints and solvents
- plastics used in upholstery
- gas fires or wood burners
- reconstituted wood products
- new curtains
- whiteboard pens and some art supplies.

At sufficiently high concentrations, formaldehyde and VOCs can cause eye, nose or throat irritations, respiratory difficulties and skin rashes. Formaldehyde and VOC emissions are usually highest when the material is new and will reduce to negligible amounts in about one year. Sealing particleboard reduces formaldehyde emissions.
Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

Carbon dioxide (CO₂)

When classroom windows are closed to conserve heat, there is likely to be a build-up of CO₂. Typically, levels of CO₂ increase during the morning until external temperatures rise to about 20°C, at which point the windows are opened and CO₂ levels reduce.

While there are unlikely to be health effects specific to CO₂, high concentrations are an early indicator of natural ventilation rates falling below the required standard. As the CO₂ concentration increases, people yawn, lack concentration and the ability to learn, and may develop headaches.

Building alterations and maintenance

Building alterations and maintenance work can be a major source of pollution. Make sure that contractors are aware of all IAQ issues and, where appropriate, include contract clauses to ensure compliance with minimum requirements. If possible, schedule work during school holidays and, ideally, at the start of the summer break.

Tradespeople repairing leaks must be aware of the dangers of mould. If it is found in building cavities, expert care is needed to ensure the:
- spores are not released into the building
- mould is treated to prevent it growing again.

Other sources

Other sources of pollutants are:
- asbestos claddings/insulation/ flooring/textured ceilings/ finishes
- combustion gases/smoke
- chemicals used in the classroom, particularly science laboratories
- volatile cosmetics and deodorants.

These are covered in the summary of pollutants (see Appendices).

Providing good IAQ

Consider having an IAQ management programme

The first step towards good IAQ is to include IAQ as part of the school's property health and safety policy (see Appendices) and make sure students and teachers are aware of the importance of IAQ.

Control indoor contaminants

There are five basic control methods for reducing indoor air contaminants:
- provide good ventilation
- manage contaminants at source
- use materials with low contaminant emissions
- seal or enclose contaminants
- extract air at source.
### Manage at source

<table>
<thead>
<tr>
<th>Category</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle fumes</strong></td>
<td>• make sure bus and car engines do not idle where exhaust fumes can enter buildings</td>
</tr>
<tr>
<td><strong>Rubbish</strong></td>
<td>• remove rubbish regularly, preferably daily after school, and store in a well-ventilated vermin-proof space where smells cannot enter buildings</td>
</tr>
<tr>
<td><strong>Spills and food scraps</strong></td>
<td>• clean up food scraps and liquid spills immediately (they attract insects and support mould and bacteria growth)</td>
</tr>
<tr>
<td><strong>Cleaning materials or maintenance supplies</strong></td>
<td>• keep in a well-ventilated storeroom so pollutants cannot enter buildings</td>
</tr>
<tr>
<td><strong>Art rooms</strong></td>
<td>• keep volatile materials in a well-ventilated storeroom so pollutants cannot enter buildings</td>
</tr>
<tr>
<td></td>
<td>• use alternative materials with low volatility where possible</td>
</tr>
<tr>
<td><strong>Science labs</strong></td>
<td>• keep chemicals and metals such as mercury secure</td>
</tr>
<tr>
<td></td>
<td>• store chemicals in a space well ventilated to the outside</td>
</tr>
<tr>
<td></td>
<td>• observe statutory requirements for labs – Hazardous Substances (Exempt Laboratories) Regulations 2001</td>
</tr>
<tr>
<td><strong>Carpets</strong></td>
<td>• control humidity to as low as possible</td>
</tr>
<tr>
<td></td>
<td>• take up and dry wet carpets using specialist operators as soon as possible (do not try to dry them in place)</td>
</tr>
<tr>
<td></td>
<td>• replace carpet that has been continuously wet for 48 hours or more</td>
</tr>
<tr>
<td></td>
<td>• loose sections of carpet, rather than fitted, are easier to clean and dry</td>
</tr>
<tr>
<td></td>
<td>• carpets treated with chemicals may not be effective and can introduce undesirable pesticides</td>
</tr>
<tr>
<td></td>
<td>• vacuuming must be frequent and thorough with fine filters (HEPA) used – ordinary filters spread allergens about</td>
</tr>
<tr>
<td></td>
<td>• vacuum clean after school to give dust time to settle</td>
</tr>
<tr>
<td></td>
<td>• use alternative flooring such as foam-backed vinyl</td>
</tr>
</tbody>
</table>
Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

