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Ventilation and Indoor Air Quality in Schools – Guidance Report 202825

Building Research Technical Report 20/2005

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Paul Ajiboye, Martin White,
Hilary Graves and David Ross
Building Research Establishment for
Office of the Deputy Prime Minister: London

Office of the Deputy Prime Minister
Eland House
Bressenden Place
London SW1E 5DU
Telephone: 020 7944 4400
Web site: www.odpm.gov.uk

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Executive Summary

This report is deliverable number 202825 of project cc2108 'Ventilation and Indoor Air Quality in Schools'. Responsibility for the ventilation of schools premises has been transferred from the Department for Education and Skills (DfES) to the Building Regulations Division of ODPM. The ventilation design of schools now falls under the control of Buildings Regulation Approved Document F. A previous literature review of research carried out in schools (BRE Client Report 216084) has highlighted the fact that little is known about the ventilation performance of schools. By comparison, within the UK, there is significant information available for other indoor environments, such as workplaces and dwellings, and the benefits derived from good ventilation and indoor air quality.

This report presents the findings of a study into the ventilation rate and indoor air quality in eight primary schools across England. Two classrooms were investigated in each school for a week. All schools had building approval post-1995 (i.e. since last revision of Approved Document F). This builds upon a pilot study that examined the same issues in two schools (White M and Mohle G, 2001). The schools for this study were selected from a list provided by the DfES.

The main findings are as follows:

- Ventilation rates were measured in each classroom for a 45 minute period each afternoon. In each school there were occasions when the ventilation rate was below the minimum rate required of 3 L/s (The School Premises Regulations, 1999). In total, 50% of measurements were below this value.

- Ventilation rate can also be estimated from carbon dioxide (CO_2) concentrations with 3 L/s being equivalent to 2100 ppm of CO_2 under equilibrium conditions. CO_2 concentrations were measured continuously daily in each classroom. Approximately 40% of classrooms achieved mean CO_2 concentrations across the day of 1000 ppm or lower and approximately 88% of classrooms achieved mean CO_2 concentrations across the day of 2100 ppm or lower.

- Temperature ranged between 17 – 25°C. For optimum comfort the levels should be between 18 and 23°C and these levels were achieved for the majority of the school day.

- Relative humidity ranged between 30 – 75%. For optimum comfort the levels should be between 40 and 75% RH and these levels were achieved for the majority of the school day.

- Levels of volatile organic compounds (VOCs) were measured in each classroom for a 45 minute period each afternoon (concurrently with ventilation measurements). Levels of total volatile organic compounds (TVOCs) were compared against a proposed guideline value of 300 µg m^{-3}. It was found that 21% of samples exceeded this limit and these high values originated from four schools. The highest level observed was approximately 700 µg m^{-3}. It was noted by the researchers that on at least some of the occasions where TVOC concentrations >300 µg m^{-3} were recorded, art work was undertaken concurrently or just prior to the measurements and such activities would tend to increase TVOC levels (e.g. from paints or solvents). An additional factor was that all the schools were fairly new (post

1995) and could have been naturally releasing chemicals from carpets, walls and furniture surfaces.

- Aldehyde levels were measured for 30 minutes in each classroom on most days, soon after the children had left at the end of the day. No levels exceeded World Health Organisation (WHO) guideline values.

- Levels of carbon monoxide (CO) and nitrogen dioxide (NO_2) were monitored continuously in each classroom daily. The CO and NO_2 levels were all within WHO guideline values.

- Bacteria levels were measured in each classroom on five occasions on one day. Measurements were also taken outside on these days. The values were compared against a European proposed rating scheme. Approximately 60% of classrooms had a 'high' rating for bacteria. The rating was typically 'low' or 'very low' outside. This result is to be expected. Children moving around, the mechanics of clothing brushing against skin etc will all dislodge skin scales and dust particles that will contain many millions of bacterial organisms. Note that it is not possible to determine the risk of infection from these results. The organisms cultured for are regarded as non-pathogenic in persons with normal immune systems. Infection risk would vary depending on a number of factors including pathogenicity of a particular organism, method and ease of transmission of the organism, duration of exposure and the susceptibility of the other children and teachers.

- Fungi were measured concurrently with bacteria. Approximately 20% of classrooms had a 'high' rating for fungi. Similar levels were detected outside of the schools and this suggests that the main source of internal fungi levels is the outside air.

- Dust mites were sampled on a single day in each classroom. All levels were rated 'low'.

- PM_{10} levels were monitored in each school. All levels were within the UK National Air Quality Strategy guideline value.

- Ultrafine particle numbers were monitored both inside and outside each classroom. There are no UK guideline values for ultrafine particles. The values were similar both inside and outside of the classrooms and this suggests the principal source is external.

Ventilation intervention studies were undertaken in two of the schools. Whilst limited, they did show that through the greater use of windows the ventilation rate can be increased with a small impact on thermal comfort . In discussions with teachers, there are a number of reasons to explain why teachers (and classroom assistants) avoid using windows as often as they could. These include the need to prevent noise and cold air entering rooms, and the desire to conserve energy by reducing heat loss.

Overall, the ventilation rate was often below the minimum recommended levels in classrooms whilst occupied. However, the more important question is whether it is a problem. In a number of classrooms relatively high TVOC levels were recorded on occasions. However, it is suggested that this is often due to new decoration and furnishings or to the use of art materials. It would be much more energy efficient to address this, if required, through source control. Lower VOC emitting products could be used and/or behavioural changes could be made such as promptly putting the tops back on solvent containers.

The bacteria counts were also rated as 'high' in a majority of classrooms. The potential implications of this are increased infections amongst children and staff.

Within this work, the implication of individual environmental parameters on health and comfort has been discussed. In addition, there will be a synergistic effect of the combination of parameters. The consequence of this cannot be assessed from this study. Furthermore, this study has not attempted to determine the impact of the indoor environment on the children's performance. The literature review showed that there have been few studies in this area, although they do show evidence of an impact on performance. Certainly within workplaces, studies have shown a relationship with increased ventilation and better performance and productivity.

Finally, this has been the largest detailed study of ventilation rate and indoor air quality within UK primary schools. Whilst the sample size is relatively small and care must be taken in interpreting the results, significant new information has been obtained and it provides a much better understanding of the indoor environment within primary schools. Further work should build on this, focusing resources on the major issues highlighted by this study (e.g. improved ventilation design and usage, reducing TVOC and bacteria levels) and extending it to other issues, such as establishing the impact of the indoor environment on children's performance.

CHAPTER 1

Introduction

This report is deliverable Number 202825 of project cc 2108 'Ventilation and Indoor Air Quality in Schools'. Responsibility for the ventilation of school premises has been transferred from the DfES to the Building Regulations Division of the ODPM. The ventilation design of schools now falls under the control of Buildings Regulation Approved Document F. A previous literature review of research carried out in schools (BRE Client Report 216084) has highlighted the fact that little is known about the ventilation performance of schools built since 1995. By comparison, within the UK, there is significant information available for other indoor environments, such as workplaces and living spaces, and the benefits derived from good ventilation and IAQ.

The purpose of main monitoring phase of this study is to examine the ventilation and indoor air quality (IAQ) levels within eight primary schools. This report summarises the ventilation and IAQ levels obtained and discusses whether they are adequate.

Ventilation rates required in schools are stipulated in the School Premises Regulations (1999). Within teaching areas, the minimum ventilation rate required is 3 L/s per person. In addition, the ventilation provision should also be capable of achieving 8 L/s per person.

There are a number of potential indoor air quality factors that could impact on the health, comfort and performance of the school occupants. These include internally generated pollutants, such as human bio-effluents, organic emissions from building materials and furnishings (e.g. the furniture, carpets, surface finishing), as well as allergens from house dust mites etc. There may also be external pollutants, such as the ingress of combustion products from traffic, or fungi. Comfort criteria also require temperature and relative humidity levels to be kept under control.

The schools studied were selected from a list supplied by the DfES. All the schools were naturally ventilated, and were built post 1995. The main monitoring phase follows on from a pilot investigation that was completed earlier in the project (White M K and Mohle G. (2001)).

The primary schools selected for this study are as follows;

- West Grove Primary School
- Moorside Primary School
- Wavendon Gate Combined School
- Bramingham Primary School
- Baltonsborough Primary School
- Gallions Primary School
- Queenswell Primary School
- Victoria Junior School

The monitoring protocol adopted in all schools is summarised in the sections that follow. Investigations focused upon ventilation rates and indoor air quality parameters. In addition, brief ventilation intervention studies were performed to see whether ventilation rates could be increased and IAQ improved.

CHAPTER 2

Measurement protocol undertaken in schools

2.1 Details of the main study

2.1.1 DETAILS OF THE SCHOOLS EXAMINED

A long list of schools built from 1995 was provided by the DfES. From this list eight schools were selected. Studies were conducted in the winter months, although in one case the weather outside was still quite warm.

Table 1 provides some details about each school; further information is in Appendix A.

Table 1: Details of the schools involved in the study

School name	Classrooms	Ventilation strategy	Location	Date
West Grove Primary	Class T53 and Reception class (T15)	Cellular classrooms. T15 – ground floor, T53 – first floor. Ventilation via openable windows	Urban in London	Sept – 02
Moorside Primary	Infants class (2W) and Junior class (6F)	Cellular classrooms. Ventilation via openable windows	Urban and next to a busy road in Manchester	Oct – 02
Wavendon Gate Combined	Class 2H (HB1) and Class 7Cr (HB12)	Semi-open plan classrooms on ground floor. Ventilation via openable windows	Suburban in Milton Keynes	Nov – 02
Bramingham Primary	Class 2 and Class 10	Semi-open plan classrooms – ground floor. Ventilation via openable windows	Suburban in Luton	Jan – 03
Baltonsborough CE VC Primary	Class 1 and Class 3	Cellular classrooms – ground floor. Ventilation via openable windows	Rural village near Glastonbury	Feb – 03
Gallions Primary School	Year 2 class and Year 6 class		Urban in London	Oct – 03
Queenswell Primary School	Reception class and Year 2 class	Cellular classrooms – ground floor. Ventilation via openable windows	Urban and next to a busy road in London	Nov – 03
Victoria Junior School	Class 6 and Class 12	Semi- open plan classrooms. C6 – first floor, C12 – ground floor. Ventilation via openable windows and trickle vents	Urban in Workington	Nov – 03

2.1.2 PARAMETERS MEASURED

The basic methodology for monitoring in all schools is provided in Appendix B. The following parameters were examined during the course of a week long investigation at each school

Indoor Air Quality parameters

- Volatile organic compounds
- Carbon monoxide and Nitrogen dioxide
- Aldehydes
- Particulate matter, including ultra-fine particles
- Fungi and bacteria
- Dust mites

Ventilation parameters

- Ventilation rate
- Carbon dioxide

Other parameters measured

- Temperature
- Relative Humidity

The following bullet points summarise how these parameters were measured in the schools.

- Volatile organic compounds were measured each day using the 'Perkin-Elmer Tenax TA' Tubes and an 'SKC' pump. Each sample was taken over 45 minutes at about 14:30 in the afternoon in conjunction with the ventilation measurements. In the first school, West Grove, two pairs of diffusive sampling Tenax TA tubes were also put out in both classrooms and left in place for the whole monitoring period.

- Aldehydes were sampled using 'Waters Sep-pak Xposure Aldehyde' cartridges. Sampling took place after the children had left at the end of each school day for four days in each classroom. This was a 30 minute sample using an 'SKC' pump set up for this purpose. The pumps were placed in the centre of the classrooms.

- PM_{10} particulates were monitored using an in-house sampler incorporating a 'Charles Austin Capex LSC' pump and a PM_{10} sampling head fitted with a preconditioned glass micro-fibre filter. Two PM_{10} samplers were used in each school. A daily sampler collected a volume of 5 litres of air per minute for approximately 7 hours each day of the school week. The second was run over a 24 hour period with its sampling head next to the other. The equipment was located in the main corridor of the school.

- Ultra-fine particulates were measured using a TSI P-Trak meter. This is a hand held instrument that also logs readings and so can either be used to take spot measurements or can be left in place to monitor over a longer period. The meter was used in both ways; e.g. at Moorside School it was used for spot measurements and at Wavendon Gate School it was left in place in one of the classrooms for a whole day.

- Fungi and bacteria samples were also taken at each school. On one day fungi and bacteria samples were taken over a one-minute period in classrooms five times during the day. A 1-minute sample of fungi and bacteria was also taken at three intervals in the outdoor environment.

- Dust mites were also sampled on a single day in the two classrooms using a specially adapted vacuum cleaner to collect a sample of dust mites on a filter from a 1 m^2 floor area.

- Ventilation rates were measured using the perfluorocarbon tracer (PFT) technique. This technique uses two components, sources and sample tubes. In the schools that are close to BRE the sources were set out during a visit made on the Friday prior to the monitoring week. For the schools in Manchester, Somerset and Workington this was not possible, so the sources were set out on first arriving at the school on the Monday morning, before the sample tubes were set up. Sampling was carried out in each classroom using a programmable 'SKC' pump with a four-point manifold. Two VOC and two PFT sampling tubes were attached to the manifold and the pumps were set in place. They were programmed to start at 14:30 and to run for 45 minutes. This drew sufficient air into each sample tube to capture an adequate sample. The pumps were placed at an appropriate location in each classroom usually near the carbon monoxide/nitrogen dioxide sampler.

- Ventilation rates were also calculated from the CO_2 measurements, based on an estimate of the CO_2 emission rate of the occupants. There is little guidance on estimating this rate. CIBSE Guides A, B and C suggest that children emit heat at a rate 85% of that of adults and BS 5925 (1991) provides metabolic rates for adults. However assessing the activity level of children in a classroom is difficult. The analysis presented here is based on taking the range of metabolic rates for light activity, 160 – 320 W (this was adjusted for children by multiplying these values by 0.85) and calculating the range of ventilation rates in L/s per person.

- Carbon monoxide and nitrogen dioxide (CO and NO_2, respectively) were measured over the five-day period using a pumped sampler system consisting of an electrochemical cell with a datalogger. These were placed in an appropriate location in each of the chosen classrooms.

- Carbon dioxide (CO_2) measurements were taken with continuously monitoring infrared 'Anagas' analysers. A passive sampling analyser was placed in each classroom each morning (around 8:30am) and logged at five minute intervals until the end of the school day (3:30pm). CO_2 spot measurements were taken throughout the day at a number of locations throughout each school.

- Temperature and Relative Humidity (RH) 'Tiny Talk' data-loggers were placed in each classroom and at an outside location and were used to record conditions continuously.

CHAPTER 3

IAQ and ventilation rates measured in schools

3.1 Indoor air quality results

Appendix C contains all the results for IAQ measurements.

3.1.1 VOLATILE ORGANIC COMPOUNDS

There are no UK guidelines for concentrations of volatile organic compounds (VOCs) or total VOCs (TVOCs) in the indoor air. Instead a number of international guidelines can be used to provide some indication as to whether levels measured in the schools are above desirable limits. A value of 300 µg m^{-3} is a useful benchmark value to adopt as a guideline value for TVOCs, being less stringent than the value suggested by some authorities and more stringent than that recommended by other groups. (Appendix D, table 1).

Volatile organic compounds (VOCs) at West Grove primary school

Tables 1 – 6 in Appendix C present the levels of VOCs found in the two classrooms. The compounds detected in significant amounts, alpha-pinene, limonene and nonanal are likely to come from scent agents used in perfumes or cleaning products or from wood products; there are no guideline levels for these compounds.

P-dichlorobenzene (p-DCB) is used as a moth repellent, toilet cleaner and, possibly, in disinfectants. The concentrations of this compound was higher in the reception class, which may be connected to its proximity of the toilets. The HSE occupational exposure limit for p-DCB is 153,000 µgm^{-3} for an 8 hour working day (industrial environment). The measured values are much lower than this (<48 µgm^{-3} for a 45 minute sample).

TVOC concentrations are below 300 µg m^{-3} in both classrooms. These results were observed for both the active sampling process as well as the diffusive sampling technique. The highest recorded mean TVOC concentration was 278 µg m^{-3} found in the reception class on 13/09/02.

The readings from the diffusive sampling tubes were in quantities consistent with those from the active samples.

VOCs at Moorside primary school

The TVOC values are shown in tables 7-9 of Appendix C. In all instances values are below 300 µg m^{-3}. The highest mean value recorded was 256 µg m^{-3} in the infant class on 18/10/02.

VOCs at Wavendon Gate combined school

TVOC results are shown in tables 10 -12 of Appendix C. In classroom 2H concentrations exceeded 300 µgm^{-3} on 50% of occasions. The highest mean value was 487 µg m^{-3}, which is

below guideline values recommended by groups from Australia and Finland (Table 1 of Appendix D).

VOCs at Bramingham primary school

Tables 13–18 in Appendix C present the concentrations of VOCs in both classrooms. No individual compounds exceeded guideline values, where these are available. The compounds detected in significant amounts included alpha-pinene, and limonene.

TVOC concentrations exceeded 300 µg m^{-3} on 50% of occasions in both classrooms. The highest mean value recorded in the school was 662 µg m^{-3} recorded in class 10 on 16/01/03. High levels of 2-butoxyethanol, alpha-pinene, limonene and Butan-1-ol were particularly observed when the TVOC figure was high.

VOCs at Baltonsborough primary school

Tables 19-24 provide the results of measurements of VOC in the school.

Mean TVOC concentrations were below 300 µg m^{-3} on each of the three sampling occasions in classroom 1. In classroom 3, the highest mean TVOC concentration (304 µg m^{-3}) was recorded on 20/02/03. High concentrations can be attributed to recent wall painting that had taken place in the classroom. Outdoor concentrations of TVOC were found to be low (mean value of 21 µg m^{-3}).

VOCs at Gallions primary school

VOC and TVOC concentrations are found in tables 25-30 in Appendix C. Concentrations of VOCs were all well below guideline values for the classrooms and outdoors.

TVOC concentrations were all well below guidelines set out in Table 1 of Appendix D, for both classrooms. The highest mean TVOC concentration recorded in the school was 137 µg m^{-3} recorded in the year 6 classroom on 22/10/03.

VOCs at Queenswell infant school

VOC and TVOC concentrations are found in Tables 31-36 in Appendix C. In most instances TVOC concentrations were below guidelines set out in table 1 of Appendix D. On one day in the reception class the elevated TVOC concentration (mean concentration 1094 µg m^{-3}) may have been due to the presence of propan-2-ol which is released during use of the p-trak particle monitor. The mean TVOC concentration on this occasion with the contribution for propan-2-ol removed was 251µg m^{-3} .

VOCs at Victoria junior school

Tables 37-42 provide the results of VOC measurements in the school (as well as an outdoor sample). Of the two classrooms (class 6 and class 12) the latter had the higher concentration of VOCs. This was due to elevated levels of alpha-pinene, butan-1-ol, methylisobutylketone and 2-ethylhexan-1-ol.

Whereas in classroom 6 TVOC levels never exceeded 300 µg m^{-3}, in classroom 12 concentrations were consistently above 300 µg m^{-3}, reaching a peak of 502 µg m^{-3} .

3.1.2 CARBON MONOXIDE (CO) AND NITROGEN DIOXIDE (NO_2)

The WHO guideline values for CO and NO_2 are found in Table 2 of Appendix D. One hour average guideline values are 26 ppm and 110 ppb, respectively.

CO and NO_2 at West Grove primary school

The results of the sampling are shown in Tables 43, 44, 69 and 70 of Appendix C. Levels of CO (<2.8 ppm) and NO_2 (<50 ppb) in all classrooms are well below the guideline values.

CO and NO_2 at Moorside primary school

The results of the sampling are shown in Tables 45, 46, 71 and 72 of Appendix C. Levels of CO (<1.2 ppm) and NO_2 (<78 ppb) in all classrooms are all below the guideline values.

CO and NO_2 at Wavendon Gate combined school

The results of the sampling are shown in Tables 47, 48, 73 and 74 of Appendix C. Levels of CO (< 0.7 ppm) and NO_2 (<102 ppb) in all classrooms are below the guideline values.

CO and NO_2 at Bramingham primary school

The results of the sampling are shown in Tables 49 – 52 and 75 – 78 of Appendix C. Levels of CO (< 0.6 ppm) in all classrooms are well below the guideline values. This is also the case in the majority of NO_2 measurements in both classrooms (<66 ppb). However on one occasion in classroom 2 an individual value of 133 ppb was recorded. On this occasion the 1-hour mean concentration, however, was 22 ppb, showing that the high level did not persist for long, and therefore the guideline value was not exceeded.

CO and NO_2 at Baltonsborough primary school

The results of the sampling are shown in Tables 53 – 56 and 79 – 82 of Appendix C. Levels of CO (<1.3 ppm) in all classrooms are well below the guideline values. This is also the case for NO_2 (<52 ppb).

CO and NO_2 at Gallions primary school

The results of the sampling are shown in Tables 57 – 60 and 83 – 86 of Appendix C. The levels of CO (<4.1 ppm) and NO_2 (<35 ppb) in both classrooms are well below the WHO guideline. The slightly higher levels in Year 2 could possibly be due to its location at the front of the school near to busy roads.

CO and NO_2 at Queenswell infant school

The results of the sampling are shown in Tables 61-64 and 87-90 of Appendix C. Levels of CO (<4.7 ppm) and NO_2 (<78 ppb) in all classrooms are well below the guideline values.

CO and NO_2 at Victoria Junior school

The results of the sampling are shown in Tables 65-68 and 91-94 of Appendix C. Levels of CO (<8.5 ppm) and NO_2 (<61 ppb) in all classrooms are well below the guideline values.

3.1.3 FORMALDEHYDE AND ACETALDEHYDE

The WHO (2000) guideline level for formaldehyde is 100 µg m^{-3} as a 30 minute average. The WHO guideline (1999) for acetaldehyde is 50 µg m^{-3} over a 1 year averaging period or 2000 µg m^{-3} over a 24 hour averaging period. The measured values reported below are as 30 minute averages.

Formaldehyde and acetaldehyde at West Grove primary school

Tables 95 and 96 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 40 and 18 µg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Moorside primary school

Tables 97 and 98 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 25 and 8 μg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Wavendon Gate combined school

Tables 99 and 100 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 62 and 23 μg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Bramingham primary school

Tables 101 and 102 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 48 and 25 μg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Baltonsborough primary school

Tables 103 and 104 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 30 and 14 μg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Gallions primary school

Tables 105 and 106 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 30 and 14 μg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Queenswell infant school

Tables 107 and 108 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 22 and 8 μg m^{-3}, respectively.

Formaldehyde and acetaldehyde at Victoria junior school

Tables 109 and 110 in Appendix C provide the results for these compounds as measured in classrooms. On all occasions concentrations of formaldehyde and acetaldehyde are well below the WHO guideline values. The maximum recorded values for formaldehyde and acetaldehyde were 65 and 14 μg m^{-3}, respectively.

3.1.4 PARTICULATE MATTER (PM_{10} AND ULTRA FINE)

PM_{10} particles

The UK National Air Quality Strategy guideline level for PM_{10} is 50 μg m^{-3} as a 24-hour mean (DEFRA, 2001). There are currently no limits in relation to ultra fine particulates.

Table 111 in Appendix C provides the full results of PM_{10} across all schools. This indicates that on no occasions did concentrations exceed the guideline value. The maximum recorded value was 43 μg m^{-3} recorded in West Grove school over each school day from 9-12/09/02.

Ultra fine particles

There are no guidelines on ultra fine particles levels in the UK. The results of these measurements are provided in the following tables (Tables 2 – 9). Values ranged from approximately 3000 to 20000 cc^{-1}. In each school results are similar inside and outside, suggesting that particulate levels in classrooms are related to those outside. Sources of these particulates are combustion products, e.g. from vehicles and industrial emissions.