| Install a central vacuum cleaning system | • ensures that contaminants that would pass through a portable vacuum cleaner filter are not discharged back into the space |
| Leaks | • fix leaks immediately to reduce chances of mould in building cavities |
| Mould (internal surface only) | • clean all wall surfaces annually  
• clean down surfaces showing signs of mould promptly with water and 70% white vinegar |
| Walked-in dirt | • install an entry mat to remove dirt and moisture from shoes – needs to be five metres long |
| Combustion gases | • get rid of unflued gas heaters because they put moisture and pollutants in the air |
| Asbestos claddings, insulation, flooring or textured spray ceilings (specialist contractor work only) | • arrange identification and removal of suspect insulation or textured sprayed ceilings, call a specialist to paint or remove claddings |
| Vermin and insects | • clear away food scraps and rubbish promptly  
• block all possible entry points for rodents, possums, birds and insects  
• eliminate places where birds can roost and foul the building with droppings  
• inspect sub-floor areas and roof spaces regularly  
• fit fly screens to doors and windows where flies are a nuisance  
• use specialists to take control measures when necessary |
| Sanitary plumbing and drainage systems | • ensure all sanitary fittings have effective water traps which always have water in them  
• make sure there are no foul air vents near windows or air intakes  
• clean and maintain external gully traps regularly  
• locate septic tanks and grease traps well away from buildings and empty them regularly |

Get rid of unflued gas heaters because they put moisture and pollutants in the air.
## Substitution of materials with low emissions

**Generally**
- ascertain from manufacturers and suppliers which products have low emissions

**Cleaning materials**
- use products with low VOC emissions

**Building materials**
- specify products with low VOC emissions
- seal particleboards

**Furnishings, carpets, vinyl flooring**
- purchase products with low VOC and formaldehyde emissions

**Paints**
- specify products with low VOC emissions
- use water-based products where possible

**Art materials**
- use low-odour or water-soluble paints and markers

### Sealing (encapsulation)

**Particleboard and medium-density fibreboard (MDF)**
- coat with a sealer where it is exposed to the air
- fit rubber carpet underlay or sheet flooring to act as sealer

**MDF**
- coat with a sealer where it is exposed to the air

**Asbestos roof and wall cladding (specialist contractor work only)**
- does not present a hazard if it is maintained in good condition
- paint roofing and cladding material (if in good condition) to prevent loose fibres becoming airborne
- remove broken or badly deteriorated claddings (using a specialist contractor) and replace with new cladding

### Local air extraction

**Toilets and locker rooms**
- install air extract to outside so pollutants cannot drift to occupied areas

**Art rooms**
- install air exhaust from kilns
- install extract to photography rooms and other areas where chemical processes, such as etching, are used
### Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

**Workshops**
- install local air extract in soldering, welding or spray-painting areas
- install extract where MDF is being cut and on machinery producing sawdust or fine sanding dust

**Kitchens**
- install extract hoods to all cooking appliances

**Science rooms**
- install fume cupboard as required by the regulations – Hazardous Substances (Exempt Laboratories) Regulations 2001

### Ventilation

**All teaching spaces**
- reduce contaminants by maintaining good ventilation rates that meet standard requirements at all times (see Table 1, page 8)
- carry out regular planned maintenance on active ventilation equipment and systems
- monitor system performance

**New furniture and fittings containing formaldehyde or VOCs**
- carry out a ‘bake-off’ by having the heating full on and maximum ventilation for three days while the room is unoccupied to rid the pollutants. (Note: make sure the ‘bake-off’ will not damage furniture and fittings)

**New buildings**
- leave the building unoccupied and well ventilated for as long as possible
- carry out a ‘bake-off’ (see above)
> SECTION 6
– Humidity and Moisture Effects
Moisture in the air

Humidity is an important factor in controlling thermal comfort and air quality. While people cannot easily detect the level of humidity:

• high relative humidity (RH) – very damp air – can make people feel chilled in cold weather and hot and sticky when it’s hot
• low RH (very dry air) can cause temporary dryness and discomfort in the nose, and skin can be dry and itchy.

In addition to its effect on people:

• damp air promotes the growth of fungi (mould) and bacteria in warm weather
• damp, warm air provides ideal conditions for dust mites.

What is relative humidity?

Relative humidity is the ratio of water vapour in the air compared to the amount it could hold if it was totally saturated. This ratio is expressed as a percentage.

An RH of 30% means that the air contains 30% of the moisture it could hold if it was totally saturated to 100%. As the air temperature increases, so does the air’s capacity to hold moisture. If the air temperature rises and its moisture content stays the same, the RH becomes lower. Keeping interiors warm in winter reduces the RH.

New Zealand, because of its narrow islands, has high RH levels of 70-80% in coastal areas and about 10% lower inland during the day. On clear nights, levels reach 90-100%. Our humidity levels tend to be high all year.

Sources of moisture

Building leaks

Constant leaks into cavity spaces not only add to the general moisture content of a building, they also provide ideal conditions for the growth of various types of mould. Some of these moulds cause rot and serious structural damage. One mould which can thrive in permanently damp conditions is stachybotrys, which is toxic. It is greenish-black and grows on hidden surfaces and repeatedly wetted materials containing cellulose, such as wood framing and the paper lining of plasterboard and ceiling tiles.

Although the occurrence of stachybotrys is relatively rare, all mould should be treated with suspicion and sealed up until a diagnosis is confirmed, and specialist help is able to eradicate it. If disturbed eg, the wall lining is broken into, stachybotrys releases spores carrying poisonous substances (mycotoxins) which will affect those who inhale or make skin contact with it. Symptoms vary from mild irritations, like a runny nose, to those similar to flu. In extreme cases, it can cause immune suppression and acute or chronic central nervous system damage.

Condensation

In buildings when the RH is high and surface temperatures are low, condensation forms on the surfaces. The moisture from the air turns into water. Condensation is more obvious on cold surfaces like glass, but is not always so noticeable on plasterboard walls. Condensation on plasterboard walls may cause...
mould to grow. A sign of mould is ‘pattern’ staining on the walls, which shows up the framing behind the wall lining.

Installing insulation helps to keep surfaces warm and reduce condensation.

**People breathing and perspiring**

After break times, when students have been playing energetic games, they return to the class still hot and perspiring and this creates even more moisture in the air.

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Each person breathes out approximately 0.20 litres of moisture an hour. 30 students over six hours will contribute about 36 litres.

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**Damp ground conditions**

Many schools have suspended timber floors. Any wet ground under the floor will continuously emit water vapour which, unless removed by ventilation or drainage, can penetrate inside. Apart from structural damage, this moisture can cause:

- odours in poorly ventilated rooms
- high condensation levels
- fungal growth
- rot in untreated timber framing.

**Built-in moisture**

Large amounts of moisture are introduced into new buildings during construction in:

- wet timber
- concrete floors
- plaster
- paint.

For example, a new 100 mm thick concrete floor contains about 10 litres of free water per square metre. A concrete classroom floor will hold about 700 litres. This must dry out into the room taking approximately four months under favourable drying conditions.

**Appliances**

Appliances are not usually a major problem in schools. However, showers, cooking classes, washing machines and dryers can all contribute to odours and moisture.

**Wet clothes**

On rainy days a significant amount of moisture is brought in on wet clothes, adding to the already damp atmosphere. A separate well-ventilated room can keep most of this moisture out of the classroom.

**Fish tanks and indoor plants**

Fish tanks and indoor plants add to the moisture in a building.

**Unflued gas heaters**

Gases exhausted inside a building from unflued gas heaters contain significant amounts of moisture i.e., 2 kg water/1 kg gas burnt.
Reducing Humidity and Moisture

Measures that can be taken to reduce moisture build-up include:

**Eliminating moisture at source**

**Leaks**

- Have building leaks fixed promptly
  - reduces risk of toxic mould growth
  - reduces risk of rot and cost of later remedial work
  - if stachybotrys mould is suspected get it tested and, if necessary, have it removed by an expert – preferably from the outside to avoid spores entering the building (otherwise interior must be vacated and sealed until cleared)

**Preventative maintenance**

- Clear gutters and downpipes, regularly paint roofs, gutters and downpipes to protect them from weather.
  - cost-effective
  - reduces risk of serious water damage
  - reduces risk of leaks

**Sub-floor**

- If the ground under the building seems fairly dry, make sure that sub-floors are well ventilated by checking:
  - sub-floor ventilators are not blocked with earth or choked with plants (Figure 16)
  - baseboard vents have not been covered in
  - nothing is stored under the floor that is restricting ventilation

  - natural ventilation is needed to clear away the rising moisture
  - a cost-effective way to prevent moisture movement into the building

- If there is inadequate natural ventilation, consider installing mechanical extract
  - provides very effective sub-floor ventilation
  - is a cost-effective way to prevent moisture movement into the building
Wet sub-floor

If the ground under the building is continually wet for more than three days at a time:

- make sure ground is shaped so surface water can drain out of the sub-floor
- have polythene fitted to cover ground with sheets well lapped and fitted tightly to piles and walls to ensure water cannot pond on the polythene (Figure 16)
- if soil is rubbed on the hand and it stains, the ground is too wet
- check for plumbing leaks

- If there is ground water around the outside of the building, consider fitting surface water drains (Figure 16)
- expensive, but may be the only solution to surface water nuisance

FIGURE 16 Keeping the sub-floor dry
## Unflued heaters

Remove all gas heaters that do not have a flue vent to the outside

- reduces moisture build-up
- reduces pollution by combustion gases

## Control measures

### Condensation

- always keep the building heated to the required standard (see *Designing Quality Learning Spaces – Heating and Insulation*)
- insulate the building to the required standard (see *Designing Quality Learning Spaces – Heating and Insulation*)
- avoid cycles of hot and cold indoor temperatures
- provide good ventilation

- reduces condensation
- warm, dry surfaces discourage mould growth
- insulation reduces heat loss and heating costs
- provides comfortable, healthy environment for teachers and students

### Built-in moisture

In new buildings:

- do not allow any floor finishes to be laid until the moisture content of a concrete floor is satisfactory (75% measured RH)
- ventilate room as much as possible for as long as possible
- delay occupation of the building to allow maximum drying

*Note: the concrete drying process cannot be speeded up*

### Appliances, showers and toilets

Install mechanical extracts over cookers and washing machines

- gets rid of moisture before it becomes a problem
- local extract units are a cost-effective way of dealing with odours
- prevents odours migrating to occupied areas