Table 2: Ultra-fine particle counts for West Grove school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Reception	12236	12043	11863
T53	14611	12068	9737
Outside	14590	12317	9242

Table 3: Ultra-fine particle counts for Moorside school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Infant Class	19800	13770	9230
Junior class	13300	9702	7170
Outside	39600	18898	8920

Table 4: Ultra-fine particle counts for Wavendon Gate school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Class 7Cr (HB12)	15141	10639	5511

Table 5: Ultra-fine particle counts for Bramingham primary school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Classroom 2	21120	7381	2731
Outside	8000	7723	7355

Table 6: Ultra-fine particle counts for Baltonsborough school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Outside	24466	6349	3544

Table 7: Ultra-fine particle counts for Gallions primary school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Year 2	6612	6164	5630
Year 6	11581	7923	5822
Outside	14985	13969	12970

Table 8: Ultra-fine particle counts for Queenswell Infant school

Location	Maximum count cc^{-1}	Average count cc^{-1}	Minimum count cc^{-1}
Reception	9848	8434	7556
Year 2	13401	12642	11598

Table 9: Ultra-fine particle counts for Victoria Junior school			
Location	**Maximum count cc^{-1}**	**Average count cc^{-1}**	**Minimum count cc^{-1}**
Outside	10198	4043	2094

3.1.5 FUNGI AND BACTERIA

Categories have been defined that describe count levels for fungi and bacteria. These categories range from 'very low' (concentrations <25 and 50 cfu m^{-3} for fungi and bacteria in non industrial indoor environments, respectively) to 'very high' (concentrations >2,000 cfu m^{-3} for both fungi and bacteria in non industrial indoor environments) and are presented in Table 3 of Appendix D. The measured values reported below for each classroom are the means of the sampled values measured over the week.

Fungi and bacteria at West Grove primary school

Table 112 provides the results for the inside and outside spaces of both classrooms. Mean concentrations of bacteria are defined as high in both classrooms (although values only just enter this category). Outside the classrooms bacteria concentrations are either low or very low. The maximum bacteria count is 1250 cfu m^{-3}.

Mean fungi concentrations are low in both classrooms but defined as intermediate outside classrooms. The maximum count is 990 cfu m^{-3}.

Fungi and bacteria at Moorside primary school

Table 113 provides the results for the inside and outside spaces of both classrooms. In the infant class the mean concentration of bacteria is defined as high. In the junior class bacteria levels are defined as intermediate. The maximum value recorded for bacteria is 950 cfu m^{-3} which is defined as high. Outside both classrooms the levels are low and very low, respectively.

Mean concentrations of fungi are defined as intermediate in both classrooms. This is also the level of fungi found outside of classrooms. The maximum recorded value was 480 cfu m^{-3} which is also defined as intermediate.

Fungi and bacteria at Wavendon Gate combined school

Table 114 provides the results for the inside and outside spaces of both classrooms. Mean levels of bacteria are between 500 – 1000 cfu m^{-3} and therefore are defined as high. The maximum recorded value was 1640 cfu m^{-3}, which also falls in the high category. Outside of the classrooms concentrations decrease and are either low or very low.

Mean fungi levels in both classrooms of 200-340 cfu m^{-3} are defined as intermediate. Outside both classrooms concentrations rise to 550 – 710 cfu m^{-3}, which is defined as high. The maximum concentration recorded is 1570 cfu m^{-3} which is also within the category definition of high.

Fungi and bacteria at Bramingham primary school

Table 115 provides the results for the inside and outside spaces of both classrooms. In both classes the mean bacteria concentrations of 400 – 480 cfu m^{-3} are defined as intermediate. The maximum value recorded was 790 cfu m^{-3}, which is in the intermediate category. Only one outside measurement was made and this was found to be very low.

Mean fungi levels of 180 – 210 cfu m^{-3} were intermediate in both classrooms. This was also the case in the one sample outside of both classes (135 cfu m^{-3}).

Fungi and bacteria at Baltonsborough primary school

Table 116 provides the results for the inside and outside spaces of both classrooms. In classroom 1 the mean bacteria levels measured of 650 cfu m^{-3} are defined as high. In class 3 bacteria levels of 370 cfu m^{-3} are intermediate. The maximum concentration recorded was 1290 cfu m^{-3} which is also defined as intermediate. Measurements were taken outside the classroom in one case and here they were found to be low.

Mean Fungi concentrations of 120-170 cfu m^{-3} are defined as intermediate in both classrooms. The outside result of 190 cfu m^{-3} is also in the intermediate category. The maximum concentration recorded was found in classroom 3 and was 340 cfu m^{-3} (intermediate).

Fungi and bacteria at Gallions primary school

Table 117 provides the results for the inside and outside spaces of both classrooms. In the classrooms mean bacteria levels of 640-910 cfu m^{-3} are defined as high. Outside the classrooms the level found of 415 cfu m^{-3} is defined as intermediate. Maximum concentration of bacteria found is 1470 cfu m^{-3} which is defined as high.

Mean fungi levels of 200–270 cfu m^{-3} are all defined as intermediate. The maximum recorded value is 420 cfu m^{-3} which is also defined in the intermediate category.

Fungi and bacteria at Queenswell primary school

Table 118 provides the results for the inside and outside spaces of both classrooms. Bacteria levels differ between the reception classroom and year 2. In the first case, the mean bacteria levels recorded of 610 cfu m^{-3} are defined as being high. In the classroom for year 2 pupils bacteria counts of 200 cfu m^{-3} are defined as intermediate. The maximum recorded level of bacteria (in the reception class) is 790 cfu m^{-3} (defined as high).

The mean fungi concentrations in the classrooms (670 – 800 cfu m^{-3}) are lower than the measurement outside the classes (1300 cfu m^{-3}). Classroom values are defined as high as are outside measurements. The maximum concentration of fungi recorded is 1370 cfu m^{-3} (outside), also deemed to be high.

Fungi and bacteria at Victoria junior school

Table 119 provides the results for the inside and outside spaces of both classrooms. Mean concentrations of bacteria are in the intermediate category for classroom 12 (330 cfu m^{-3}) and the outside measurement (230 cfu m^{-3}). In classroom 6 bacteria levels reach a mean level of 510 cfu m^{-3}, which is defined as high. The maximum recorded value is 870 cfu m^{-3} which is also defined as high.

Mean concentrations of fungi are defined as low for class 6 (50 cfu m^{-3}) and the outside measurement (74 cfu m^{-3}), and defined as intermediate in class 12 (440 cfu m^{-3}). The maximum concentration recorded is 1810 cfu m^{-3}, which is defined as high.

3.1.6 DUST MITES

Table 4 of Appendix D provides the guidance levels for concentration of dust mites and identifies when values can be described as low, moderate or high (values < 100, < 500 and > 500 mites g^{-1} of dust, respectively).

Tables 120 to 127 provide the results of all dust mite measurements in schools. These indicate that concentrations are all well within the low categorization defined by standards.

3.2 Ventilation rates and carbon dioxide (CO_2)

Guidelines on the minimum ventilation rate required in schools stipulates that 3 L/s per person is needed and that there should be provision that this can be increased to 8 L/s per person (The School Premises Regulations (1999)). The higher ventilation rate indicates that CO_2 concentrations within a space are maintained at about 1000 ppm. The lower ventilation rate indicates CO_2 concentrations of approximately 2100 ppm. In this section all CO_2 concentration levels reported are instantaneous measurements.

Ventilation at West Grove primary school

Ventilation rates measured using the PFT technique are provided in Table 128 of Appendix C. On three occasions, twice in the reception class and once in classroom T53, the minimum recommended level of ventilation of 3 L/s per person was not achieved. On these occasions the classroom in question was empty and the windows were closed.

Because the weather was still warm during this school's monitoring period the staff used the windows for ventilation and ventilation rates when the rooms were in use ranged from 4.9 to 8.7 L/s per person.

Carbon dioxide measurements at West Grove primary school

Figures 1 and 2 show the CO_2 data recorded on each day within each classroom. CO_2 levels in both classrooms ranged from just below 200-1300 ppm. Peak concentrations are observed in the morning and around midday in the reception class. These peaks were not as obvious in class T53.

Windows and doors were used to modify the environment in both rooms during the week. This was because outside temperatures were high. The Reception classroom was only used during the mornings between 09:00 and 12:00.

Ventilation at Moorside primary school

The ventilation rates measured by the PFT technique are provided in Table 129 of Appendix C. The results show that generally both classrooms exceeded the minimum recommended ventilation rate of 3 L/s per person and ranged between 3 and 6.5 L/s per person. However on one day in class 2W the PFT ventilation rate was below the recommended level. At the time this test was run the classroom was empty and windows and the door were shut. One observation that was made during measurements was the limited extent to which teachers opened the windows.

Carbon dioxide measurements at Moorside primary school

Figures 5 and 6 present the CO_2 data recorded on each day. CO_2 levels ranged between 300–2000 ppm in the infants class during the week. Concentrations were above 1000 ppm for a considerable period of time. The main door and partition with the next room were usually open and windows were used infrequently. The high concentration of CO_2 recorded on the Thursday afternoon (1750 ppm spot measurement) corresponded to a period when children were active and classroom windows were closed.

The junior class CO_2 levels generally ranged between 300 and 1800 ppm during the week. CO_2 concentrations exceeded 1000 ppm for much of the week, but only on two days did peak

concentrations exceed 2100 ppm. On two days CO_2 concentrations were over 1000 ppm for a long part of the day. The peak level of CO_2 of 3200 ppm occurred at a time when windows and doors were closed (they were in use less often than in the other room studied).

Ventilation at Wavendon Gate combined school

The ventilation rates measured by the PFT technique are given in Table 130. In class HB1, there was just one occasion (20% of the samples) when the ventilation rate measured **exceeded** the minimum recommended level and on this occasion the windows in the classroom had been opened. The ventilation rates ranged from 1.3 to 5.1 L/s per person.

In class HB12 the situation was much better as the minimum ventilation requirements were met in the four measurements made. Windows were more often used within this classroom to modify the internal environment.

Carbon Dioxide measurements at Wavendon Gate combined school

Figures 9 and 10 present the CO_2 concentrations over the course of a week. CO_2 levels in class 2H ranged between 320-5000 ppm during the week. The peak value reached was 5000 ppm, which coincided with the day when bad weather meant that all windows were closed.

In class 7Cr (HB12) CO_2 levels generally ranged between 300 and 3500 ppm during the week. The peak levels reached were observed when the windows were closed. Opening the window was a regular practice in this class.

Ventilation at Bramingham primary school

The ventilation rates measured by the PFT technique are given in Table 131 of Appendix C. These show that in class 2 the minimum ventilation rate was never achieved. The highest achieved rate was 1.87 L/s per person (at least 33% lower than the minimum rate required) and the lowest rate achieved was 0.8 L/s per person. In class 10 ventilation rates were also poor, with the minimum provision being supplied on one of the five occasions when measurements were taken, with rates ranging from 0.47 L/s per person to 12.1 L/s per person. The maximum ventilation rate achieved was well in excess of 8L/s per person.

Carbon dioxide measurements at Bramingham primary school

Figures 13 and 14 present the CO_2 concentrations over the course of a week. CO_2 levels vary between approximately 310 to 2830 ppm in classroom 2. Concentrations were above 1000 ppm for the most part of all days. On a number of days peak concentrations also exceeded 2100 ppm.

In classroom 10 concentrations were frequently above 1000 ppm, and on one day continued to rise throughout the day without dropping back; a maximum level was reached on this day of 2800 ppm. Generally concentrations of CO_2 rarely exceeded 2100 ppm despite the low ventilation rates.

Ventilation at Baltonsborough primary school

Table 132 of Appendix C provides the ventilation rates, as defined by the PFT technique, in both classrooms. In classroom 1 measurements were taken on three of the five days. On two occasions the ventilation rate was well below the recommended minimum value (0.9 & 1.68 L/s per person). On the third occasion the ventilation rate was as high as 5.3 L/s per person. In class 3 ventilation rates were higher than the minimum recommended value on 50% of the occasions when measurements were taken. On the two occasions that the ventilation rate was below the recommended value this was only slightly lower than 3 L/s per person (the lowest

value was 2.5 L/s per person). The highest value recorded in classroom 3 was very much higher than on all other occasions, with values reaching nearly 21 L/s per person.

Carbon dioxide measurements at Baltonsborough primary school

Figures 17 and 18 present the CO_2 concentrations over the course of a week for both classrooms. CO_2 levels in classroom 1 ranged between 460 – 4460 ppm. On most days the concentration of CO_2 exceeded 1000 ppm. The last day of the tests (Friday) was the only period when CO_2 concentrations were mostly below 1000 ppm.

In classroom 3 CO_2 concentrations ranged between 280 – 2550 ppm. On all days CO_2 concentrations were mostly over 1000 ppm. Peak concentrations of CO_2 would often exceed 2100 ppm, but these occurred for relatively short periods of a day. At the point when the ventilation rate was measured at 21 L/s per person, the CO_2 levels had dropped from 1900 ppm to 800 ppm due to opening the window.

Ventilation at Gallions primary school

Table 133 of Appendix C provides the ventilation rates measured in the school by the PFT technique. On 50% of all occasions when measurements were taken the ventilation rate in both the year 2 and year 6 classrooms were below the minimum required (with a minimum of 1.3 L/s per person). Only on one occasion (out of a total of eight) did the ventilation rate exceed 8 L/s per person (the peak value was approximately 8.6 L/s per person).

Carbon dioxide measurements at Gallions primary school

Figures 21 and 22 present the CO_2 concentrations over the course of a week for both classrooms. In the classroom for year 2 CO_2 concentrations ranged between 290 – 1760 ppm. Concentrations were above 1000 ppm for a significant part of each day. On only one out of four days did CO_2 concentrations approach 2100 ppm, and this occurred towards the end of the day.

In the classroom for year 6 children CO_2 concentrations ranged between 260 – 2030 ppm. Unlike the situation in the classroom for year 2 pupils the level of CO_2 was broadly kept below 1000 ppm. Only on one day in the four day tests did CO_2 concentrations approach 2100 ppm and this was for a short period towards the end of the day.

Ventilation at Queenswell infant school

Table 134 of Appendix C provides the ventilation rates measured in the school by the PFT technique. In the reception class the minimum ventilation rates were not achieved on two of the five occasions for which measurements were taken. The lowest value obtained was in the order to 1 L/s per person (over 60% less than the minimum requirement) but a level of nearly 8 L/s per person was achieved on another day. The ventilation rates measured in the year 2 class were generally better in that only on one of the five occasions did the minimum rate fall below recommended levels.

Carbon dioxide measurements at Queenswell infant school

Figures 25 and 26 present the CO_2 concentrations over the course of a week for both classrooms. In the reception classroom concentrations ranged between 160 – 1770 ppm. CO_2 concentrations were frequently over 1000 ppm and were particularly higher on one day (Friday) when the ventilation rate was very low. There were, however, other days when concentrations were brought rapidly down, presumably through use of windows and doors.

In the year 2 classroom CO_2 concentrations ranged between 60 – 2530 ppm. On three of the four days for which measurements were taken CO_2 levels were kept below 1000 ppm. On the fourth day concentrations increased gradually until about midday, when afterwards a much steeper increase in CO_2 concentration took place until the end of the day. Towards the end of the day CO_2 concentrations were in excess of 2100 ppm.

Ventilation at Victoria junior school

Table 135 of Appendix C provides the ventilation rates in both classrooms, as determined by the PFT technique. In all, eight measurements were taken across both classrooms. In only one case (for classroom 12) did the ventilation rate meet the minimum required (in this case 3.56 L/s per person). The lowest ventilation rate recorded was over 6 times lower than the minimum needed at 0.47 l/s per person.

Carbon dioxide measurements at Victoria junior school

Figures 29 and 30 present the CO_2 concentrations over the course of a week for both classrooms. In class 12 CO_2 concentration ranges between 340 – 4560 ppm. On four out of the five days when measurements were taken CO_2 levels rose throughout the day and were largely over 1000 ppm. On three of these days CO_2 concentrations were mainly above 2100 ppm. Daily mean values of 2695, 1830, 2967, 1327 and 2746 ppm, were obtained.

In class 6 the CO_2 concentrations ranged between 420 – 3760 ppm. On all days the mean value for CO_2 exceeded 1000 ppm and on two days were above 2100 ppm.

3.3 Temperature and Relative Humidity

Table 5 in Appendix D provides CIBSE guidelines on temperature and relative humidity (RH) levels in educational buildings and classrooms. Temperature recommendations range between 18 – 23°C, and RH between 40 – 75%.

Temperature and relative humidity at West Grove Primary School

Figure 3 shows the results for temperatures and relative humidity in the Reception class, which ranged from 19°C – 21.3°C and 51% and 75%, respectively.

Figure 4 shows the results for temperatures and relative humidity in Class T53, which ranged from 19°C – 25°C and 45% and 70%, respectively.

All these values are within comfort criteria for most of the school day.

Temperature and relative humidity results at Moorside primary school

Figure 7 shows the results for temperatures and relative humidity in the class 2W, which ranged from 19 to 24°C and 35 to 52%, respectively.

Figure 8 shows the results for temperatures and relative humidity in the class 6F, which ranged from 16 to 24°C and 33 and 60%, respectively.

All these values are within comfort criteria for most of the school day.

Temperature and relative humidity results at Wavendon Gate Combined school

Figure 11 shows the results for temperatures and relative humidity in the class 2H, which ranged from 17 to 24°C and 50 and 74%, respectively.

Figure 12 shows the results for temperatures and relative humidity in the class 7Cr, which ranged from 14 to 24°C and 36 and 70%, respectively.

All these values are within comfort criteria for most of the school day.

Note that although the temperature was low at 8:00 am on Monday morning (14°C), it had increased to 18°C by 9:00am.

Temperature and relative humidity results at Bramingham primary school

Figure 15 shows the results for temperatures and relative humidity in the class 2 (the official monitoring period was from the 13th – 17th). Temperature ranged between approximately 17 to 22°C during the period that the school was open. RH ranged between approximately 38 and 65% during weekdays.

Figure 16 shows the results for temperatures and relative humidity in the class 10. Temperature ranged between approximately 17 to 22°C (the monitoring period was from the 13th – 17th). Lower temperatures were mainly experienced at weekends and not during occupied periods for when the official measurements were being taken. RH ranged between approximately 31 to 100%; there were problems with the detection sensor so these results are not reliable throughout the period.

All these values are within comfort criteria for most of the school day.

Temperature and relative humidity results at Baltonsborough primary school

Figure 19 shows the results of temperature and relative humidity in class 1. Temperature ranged between approximately 14 to 22°C and RH ranged between approximately 29 to 50%. The low temperature occurred first thing Monday morning. Within a short time the temperature had reached about 19°C.

Figure 20 shows the results of temperature and relative humidity in class 3. Temperature ranged between approximately 13 to 21°C and RH ranged between approximately 30 to 50%. The low temperature occurred first thing Monday morning. Within a short time the temperature had reached about 19°C.

All these values are within comfort criteria for most of the school day.

Temperature and relative humidity results at Gallions primary school

Figure 23 shows the results of temperature and relative humidity in the year 2 class. Temperature ranged between approximately 19 to 23°C.

Figure 24 shows the results of temperature and relative humidity in the year 6 class. Temperature ranged between approximately 19 to 24°C.

Very low values were obtained for RH that are attributed to errors in the detection sensors. As a result there are no reliable values for RH from either classroom.

Temperature and relative humidity results at Queenswell infant school

Figure 27 shows the results of temperature and relative humidity in the reception class. Temperature ranged between approximately 18 to 22°C and RH ranged between approximately 36 to 62% (values were below 40% for the first couple of hours of the first day of the week).

Figure 28 shows the results of temperature and relative humidity in the year 2 class. Temperature ranged between approximately 19 to 23°C and RH ranged between approximately 32 to 51% (values were below 40% for the first couple of hours of the first day of the week).

All these values are within acceptable levels for most of the school day.

Temperature and relative humidity results at Victoria junior school

Figure 31 shows the results of temperature and relative humidity in class 6 and 12, as well as in the outdoor environment.

In class 6 temperature ranged between approximately 16 to 21°C and RH ranged between approximately 44 to 65%.

In class 12 temperature ranged between approximately 17 to 21°C and RH ranged between approximately 30 to 49%.

All these values are within acceptable levels for most of the school day.

CHAPTER 4

Summary of indoor air quality across schools

The following table summarises the IAQ measurements found across all schools.

Table 10: Summary of IAQ directly measured in all school classrooms

Parameter	N	mean	max	exceedences	n	(%)
TVOC (µg m^{-3})	132	199	704	Guideline value 300 (see Table 1 in Appendix D)	27	(21)
CO (ppm)	77	0??	4	26	0	(0)
NO_2 (ppb)	77	24	45	110	0	(0)
Formaldehyde (µg m^{-3})	66	25	65	100	0	(0)
Acetaldehyde (µg m^{-3})	66	8	25	2000	0	(0)
PM_{10} (µg m^{-3})	8	29	43	50	0	(0)
Ultra fine particles	13	8745	13770	none	-	-
Bacteria (cfu m^{-3})	17	519	906	high > 500	10	(59)
Fungi (cfu m^{-3})	17	314	802	high > 500	3	(18)
Dust mites (g^{-1})	31	4	20	high > 500	0	(0)
Temperature	Range: 17 to 24°C					
Humidity	Range: 30 to 75%					

Notes

N = number of mean samples from all classrooms

Mean = average value for mean concentrations found across all classrooms

Max = maximum concentration of pollutant found across all classrooms

n = number of times that recommended (or guideline) values are exceeded

Relatively high TVOC concentrations (>300µg m^{-3}) were recorded on some occasions in Wavendon Gate (2 occurrences), Bramingham (5 occurrences), Baltonsborough (1 occurrence) and Victoria (5 occurrences).

Bacteria concentrations were high in West Grove (2 occurrences), Moorside (1 occurrence), Wavendon Gate (2 occurrences), Baltonsborough (1 occurrence), Gallions (2 occurrences), Queenswell (1 occurrence) and Victoria (1 occurrence).

Fungi concentrations were high outside classrooms but not within.

CHAPTER 5

Summary of ventilation rates across all classrooms

The following table summarises the ventilation rates that were measured across all schools.

Table 11: Summary of ventilation rates directly measured in all schools

School	N	Ventilation rates (L/s per person)					
		< 3		< 8		max	min
			(%)		(%)		
West Grove	10	3	(30)	9	(80)	8.7	1.6
Moorside	10	2	(20)	10	(100)	6.5	1.8
Wavendon Gate	9	4	(44)	9	(100)	7.7	1.3
Bramingham	10	9	(90)	9	(90)	12.1	0.5
Baltonsborough	7	4	(57)	6	(85)	20.9	0.9
Gallions	8	4	(50)	7	(87)	8.6	1.3
Queenswell	10	3	(30)	10	(100)	7.9	0.9
Victoria	8	7	(87)	8	(100)	3.6	0.5

Notes

N = number of daily mean samples from the school (based on average ventilation rates in a class during the occupied part of the day)

Max = maximum ventilation rate recorded in the school classrooms

Min = minimum ventilation rate measured in the school classrooms

(The ventilation rates are calculated using the PFT technique)

CHAPTER 6

Summary of daily average CO_2 concentrations across all classrooms

Figure 33 shows the frequency distribution of daily mean concentrations of CO_2 across all of the schools. This indicates that approximately 40% of the classrooms achieved CO_2 concentrations of 1000 ppm or lower. Approximately 88% of classrooms achieved CO_2 concentrations of 2100 ppm or lower.

CHAPTER 7

Ventilation approach in relation to ventilation performance

Table 12 reiterates the ventilation approach in each school and contrasts this with the ventilation and IAQ performance data obtained.

Table 12: Ventilation approach, ventilation rates and IAQ

School name	Ventilation strategy	Location	Ventilation performance (%)		IAQ problems encountered
			< 3 L/s/p	*< 8 L/s/p*	*comment*
West Grove Primary	Cellular classrooms. T15 – ground floor,T53 – first floor. Ventilation via openable windows and trickle vents	Urban in London	(30)	(80)	None
Moorside Primary	Cellular classrooms. Ventilation via openable windows and trickle vents	Urban and next to a busy road in Manchester	(20)	(100)	High bacteria counts
Wavendon Gate Combined	Semi-open plan classrooms on ground floor. Ventilation via openable windows and trickle vents	Urban in Milton Keynes	(44)	(100)	High TVOC concentrations and bacteria counts
Bramingham Primary	Semi-open plan classrooms – ground floor. Ventilation via openable windows and trickle vents	Urban in Luton	(90)	(90)	High TVOC concentrations
Baltonsborough CE VC Primary	Cellular classrooms – ground floor. Ventilation via openable windows and trickle vents	Semi-urban in Glastonbury	(57)	(85)	High TVOC concentrations and bacteria counts
Gallions Primary School		London	(50)	(87)	High bacteria counts
Queenswell Infants School	Cellular classrooms – ground floor. Ventilation via openable windows and trickle vents	Urban and next to a busy road in London	(30)	(100)	High bacteria counts
Victoria Junior School	Semi- open plan classrooms. C6 is – first floor, C12 – ground floor. Ventilation via openable windows and trickle vents	Urban in Workington	(87)	(100)	High TVOC concentrations and bacteria counts

Notes

< 3 L/s/p = less than 3 litres per second per person

< 8 L/s/p = less than 8 litres per second per person

Table 12 indicates that where semi open-plan classes were encountered, higher incidences of poor ventilation rates occurred. Semi open-plan classes are present at Wavendon Gate, Bramingham and Victoria Junior Primary schools. In these schools minimum ventilation rates of 3 L/s per person were not achieved between 44 – 90 % of the sampling periods. In contrast the cellular planned classrooms of the other schools failed to achieve minimum ventilation rates on between 30 – 57 % of sampling periods. These results are supported by the ventilation rates achieved against the benchmark of 8 L/s per person.