Vent drying machines to the outside

Install mechanical extracts in showers, toilets and cloakrooms

### Fish tanks and pot plants

Keep plants to a minimum and do not over-water

- reduces moisture build-up

Keep fish tanks covered
Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

General ventilation and heating

People breathing and perspiring

For passive ventilation ensure:
- all windows and window opening gear are in working order
- windows are suitable for opening in all weathers without draughts or excessive heat loss (see Section 3 – Passive Ventilation)
- there is sufficient heat in winter
- windows are actually opened and teachers understand the need for this

Install HRS
- reduces RH in winter
- clears excess moisture by ventilation

Install HVAC
- reduces RH all year round
- clears excess moisture by ventilation

Heating

Keep temperatures at the recommended minimums at all times (see Designing Quality Learning Spaces – Heating and Insulation)
- keeping the air warm reduces RH
> SECTION 7
– Specialist Teaching Spaces
Multi-purpose halls are used for a wide range of activities, which often means there are conflicting acoustic, heating, ventilation and lighting requirements.

Ventilation may be needed:
- for large inactive groups – assemblies, prize-givings and recitals
- for large active groups – gymnastics or dancing
- for small active or inactive groups – teaching and rehearsals
- to clear away heat build-up from drama lighting
- on hot or cold days when curtains are drawn for black-out.

To cope with such diverse conditions, multi-purpose halls must have flexibility in the way ventilation is controlled and may require a combination of passive and active systems.

The large volume of air in large rooms enables them to cope very well with small groups of people with the minimum of natural ventilation in most conditions. When they are full to capacity in warm weather, mechanical extract may be needed to move large quantities of air.

Some form of active cooling will often be required because of the close proximity of a large number of people. Roof-top packaged air conditioning units with heat/cold recovery can be effective. However, air distribution over the whole space is equally important.

These conflicting conditions require a fine balance between ventilation control and maintenance of comfortable air temperature.

### Multi-purpose Halls

Considerations include:

#### Passive ventilation

- **Reduce solar heat gain** (see Section 3 – Passive Ventilation)
  - many halls have large windows or roof lights which cause unwanted heat build-up
- **Cross-ventilation** (see Section 1 – Ventilation Concepts)
  - cross-ventilation is possible in many halls and will help with good passive ventilation
- **Ventilation options**
  - provide a range of window sizes and positions to give flexibility
- **Stack effect**
  - thermal ventilation occurs in halls with vents up high
- **Trickle ventilation**
  - maintain steady ventilation at all times regardless of occupancy

#### Active ventilation

- **Mechanical extract**
  - some mechanical extract may help to supplement passive ventilation when needed
  - mechanical extract ventilation must be carefully designed to minimise noise
- **Air conditioning (AC)**
  - some form of air cooling may be desirable where large numbers of people will be accommodated for long periods in warm, humid weather
  - AC system must be designed to minimise noise
In gyms good ventilation is critical and heating is not so important. Table 1 suggests a high rate of ventilation in gyms – between 10 and 13 litres per second per occupant.

The large volume of air in gyms makes them well able to cope with small groups of people in most conditions. Condensation can be a problem because of the low surface temperatures coupled with high humidity caused by high respiration rates. When there are large groups in humid weather, a high mechanical ventilation rate is required.

Gyms

Considerations include:

**Passive ventilation**

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce solar heat gain (see Section 3 – Passive Ventilation)</td>
<td>gyms need good lighting but unshaded large windows cause unwanted heat build-up</td>
</tr>
<tr>
<td>Cross-ventilation (see Section 1 – Ventilation Concepts)</td>
<td>cross-ventilation is possible in many gyms and will help with good passive ventilation</td>
</tr>
<tr>
<td>Stack effect</td>
<td>thermal ventilation may be obtained in gyms with vents up high</td>
</tr>
<tr>
<td>Large windows</td>
<td>plenty of large, opening windows at high and low levels</td>
</tr>
<tr>
<td>Spectators</td>
<td>requirements are different from participants – in cold weather, warm clothing may be the best answer</td>
</tr>
<tr>
<td>Trickle ventilation</td>
<td>maintain steady ventilation at all times regardless of occupancy</td>
</tr>
</tbody>
</table>

**Humidity**

| Humidity | Expensive wooden floors can be damaged by high humidity and moisture |

**Active ventilation**

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continual mechanical ventilation with time delay to run for a time after occupants have left</td>
<td>time delay mechanical ventilation</td>
</tr>
<tr>
<td></td>
<td>short burst capacity after use of gym</td>
</tr>
<tr>
<td></td>
<td>reduces condensation</td>
</tr>
</tbody>
</table>
The ventilation requirements for libraries are the same as for classrooms. Because there tends to be less physical activity, and often fewer occupants, there can be a tendency to overlook ventilation requirements.

Libraries

Considerations include:

**Passive ventilation**

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trickle ventilation</td>
<td>• maintain steady ventilation at all times regardless of occupancy</td>
</tr>
<tr>
<td>Opening windows</td>
<td>• keep windows open when the room is occupied</td>
</tr>
</tbody>
</table>
| Reduce solar heat gain (see Section 3 – Passive Ventilation) | • libraries do not need large windows  
|                             | • natural light damages books                     |
| Dust                        | • books produce dust  
|                             | • clean shelves regularly                        |

**Active ventilation**

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active ventilation</td>
<td>• consider using air conditioning where audio visual equipment is used regularly and/or there are large numbers of computers</td>
</tr>
</tbody>
</table>
The acoustic requirements of music rooms (see Designing Quality Learning Spaces – Acoustics) may call for special solutions to ventilation. The need to either contain the noise within the room, or keep it out, may limit the scope for natural ventilation.

Small practice rooms may not be on an outside wall. Otherwise, ventilation requirements are the same as for classrooms.

### Music Rooms

Considerations include:

**Passive ventilation**

To reduce noise through windows from the outside, build additional windows outside the existing windows (see Section 3 – Passive Ventilation)

- will only reduce noise from the outside, not eliminate it
- expensive

**Active ventilation**

Install HRS (see Section 3 – Passive Ventilation)

- windows can be kept closed in cool weather
- expensive

Install air conditioning (see Section 2 – Active Ventilation)

- windows can be kept closed in all weathers
- room can be cool in hot weather
- humidity is reduced in hot weather
- humidity can damage some musical instruments
- particularly suitable for small practice rooms
- expensive
Students are moderately active in design, art and technology rooms. This is reflected in the requirement in Table 1 for a ventilation rate of 10 litres per second per person.

These rooms are likely to produce air pollutants such as:

- fumes and gases from soldering, welding and brazing
- VOCs from paint spraying, fixatives, markers and glues
- dust from cutting and sanding wood and plastics
- fibres from fabrics
- flue gases and odours from cooking.

The best way to deal with these is extraction at the source. Although this puts an extra heating load on the rooms, it is important that students are comfortable when operating machinery.

Dust from MDF board is potentially explosive and this dust may not be completely removed by normal machine extract systems. Consider redesigning the materials technology spaces in line with the Ministry of Education Architectural Design Guidelines for Technology Spaces, to create a separate machine space that is well ventilated and where hand work that creates dust not extractable at source can be carried out.

### Design, Art and Technology Rooms

Considerations include:

#### Fumes and VOCs

| General extract of fumes | • ensures that fumes from glues, markers and fixative sprays are extracted promptly  
|                         | • extracts fumes on days when air movement is low  
|                         | • highly volatile materials should be used in one area close to the extract |

| Extract hoods for cookers | • ensures that combustion gases, odours and moisture are cleared away quickly |

| Booths for spray painting | • dedicated booths with extract and air supply which takes fumes away quickly, even on still days  
|                         | • protects non-users  
|                         | • suitable masks and overalls need to be worn  
|                         | • portable zip-up booths are available  
|                         | • always supervise spraying |

| Extract for welding and brazing fumes | • provide a dedicated area with good extract  
|                                     | • carry out work in a protected outside area |

| Options for minor use of volatile materials | • use fixative and spray cans outside  
|                                           | • restrict use of sprays and glues to a small room with good extract  
|                                           | • construct a portable PVC booth |

#### Dust

| Dust extraction | • extract all dust at the machine |

| Other considerations | • avoid convectors heaters and fans — they cause turbulence and keep the dust in the air  
|                      | • clean up regularly including shelves, sills and equipment  
|                      | • re-design the materials technology space to provide a separate well-ventilated machine and hand sanding bay. |
> SECTION 8

– Children with Special Education Needs
Schools for all people

When considering ventilation and air quality for a student with special education needs, there may be some conflict between their physical needs and the needs of other students. The room temperature that suits someone with a physical difficulty that limits their movement may be uncomfortably hot for more physically active students.

The standard of ventilation recommended in this guide will be satisfactory for most students with special education needs and the need for good IAQ applies to all. Some exceptions might be students who:

• need to be free from draughts and require a warmer background temperature because they:
  – are confined to a wheelchair or have physical difficulties that limit them to a sedentary lifestyle
  – have a sight impairment that restricts their movements
• require a high rate of ventilation and cooler background temperature because they are very active
• may react to cool air or airborne pollutants eg, those with asthma.

Planning ahead

Making provision for students with special education needs must be an integral part of a school’s policies and practices. This provision must be considered at all stages of planning and construction of new buildings and refurbishments. Schools should take account of both existing and future students likely to attend the school. Generally, planning and design which makes provision for students with disabilities benefits all students and teachers.

Creative problem-solving

Because of the potential for conflict between various physical needs, careful thought and creative problem-solving are called for. The need for a range of ventilation options is important (see Sections 2 and 3).

Practical suggestions

Some ideas to help resolve conflicting requirements:

• make sure students with special requirements are dressed appropriately
• use a ceiling fan to prevent stratification of the air and uneven heating (see Designing Quality Learning Spaces – Heating and Insulation)
• make sure sedentary students spend most of their time in areas of the room that have less air movement and are warmer in cold weather
• place very active students in good natural air movement areas
• provide table or pedestal fans for localised air movement in hot, still weather.
SECTION 9

– Planning New Buildings and Extensions
– Statutory Requirements for Ventilation and Indoor Air Quality
Where new buildings or substantial alterations or extensions are planned, an architect will be appointed. The architect will be aware of the statutory requirements for ventilation and air quality. However, to ensure the best outcome, principals and boards of trustees also need to be aware of important factors about ventilation and air quality. They also need to have a basic understanding of design and building processes.