High TVOC concentrations and bacteria counts are found in both the semi open-plan and cellular classrooms. Given this, there appears to be no relationship between IAQ parameters and the design plan of classrooms.

Proximity to busy roads and general urbanised location of schools has no discernable impact on IAQ (otherwise NO_2 and CO concentrations would be elevated given that they are derived from road side vehicles). However, if openable windows are not used because of traffic related noise, this could explain why no link has been established between IAQ and proximity to busy roads. The poor ventilation rates measured confirm that windows are not used as often as they should be for good ventilation.

CHAPTER 8

Intervention studies to improve ventilation rates and IAQ

For the last two schools, intervention studies were carried out. Windows were opened during the school day and the impact on ventilation and thermal comfort was determined.

8.1 Use of windows to achieve better ventilation

On the fourth day at the Victoria Junior school class 12 was used to see whether leaving windows open all day long would improve ventilation and IAQ. Figure 29 shows this intervention study as a curve labelled 'Thursday'. On all other days the windows were left closed during teaching periods.

Figure 29 provides clear evidence that CO_2 rates are lowered throughout the day as a consequence of the window in classroom 12 being left open. The mean values of CO_2 in classroom 12 are 1330 ppm (with mean measured ventilation rate over the day of 3.56 L/s per person). On other days CO_2 concentrations varied from between approximately 1830 to 2970 ppm (with corresponding mean ventilation rates of between 0.47 to 1.67 L/s per person).

Figure 32 shows temperature variations from both classes at Victoria School (outside temperature is also included). On the day of the intervention study the classroom temperature was lowered by approximately 2°C across the whole day; the lowest temperature value was approximately 17°C. Therefore, although the ventilation was improved, it was at some cost to thermal comfort and probably also to heating efficiency.

In the year 2 classroom of Queenswell Primary school windows were used throughout the week. Figure 26 shows the impact on CO_2 concentrations during the course of each day. On the Thursday two windows were left open throughout the day. This kept CO_2 levels below 2100 ppm until approximately 14.15pm. A maximum concentration of 2530 ppm was measured towards the end of the school day. The mean concentration of CO_2 over the course of the day was approximately 1350 ppm. On the three preceding days a minimum of 5 windows were left open in the classroom. As a consequence CO_2 levels were better controlled and were always kept below 1000 ppm. Table 134 of Appendix C shows that on the Thursday (day 4) a mean daily ventilation rate of 1.71 L/s per person was obtained. On the three preceding days the mean ventilation rate ranged between 4.23 to 7.25 L/s per person. Despite the use of the windows the temperature was comfortable at all times. It is not known what impact the window opening has on energy efficiency.

8.2 Attitudes of teaching staff

There was no investigation into the attitude of classroom teachers and their assistants. However a number of anecdotal stories provide some useful reasons why poor ventilation occurs in school classrooms.

It proved difficult to persuade teaching staff to open windows so that ventilation could be enhanced in classrooms. Reasons given for keeping windows closed are summarised below.

- Avoiding cold classrooms.
- Preventing external noise from hindering learning in classrooms.
- Reducing energy consumption due to enhanced heat loss during the winter.

A further important theme was drawn out from discussions held with teachers. Some teachers would base classroom ventilation needs on their own comfort criteria, whilst others would try to assess the needs of children.

CHAPTER 9

Conclusions

The main conclusions from this study are as follows:

- Ventilation rates were measured in each classroom for a 45 minute period each afternoon. In each school there were occasions when the ventilation rate was below the minimum rate required of 3 L/s (The School Premises Regulations, 1999). In total 50% of measurements were below this value.

- Ventilation rate can also be estimated from carbon dioxide (CO_2) concentrations with 3 L/s being equivalent to 2100 ppm of CO_2 under equilibrium conditions. CO_2 was measured continuously daily in each classroom. Approximately 40% of classrooms achieved CO_2 concentrations of 1000 ppm or lower and approximately 88% of classrooms achieved CO_2 concentrations of 2100 ppm or lower.

- Temperature ranged between 17 – 25°C. For optimum comfort the levels should be between 18 and 23°C and these levels were achieved for the majority of the school day.

- Relative humidity ranged between 30 – 75%. For optimum comfort the levels should be between 40 and 75% RH and these levels were achieved for the majority of the school day.

- Levels of volatile organic compounds (VOCs) were measured in each classroom for a 45 minute period each afternoon (concurrently with ventilation measurements). Levels of total volatile organic compounds (TVOCs) were compared against a proposed guideline value of 300 µg m^{-3}. It was found that 21% of samples exceeded this limit and these high values originated from four schools. The highest level observed was approximately 700 µg m^{-3} . It was noted by the researchers that on at least some of the occasions where TVOC concentration >300 µg m^{-3} was recorded, art work was undertaken concurrently or just prior to the measurements and such activities would tend to increase TVOC levels (e.g. from paints or solvents). An additional factor was that all the schools were fairly new (post 1995) and could have been naturally releasing chemicals from carpets, walls and furniture surfaces.

- Aldehyde levels were measured for 30 minutes in each classroom on most days, soon after the children had left at the end of the day. No levels exceeded World Health Organization (WHO) guideline values.

- Levels of carbon monoxide (CO) and nitrogen dioxide (NO_2) were monitored continuously in each classroom daily. The CO and NO_2 levels were all within WHO guideline values.

- Bacteria levels were measured in each classroom on five occasions on one day. Measurements were also taken outside on these days. The values were compared against a European proposed rating scheme. Approximately 60% of classrooms had a 'high' rating for bacteria. The rating was typically 'low' or 'very low' outside. This result is to be expected. Children moving around, the mechanics of clothing brushing against skin etc will all dislodge skin scales and dust particles that will contain many millions of bacterial organisms. Note that it is not possible to determine the risk of infection from these results.

The organisms cultured for are regarded as non-pathogenic in persons with normal immune systems. Infection risk would vary depending on a number of factors including pathogenicity of a particular organism, method and ease of transmission of the organism, duration of exposure and the susceptibility of the other children and teachers.

- Fungi were measured concurrently with bacteria. Approximately 20% of classrooms had a 'high' rating for fungi. Similar levels were detected outside of the schools and this suggests that the main source of internal fungi levels is the outside air.

- Dust mites were sampled on a single day in each classroom. All levels were rated 'low'.

- PM_{10} levels were monitored in each school. All levels were within the UK National Air Quality Strategy guideline value.

- Ultrafine particle numbers were monitored both inside and outside each classroom. There are no UK guideline values for particles. The values were similar both inside and outside of the classrooms and this suggests the principal source is external.

Intervention studies were undertaken in two of the schools. Whilst limited, they did show that through the greater use of windows the ventilation rate can be increased with a small impact on thermal comfort. In discussions with teachers, there are a number of reasons to explain why teachers (and classroom assistants) avoid using windows as often as they could. These include the need to prevent noise and cold air entering rooms, and the desire to conserve energy by reducing heat loss.

Overall, the ventilation rate was often below the minimum recommended levels in classrooms whilst occupied. However, the more important question is whether it is a problem. In a number of classrooms relatively high TVOC levels were recorded on occasions. However, it is suggested that this is often due to new decoration and furnishings or to the use of art materials. It would be much more energy efficient to address this, if required, through source control. Lower VOC emitting products could be used and/or behavioural changes could be made such as promptly putting the tops back on solvent containers.

The bacteria counts were also rated as 'high' in a majority of classrooms. The potential implications of this are increased infections amongst children and staff.

Within this work, the implication of individual environmental parameters on health and comfort has been discussed. In addition, there will be a synergistic effect of the combination of parameters. The consequence of this cannot be assessed from this study. Furthermore, this study has not attempted to determine the impact of the indoor environment on the children's performance. The literature review showed that there have been few studies in this area, although they do show evidence of an impact on performance. Certainly within workplaces, studies have shown a relationship with increased ventilation and better performance and productivity.

Finally, this has been the largest detailed study of ventilation rate and indoor air quality within UK primary schools. Whilst the sample size is relatively small and care must be taken in interpreting the results, significant new information has been obtained and it provides a much better understanding of the indoor environment within primary schools. Further work should build on this, focusing resources on the major issues highlighted by this study (e.g. improved ventilation design and usage, reducing TVOC and bacteria levels) and extending it to other issues such as establishing the impact of the indoor environment on children's performance.

CHAPTER 10

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CHAPTER 11

Figures

Figure 1. West Grove School – Carbon Dioxide Measurements

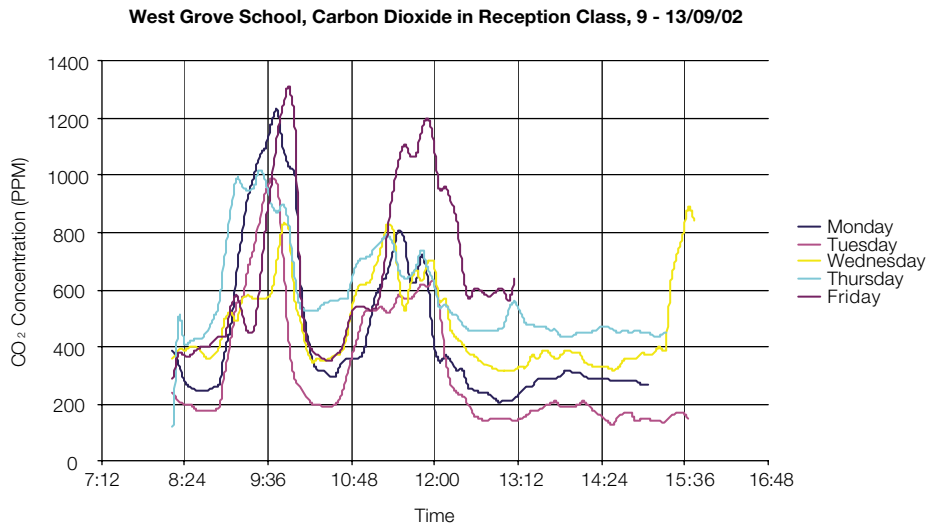


Figure 2. West Grove School – Carbon Dioxide Measurements

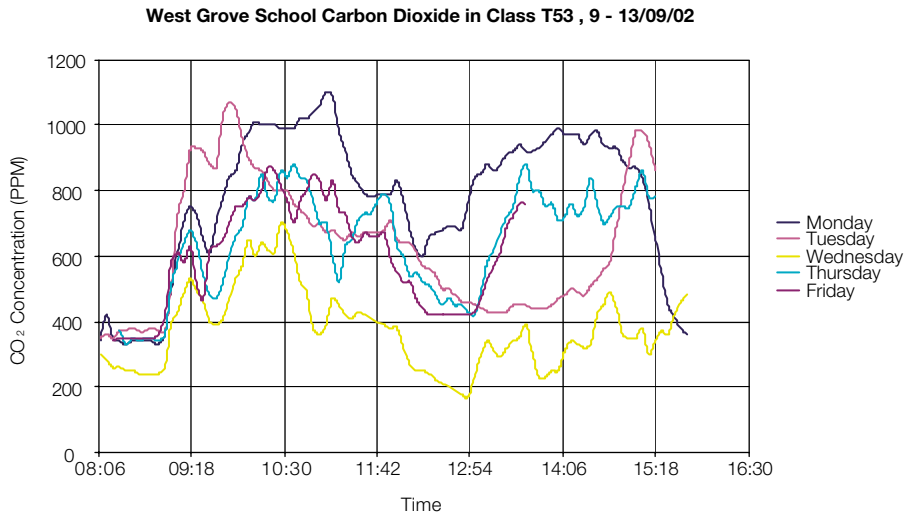


Figure 3. West Grove School – Temperature and Humidity

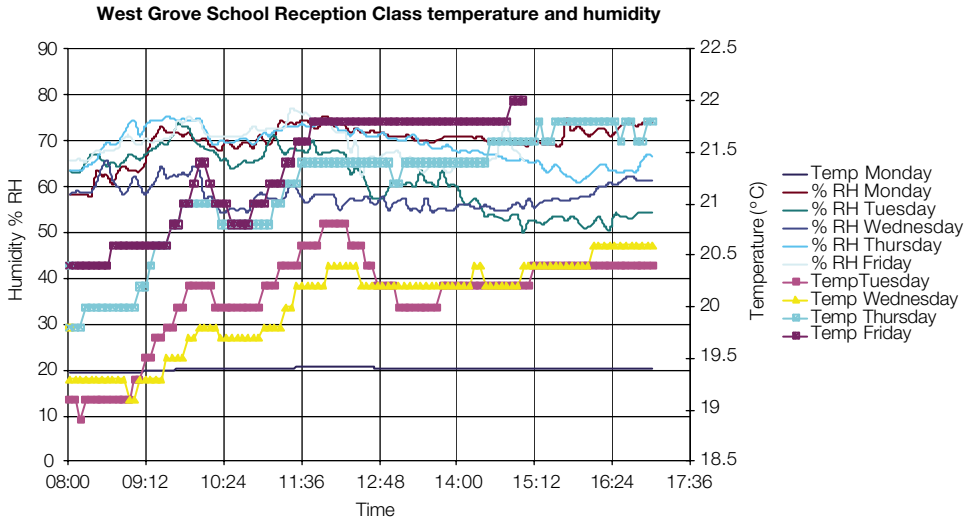


Figure 4. West Grove School – Temperature and Humidity

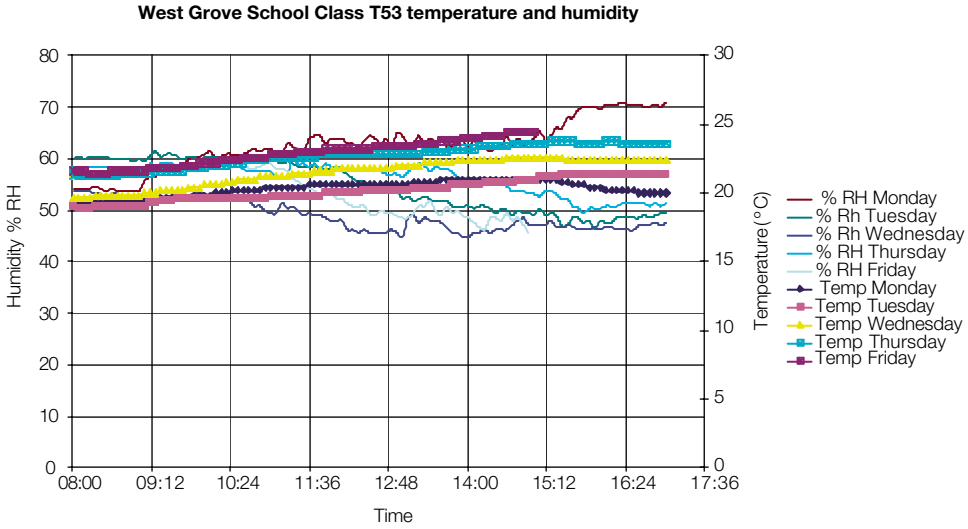


Figure 5. Moorside School – Carbon Dioxide Measurements

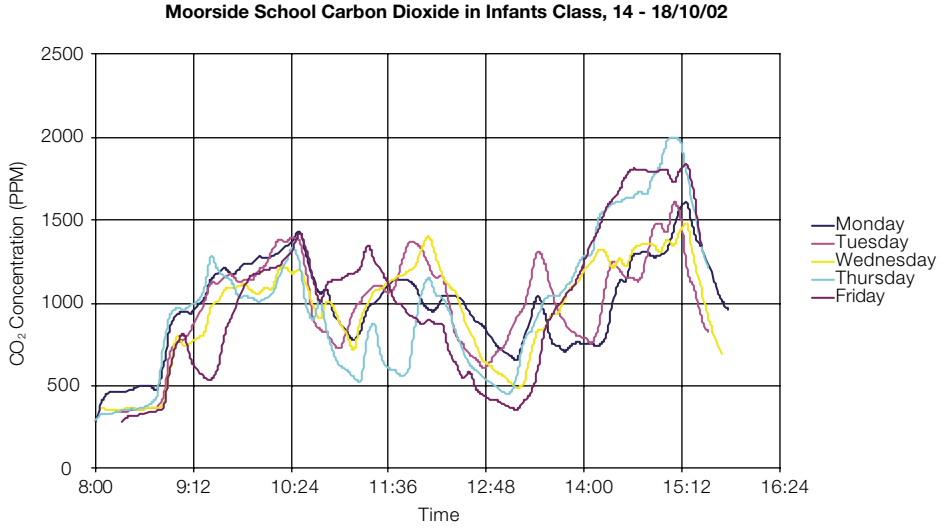


Figure 6. Moorside School – Carbon Dioxide Measurements

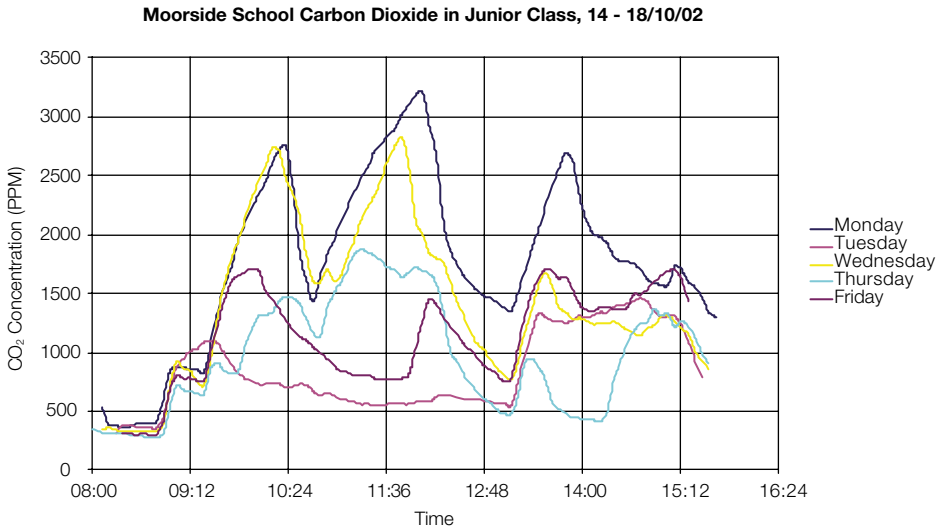


Figure 7. Moorside School – Temperature and Humidity

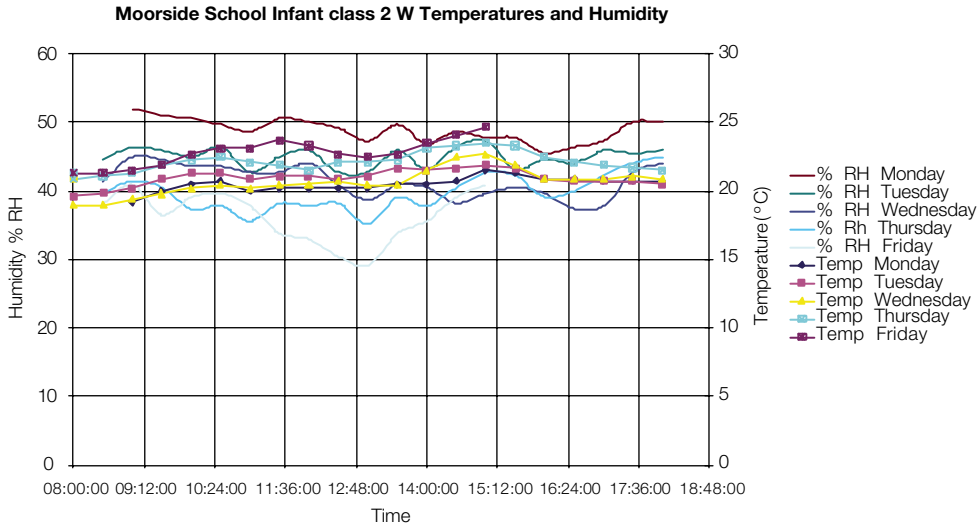


Figure 8. Moorside School – Temperature and Humidity

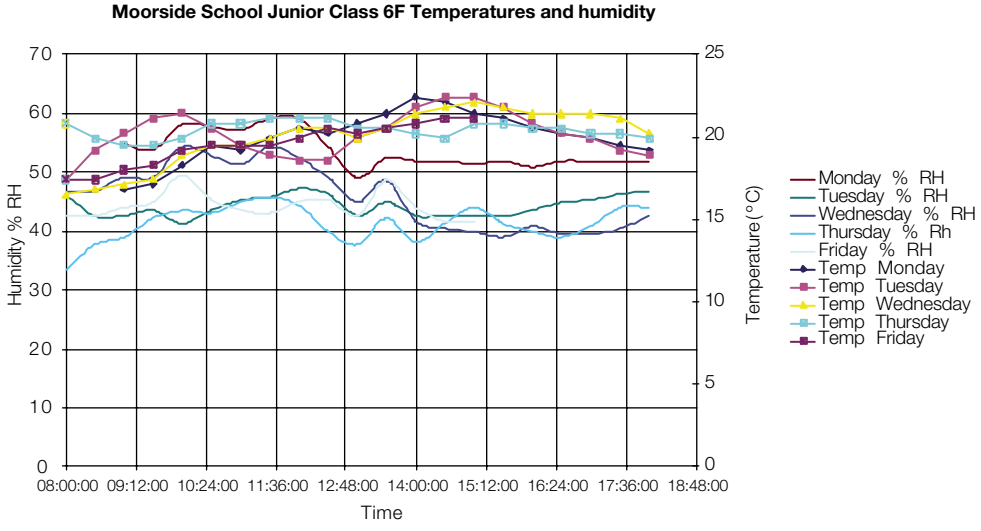


Figure 9. Wavendon Gate School – Carbon Dioxide Measurements

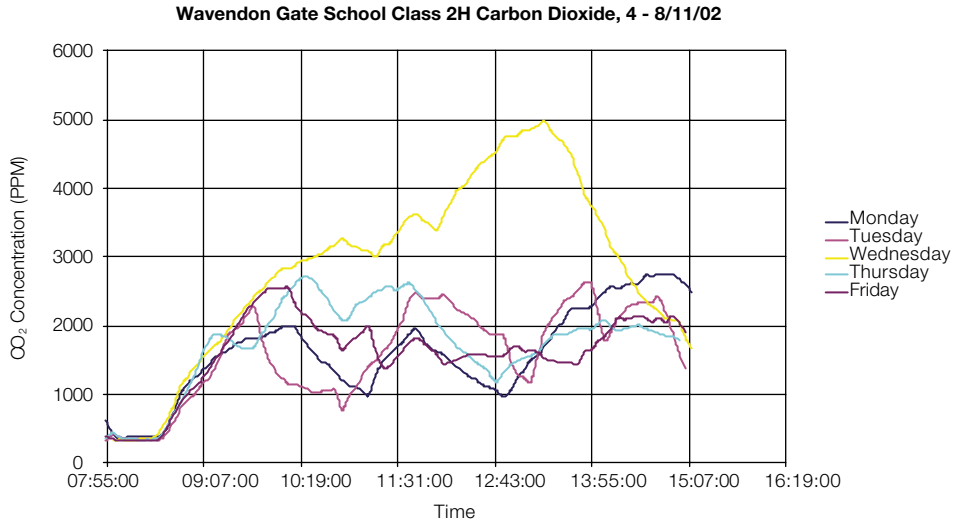


Figure 10. Wavendon Gate School – Carbon Dioxide Measurements

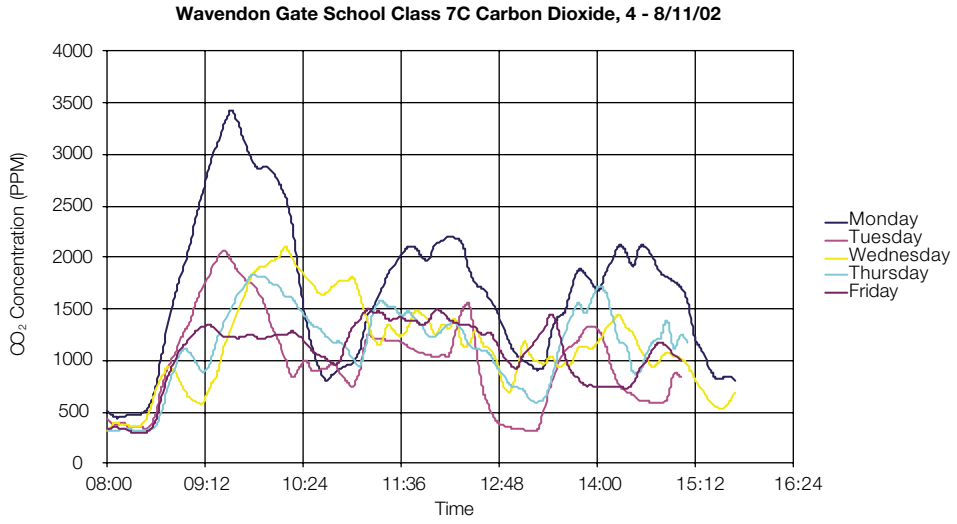


Figure 11. Wavendon Gate School – Temperature and Humidity Measurements

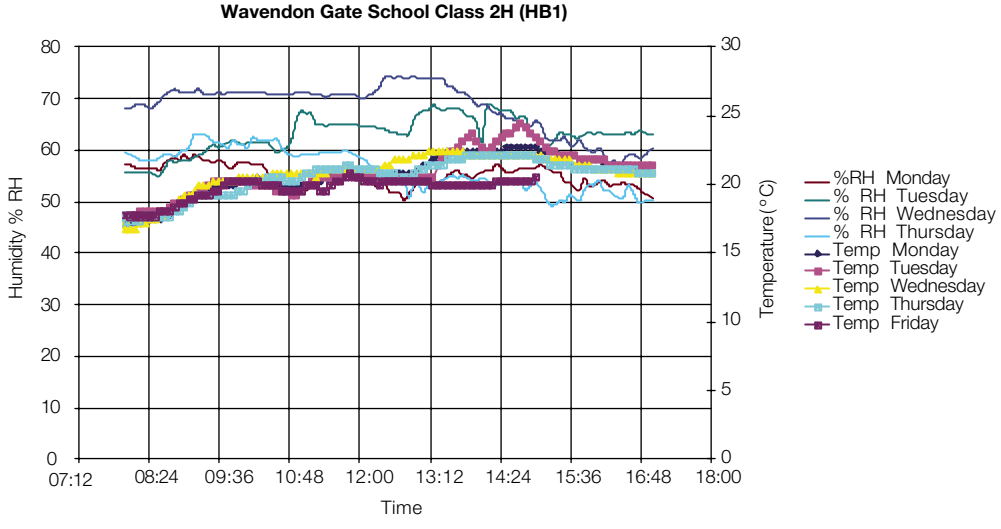


Figure 12. Wavendon Gate School – Temperature and Humidity Measurements

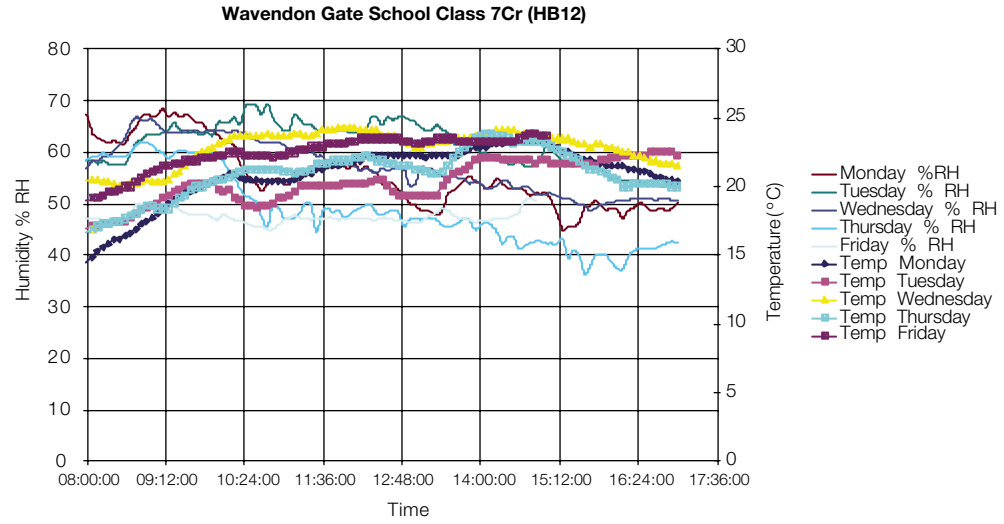


Figure 13. Bramingham Primary School – Carbon Dioxide Measurements

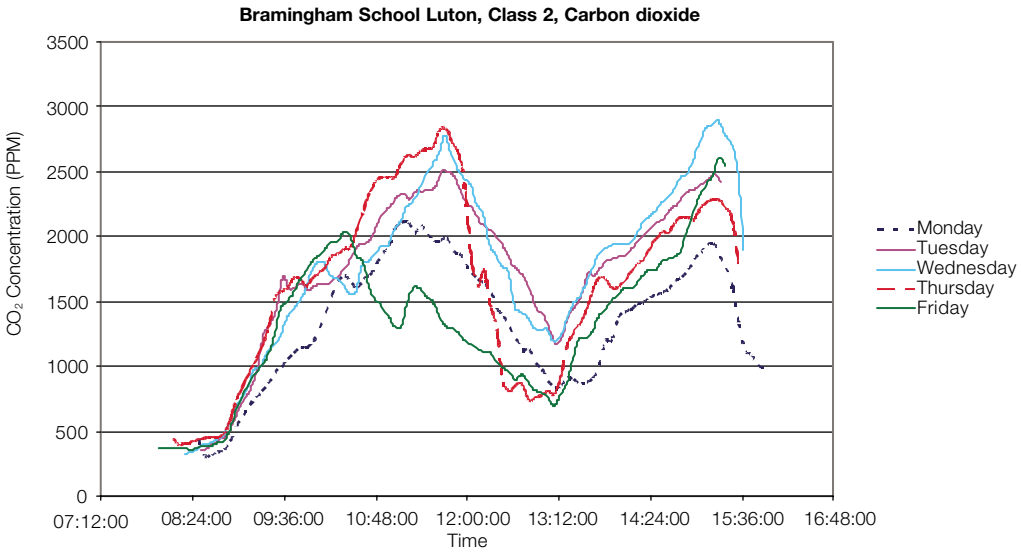


Figure 14. Bramingham Primary School – Carbon Dioxide Measurements

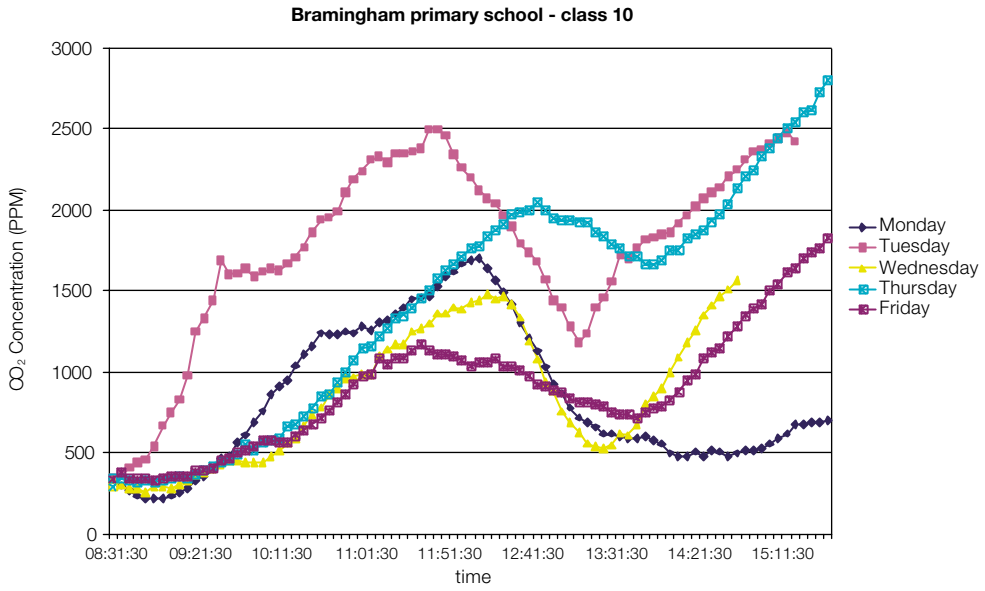


Figure 15. Bramingham Primary School – Temperature and Humidity Measurements

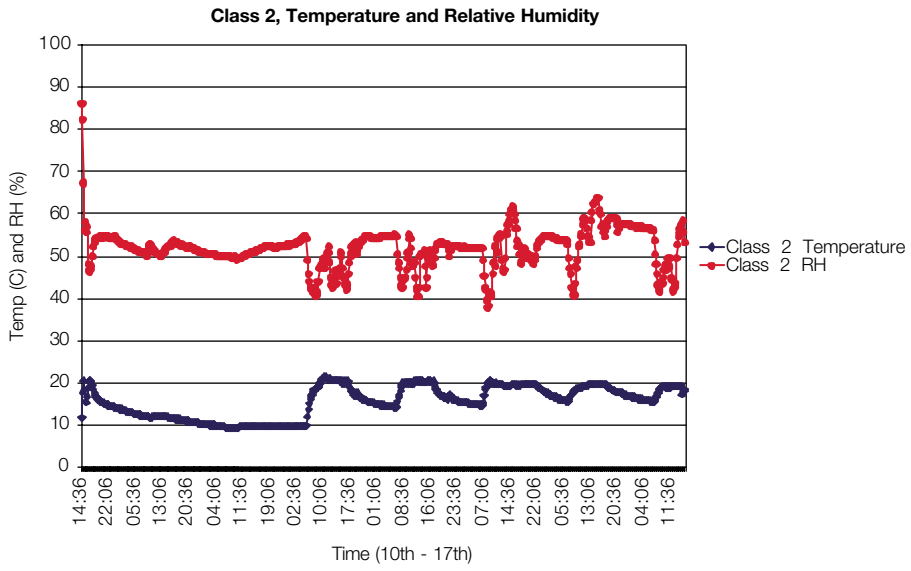


Figure 16. Bramingham Primary School – Temperature and Humidity Measurements

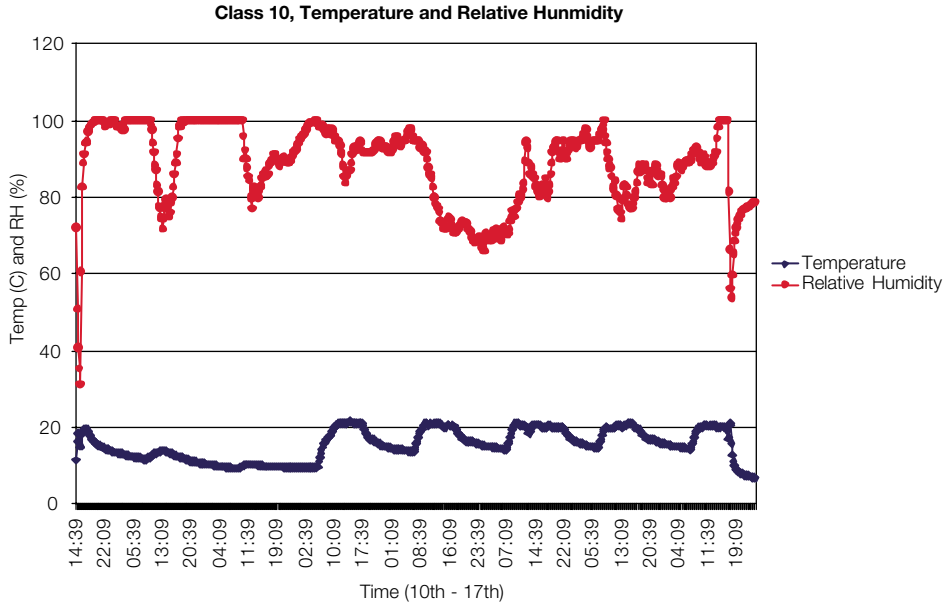


Figure 17. Baltonsborough Primary School – Carbon Dioxide Measurements

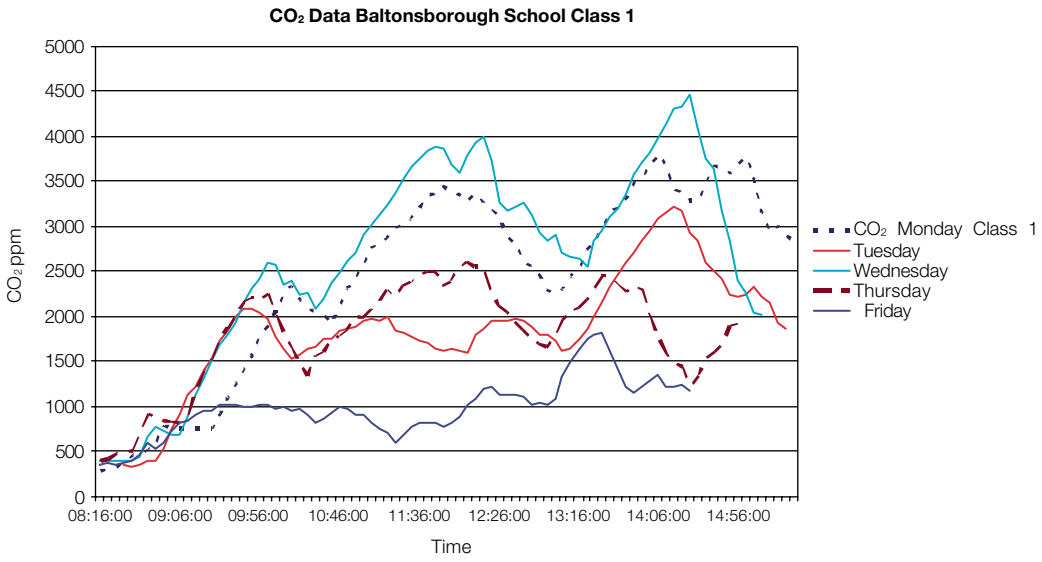


Figure 18. Baltonsborough Primary School – Carbon Dioxide Measurements

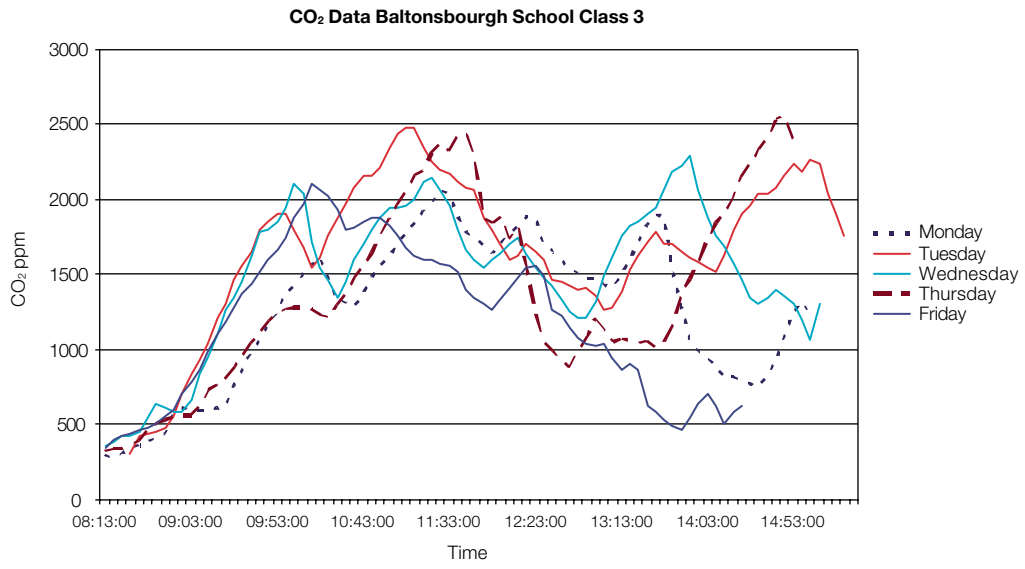


Figure 19. Baltonsborough Primary School – Temperature and Humidity Measurements

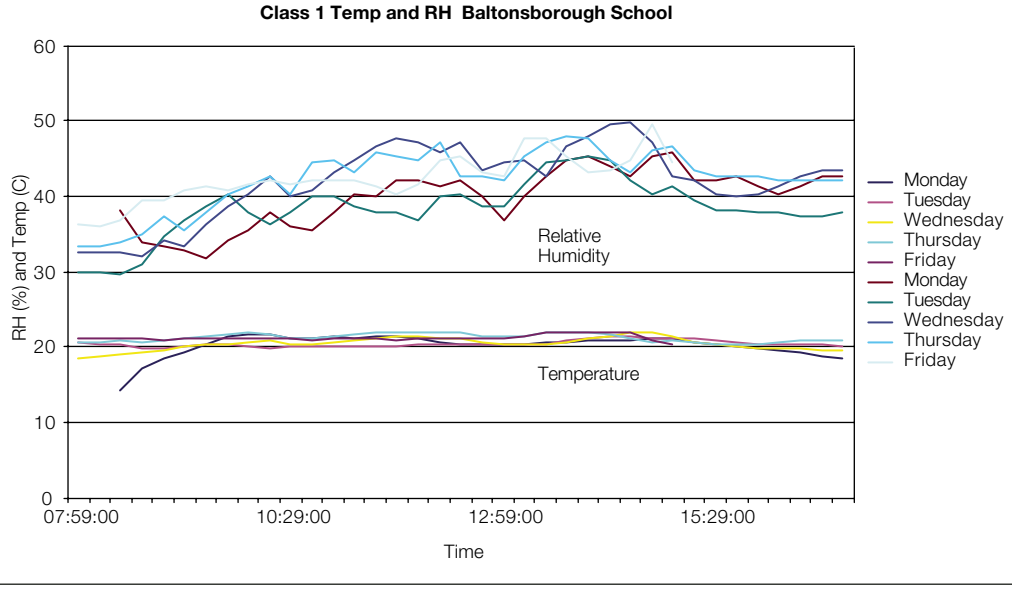


Figure 20. Baltonsborough Primary School – Temperature and Humidity Measurements

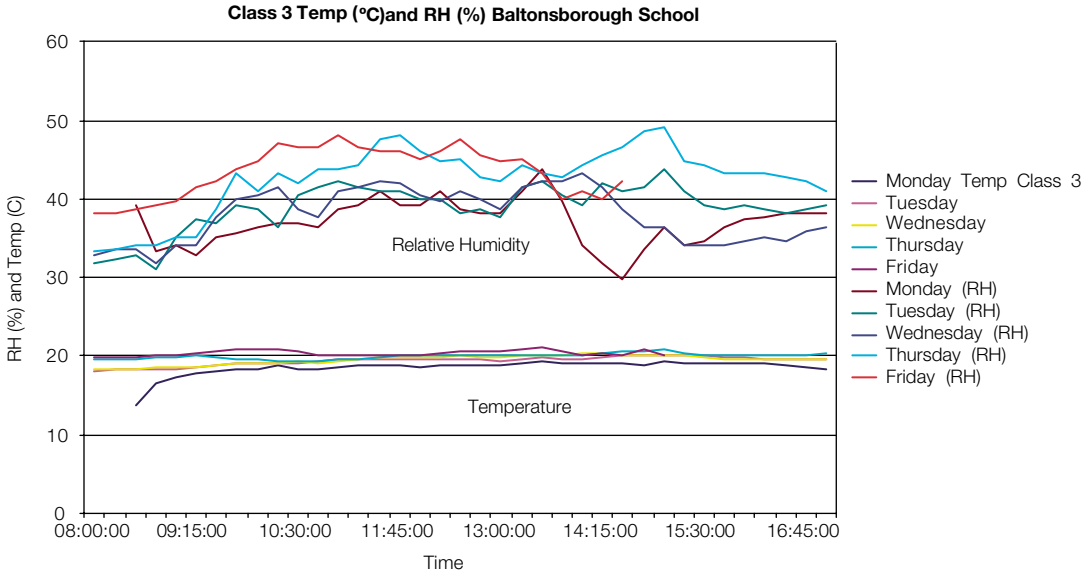


Figure 21. Gallions Primary School – Carbon Dioxide Measurements

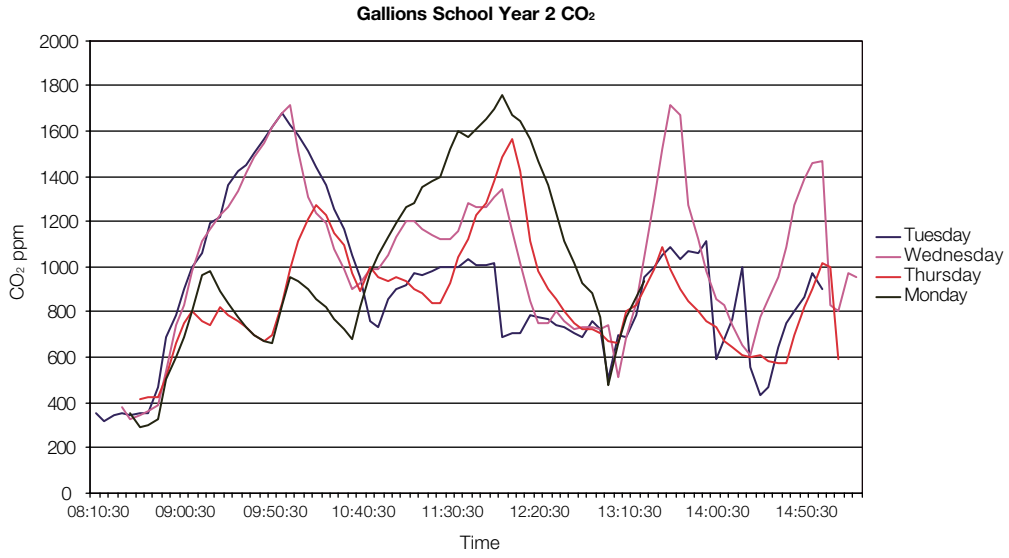


Figure 22. Gallions Primary School – Carbon Dioxide Measurements

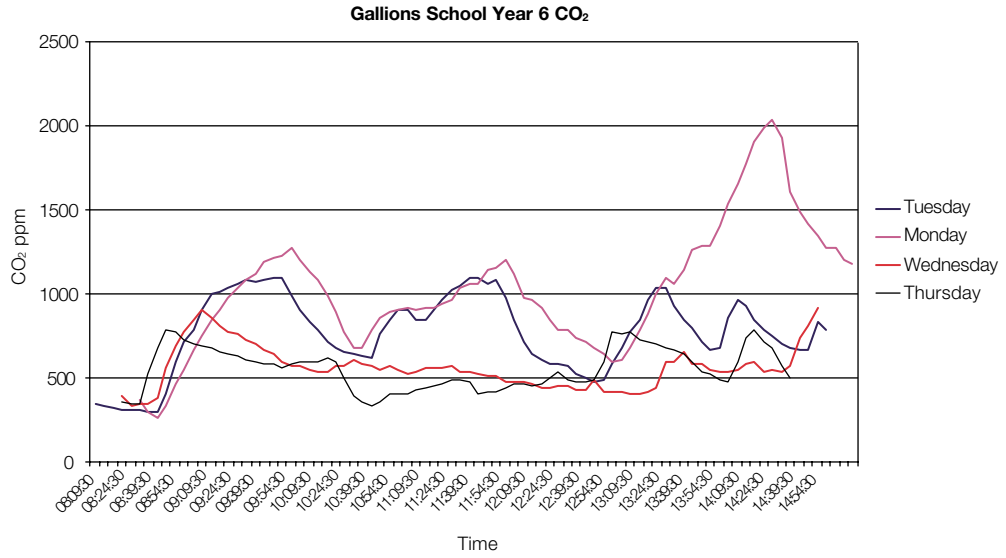


Figure 23. Gallions Primary School – Temperature and Humidity Measurements

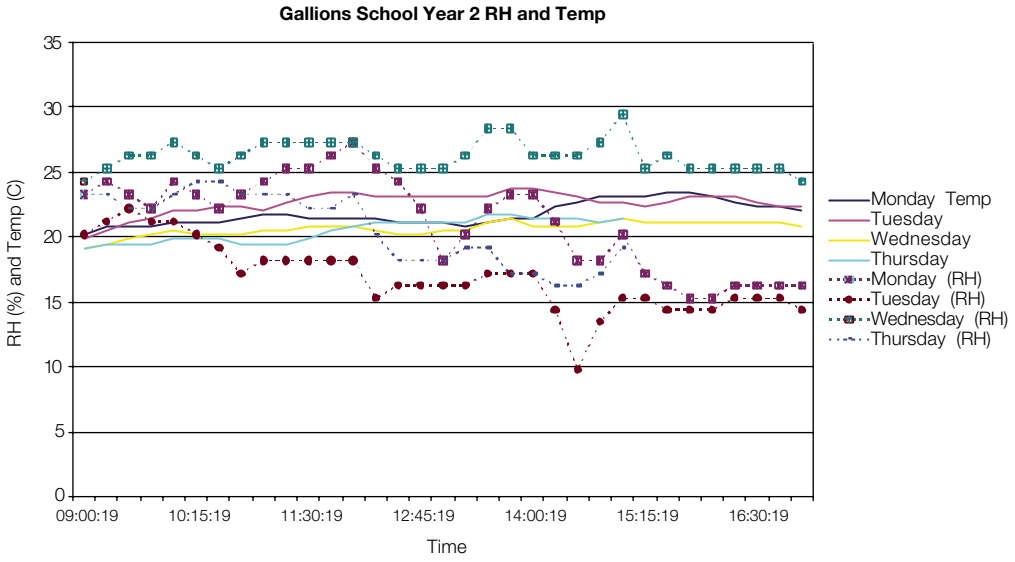


Figure 24. Gallions Primary School – Temperature and Humidity Measurements

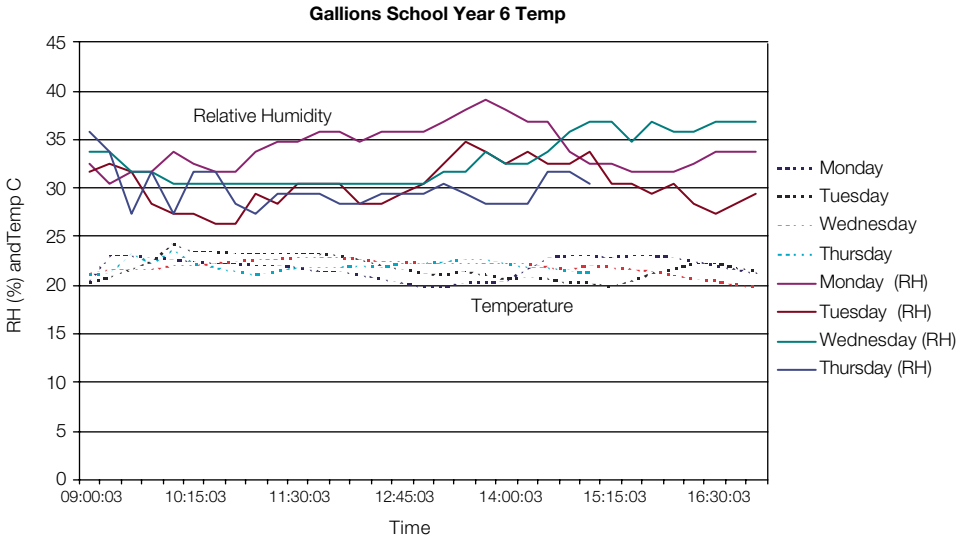


Figure 25. Queenswell Infant School – Carbon Dioxide Measurements

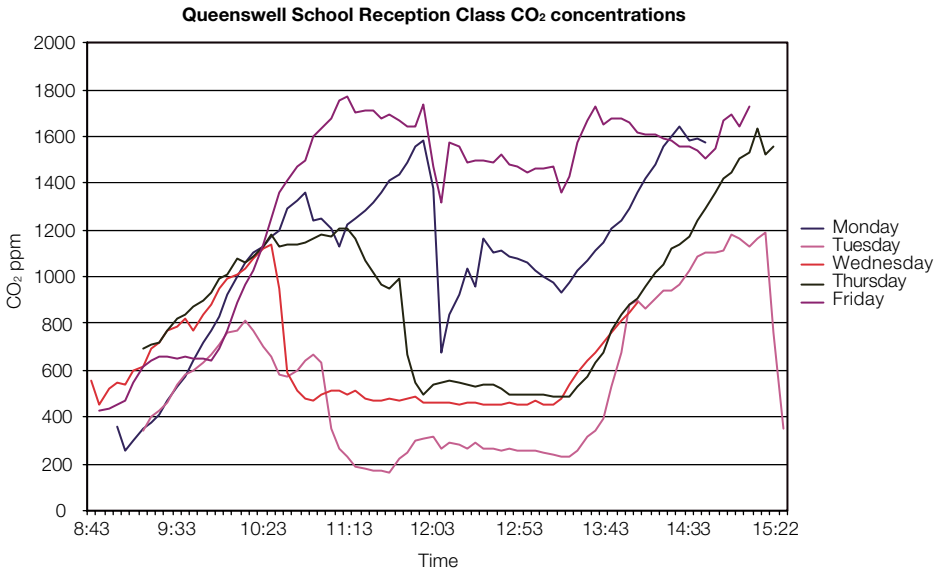


Figure 26. Queenswell Infant School – Carbon Dioxide Measurements

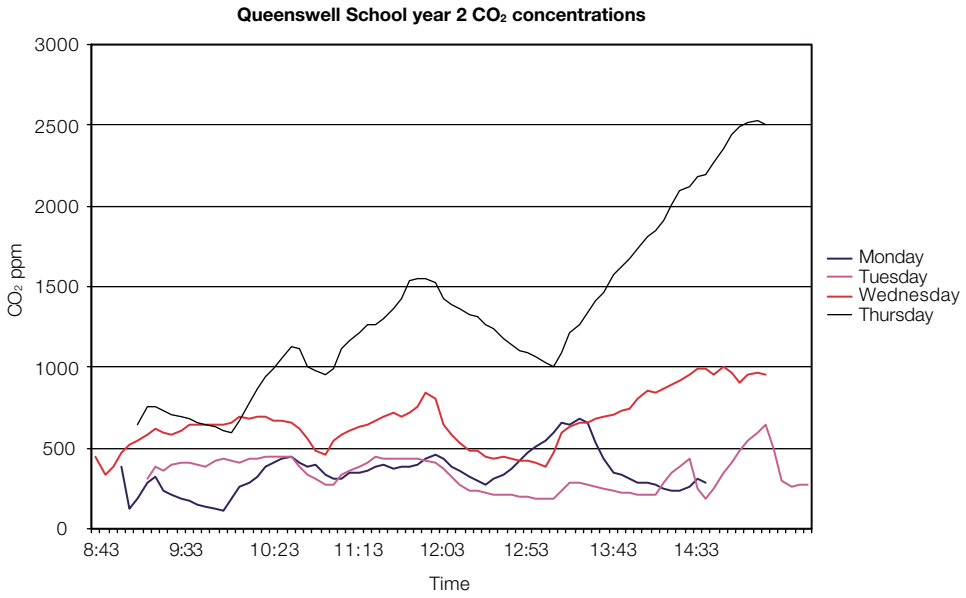


Figure 27. Queenswell Infant School – Temperature and Humidity Measurements

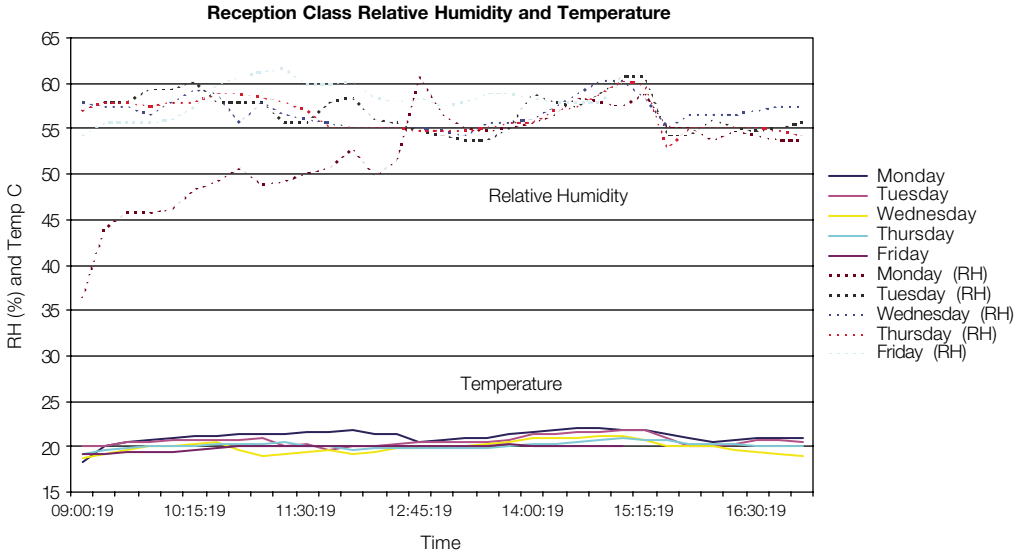


Figure 28. Queenwsell Infant School – Temperature and Humidity Measurements

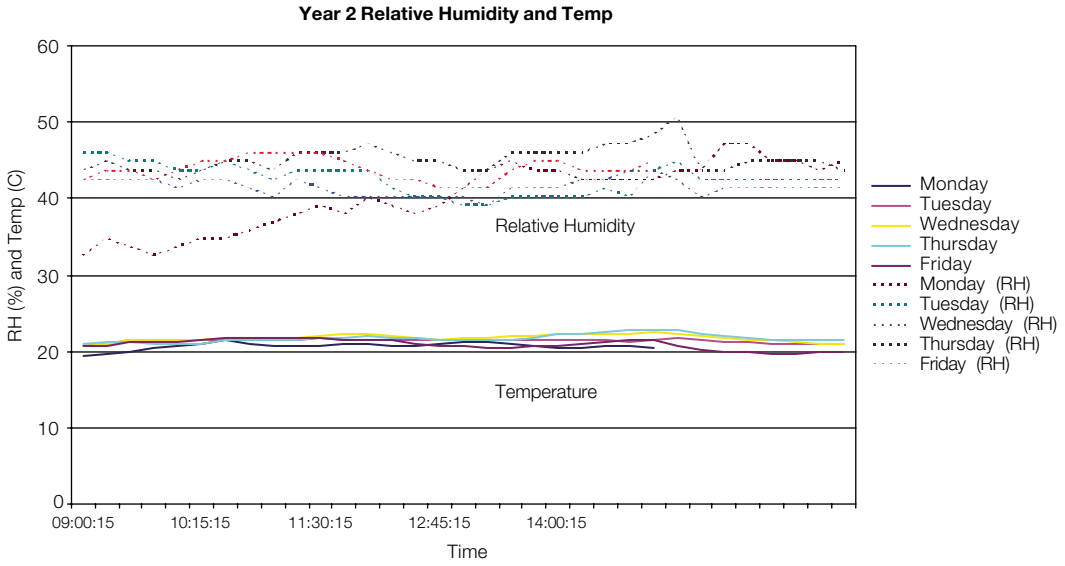


Figure 29. Victoria Junior School – Carbon Dioxide Measurements

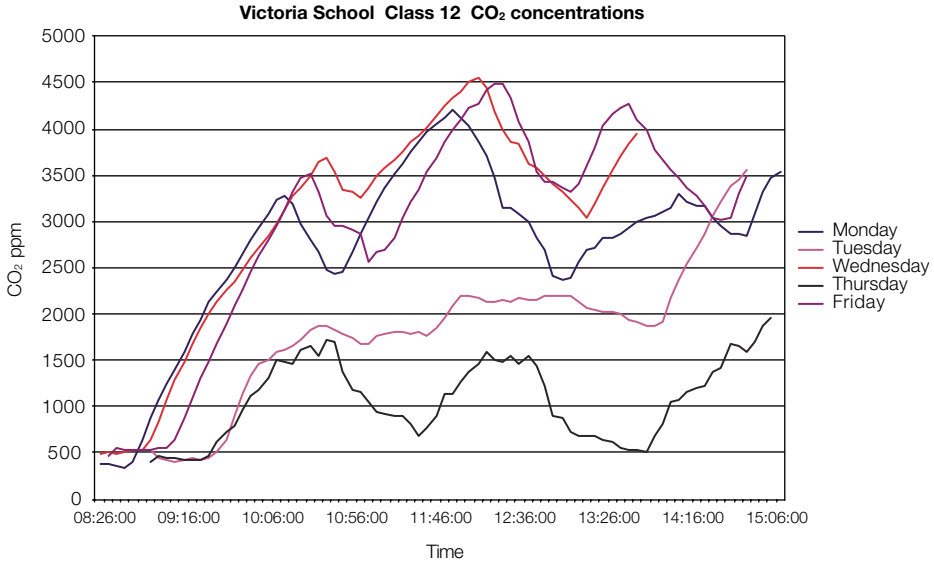


Figure 30. Victoria Junior School – Carbon Dioxide Measurements

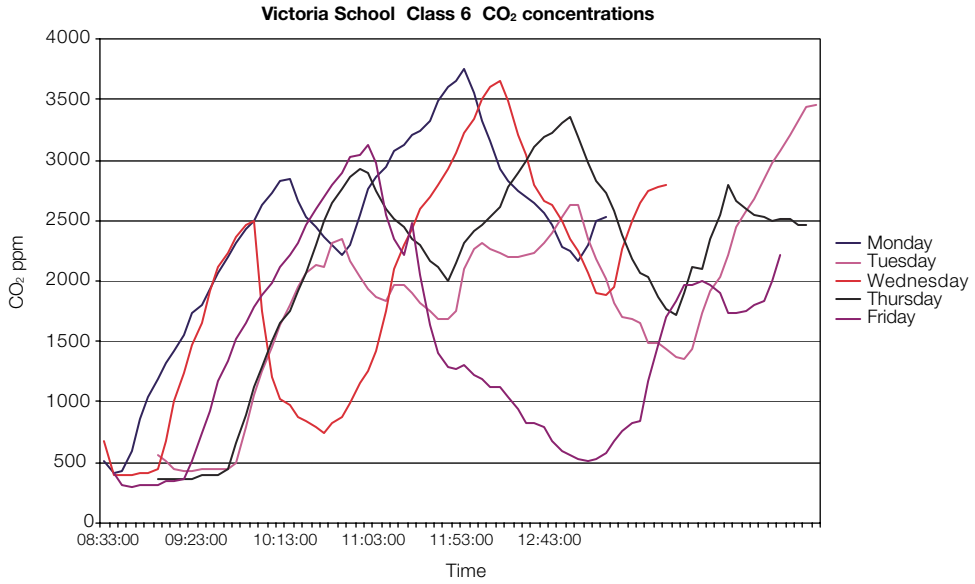


Figure 31. Victoria Junior School – Temperature and Humidity Measurements

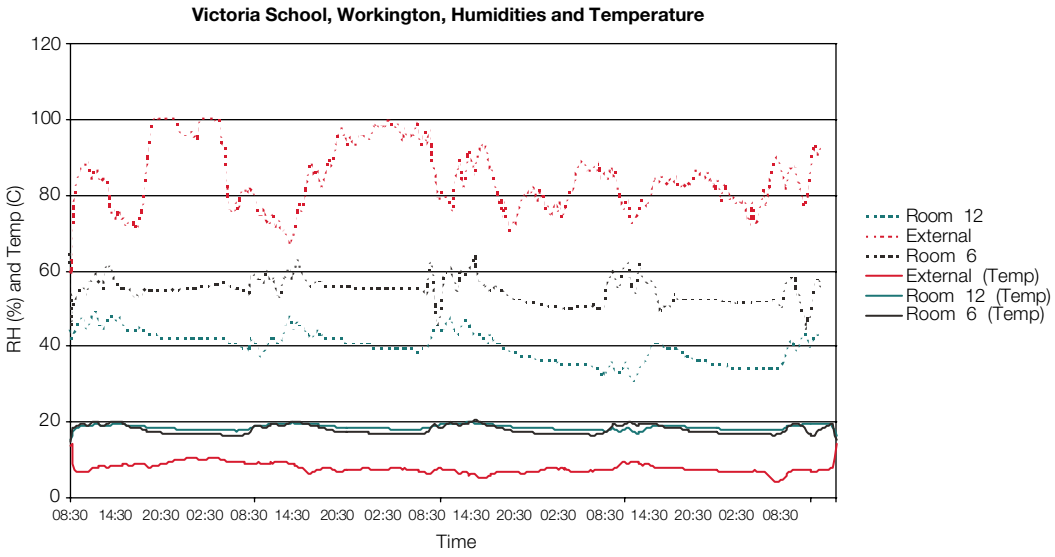


Figure 32. Victoria Junior School – Temperature alone

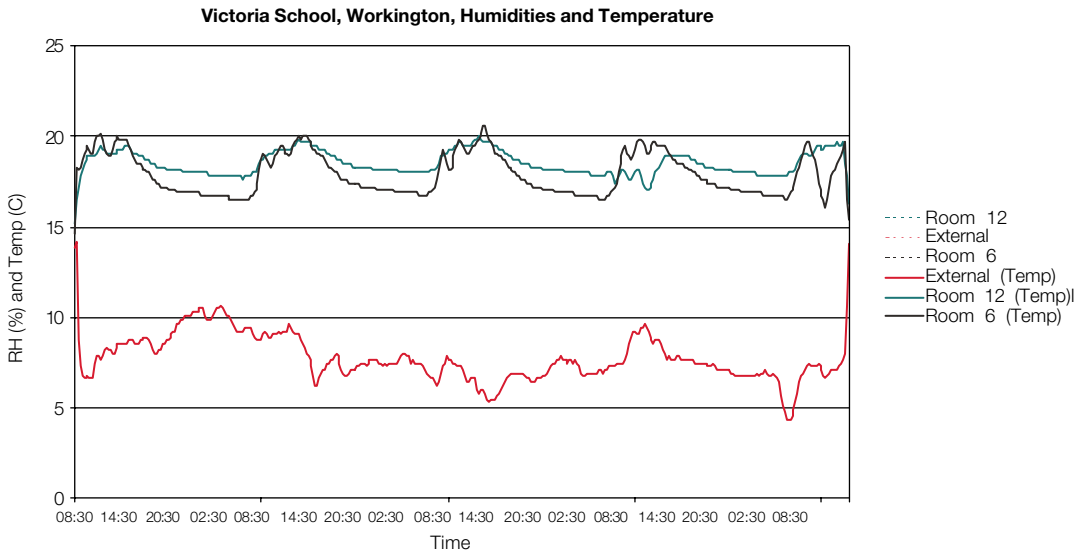
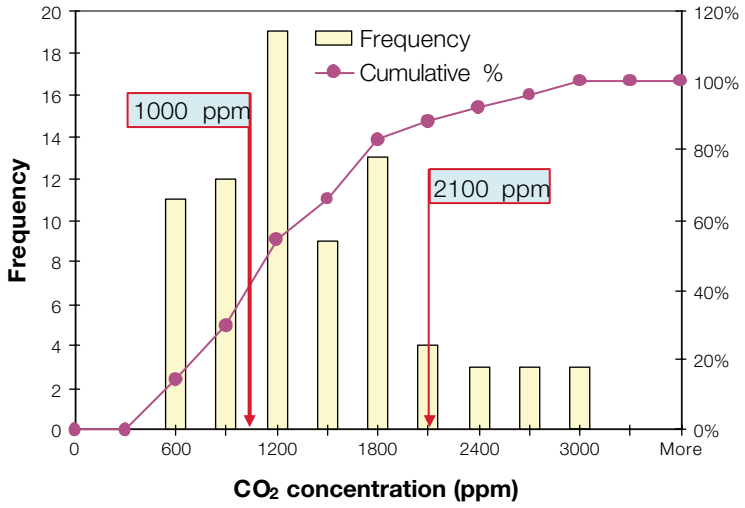


Figure 33. Frequency distribution of daily mean concentration of CO_2 across all classrooms



CHAPTER 12

Appendix A – The schools and measurement protocol

12.1 Monitoring procedure within the schools

12.1.1 WEST GROVE PRIMARY SCHOOL

Monitoring took place at West Grove primary school over a five day period from 9th September to the 13th September 2002. An initial visit was made on the 6th September to set out equipment in the most suitable locations. Two classrooms were identified as being suitable:

- Class 4M (T53) is located on the first floor at the eastern end of the front of the building. The room population was nominally 30 pupils, 1 teacher and 1-2 classroom assistants per day.

- Reception (T15) class is located on the ground floor at the western end of the rear of the building. The room population was nominally 30 pupils, 1 teacher and 1-2 classroom assistants per day. For the pupils of this class the school day ended at 12:00 midday.

The PM_{10} 7-hour sampler was placed in the main corridor and out of the way of the pupils. The 24-hour sampler was set up next to this with the sample head set up next to the 7-hour sample head.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and at an outside location and logged continuously during the whole period.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (T15, T53)

- In adjacent rooms (T17, Nursery, T25, T27, Hall, T49, T36)

- Outside (Playground)

The ultra-fine particulate monitor was used at these locations on one of the days.

Chart summary of the monitoring approach taken within the classrooms

West Grove primary school	
Class 4M (T53)	The CO/NO_2 sampler was placed on a beam above the front windows, where it was left for the whole week and a sample tube was run from it to the room centre where it hung down to just above adult head height. The CO_2 analyser was to have been placed next to the CO/NO_2 sample tube so that it sampled from approximately the same location. However, the girder was too high for this to be done safely on a daily basis so it was placed on a table at the front of the class each day. The VOC/PFT sample tubes and pump were placed next to the CO_2 analyser for the same reasons.
Reception class (T15)	The CO/NO_2 sampler was placed on a high shelf at the side of the classroom and left there for the whole week. The CO_2 analyser and the VOC/PFT tubes and pump were placed next to the CO/NO_2 sampler each day.

12.1.2 MOORSIDE PRIMARY SCHOOL

Monitoring took place at Moorside Primary School from 14th October until 18th October 2002. No initial visit was made to this school as it was too far away. Two classrooms were selected, these were:

- 2W (Infant 6) is located on the ground floor. The room population was nominally 28 pupils and 1 teacher.

- 6F (Junior 7) is located on the first floor. The room population was nominally 24 pupils and 1 teacher.

The PM_{10} 7-hour sampler was placed in the foyer by the main entrance. The 24-hour sampler was set up next to this with the sample head set up next to the 7-hour sample head.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and at an outside location and logged continuously during the whole period.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (2W, 6F)

- In adjacent rooms (Juniors 8 and 4, 3B, 2P, 1L, Library, Nursery, Hall)

- Outside (playground)

An ultra-fine particulate monitor was used to sample air inside and outside classrooms. It was used in all the above locations (except the library) and at three locations outside that were near to the road and play ground area.

Chart summary of the monitoring approach taken within the classrooms

Moorside primary school	
Infants class 2W	The CO/NO_2 sampler was placed on the top of the blackboard at the front of the class where it was left for the whole week. The CO_2 analyser and the VOC/PFT samplers were placed next to this on each day.
Junior class 6F	The CO/NO_2 sampler was placed on the top of the blackboard at the front of the class and left for the whole week. The CO_2 analyser and the VOC/PFT samplers were placed next to this each day.

12.1.3 WAVENDON GATE COMBINED SCHOOL

Monitoring took place at Wavendon Gate Combined School from 4th November until 8th November 2002. The equipment was set up on November 1st. Two classrooms were selected for the study:

- Class 2H (HB1) at the eastern end of the main corridor with occupancy level of nominally 29 pupils and one teacher.