To meet all board of trustee requirements, there must be compliance with the New Zealand Building Code (NZBC). So that project money is well spent, boards should monitor ventilation and air quality requirements throughout the entire design and building process. For a good outcome it is vital that:

**Boards of trustees realise:**
- the importance of addressing ventilation and air quality requirements in school design
- ventilation and air quality need to be taken into account early in the design stage
- poor ventilation and air quality have an adverse effect on teachers and students.

**Teachers and educators understand that:**
- good ventilation and air quality in teaching spaces are important for health and general wellbeing
- a comfortable environment is a good learning environment.

**Architects and designers understand the:**
- ventilation and air quality requirements for schools
- climatic, technical and practical elements of ventilation and air quality
- importance of ventilation and air quality for health and wellbeing
- requirements of children with special education needs.

**Monitoring the design process**

**Key principles**
Principles that can be applied at the appropriate stages are set out in the Ministry of Education Property Management Handbook:

**At the initial assessment stage**
- make sure that checks are carried out to find any pollutants or residues on, or in the vicinity of, the site that could affect air quality such as:
  - previous use for land-fill, market gardening, timber treatment or toxic manufacturing processes
  - air pollutants from nearby industry or services such as dry-cleaning
  - proximity to major roads
  - the state of surface water drainage and sub-soil moisture
  - local climatic conditions
- ensure the architect is fully briefed on the:
  - statutory requirements (NZBC)
  - Ministry of Education requirements
  - NZS 4303 requirements
  - recommendations in this publication
- ventilation and air quality requirements for your school, including activities that need special ventilation.

**At the design stage**
- ask the architect:
  - to show how the local climate might influence ventilation and IAQ needs
  - how the required standard of ventilation will be achieved
  - how the window design will facilitate ventilation and control solar heat gain
  - what measures will be taken to deal with humidity, condensation and moisture to prevent mould growth
  - how air quality and ventilation relate to heating and insulation issues in the school (see Designing Quality Learning Spaces – Heating and Insulation).

The architect’s (or engineer’s) answer to these questions will involve some calculations and technical explanations which you are not expected to understand. The important point is that you are ensuring the architect has:
- given sufficient thought to these issues
- designed accordingly
- is providing specific information about how a good outcome will be achieved.

**At practical completion**
- once the building is in use, ask the architect to demonstrate that the required ventilation levels have been met by testing CO₂ levels. It is also helpful to then take a poll of students and teachers to ensure IAQ is comfortable.
There are two sources of statutory requirements for ventilation of teaching spaces (see Figure 17).

**The New Zealand Building Code**

Approved *Document G4 Ventilation* has the objective of "safeguarding people from illness or loss of amenity due to lack of fresh air". Its basic requirements are that:

- natural ventilation shall be achieved by providing a net openable area of windows, or other opening, not less than 5% of the floor area
- mechanical ventilation shall comply with NZS 4303 *Ventilation for Acceptable Indoor Air Quality*.

**NZS 4303**

This standard is not a mandatory requirement but is an Acceptable Solution under the NZBC. NZS 4303 prescribes the supply rates of outdoor air needed for acceptable IAQ, whether provided by natural or mechanical means. (See Table 1 of this guide which is adapted from Table 2 of NZS 4303.)

There may be many circumstances where a better standard of ventilation is preferable.

**Minimum requirements**

The requirements of the NZBC are a minimum. Provision of an openable area of 5% of the floor area is unlikely to provide satisfactory ventilation. The Ministry of Education recommends that:

- the advice given in this Guideline is followed wherever possible
- ventilation in school classrooms is designed to meet the requirements of NZS 4303.
> APPENDICES
– Flow diagram for Ventilation and Indoor Air Quality Assessment
– Ventilation and Indoor Air Quality Survey Form
– Indoor Air Quality Best Practice
– Summary of Pollutants, their Sources, Possible Effects and Control Measures
– References
Flow diagram for Ventilation and Indoor Air Quality Assessment

**Report of symptoms:**
- allergic reactions
- illnesses
- asthma attacks
- smells
- stuffiness

**Preliminary investigation:**
- interview pupils and staff
- speak to parents
- consult local GP
- carry out preliminary inspection

Has the preliminary investigation suggested an explanation/cause of the symptoms?

**Carry out advanced investigation:**
- identify all possible causes
- interview a wider group of people
- investigate
  - ventilation systems
  - ducting
  - leaks
  - drainage systems
- form a wide range of hypotheses
- test all hypotheses

Has the advanced investigation suggested an explanation/cause of the symptoms?

**Bring in appropriate specialist assistance:**
- ventilation engineer
- building technician
- medical officer of health
- drainage engineer

**Have you found the cause of the problem?**

Control:
- take corrective action
- measure/ascertain effectiveness of corrective action

Prevention:
- check for other potential sources of the same problem
- put in place a proactive checking system

Has the problem been solved?