- Class 7Cr (HB12) at the western end of the main corridor with occupancy level of nominally 29 pupils and one teacher.

The classrooms are open planned in their arrangement within the school. A central corridor connects classrooms throughout the length of the school. From the corridor there is a resource area and the classroom or homebase (HB) is off this. During lessons children can be in the classroom or the resource area.

The PM_{10} seven-hour sampler was placed in the main corridor just beyond the reception area. The 24-hour sampler was set up next to this.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and a number of outdoor locations.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (2H, 7Cr)

- In adjacent rooms (4Ma, Hall, Rc and Ro, 1Ho and 1V)

- Outside (playground, Car park, special resources room)

For one day the ultra-fine particulate monitor was placed next to the CO/NO_2 sampler in Class 7Cr.

Chart summary of the monitoring approach taken within the classrooms

Wavendon Gate primary school	
Class 2H (HB1)	The CO/NO_2 sampler was placed over the entry into the homebase on the lintel. The VOC/PFT sampler and the CO_2 analyser were placed next to this each day.
Class 7Cr (HB12)	The CO/NO_2 sampler was placed over the entry into the homebase on the lintel. The VOC/PFT sampler and the CO_2 analyser were placed next to this. On one day the ultra-fine particulate monitor was placed next to the CO/NO_2 sampler and left to run for the whole day.

12.1.4 BRAMINGHAM PRIMARY SCHOOL

Monitoring took place at Bramingham Primary School from 13th January until 17th, 2003. An initial visit was made on the 10th January to set out equipment. The two classrooms selected for this study were:

- Class 2 at the North/West side of the school with an occupancy level of nominally 26 pupils and two teachers.

- Class 10 at the South/East side of the school with an occupancy level of nominally 29 pupils and 2 teachers.

The layout of these classrooms is cellular with groups of three connected to each other by doors. The corridor outside each group of classrooms widens to encompass a work area where pupils may work in small groups or with tutors. During lessons children can be in the classroom or the work area.

The PM_{10} 7-hour sampler was placed in the foyer of the main entrance near the reception area and the 24-hour sampler was set up next to this.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and a number of outdoor locations.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (2, 10)

- In adjacent rooms (1, 4, 6, 8, 12 and main hall)

- Outside (Car park)

The ultra-fine particulate monitor was placed next to the CO/NO_2 sampler in Class 7Cr for one day.

Chart summary of the monitoring approach taken within the classrooms

Bramingham primary school	
Class 2	The CO/NO_2 sampler was placed on shelves by the doorway into class 3. The VOC/PFT sampler and the CO_2 analyser were placed next to this each day. On day 2 and day 4 a duplicate VOC/PFT sampler was placed on a table at the side of the class.
Class 10	The CO/NO_2 sampler was placed on a shelf on the eastern wall of the classroom. The VOC/PFT sampler and the CO_2 analyser were placed next to this. On day 3 and day 5 a duplicate VOC/PFT sampler was placed on a table at the side of the class.

12.1.5 BALTONSBOROUGH PRIMARY SCHOOL

Monitoring took place at Baltonsborough Primary School from 17th February until 20th February 2003. It was not possible to make an initial visit to this school due to the prohibitive distance. The two classrooms selected for test were:

- Class 1 at the Northern end of the main corridor. The room population was nominally 19 pupils and 4 teachers.

- Class 3 at the Southern end of the main corridor. The room population was nominally 29 pupils and 1 teacher.

The school has three cellular classrooms laid out along a corridor that widens out to form the library/resource and work areas. During lessons children can be in the classroom or the resource area.

The PM_{10} 7-hour sampler was placed just inside the library area just outside class 2. The 24-hour sampler was set up next to this.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and at an outside location and logged continuously during the whole period.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (1, 3)
- In adjacent rooms (2, library area)
- Outside (playground, Car park)

The ultra-fine particulate monitor was placed next to the CO/NO_2 sampler in Class 1 for one day.

Chart summary of the monitoring approach taken within the classrooms

Baltonsborough primary school	
Class 1	The CO/NO_2 sampler was placed on a shelf behind the teacher's desk. The VOC/PFT sampler and the CO_2 analyser were placed next to this each day.
Class 3	The CO/NO_2 sampler was placed on a shelf on the north side of the room. The VOC/PFT sampler and the CO_2 analyser were placed next to this.

12.1.6 GALLIONS PRIMARY SCHOOL

Monitoring took place at Gallions Primary School from 20th October until 23rd October 2003. An initial visit was made on the 17th October to set out equipment in the most suitable locations. Two classrooms were identified as being suitable:

- Year 2 classroom in the blue wing. The room population was nominally 26 pupils and 2 teachers.
- Year 6 classroom in the red wing. The room population was nominally 26 pupils and 1 teacher.

The layout of the classrooms in this school is cellular. A main corridor runs the entire length of the school and the classrooms are in wing off this. The classrooms have a conventional doorway. During lessons children are generally in the classroom or small groups and single children are with tutors in other areas.

The PM_{10} 7-hour sampler was placed in the main corridor near the secretaries' office, the 24-hour sampler was set up next to this with the sample head set up next to the 7-hour sample head.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and a number of outdoor locations.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (Year 2 [Samba] and Year 6 [Flamenco])
- In adjacent rooms (Soul, Blues, Disco, Marimba, Reggae, Classical)
- Outside (front of school)

Chart summary of the monitoring approach taken within the classrooms

Gallions primary school	
Year 2	The CO/NO_2 sampler was placed on the top of the blackboard (this was wide enough to form a shelf). The VOC/PFT sampler and the CO_2 analyser were placed next to this each day.
Year 6	The CO/NO_2 sampler was placed on top of the blackboard. The VOC/PFT sampler and the CO_2 analyser were placed next to this. On one day the ultra-fine particulate monitor was placed next to the CO/NO_2 sampler and left to run for the whole day.

12.1.7 QUEENSWELL INFANT SCHOOL

Monitoring took place at Queenswell Infant School from 17th November until 21st November 2003. An initial visit was made on the 14th November to set out the equipment. The two classrooms selected for the study were:

- Reception at the eastern end of the main corridor with occupancy level of nominally 20 pupils and one teacher.
- Year 2 at the western end of the main corridor with occupancy level nominally 20 pupils and one teacher.

Classrooms in this school are arranged in a cellular fashion. In the corridors there are a number of open areas used as teaching areas for single pupils or small groups. During lessons children are generally in the classroom or being tutored.

The PM_{10} seven-hour sampler was placed in the main corridor just beyond the reception area and the 24-hour sampler was set up next to this.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and at a number of outside locations.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (Reception, Year 2)
- In adjacent rooms (Y2N, Hall, F2A, F2K)
- Outside (Small playground)

Chart summary of the monitoring approach taken within the classrooms

Queenswell infant school	
Reception	The CO/NO_2 sampler was placed on a table against one wall. The VOC/PFT sampler and the CO_2 analyser were placed next to this each day. The ultra-fine particulate monitor was placed next to the CO/NO_2 sampler in the classroom for the morning of day 1.
Year 2	The CO/NO_2 sampler was placed on a window sill . The VOC/PFT sampler and the CO_2 analyser were placed next to this. On one day the ultra-fine particulate monitor was placed next to the CO/NO_2 sampler and left to run for the afternoon of day 1.

12.1.8 VICTORIA JUNIOR SCHOOL

Monitoring took place at Victoria Junior School from 24th November until 28th November 2003. No initial visit was made because of the prohibitive distance. The two classrooms selected for this study were:

- Class 6 at the North end of the building upstairs with occupancy levels of nominally 29 pupils and one teacher.

- Class 12 at the south end of the building on the ground floor with occupancy levels of nominally 29 pupils and one teacher.

The layout of the classrooms in this school follows an open plan arrangement. A main corridor runs the entire length of the school with classrooms running off it. The ground floor corridor is used as a resource and tutoring area. The corridor upstairs is used as the IT area. The classrooms do not have a conventional doorway, instead there is a large entryway which in some of the classrooms can be closed off by a curtain or blinds. During lessons children can be in the classroom or the resource areas.

The PM_{10} seven-hour sampler was placed in the main corridor just beyond the reception area and the 24-hour sampler was set up next to it.

Temperature and relative humidity 'Tiny Talk' data-loggers were placed in each classroom and at a number of outdoor locations.

Spot measurements of CO_2 were made on a daily basis in the following areas:

- In the classrooms being studied (6, 12)

- In adjacent rooms (2, 5, 8, 10, Hall)

- Outside (playground)

Chart summary of the monitoring approach taken within the classrooms

Victoria junior school	
Class 6	The CO/NO_2 sampler was placed on a shelf on the south wall of the room. The VOC/PFT sampler and the CO_2 analyser were placed next to this each day. On Day 3 the ultra-fine particulate monitor was placed next to the CO/NO_2 sampler for the afternoon.
Class 12	The CO/NO_2 sampler was placed over the entry into the homebase on the lintel. The VOC/PFT sampler and the CO_2 analyser were placed next to this. On Day 3 the ultra -fine particulate monitor was placed next to the CO/NO_2 sampler and left to run for the morning.

CHAPTER 13

Appendix B – Monitoring Methodology

The monitoring methodology for measuring the indoor air quality and ventilation of schools will follow the methods outlined below. It is based on a minimum of one week's occupied monitoring to obtain an accurate assessment of the typical conditions. Winter months are chosen as it is then, that the indoor air quality is most likely to be governed by reduced ventilation rates.

In all cases the monitoring was performed in typical and representative teaching areas of the school. These were selected with the assistance of the school head teacher. Most measurements were taken in the occupied period of the day. However, some specific tests of pollutants such as VOCs were made over at least one unoccupied period when the school was closed and effectively un-ventilated.

13.1 VOCs and aldehydes

This will follow an established methodology for measuring:

- formaldehyde
- acetaldehyde
- VOCs
- TVOC

An active system was required for the occupied period and samples taken for 30-45 minutes each day. The location was agreed as observed above. A check of the outdoor conditions was made.

13.2 Carbon monoxide

Several spot measurements of CO have been made both inside and outside of the school. Possible internal sources (combustion devices) were identified and measurements taken in those locations.

13.3 Particles

A particle counter was used to measure the number of particles (size range 0.1 to 10 microns) on a spot basis at various times and locations. Mass concentration of PM_{10} required impactors to be operated so care was taken when using them in teaching areas.

An ultra-fine particulate meter was also used in the schools. This measured particulates as small as 8 nm continuously and logged the results. As yet there is no established standard for these particles. The collection of these results was for interest alone. The protocol for using the ultra-fine meter has not been defined.

13.4 Microbiological

Samples taken in specified areas for culturing at 25 and 37°C. Samples will be taken using the hand held samplers for a period of approximately one minute. Areas in which there are known to be problems with damp conditions would be selected preferentially.

13.5 Dust mites

House dust mites were measured in areas with appropriate levels of carpeting or soft-furnishing.

13.6 Ventilation measurement

A key area of the monitoring process was to determine the ventilation of the chosen area of the school. The PFT method of measuring average ventilation rates was used. The tubes were used in a pumped sampling system operating for approximately 1 hour in each location. (Passive sampling was not possible unless the sample tubes were sealed at the end of each occupied day and re-opened the following day.) The sources were deployed at least 3-4 hours before the sampling periods begin.

13.7 Carbon dioxide

Carbon dioxide was important to measure as an indicator of overall fresh air supply and indoor air quality. It was used to derive the approximate ventilation rate of the monitored space when the occupancy is known. At the end of occupied periods the decay enabled the ventilation rate to be determined more accurately. This may be the background infiltration rate at the end of the day. Whenever possible the monitoring interval was no longer than 15 minutes.

13.8 Temperature and humidity

The space temperatures and humidities were recorded for comfort reasons. In addition they were needed to undertake the analysis of the PFT results. Simple ‘tinytalk’ loggers set to record at 15 minute intervals were adequate.

CHAPTER 14

Appendix C – Detailed results tables

14.1 Volatile Organic Compounds

Table 1: TVOCs and VOCs with guideline values determined in West Grove School, Reception class					
	Date of Sampling				
Compound µg m^{-3}	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Benzene	0.6, 0.5	0.6, 0.5	0.5, 0.5	0.7, 0.8	0.7, 0.7
Toluene	3.2, 3.1	2.7, 3.4	1.5, 1.6	1.5, 1.8	3.2, 3.2
Tetrachloroethylene	2.1, 4.3	ND*, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	1.1, 1.0	0.5, 0.5	0.4, 0.3	0.4, 0.4	0.9, 0.9
M/p-xylene	3.1, 2.8	1.7, 1.8	10, 0.8	1.0, 1.4	2.9, 2.9
Styrene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
2-butoxyethanol	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
TVOCs	209.5, 192.1	69.3, 79.2	32.3, 28.4	61.5, 60.9	262.0, 293.2

*ND = not detected, detection limit will be in the range 0.2-10 µg m^{-3} depending on the detector response for the compounds

Table 2: Other significant compounds found in West Grove School, Reception class					
	Date of Sampling				
Compound µg m^{-3}	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Alpha-pinene	9.0, 7.7	2.3, 2.3	1.1, 1.1	1.3, 1.4	7.9, 7.6
Limonene	27.0, 25.2	2.5, 3.2	1.6, 1.0	7.8, 8.2	94.7, 97.0
p-dichlorobenzene	28.3, 26.0	45.2, 48.1	7.6, 7.0	7.2, 7.3	31.5, 33.3
Nonanal	7.2, 7.4	3.7, 3.8	2.7, 3.0	5.7, 5.9	9.3, 9.4

Table 3: TVOCs and VOCs with WHO guideline values determined in West Grove School, Class T53					
	Date of Sampling				
Compound µg m^{-3}	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Benzene	0.8, 0.7	0.8, 0.8	0.5, 0.6	0.8, 0.9	0.6, 0.6
Toluene	5.7, 5.5	5.5, 5.6	3.0, 3.4	2.5, 2.7	3.7, 3.7
Tetrachloroethylene	1.8, 1.9	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	0.9, 0.8	1.5, 1.6	0.5, 0.6	0.6, 0.7	0.7, 0.8
M/p-xylene	2.9, 2.9	5.4, 5.6	1.7, 2.0	2.2, 2.4	2.1, 2.6
Styrene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
2-butoxyethanol	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
TVOCs	88.6, 73.6	117.5, 151.3	69.6, 75.9	71.0, 84.8	74.2, 80.4

Table 4: Other significant compounds found in West Grove School, Class T53

	Date of Sampling				
Compound µg m^{-3}	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Alpha-pinene	1.6, 1.6	6.9, 6.9	3.0, 3.5	4.4, 4.1	5.0, 5.5
Limonene	1.3, 1.1	15.4, 15.5	15.2, 15.6	9.0, 9.9	6.7, 7.1
p-dichlorobenzene	3.7, 3.1	7.3, 9.1	5.5, 6.7	6.7, 8.2	6.8, 8.8
Nonanal	3.8, 3.9	7.3, 9.1	5.5, 6.7	6.7, 8.2	6.8, 8.8

Table 5: TVOCs and VOCs with WHO guideline values determined in both West Grove School classrooms using diffusive sampling

	Classroom	
Compound µg m^{-3}	**Reception**	**T53**
Acrylonitrile	ND, ND	ND, ND
Chloroform	ND, ND	ND, ND
Carbon tetrachloride	ND, ND	ND, ND
Benzene	1.3, 1.2	1.5, 1.6
1,2-dichloroethane	ND, ND	ND, ND
Trichlorethylene	ND, ND	ND, ND
Methyl methacrylate	ND, ND	ND, ND
Toluene	5.1, 4.5	4.7, 5.2
Tetrachloroethylene	ND, ND	ND, ND
Chlorobenzene	ND, ND	ND, ND
Ethylbenzene	1.1, 0.9	1.5, 1.7
M/p-xylene	3.2, 3.1	5.0, 5.1
Styrene	ND, ND	ND, ND
2-butoxyethanol	ND, ND	ND, ND
1,1,2,2-tetrachloroethane	ND, ND	ND, ND
1,2,4-trichlorobenzene	ND, ND	ND, ND
TVOCs	119.5, 121.8	58.8, 53.4

Note: Due to a short exposure period of 4 days the detection limits obtained using diffusive sampling were higher than for active sampling (0.5-50 µg m^{-3} depending on the detector response for the compound).

Table 6: TVOCs and VOCs with WHO guidelines values determined outside West Grove School	
	Date of Sampling
Compound µg m^{-3}	09/09/02
Acrylonitrile	ND, ND
Chloroform	ND, ND
Carbon tetrachloride	ND, ND
Benzene	0.8, 0.9
1,2-dichloroethane	ND, ND
Trichloroet hylene	ND, ND
Methyl methacrylate	ND, ND
Toluene	3.8, 3.9
Tetrachloroethylene	ND, ND
Chlorobenzene	ND, ND
Ethylbenzene	0.6, 0.6
M/p-xylene	1.9, 2.0
Styrene	ND, ND
2-butoxyethanol	ND, ND
1,1,2,2-tetrachloroethane	ND, ND
1,2,4-trichlorobenzene	ND, ND
TVOCs	16.1, 30.8

Table 7: TVOCs found in Moorside School, Junior class 6F					
	Date of Sampling				
Compound µg m^{-3}	14/10/02	15/10/02	16/10/02	17/10/02	18/10/02
TVOCs	154.3, 159.5	124.7, 106.5	69.4, 67.9	128.6, 138.4	107.9, 117.8

Table 8: TVOCs found in Moorside School, Infant Class 2W					
	Date of Sampling				
Compound µg m^{-3}	14/10/02	15/10/02	16/10/02	17/10/02	18/10/02
TVOCs	109.9, 117.8	176.9, 158.5	94.5, 112.5	225.5	268.4, 244.0

Table 9: TVOCs found outside Moorside School	
	Date of Sampling
Compound µg m^{-3}	
TVOCs	9.1, 9.7

Table 10: TVOCs found in Wavendon Gate School, Class 2H (HB1)					
	Date of Sampling				
Compound µg m^{-3}	04/11/02	05/11/02	06/11/02	07/11/02	08/11/02
TVOCs	353.5, 303.8	128.2, 140.7	316.1, 98.5	143.2, 132.8	475.9, 497.9

Table 11: TVOCs found in Wavendon Gate School, Class 7Cr (HB12)					
	Date of Sampling				
Compound µg m^{-3}	04/11/02	05/11/02	06/11/02	07/11/02	08/11/02
TVOCs	–	140.1, 160.4	176.0	250.2,289.1	193.4, 242.5

– = No result obtained

Table 12: TVOCs found outside Wavendon Gate School	
	Date of Sampling
Compound µg m^{-3}	
TVOCs	7.5, 7.9

Table 13: TVOCs and VOCs with WHO guideline values determined in Bramingham School, class 2					
	Date of Sampling				
Compound µg m^{-3}	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Benzene	0.5, 0.6	0.7, 0.6	0.6, 0.6	0.7, 0.8	0.9, 1.0
Toluene	6.4, 5.1	9.1, 7.2	8.8, 8.4	9.8, 8.9	7.6, 7.7
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	1.7, 1.1	1.5, 1.2	1.2, 1.4	1.6, 1.4	1.7, 1.1
M/p-xylene	6.8, 4.3	4.5, 5.0	3.5, 4.8	5.4, 5.7	5.8, 4.8
Styrene	0.8, 0.7	1.0, 0.9	0.6, 0.5	0.6, 0.5	0.8, 0.7
2-butoxyethanol	26.8, 21.7	35.1, 28.2	33.8, 28.8	30.6, 27.0	28.0, 24.4
TVOCs	264, 230	335, 283	341, 306	416, 377	289, 262

Table 14: Other significant compounds found in Bramingham School, Class 2					
	Date of Sampling				
Compound µg m^{-3}	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Alpha-pinene	10.2, 11.2	12.5, 12.8	11.7, 11.0	13.4, 13.3	9.6, 9.6
Limonene	16.6, 15.5	20.1, 18.4	33.1, 27.8	75.7, 68.7	17.2, 15.6
Butan-1-ol	21.7, 19.8	28.5, 28.7	29.4, 36.7	50.0, 42.7	38.4, 41.0
Butyl Acetate	15.5, 7.6	11.2, 12.5	7.7, 12.5	13.7, 13.6	16.2, 10.7
2-ethylhexan-1-ol	36.5, 33.1	49.1, 49.3	48.6, 40.5	49.7, 45.0	34.9, 30.9

Table 15: TVOCs and VOCs with WHO guideline values determined in Bramingham School, Class 10

	Date of Sampling				
Compound µg m^{-3}	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Benzene	0.6, 0.4	0.6, 0.5	0.8, 0.6	0.9, 0.6	1.1, 1.1
Toluene	8.3, 8.6	6.0, 6.3	13.4, 11.1	15.0, 15.0	8.2, 9.0
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	1.1, 0.9	1.5, 1.3	2.4, 1.9	2.7, 2.8	1.7, 1.5
M/p-exlene	3.9, 3.5	5.5, 5.2	7.0, 6.5	8.3, 7.3	5.4, 4.5
Styrene	4.9, 0.5	0.8, 0.8	1.3, 1.3	1.9, 1.7	1.0, 1.0
2-butoxyethanol	29.8, 28.5	86.7, 77.0	121.0, 99.1	396, 365	67.6, 80.5
TVOCs	169, 156	234, 204	669, 567	704, 620	280, 306

Table 16: Other significant compounds found in Bramingham School, Class 10

	Date of Sampling				
Compound µg m^{-3}	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Alpha-pinene	5.7, 4.7	9.8, 9.2	18.9, 16.9	24.4, 18.3	9.9, 9.8
Limonene	5.1, 4.8	21.1, 18.4	26.4, 21.8	58.6, 51.0	15.2, 15.2
Butan-1-ol	26.9, 17.5	29.3, 31.6	58.1, 53.1	54.1, 46.6	28.3, 25.3
Butyl Acetate	6.8, 6.1	14.3, 12.8	15.2, 14.5	19.0, 17.3	12.0, 8.4
2-ethylhexan-1-ol	5.9, 5.0	7.9, 5.6	15.3, 12.5	19.4, 16.8	9.0, 10.3
1-methoxypropan-2-ol	5.5, 4.8	7.9, 5.6	15.3, 12.5	19.4, 16.8	9.0, 10.3

Table 17: TVOCs and VOCs with WHO guideline values determined in both Bramingham School classrooms using diffusive sampling

No diffusive sampling undertaken at this school

Table 18: TVOCs and VOCs with WHO guidelines determined values outside Bramingham School	
	Date of Sampling
Compound µg m^{-3}	13/01/03
Acrylonitrile	ND, ND
Chloroform	ND, ND
Carbon tetrachloride	ND, ND
Benzene	0.7, 0.6
1,2-dichl oroethane	ND, ND
Trichloroethylene	ND, ND
Methyl methacrylate	ND, ND
Toluene	1.7, 2.0
Tetrachloroethylene	ND, ND
Chlorobenzene	ND, ND
Ethylbenzene	0.6, 0.8
M/p-xylene	2.5, 3.6
Styrene	ND, ND
2-butoxyethanol	ND, ND
1,1,2,2-tetrachloroethane	ND, ND
1,2,4-trichlorobenzene	ND, ND
TVOCs	18, 23

Table 19: TVOCs and VOCs with WHO guideline values determined in Baltonsborough School, Classroom 1				
	Date of Sampling			
Compound µg m^{-3}	17/02/03	18/02/03	19/02/03	20/02/03
Benzene	1.1, 0.9	1.1, 1.1	–	0.7, 0.8
Toluene	5.9, 5.2	4.1, 3.8	–	3.9, 3.7
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	1.2, 1.0	0.7, 0.6	–	0.6, 0.4
M/p-xylene	4.3, 3.6	4.0, 4.3	–	2.3, 1.7
Styrene	ND	ND	ND	ND
2-butoxyethanol	9.8, 7.7	8.4, 6.7	–	10.1, 9.1
TVOCs	309, 266	152, 140	–	162, 136

Table 20: Other significant compounds found in Baltonsborough School, Classroom 1				
	Date of Sampling			
Compound µg m^{-3}	17/02/03	18/02/03	19/02/03	20/02/03
Alpha-pinene	24.7, 21.8	12.6, 12.1	–	13.4, 14.7
Limonene	60.9, 51.6	17.2, 15.7	–	23.4, 20.4
3-carene	4.5, 4.0	2.7, 2.5	–	3.1, 3.1
2-ethylhexan-1-ol	13.5, 11.4	9.7, 8.7	–	12.5, 9.5