YES

NO
Ventilation and Indoor Air Quality Survey Form

Use this survey form to help you assess the ventilation and air quality in your classrooms.

1. Are students listless, yawning and sleepy in any of the classrooms in cold weather?
   Yes ☐ No ☐
   Comment: This is one indication that carbon dioxide levels are building up in classrooms. Check that:
   • windows are being opened
   • sufficient fresh air is circulating through the room.
   Consider having some rooms monitored for CO$_2$ build up.

2. Are students listless, yawning and sleepy in any of the classrooms in warm weather?
   Yes ☐ No ☐
   Comment: This may indicate that:
   • there are insufficient opening windows
   • the windows will not open
   • the room is overheated through solar heat gain.
   In warm regions consider some form of active ventilation system which can cool the air.

3. Are windows not being opened sufficiently to provide adequate ventilation?
   Yes ☐ No ☐
   Comment: Windows may not be opened because:
   • they don’t work properly
   • the heating is not adequate to cope with the heat loss caused by opening the windows
   • they are the wrong size or in the wrong place
   • there is too much noise outside.

4. Do students or teachers suffer from an unusual number of colds, unspecified illnesses or headaches?
   Yes ☐ No ☐
   Comment: This may be another indication that CO$_2$ levels are high. If the room is ventilated adequately, smells may indicate the air is polluted from:
   • mould caused by dampness
   • gases.

5. Are there complaints about smells and mustiness?
   Yes ☐ No ☐
   Comment: Smells may come from:
   • mould and dampness on walls or in carpets
   • nearby toilets or septic tanks
   • badly placed exhausts from kitchens and labs
   • students perspiring after active breaks
   • new furniture.

6. Is there an unusual number of allergic reactions, such as asthma attacks, among students and teachers?
   Yes ☐ No ☐
   Comment: Allergic reactions could be a sign that:
   • mould is growing in the building
   • carpets and soft furnishings contain a high level of dust mites
   • cleaning is unsatisfactory.

7. Are there any persistent leaks in the building?
   Yes ☐ No ☐
   Comment: Leaks have the potential to:
   • cause structural damage
   • support the growth of toxic or allergic moulds
   • increase the humidity and dampness in the building.
   Leaks must be fixed promptly.

8. Do windows sometimes run wet with condensation?
   Yes ☐ No ☐
   Comment: Measures should be taken to reduce internal humidity.

9. Have you started an IAQ management plan?
   Yes ☐ No ☐
   Comment: An active IAQ management plan is an effective way to monitor and control ventilation and air quality in your school.
Indoor Air Quality Best Practice

Make ventilation and IAQ part of the school’s property health and safety policy:
• helps to identify unsatisfactory situations and practices
Encourage teachers and students to participate in its development
• encourages knowledge about when windows should be open
Do spot checks on CO\textsubscript{2} levels in occupied classrooms:
Consider sharing the cost of a CO\textsubscript{2} data logger with other schools
• raises awareness
• gives guidance on potential problems
Turn heating on early on cold mornings or have a low level of heat on all night during the week
• makes rooms warm enough to allow windows to be opened from the start of the day
• may be cost-effective
• reduces condensation
Keep window catches, hinges, stays and opening gear in good working order
• windows that don’t work are not opened
Free up and repair painted wooden windows and replace broken sash cords
• ventilation in many older buildings is restricted by the number of windows that can be opened because of poor maintenance
Ensure someone in the school is made responsible to
• investigate complaints
• help identify possible sources of pollution
• obtain expert help when necessary
• encourage awareness
Establish a complaints procedure to ensure
• details of complaints are recorded
• complaints are followed up and investigation is carried out
• if problems cannot be solved promptly there is no relaxation of effort
• progress reports are given
Be proactive
• don’t wait for complaints
• carry out checks and question people eg, every six months
Control indoor contaminants
• use materials with low contaminant emissions
• seal or enclose contaminants
• extract air at source
• more details about controlling contaminants can be found in Section 5
Reduce humidity and moisture
• Section 6 gives detailed practical advice on how to achieve this
### Summary of Pollutants, their Sources, Possible Effects and Control Measures

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Possible sources</th>
<th>Possible effects</th>
<th>Control measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon dioxide (CO2)</strong></td>
<td>Occupants breathing</td>
<td>Stuffiness and odours</td>
<td>Make sure that recommended ventilation rates are achieved to replace contaminated air</td>
</tr>
<tr>
<td></td>
<td>All combustion processes such as unflued gas heaters</td>
<td>Unlikely to be a health hazard, but at low concentrations may cause headaches and dizziness</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High concentrations are an indicator of low ventilation rates</td>
<td></td>
</tr>
<tr>
<td><strong>Carbon monoxide</strong></td>
<td>All combustion processes such as unflued gas heaters</td>
<td>Headaches at low concentrations</td>
<td>Good ventilation</td>
</tr>
<tr>
<td></td>
<td>Industrial sources outside the site</td>
<td></td>
<td>No unflued heaters</td>
</tr>
<tr>
<td></td>
<td>Vehicle exhaust fumes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oxides of nitrogen</strong></td>
<td>Outside industrial sources</td>
<td>No effects at low concentrations likely in schools</td>
<td>Good ventilation</td>
</tr>
<tr>
<td></td>
<td>All combustion processes</td>
<td></td>
<td>No unflued heaters</td>
</tr>
<tr>
<td></td>
<td>Unflued gas heaters</td>
<td></td>
<td>Vent activities such as welding at source</td>
</tr>
<tr>
<td></td>
<td>Welding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vehicle exhaust</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fungi (moulds)</strong></td>
<td>Growth is possible in damp conditions and where there is high humidity and condensation</td>
<td>May cause allergic reaction in some people</td>
<td>Maintain relative humidity below 70%</td>
</tr>
<tr>
<td></td>
<td>Moulds grow on most surfaces if conditions are suitable</td>
<td>Respiratory problems, coughs and colds</td>
<td>High level of heat insulation to reduce condensation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Good building maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maintenance of ventilating systems and ducts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clean to remove moulds regularly</td>
</tr>
<tr>
<td><strong>Stachybotrys</strong></td>
<td>Stachybotrys is a mould common in leaking wall and roof cavities</td>
<td>The spores are toxic</td>
<td>Have leaks fixed promptly by experts</td>
</tr>
<tr>
<td></td>
<td>High levels of spores are likely when linings are removed</td>
<td>Reactions between mild irritation like a runny nose, to acute central nervous system damage</td>
<td>Repair by expert</td>
</tr>
</tbody>
</table>
### Designing Quality Learning Spaces: Ventilation and Indoor Air Quality

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Possible sources</th>
<th>Possible effects</th>
<th>Control measures</th>
</tr>
</thead>
</table>
| **Bacteria and viruses** | Carried in by people, animals and insects and attached to airborne dust and moisture particles | Most infectious diseases, colds, flu etc | Good ventilation  
                           | Wet carpets                                                                 |                           | Good cleaning policy  
                           |                                                                                       |                           | Maintenance of ventilating systems and ducts  
                           |                                                                                       |                           | Isolation of known carriers |
| **Legionnaire's disease** | bacteria thrive in warm, damp conditions such as evaporative coolers, hot water systems and compost | Chronic respiratory disease | Maintenance and cleaning of water spray systems  
                           |                                                                                       |                           | Hot water heaters set at 60°C minimum  
                           |                                                                                       |                           | Wear masks when handling soil |
| **Dust mites**         | Carpet and soft furnishings                                                      | Allergic reaction, particularly in asthmatics | Maintain warm, dry conditions  
                           |                                                                                       |                           | Good carpet and furniture cleaning policy  
                           |                                                                                       |                           | Use vinyl flooring |
| **Dust (particles) and fibres** | Pollens and spores from outdoor sources  
                           | Fibres from clothing, upholstery, carpets and animals  
                           | Dust  
                           | Fibre-glass insulation                                                                 | Respiratory problems  
                           |                                                                                       | Skin reactions          | Good ventilation  
                           |                                                                                       |                           | Good cleaning policy  
                           |                                                                                       |                           | Mechanical ventilation with filters |
| **Asbestos**           | Hot water pipe insulation in heating plant (usually industrial and now rare)  
                           | Sprayed textured ceilings                                                                 | Carcinogenic Asbestosis | Employ specialists to remove insulation or textured coatings  
                           | Asbestos cement, roofing, wall cladding.  
                           | Is not a hazard if in good condition                                                      | Carcinogenic Asbestosis | Keep cladding paint in good condition  
                           |                                                                                       |                           | Paint cladding  
                           |                                                                                       |                           | Employ specialists to remove damaged cladding |


### Pollutant: Fibre-glass
- **Possible sources**: Insulation in roofs and walls
- **Possible effects**: A skin, eye and nose irritant
- **Control measures**:
  - Ensure insulation is contained within the building cavities
  - Use natural fibre insulation
  - Use Dacron insulation

### Pollutant: Formaldehyde
- **Possible sources**: Particleboard, plywood, carpets, furniture and fabrics
- **Possible effects**: Allergic reactions, eye, skin and throat irritations, Possible carcinogenic
- **Control measures**:
  - Good ventilation
  - Use low emission products
  - Seal particleboard with low VOC sealer
  - Use ‘bake-off’ technique

### Pollutant: Volatile organic compounds (VOCs)
- **Possible sources**: Gases given off by paints, cleaning materials, adhesives, Polyurethane carpets, Furniture, Art marker pens
- **Possible effects**: At low levels they are not a concern. At occasional higher levels they can cause nose and skin irritations, headaches and breathing problems
- **Control measures**:
  - Good ventilation
  - Use products with low VOCs

### Pollutant: Heavy metals
- **Possible sources**: Lead-based paint, Mercury spills
- **Possible effects**: Unlikely to be in sufficient concentration to cause problems. In sufficient concentrations can cause a variety of serious reactions
- **Control measures**: Test and remove suspected contamination by specialist experts
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