Table 21: TVOCs and VOCs with WHO guideline values in Baltonsborough School, Class 3

	Date of Sampling			
Compound µg m^{-3}	17/02/03	18/02/03	19/02/03	20/02/03
Benzene	0.9	1.0, 1.2	1.4, 1.4	1.2, 1.0
Toluene	2.5	4.0, 4.0	3.7, 4.1	7.2, 5.9
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	0.3	0.7, 0.5	0.5, 0.4	1.1, 0.9
M/p-exlene	1.0	1.9, 1.5	1.7, 1.5	4.1, 3.0
Styrene	ND, ND	ND, ND	ND, ND	ND, ND
2-butoxyethanol	1.8	3.5, 5.2	4.5, 1.5	25.8, 17.2
TVOCs	80	117, 116	125, 112	326, 282

Table 22: Other significant compounds found in Baltonsborough School, Class 3

	Date of Sampling			
Compound µg m^{-3}	17/02/03	18/02/03	19/02/03	20/02/03
Alpha-pinene	6.3	12.4, 15.0	9.1, 9.0	28.4, 24.3
Limonene	11.5	10.2, 9.9	22.3, 20.1	40.2, 34.7
3-carene	1.2	2.8, 2.8	2.2, 2.2	6.0, 5.5
2-ethylhexan-1-ol	8.6	11.3, 10.2	12.0, 10.8	24.2, 20.5

Table 23: TVOCs and VOCs with WHO guideline values determined in both School classrooms using diffusive sampling

No diffusive sampling undertaken at this school

Table 24: TVOCs and VOCs with WHO guideline values determined outside Baltonsborough School	
	Date of Sampling
Compound µg m^{-3}	17/02/03
Acrylonitrile	ND, ND
Chloroform	ND, ND
Carbon tetrachloride	ND, ND
Benzene	0.8, 0.7
1,2-dichloroethane	ND, ND
Trichloroethylene	ND, ND
Methyl methacrylate	ND, ND
Toluene	0.4, 0.5
Tetrachloroethylene	ND, ND
Chlorobenzene	ND, ND
Ethylbenzene	ND, ND
M/p-xylene	ND, 0.2
Styrene	ND, ND
2-butoxyethanol	ND, ND
1,1,2,2-tetrachloroethane	ND, ND
1,2,4-trichlorobenzene	ND, ND
TVOCs	29, 12

Table 25: TVOCs and VOCs with WHO guideline values determined in Gallions School, Year 2 classroom					
	Date of Sampling				
Compound µg m^{-3}	20/10/03	21/10/03	22/10/03	23/10/03	24/10/03
Benzene	0.5, 0.5	0.5	0.8, 0.7	1.1, 1.3	0.6, 0.5
Toluene	5.6, 5.3	2.0	6.4, 4.7	6.3, 5.7	2.8, 2.1
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	1.4, 1.2	0.3	0.6, 0.5	0.9, 0.7	0.4, 0.3
M/p-xylene	3.2, 3.1	0.9	2.1, 1.5	2.9, 2.1	0.9, 0.8
Styrene	ND, 1.2	ND, ND	0.2, ND	ND, ND	ND, ND
2-butoxyethanol	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
TVOCs	62.4, 61.7	22.0	65.0, 44.5	64.6, 57.4	44.7, 32.2

Table 26: Other significant compounds found in Gallions School, Year 2 classroom					
	Date of Sampling				
Compound µg m^{-3}	20/10/03	21/10/03	22/10/03	23/10/03	24/10/03
Alpha-pinene	2.3, 2.0	0.6	1.8, 1.4	3.2, 3.1	2.1, 1.7
Limonene	1.6, 1.6	0.5	1.6, 1.2	8.5, 7.5	1.6, 1.3
n-butane	ND, ND	ND, ND	ND, ND	7.4, 7.7	ND, ND
Propan-2-ol, IPA	6.2, 5.7	14.7	17.2, 19.1	ND, ND	ND, ND
Decamethylcyclopentasiloxane	4.8, 4.6	1.4	10.3, 7.1	2.6, 2.1	3.1, 2.2
Nonanal	6.9, 6.1	1.4	10.3, 7.1	2.6, 2.1	3.1, 2.2
Alpha-terpineol	ND, ND	ND, ND	ND, ND	6.0, 4.7	0.6, 0.6

Table 27: TVOCs and VOCs with WHO guideline values determined in Gallions School, Year 6 classroom					
	Date of Sampling				
Compound µg m^{-3}	20/10/03	21/10/03	22/10/03	23/10/03	24/10/03
Benzene	0.4, 0.5	1.0, 0.9	1.3, 0.9	1.4, 1.3	0.8, 0.8
Toluene	2.2, 2.2	7.1, 5.8	9.2, 5.9	6.8, 5.3	3.6, 3.1
Tetrachloroethylene	1.8, 1.9	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	0.8, 0.7	1.8, 1.2	1.7, 0.9	2.2, 1.6	0.8, 0.7
M/p-exlene	1.9, 2.0	4.1, 2.9	3.8, 2.3	3.7, 2.8	1.4, 1.3
Styrene	0.2, 0.2	0.5, 0.6	0.6, 0.4	1.0, 0.6	0.5, 0.3
2-butoxyethanol	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
TVOCs	73.2, 73.8	130.2, 93.8	169.5, 103.5	110.4, 90.3	79.5, 71.3

Table 28: Other significant compounds found in Gallions School, Year 6 classroom					
	Date of Sampling				
Compound µg m^{-3}	20/10/03	21/10/03	22/10/03	23/10/03	24/10/03
Alpha-pinene	2.9, 2.5	4.8, 5.1	5.7, 4.3	9.1, 7.4	3.2, 2.8
Limonene	1.7, 1.7	2.7, 2.1	20.7, 13.4	5.8, 5.0	2.5, 2.5
n-heptane	5.9, 5.7	10.5, 9.4	20.7, 15.4	5.0, 4.1	7.8, 7.5
Propan-2-ol, IPA	20.5, 27.7	ND, ND	ND, ND	ND, ND	ND, ND
Methylcyclohexane	4.7, 5.0	5.6, 6.0	9.6, 8.9	2.6, 2.8	3.0, 3.1
b-caryophyllene	2.2, 1.7	5.5, 4.3	1.0, 0.6	1.6, 1.4	1.2, 1.2
Hydrocarbon RT 51.7 min	3.7, 3.2	7.2, 5.4	7.9, 5.2	9.3, 7.4	5.7, 5.3

Table 29: TVOCs and VOCs found in both Gallions School classrooms using diffusive sampling
No diffusive sampling undertaken at this school.

Table 30: TVOCs and VOCs with WHO guideline values determined outside Gallions School	
	Date of Sampling
Compound µg m^{-3}	20/10/03
Acrylonitrile	ND, ND
Chloroform	ND, ND
Carbon tetrachloride	ND, ND
Benzene	0.6, 0.6
1,2-dichloroethane	ND, ND
Trichloroethylene	ND, ND
Methyl methacrylate	ND, ND
Toluene	1.1, 1.0
Tetrachloroethylene	ND, ND
Chlorobenzene	ND, ND
Ethylbenzene	1.3, 1.1
M/p-xylene	3.9, 3.7
Styrene	ND, ND
2-butoxyethanol	ND, ND
1,1,2,2-tetrachloroethane	ND, ND
1,2,4-trichlorobenzene	ND, ND
TVOCs	13.5, 11.6

Table 31: TVOCs and VOCs with WHO guideline values determined in Queenswell School, Reception class					
	Date of Sampling				
Compound µg m^{-3}	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Acrylonitrile	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Chloroform	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Carbon tetrachloride	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Benzene	1.0, 1.1	0.6, 0.5	0.6, 0.5	0.8, 0.7	1.0, 0.9
1,2-dichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Trichloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Methyl methacrylate	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Toluene	12.2, 9.4	4.6, 4.1	4.3, 3.1	4.6, 4.1	14.2, 13.2
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Chlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	2.4, 1.9	0.6, 0.7	0.5, 0.4	1.0, 0.7	1.3, 1.3
M/p-xylene	4.4, 3.6	1.6, 1.8	1.5, 1.2	2.3, 1.9	3.0, 2.7
Styrene	0.9, 0.6	ND, ND	ND, ND	ND, ND	0.5, 0.6
2-butoxyethanol	20.6, 13.8	ND, ND	ND, ND	ND, ND	ND, ND
1,1,2,2tetrachloroethane	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
1,2,4trichlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
TVOCs 2 (including propan-2-ol)	700.2, 1487	127.2, 98.1	164.9, 116.1	171.1, 141.2	215.8, 190.9
TVOCs 2 (excluding propan-2-ol)	277.8, 223.9	127.2, 96.0	161.7, 114.6	162.9, 136.6	212.6, 187.4

2 = TVOC values provided with and without the inclusion of propan-2-ol as there is the possibility that use of the p-trak prior to or during sampling released propan-2-ol into the atmosphere

Table 32: Other significant compounds found in Queenswell School, Reception class					
	Date of Sampling				
Compound µg m^{-3}	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Methoxypropanol	2.8, 6.6	4.9, 2.4	29.4, 19.4	9.6, 9.7	10.3, 6.3
Alpha-pinene	18.2, 20.3	10.4, 8.1	11.1, 9.2	5.8, 5.7	20.3, 18.3
Limonene	12.8, 10.2	24.2, 20.4	50.1, 37.7	69.7, 59.5	18.7, 17.6
2-ethylhexan-1-ol	18.7, 16.8	10.4, 9.1	10.9, 8.5	7.6, 7.6	15.4, 13.3
Phenol	17.5, 12.7	8.4, 4. 8	6.4, 5.4	6.2, 5.2	10.6, 9.6

Table 33: TVOCs and VOCs with WHO guideline values determined in Queenswell School, Year 2					
	Date of Sampling				
Compound µg m^{-3}	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03[1]
Acrylonitrile	ND, ND	ND, ND	ND, ND	ND, ND	–
Chloroform	ND, ND	ND, ND	ND, ND	ND, ND	–
Carbon tetrachloride	ND, ND	ND, ND	ND, ND	ND, ND	–
Benzene	1.4, 1.2	0.6, 0.4	0.7, 0.6	0.7, 0.8	–
1,2-dichloroethane	ND, ND	ND, ND	ND, ND	ND, ND	–
Trichloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	–
Methyl methacrylate	ND, ND	ND, ND	ND, ND	ND, ND	–
Toluene	9.0, 6.5	3.8, 2.7	12.8, 12.5	14.2, 12.8	–
Tetrachloroethylene	3.4, 2.1	ND, ND	ND, ND	ND, ND	–
Chlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	–
Ethylbenzene	1.6, 1.2	0.6, 0.7	0.6, 0.6	1.3, 1.2	–
M/p-xylene	3.7, 3.3	1.2, 0.9	1.6, 1.6	2.5, 2.4	–
Styrene	1.2, 0.4	ND, ND	ND, ND	0.6, 0.4	–
2-butoxyethanol	ND, ND	ND, ND	ND, ND	ND, ND	–
1,1,2,2-tetrachloroethane	ND, ND	ND, ND	ND, ND	ND, ND	–
1,2,4-trichlorobenzene	ND, ND	ND, ND	ND, ND	ND, ND	–
TVOCs 2 (including propan-2-ol)	139.8, 109.6	129.1, 166.5	177.8, 151.5	271.5, 272.2	–
TVOCs 2 (excluding propan-2-ol)	137.5, 105.5	72.8, 57.7	170.4, 146.3	221.9, 207.0	–

1 = No results obtained

2 = TVOC values provided with and without the inclusion of propan-2-ol as there is the possibility that use of the p-trak prior to or during sampling released propan-2-ol into the atmosphere

Table 34: Other significant compounds found in Queenswell School, Year 2					
	Date of Sampling				
Compound µg m^{-3}	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Alpha-pinene	2.9, 2.6	4.9, 4.6	4.1, 4.0	11.7, 10.8	–
Limonene	5.6, 4.8	2.8, 2.6	51.6, 49.9	30.0, 26.4	–
2-ethylhexan-1-ol	9.2, 7.0	6.6, 5.5	7.5, 8.1	20.8, 20.0	–
Phenol	9.4, 7.7	5.2, 2.9	5.2, 3.7	11.2, 9.8	–
Unknown (RT 48.9 min)	(9.2), (6.8)	(5.2), (4.4)	(5.6), (6.2)	(8.5), (7.4)	–

( ) Calibrated using the response factor for toluene as no response factor available for this compound

Table 35: TVOCs and VOCs with WHO guideline values determined in both Queenswell School classrooms using diffusive sampling
No diffusive sampling undertaken at this school

Table 36: TVOCs and VOCs with WHO guideline values determined outside Queenswell School

	Date of Sampling
Compound µg m^{-3}	17/11/03
Acrylonitrile	ND, ND
Chloroform	ND, ND
Carbon tetrachloride	ND, ND
Benzene	1.5, 1.4
1,2-dichloroethane	ND, ND
Trichloroethylene	ND, ND
Methyl methacrylate	ND, ND
Toluene	5.2, 4.7
Tetrachloroethylene	ND, ND
Chlorobenzene	ND, ND
Ethylbenzene	0.8, 0.7
M/p-xylene	2.8, 2.5
Styrene	ND, ND
2-butoxyethanol	ND, ND
1,1,2,2-tetrachloroethane	ND, ND
1,2,4-trichlorobenzene	ND, ND
TVOCs 2 (including propan-2-ol)	74.4, 68.2
TVOCs 2 (excluding propan-2-ol)	17.1, 18.4

Table 37: TVOCs and VOCs found in Victoria School, Class 6

	Date of Sampling				
Compound µg m^{-3}	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Benzene	0.7, 0.6	0.4, 0.4	–	0.5, 0.8	–
Toluene	5.7, 5.1	6.3, 5.9	–	5.9, 7.6	–
Tetrachloroethylene	ND, ND	ND, ND	–	ND, ND	–
Ethylbenzene	0.6, 0.6	1.1, 0.9	–	0.6, 0.8	–
M/p-xylene	1.8, 1.5	2.5, 2.4	–	2.5, 2.4	–
Styrene	ND, ND	ND, ND	–	ND, ND	–
2-butoxyethanol	ND, ND	ND, ND	–	ND, ND	–
TVOCs	181, 169	263, 233	–	195, 210	–

Table 38: Other significant compounds found in Victoria School, Class 6

	Date of Sampling				
Compound µg m^{-3}	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Alpha-pinene	11.8, 10.5	21.1, 18.4	–	13.7, 13.5	–
Butan-1-ol	5.8, 5.1	13.8, 11.5	–	9.8, 7.6	–
Undecane	6.4, 5.7	9.9, 9.6	–	7.3, 7.5	–
2-ethylhexan-1-ol	18.6, 16.9	27.7, 23.7	–	18.1, 17.4	–

Table 39: TVOCs and VOCs found in Victoria School, Class 12					
	Date of Sampling				
Compound µg m^{-3}	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Benzene	0.8, 0.8	0.4, 0.5	0.5, 0.6	0.5, 0.5	0.8, 0.8
Toluene	16.1, 15.1	15.1, 14.7	14.4, 13.0	6.7, 6.3	14.2, 11.1
Tetrachloroethylene	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
Ethylbenzene	2.3, 1.9	5.1, 4.8	3.3, 2.7	1.9, 1.4	3.1, 2.3
M/p-exlene	4.5, 4.4	6.7, 6.6	4.4, 3.5	3.4, 2.6	4.4, 3.3
Styrene	1.5, 1.5	1.1, 0.9	2.1, 2.4	0.7, 0.5	1.8, 1.7
2-butoxyethanol	ND, ND	ND, ND	ND, ND	ND, ND	ND, ND
TVOCs	516, 487	508, 480	525, 479	391, 323	498, 383

Table 40: Other significant compounds found in Victoria School, Class 12					
	Date of Sampling				
Compound µg m^{-3}	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Alpha-pinene	31.5, 31.9	15.3, 21.4	25.3, 21.3	12.4, 13.1	26.3, 22.5
Butan-1-ol	56.3, 53.2	36.9, 43.7	38.6, 40.7	19.1, 21.5	48.1, 39.4
Methylisobutyl Ketone	38.8, 34.7	49.1, 48.9	8.9, 9.7	1.8, 1.3	2.2, 2.2
2-ethylhexan-1-ol	36.7, 33.5	36.7, 29.9	35.4, 32.2	29.0, 24.8	37.2, 30.8
Undecane	19.9, 18.9	28.7, 25.2	28.0, 26.1	24.5, 20.8	24.4, 19.3

Table 41: TVOCs and VOCs found in both Victoria School classrooms using diffusive sampling
No diffusive sampling undertaken on this school

Table 42: TVOCs and VOCs with WHO guideline values determined outside Victoria School	
	Date of Sampling
Compound µg m^{-3}	24/11/03
Acrylonitrile	ND, ND
Chloroform	ND, ND
Carbon tetrachloride	ND, ND
Benzene	0.6, 0.5
1,2-dichloroethane	ND, ND
Trichloroethylene	ND, ND
Methyl methacrylate	ND, ND
Toluene	1.1, 1.1
Tetrachloroethylene	ND, ND
Chlorobenzene	ND, ND
Ethylbenzene	0.3, 0.3
M/p-xylene	0.6, 0.6
Styrene	ND, ND
2-butoxyethanol	ND, ND
1,1,2,2-tetrachloroethane	ND, ND
1,2,4-trichlorobenzene	ND, ND
TVOCs	4.5, 3.8

14.2 Carbon Monoxide and Nitrogen Dioxide

Table 43: Concentrations (ppm) of CO determined during sampling of the Reception Class of West Grove School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Min	0.1	0.1	<0.1	<0.1	<0.1
Max	0.7	0.7	0.5	0.6	0.6
Average	0.4	0.3	0.2	0.3	0.2

Table 44: Concentrations (ppm) of CO determined during sampling of Class T53 of West Grove School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Min	<0.1	0.7	1.2	0.9	0.8
Max	2.8	1.0	1.3	1.3	1.3
Average	1.3	0.9	1.2	1.2	1.1

Table 45: Concentrations (ppm) of CO determined during sampling of the Infants Class of Moorside School

	Date of Sampling			
Recorded during school hours (assumed 9am to 4pm)	15/10/02	16/10/02	17/10/02	18/10/02
Min	0.1	<0.1	0.3	0.1
Max	0.6	0.5	1.2	1.5
Average	0.2	0.2	0.7	0.5

Table 46: Concentrations (ppm) of CO determined during sampling of the Junior Class of Moorside School

	Date of Sampling			
Recorded during school hours (assumed 9am to 4pm)	15/10/02	16/10/02	17/10/02	18/10/02
Min	0.2	0.2	0.7	0.2
Max	0.3	0.5	1.3	1.4
Average	0.2	0.3	0.9	0.7

Table 47: Concentrations (ppm) of CO determined during sampling of Class 2H (HB1) of Wavendon Gate School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	04/11/02	05/11/02	06/11/02	07/11/02	08/11/02
Min	0.3	<0.1	<0.1	<0.1	<0.2
Max	0.7	0.6	0.5	0.4	0.4
Average	0.3	0.2	0.2	0.2	0.1

Table 48: Concentrations (ppm) of CO determined during sampling of Class 7Cr (HB12) of Wavendon Gate School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	04/11/02	05/11/02	06/11/02	07/11/02	08/11/02
Min	<0.1	<0.1	<0.1	0.2	0.2
Max	0.6	0.4	0.4	0.3	0.3
Average	0.1	0.1	0.2	0.2	0.2

Table 49: Concentrations (ppm) of CO determined during sampling of Class 2, Bramingham School

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	0.2	0.1	0.1	0.2	0.2
Max	0.3	0.2	0.2	0.4	0.4
Average	0.2	0.2	0.2	0.3	0.3

Table 50: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Class 2, Bramingham School

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	0.2	0.1	0.1	0.2	0.2
Max	0.3	0.2	0.2	0.4	0.4
Average	0.2	0.2	0.2	0.3	0.3

Table 51: Concentrations (ppm) of CO determined during sampling of Class 10, Bramingham School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	<0.1	<0.1	<0.1	<0.1	<0.1
Max	0.5	0.3	0.8	0.6	1.1
Average	0.1	0.1	0.1	0.3	0.3

Table 52: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Class 2, Bramingham School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	0.1	<0.1	0.1	0.1	<0.1
Max	0.3	0.2	0.4	0.4	0.5
Average	0.2	0.1	0.1	0.3	0.3

Table 53: Concentrations (ppm) of CO determined during sampling of Class 1 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	0.3	0.2	0.3	0.2	0.3
Max	0.4	0.4	0.4	0.4	0.4
Average	0.3	0.3	0.4	0.3	0.3

Table 54: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Class 1 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	0.3	0.3	0.3	0.3	0.3
Max	0.4	0.4	0.4	0.4	0.3
Average	0.3	0.3	0.4	0.3	0.3

Table 55: Concentrations (ppm) of CO determined during sampling of Class 3 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	<0.1	<0.1	0.1	<0.1	<0.1
Max	1.3	0.8	0.7	0.5	0.4
Average	0.3	0.3	0.3	0.2	0.2

Table 56: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Class 3 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	0.1	0.1	0.1	<0.1	0.1
Max	0.6	0.5	0.6	0.4	0.3
Average	0.3	0.3	0.3	0.2	0.2

Table 57: Concentrations (ppm) of CO determined during sampling of Year 2 of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	20/10/2003	21/10/2003	22/10/2003	23/10/03	20/10/2003
Min	0.9	2.9	2.9	3.3	0.9
Max	2.8	3.5	3.3	4.1	2.8
Average	2.1	3.2	3.2	3.8	2.1

Table 58: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Year 2 classroom of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	20/10/2003	21/10/2003	22/10/2003	23/10/03	20/10/2003
Min	1.0	2.9	3.0	3.4	1.0
Max	2.8	3.5	3.3	4.0	2.8
Average	2.1	3.2	3.3	3.8	2.1

Table 59: Concentrations (ppm) of CO determined during sampling of Year 6 classroom of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	20/10/2003	21/10/2003	22/10/2003	23/10/03	20/10/2003
Min	0.3	0.2	0.1	<0.1	0.3
Max	0.4	0.6	0.5	0.4	0.4
Average	0.3	0.4	0.3	0.2	0.3

Table 60: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Year 6 of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	20/10/2003	21/10/2003	22/10/2003	23/10/03	20/10/2003
Min	0.3	0.2	0.1	0.1	0.3
Max	0.4	0.6	0.4	0.3	0.4
Average	0.3	0.4	0.4	0.2	0.3

Table 61: Concentrations (ppm) of CO determined during sampling of Queenswell School, Reception class

	Date of Sampling				
Recorded during school hours (assumed 9am to 3:30pm)	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Min	<0.1	<0.1	<0.1	<0.1	<0.1
Max	4.7	0.8	2.3	0.9	0.8
Average	0.3	0.3	0.5	0.5	0.5

Table 62: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Queenswell School, Reception Class

	Date of Sampling				
Recorded during school hours (15 min running mean)	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Min	<0.1	<0.1	<0.1	<0.1	<0.1
Max	2.5	0.6	1.4	0.8	0.8
Average	0.3	0.3	0.5	0.5	0.5

Table 63: Concentrations (ppm) of CO determined during sampling of the Queenswell School, Year 2

	Date of Sampling			
Recorded during school hours (assumed 9am to 4pm)	17/11/03	18/11/03	19/11/03	20/11/03
Min	0.2	<0.1	<0.1	0.2
Max	0.4	0.2	0.4	0.5
Average	0.3	0.1	0.2	0.3

No results obtained for Year 2 classroom for 21/11/03

Table 64: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Queenswell school, Year 2

	Date of Sampling			
Recorded during school hours (15 min running mean)	17/11/03	18/11/03	19/11/03	20/11/03
Min	0.2	0.1	0.1	0.2
Max	0.4	0.2	0.4	0.4
Average	0.3	0.1	0.2	0.3

Table 65: Concentrations (ppm) of CO determined during sampling of Victoria School, Class 6

	Date of Sampling				
Recorded during school hours (assumed 9am to 0330pm)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	0.1	0.1	0.2	0.2	0.2
Max	0.5	0.3	0.4	0.4	0.7
Average	0.4	0.2	0.3	0.3	0.4

Table 66: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Victoria School, Class 6

	Date of Sampling				
Recorded during school hours (15 min running mean)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	0.2	0.1	0.2	0.2	0.3
Max	0.5	0.3	0.4	0.4	0.6
Average	0.4	0.2	0.3	0.3	0.4

Table 67: Concentrations (ppm) of CO determined during sampling of Victoria School, Class 12

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	<0.1	<0.1	<0.1	<0.1	<0.1
Max	<0.1	0.5	0.6	8.5	1.8
Average	<0.1	<0.1	<0.1	0.1	<0.1

Table 68: Concentrations (ppm) of CO (15 min running mean) determined during sampling of Victoria School, Class 12

	Date of Sampling				
Recorded during school hours (15 min running mean)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	<0.1	<0.1	<0.1	<0.1	<0.1
Max	<0.1	0.4	0.4	4.2	1.0
Average	<0.1	<0.1	<0.1	<0.1	<0.1

Table 69: Concentrations (ppb) of NO_2 determined during sampling of the Reception Class of West Grove School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Min	<20	21	21	30	<20
Max	36	42	45	50	48
Average	27	31	34	40	29

Table 70: Concentrations (ppb) of NO_2 determined during sampling of Class T53 of West Grove School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	09/09/02	10/09/02	11/09/02	12/09/02	13/09/02
Min	<20	<20	<20	<20	<20
Max	36	41	33	40	39
Average	<20	<20	<20	<20	<20

Table 71: Concentrations (ppb) of NO_2 determined during sampling of the Infant Class of Moorside School

	Date of Sampling			
Recorded during school hours (assumed 9am to 4pm)	15/10/02	16/10/02	17/10/02	18/10/02
Min	<20	<20	29	22
Max	34	35	46	41
Average	26	26	37	30

Table 72: Concentrations (ppb) of NO_2 determined during sampling of the Junior Class of Moorside School

	Date of Sampling			
Recorded during school hours (assumed 9am to 4pm)	15/10/02	16/10/02	17/10/02	18/10/02
Min	<20	<20	<20	<20
Max	61	75	78	78
Average	36	36	45	37

Table 73: Concentrations (ppb) of NO_2 determined during sampling of Class 2H (HB1) of Wavendon Gate School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	04/11/02	05/11/02	06/11/02	07/11/02	08/11/02
Min	20	<20	<20	<20	<20
Max	33	42	31	27	33
Average	27	28	24	21	24

Table 74: Concentrations (ppb) of NO_2 determined during sampling of Class 7Cr (HB12) of Wavendon Gate School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	04/11/02	05/11/02	06/11/02	07/11/02	08/11/02
Min	<20	<20	<20	<20	<20
Max	50	69	102	65	60
Average	29	36	45	28	32

Table 75: Concentrations (ppb) of NO_2 determined during sampling of Bramingham School, Class 2

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	<20	<20	<20	<20	<20
Max	133	60	58	51	66
Average	<20	<20	<20	<20	<20

Table 76: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Bramingham School, Class 2

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	<20	<20	<20	<20	<20
Max	22	24	25	23	25
Average	<20	<20	<20	<20	<20

Table 77: Concentrations (ppb) of NO_2 determined during sampling of Bramingham School, Class 10

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	<20	<20	<20	<20	<20
Max	35	33	40	28	33
Average	26	25	25	23	25

Table 78: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Bramingham School, Class 10

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	13/01/03	14/01/03	15/01/03	16/01/03	17/01/03
Min	20	20	20	22	23
Max	3	28	31	24	27
Average	26	25	25	23	25

Table 79: Concentrations (ppb) of NO_2 determined during sampling of Class 1 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	<20	<20	<20	<20	<20
Max	37	29	35	30	40
Average	<20	<20	<20	<20	<20

Table 80: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Baltonsborough School, Class 1

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	<20	<20	<20	<20	<20
Max	<20	<20	<20	<20	<20
Average	<20	<20	<20	<20	<20

Table 81: Concentrations (ppb) of NO_2 determined during sampling of Class 3 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	<20	<20	<20	<20	<20
Max	52	32	32	32	39
Average	21	22	22	22	23

Table 82: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Class 3 of Baltonsborough School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/02/03	18/02/03	19/02/03	20/02/03	21/02/03
Min	<20	21	22	20	<20
Max	24	23	24	23	25
Average	21	22	23	22	22

Table 83: Concentrations (ppb) of NO_2 determined during sampling of year 2 of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	20/10/03	21/10/03	22/10/03	23/10/03	20/10/2003
Min	<20	<20	<20	<20	<20
Max	<20	25	29	35	<20
Average	<20	<20	20	<20	<20

Table 84: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of year 2 of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	20/10/03	21/10/03	22/10/03	23/10/03	20/10/2003
Min	<20	<20	<20	<20	<20
Max	<20	24	26	28	<20
Average	<20	<20	20	<20	<20

Table 85: Concentrations (ppb) of NO_2 determined during sampling of year 6 of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	20/10/03	21/10/03	22/10/03	23/10/03	20/10/2003
Min	<20	<20	<20	<20	<20
Max	26	31	28	31	26
Average	<20	<20	<20	<20	<20

Table 86: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of year 6 of Gallions School

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	20/10/03	21/10/03	22/10/03	23/10/03	20/10/2003
Min	<20	<20	<20	<20	<20
Max	21	28	24	26	21
Average	<20	<20	<20	<20	<20

Table 87: Concentrations (ppb) of NO_2 determined during sampling of Queenswell School, Reception Class

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Min	<20	<20	<20	<20	<20
Max	30	22	26	24	21
Average	<20	<20	<20	<20	<20

Table 88: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Queenswell School, Reception Class

	Date of Sampling				
Recorded during school hours (1 hour running mean)	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Min	<20	<20	<20	<20	<20
Max	23	<20	23	20	<20
Average	<20	<20	<20	<20	<20

Table 89: Concentrations (ppb) of NO_2 determined during sampling of Queenswell School, Year 2

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Min	<20	<20	<20	<20	–
Max	37	25	27	78	–
Average	26	<20	<20	<20	–

— = No results obtained for this classroom on this day — = No results obtained

Table 90: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Queenswell School, Year 2

	Date of Sampling				
Recorded during school hours (15 min running mean)	17/11/03	18/11/03	19/11/03	20/11/03	21/11/03
Min	<20	<20	<20	<20	–
Max	30	22	24	41	–
Average	26	<20	<20	<20	–

Table 91: Concentrations (ppb) of NO_2 determined during sampling of Victoria School, Class 6

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	<20	<20	<20	<20	<20
Max	21	<20	36	<20	35
Average	<20	<20	<20	<20	<20

Table 92: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Victoria School, Class 6

	Date of Sampling				
Recorded during school hours (1 hour running mean)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	<20	<20	<20	<20	<20
Max	<20	<20	32	<20	29
Average	<20	<20	<20	<20	<20

Table 93: Concentrations (ppb) of NO_2 determined during sampling of Victoria School, class 12

	Date of Sampling				
Recorded during school hours (assumed 9am to 4pm)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	<20	<20	<20	–	<20
Max	<20	<20	<20	–	61
Average	<20	<20	<20	–	32

Table 94: Concentrations (ppb) of NO_2 (1-hour running mean) determined during sampling of Victoria School, Class 12

	Date of Sampling				
Recorded during school hours (1 hour running mean)	24/11/03	25/11/03	26/11/03	27/11/03	28/11/03
Min	<20	<20	<20	–	<20
Max	<20	<20	<20	–	49
Average	<20	<20	<20	–	32

14.3 Formaldehyde and Acetaldehyde

Table 95: Concentrations of formaldehyde and acetaldehyde found in the Reception Class of West Grove School and outside

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
09/09/02	Outside	2	3
09/09/02	Reception class	40	18
10/09/02	Reception class	13	9
11/09/02	Reception class	14	5
12/09/02	Reception class	15	4

Table 96: Concentrations of formaldehyde and acetaldehyde found in Class T53 of West Grove School

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
09/09/02	Class T53	5	5
10/09/02	Class T53	25	12
11/09/02	Class T53	14	5
12/09/02	Class T53	11	8

Table 97: Concentrations of formaldehyde and acetaldehyde found in the Infant Class of Moorside School and outside

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
14/10/02	Outside	5	1
14/10/02	Infant class	25	7
15/10/02	Infant Class	18	4
16/10/02	Infant Class	9	2
17/10/02	Infant Class	21	7

Table 98: Concentrations of formaldehyde and acetaldehyde found in the Junior Class 6 of Moorside School

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
14/10/02	Junior Class 6	26	8
15/10/02	Junior Class 6	12	3
16/10/02	Junior Class 6	11	3
17/10/02	Junior Class 6	22	7

Table 99: Concentrations of formaldehyde and acetaldehyde found in Class HB1 of Wavendon Gate Primary School

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
04/11/02	Outside	2	3
04/11/02	Class 1	62	14
05/11/02	Class 1	42	23
06/11/02	Class 1	47	21
07/11/02	Class 1	53	11

Table 100: Concentrations of formaldehyde and acetaldehyde found in Class HB12 of Wavendon Primary School

Date of Sampling	Location	Concentration (μg m^{-3})	
		Formaldehyde	Acetaldehyde
04/11/02	Class 12	23	2
05/11/02	Class 12	34	10
06/11/02	Class 12	22	6
07/11/02	Class 12	15	2

Table 101: Concentrations of formaldehyde and acetaldehyde found in Bramingham School, Class 2 and outside

Date of Sampling	Location	Concentration (μg m^{-3})	
		Formaldehyde	Acetaldehyde
13/01/03	Outside	3	<1
13/01/03	Class 2	24	6
14/01/03	Class 2	26	6
15/01/03	Class 2	33	14
16/01/03	Class 2	26	11

Table 102: Concentrations of formaldehyde and acetaldehyde found in Bramingham School, Class 10

Date of Sampling	Location	Concentration (μg m^{-3})	
		Formaldehyde	Acetaldehyde
13/01/03	Class 10	29	5
14/01/03	Class 10	33	18
15/01/03	Class 10	42	15
16/01/03	Class 10	48	25

Table 103: Concentrations of formaldehyde and acetaldehyde found in Baltonsborough School, Class 1 and outside

Date of Sampling	Location	Concentration (μg m^{-3})	
		Formaldehyde	Acetaldehyde
17/02/03	Outside	1	2
17/02/03	Class 1	29	13
18/02/03	Class 1	30	12
19/02/03	Class 1	27	12
20/02/03	Class 1	17	8

Table 104: Concentrations of formaldehyde and acetaldehyde found in Baltonsborough School, Class 3			
Date of Sampling	**Location**	**Concentration (µg m^{-3})**	
		Formaldehyde	**Acetaldehyde**
17/02/03	Class 3	14	7
18/02/03	Class 3	14	6
19/02/03	Class 3	8	4
20/02/03	Class 3	19	14

Table 105: Concentrations of formaldehyde and acetaldehyde found in Gallions School, Year 2 and outside			
Date of Sampling	**Location**	**Concentration (µg m^{-3})**	
		Formaldehyde	**Acetaldehyde**
20/10/03	Outside	<1	2
20/10/03	Class 2	15	5
21/10/03	Class 2	9	5
22/10/03	Class 2	11	2
23/10/03	Class 2	13	5

Table 106: Concentrations of formaldehyde and acetaldehyde found in Gallions School, Year 6			
Date of Sampling	**Location**	**Concentration (µg m^{-3})**	
		Formaldehyde	**Acetaldehyde**
20/10/03	Class 6	16	3
21/10/03	Class 6	8	8
22/10/03	Class 6	17	4
23/10/03	Class 6	22	8

Table 107: Concentrations of formaldehyde and acetaldehyde found in Queenswell School, Reception class and outside			
Date of Sampling	**Location**	**Concentration (µg m^{-3})**	
		Formaldehyde	**Acetaldehyde**
17/11/03	Outside	2	<2
17/11/ 03	Reception	20	8
18/11/03	Reception	19	4
19/11/03	Reception	15	6
20/11/03	Reception	17	6

Table 108: Concentrations of formaldehyde and acetaldehyde found in Queenswell School, Year 2

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
17/11/03	Year 2	9	4
17/11/03	Year 2	11	5
18/11/03	Year 2	9	5
19/11/03	Year 2	23	9

Table 109: Concentrations of formaldehyde and acetaldehyde found in Victoria School, Class 6 and outside

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
24/11/03	Outside	<1	<2
24/11/03	Room 6	34	8
25/11/03	Room 6	42	9
26/11/03	Room 6	42	9
27/11/03	Room 6	29	6

Table 110: Concentrations of formaldehyde and acetaldehyde found in Victoria School, Class 12

Date of Sampling	Location	Concentration (µg m^{-3})	
		Formaldehyde	Acetaldehyde
24/11/03	Room 12	51	14
25/11/03	Room 12	65	13
26/11/03	Room 12	55	13
27/11/03	Room 12	49	9

14.4 PM_{10}

Table 111: PM_{10} levels recorded in all schools

Sampling Dates	Location	Daily (7-hour) Sampling (µg m^{-3})	24-hour sampling (µg m^{-3})
09-12/09/02	West Grove School	43.0	42.6
14-18/10/02	Moorside School	28.3	19.5
04-08/11/02	Wavendon Gate School	23.8	33.2
13-17/01/03	Bramingham School	26.4	33.8
17-21/02/03	Baltonsborough School	12.2	27.8
20-23/10/03	Gallions School	34.9	16.8
17-21/11/03	Queenswell School	35.3	24.5
24-28/11/03	Victoria School	36.6	30.1

14.5 Bacteria and Fungi

Table 112: Bacteria & Fungi levels found in West Grove School airborne count/cfu/m^3 air			
Colony Counts		**Bacteria cfu/m^3**	**Fungi cfu/m^3**
Reception	Mean	509	461
	Min	60	240
	Max	950	590
T53	Mean	539	425
	Min	20	90
	Max	1250	990
Outside reception	Mean	120	678
	Min	30	500
	Max	190	790
Outside T53	Mean	88	778
	Min	40	570
	Max	160	970

Table 113: Bacteria & Fungi Levels found in Moorside School airborne count/cfu/m^3 air			
Colony Counts		**Bacteria cfu/m^3**	**Fungi cfu/m^3**
Infants	Mean	534	144
	Min	80	40
	Max	950	220
Juniors	Mean	446	206
	Min	60	80
	Max	870	490
Outside Infants	Mean	90	263
	Min	60	100
	Max	120	480
Outside Juniors	Mean	110	260
	Min	80	130
	Max	150	340

Table 114: Bacteria & Fungi levels found in Wavendon Gate School airborne count/cfu/m³ air			
Colony Counts		**Bacteria cfu/m³**	**Fungi cfu/m³**
Class 2 (HB 1)	Mean	881	335
	Min	80	30
	Max	1640	540
Class 7 (HB 7)	Mean	609	196
	Min	10	40
	Max	960	320
Outside class 1	Mean	50	712
	Min	0	420
	Max	130	1570
Outside class 7	Mean	128	554
	Min	70	300
	Max	200	1200

Table 115: Bacteria & Fungi levels found in Bramingham School airborne count/cfu/m³ air			
Colony Counts		**Bacteria cfu/m³**	**Fungi cfu/m³**
Class 2	Mean	480	182
	Min	30	100
	Max	790	270
Class 10	Mean	397	212
	Min	20	80
	Max	740	350
Outside Class 2	Mean	44	135
	Min	10	50
	Max	80	270

Table 116: Bacteria & Fungi levels found in Baltonsborough School airborne count/cfu/m³ air			
Colony Counts		**Bacteria cfu/m³**	**Fungi cfu/m³**
Class 1	Mean	650	120
	Min	160	60
	Max	1290	300
Class 3	Mean	365	169
	Min	40	40
	Max	1190	340
outside	Mean	217	190
	Min	110	90
	Max	330	250

Table 117: Bacteria & Fungi levels found in the Gallions School airborne count/cfu/m^3 air			
Colony Counts		**Bacteria cfu/m^3**	**Fungi cfu/m^3**
Year 2	Mean	906	205
	Min	350	100
	Max	1240	420
Year 6	Mean	640	203
	Min	190	90
	Max	1470	280
outside	Mean	415	270
	Min	190	230
	Max	800	320

Table 118: Bacteria & Fungi levels found in Queenswell School airborne count/cfu/m^3 air			
Colony Counts		**Bacteria cfu/m^3**	**Fungi cfu/m^3**
Reception	Mean	610	672
	Min	400	230
	Max	790	1190
Year 2	Mean	199	802
	Min	10	430
	Max	380	1140
Outside	Mean	85	1295
	Min	60	1160
	Max	120	1370

Table 119: Bacteria & Fungi levels found in Victoria School airborne count/cfu/m^3 air			
Colony Counts		**Bacteria cfu/m^3**	**Fungi cfu/m^3**
Class 6	Mean	506	50
	Min	90	0
	Max	870	130
Class 12	Mean	324	438
	Min	120	30
	Max	780	1810
Outside	Mean	226	74
	Min	110	60
	Max	370	90

14.6 Dust mites

Table 120: Dust mites levels found in West Grove School

Location	Mites (g^{-1})
Reception class	2
Reception class	1
Reception class	0
TS3	4
TS3	8

Table 121: Dust mites levels found in Moorside Primary School

Location	Mites (g^{-1})
Infant class	5
Infant class	0
Junior class	0
Junior class	2

Table 122: Dust mites levels found in Wavendon Gate Primary School

Location	Mites (g^{-1})
Class 2 (HB 1)	0
Class 2 (HB1)	0
Class 7 (HB7)	10
Class 7 (HB7)	20

Table 123: Dust mites levels found in Bramingham Primary School

Location	Mites (g^{-1})
Class 2	4
Class 2	6
Class 10	0
Class 10	5

Table 124: Dust mites levels found in Baltonsborough School

Location	Mites (g^{-1})
Class 1	3
Class 2	0
Class 3	9
Class 3	2

Table 125: Dust mites levels found in Gallions School	
Location	**Mites (g^{-1})**
Year 2	5
Year 2	2
Year 6	6
Year 6	7

Table 126: Dust mites levels found in Queenswell School	
Location	**Mites (g^{-1})**
Reception class	1
Reception class	0
Year 2	9
Year 2	4

Table 127: Dust mites levels found in Victoria School	
Location	**Mites (g^{-1})**
Class 12	2
Class 12	0

14.7 Ventilation and Carbon Dioxide

Table 128: Ventilation & CO_2 Levels found in West Grove School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
Recep	1	1.6	–	–	T53	1	6.1	8	16
Recep	2	8.7	–	–	T53	2	2.1	–	–
Recep	3	7.3	–	–	T53	3	4.9	–	–
Recep	4	7.9	–	–	T53	4	7.1	12.5	25
Recep	5	1.6	–	–	T53	5	6.0		

Table 129: Ventilation & CO_2 Levels found in Moorside School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
2W	1	3.4	4.1	8.2	C6	1	2.7	3.7	7.4
2W	2	1.8	4	8.1	C6	2	6.5	5.3	11
2W	3	4.7	4.6	9	C6	3	6.0	5.2	10.3
2W	4	4.3	3	6.2	C6	4	4.3	5.2	10.3
2W	5	3.0	3.4	6.9	C6	5	3.0	3.8	7.5

Table 130: Ventilation & CO_2 Levels found in Wavendon Gate School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
HB1	1	1.3	2.1	4.2	HB12	1	–	2.9	5.8
HB1	2	5.1	2.5	4.9	HB12	2	7.7	9.6	19
HB1	3	1.8	2.7	5.4	HB12	3	7.2	7.1	13.2
HB1	4	2.6	3.3	6.6	HB12	4	5.4	4.9	9.7
HB1	5	1.7	2.9	5.7	HB12	5	6.3	6.5	12.8

Table 131: Ventilation & CO_2 Levels found in Bramingham School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
2	1	1.87			10	1	12.1		
2	2	1.28			10	2	2.49		
2	3	0.81			10	3	0.69		
2	4	0.88			10	4	0.47		
2	5	1.08			10	5	1.75		

Table 132: Ventilation & CO_2 Levels found in Baltonsborough School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
1	1	1.68			3	1	20.98		
1	2	0.9			3	2	2.51		
1	3	–			3	3	5.83		
1	4	5.28			3	4	2.63		
1	5	–			3	5	–		

Table 133: Ventilation & CO_2 Levels found in Gallions School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
Year 2	1	1.84			Year 6	1	5.38		
Year 2	2	8.56			Year 6	2	3.22		
Year 2	3	4.80			Year 6	3	2.34		
Year 2	4	2.15			Year 6	4	1.33		
Year 2	5	–			Year 6	5	–		

Table 134: Ventilation & CO_2 Levels found in Queenswell School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
Recep	1	1.31			Year 2	1	7.45		
Recep	2	5.16			Year 2	2	5.11		
Recep	3	7.94			Year 2	3	4.23		
Recep	4	3.3			Year 2	4	1.71		
Recep	5	0.99			Year 2	5	3.16		

Table 135: Ventilation & CO_2 Levels found in Victoria School

Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person		Class	Day	Ventilation Rate L/sec per person	CO_2 Rate L/sec per person	
			M = 160 w	M = 320 w				M = 160 w	M = 320 w
R6	1	2.61			R12	1	0.47		
R6	2	1.45			R12	2	1.67		
R6	3	–			R12	3	1.42		
R6	4	1.86			R12	4	3.56		
R6	5	–			R12	5	2.19		

CHAPTER 15

Appendix D – Guideline values for IAQ results

Table 1: Proposed Guidelines for Acceptable TVOC Concentrations in Indoor Air

Author	Concentration (µg m^{-3})	Comment	Reference
National Health and Medical Research Council (Australia)	500	No single compound should contribute >50%	Dingle & Murray (1993)
Mølhave, L	<200	Comfort range	ECA (1992)
	200-3,000	Multifactorial exposure	
	3000-25,000	Discomfort	
	>25,000	Toxic	
Seifert, B	300	Target guideline value (no individual compound should exceed 10% of target value)	(ECA 1992)
Finnish Society of Indoor Air Quality and Climate	<200	Target values of indoor climate; best air quality; 90% of occupants satisfied	FiSIAQ (1995)
	<300	Intermediate air quality – room may have slight odour	
	<600	Minimum requirement	
Japanese Ministry of Health, Labour and Welfare	<400	Advisable for residential air	Japanese Ministry of Health, Labour and Welfare (2000)

References:

Dingle, P and Murray, F. Control and regulations of indoor air: an Australian perspective. Indoor Environment, 2, 217, 1993.

European Concerted Action. Guidelines for ventilation requirements in buildings. ECA Indoor air quality and its impact on man, Report No. 11, Commission of European communities, Luxembourg, report EUR 14449 EN, 1992.

Finnish Society of Indoor air Quality and Climate. Classification of indoor climate, construction and finishing materials, 1995.

Japanese Ministry of Health, Labour and Welfare 2000, Committee on Sick House Syndrome: Indoor air pollution, Progress report No. 1 – Summary discussions from the 1st to 3rd meetings, 26/6/00.

Table 2: WHO guideline values, tolerable concentrations and carcinogenic risk estimates for individual substances

Substance	Time-weighted average guideline value (GV) or tolerable concentration (TC) (µg m^{-3})	Averaging time	Unit risk[a]	Ref.
Carbon monoxide	100,000 (≅ 86 ppm) 60,000 30,000 (≅26 ppm) 10,000	15 min 30 min 1 hour 8 hours		WHO, 2000
Formaldehyde	100	30 min		WHO, 2000
Acetaldehyde	2,000 (TC) 50 (TC)	24 hours 1 year		WHO, 1999
Nitrogen dioxide	200 (≅ 110 ppb) 40	1 hour annual		WHO, 1999
Acrylonitrile			2×10^{-5}	WHO, 2000
Chloroform			4.2×10^{-7}	WHO, 1999
Carbon tetrachloride	6.1 (TC)	1 year		WHO, 1999
Benzene			6×10^{-6}	WHO, 2000
1,2-dichloroethane	700 (GV)	24 hours		WHO, 2000
Trichloroethylene			4.3×10^{-7}	WHO, 2000
Methyl methacrylate	200 (TC)	1 year		WHO, 1999
Toluene	260 (GV)	1 week		WHO, 2000
Tetrachloroethylene	250 (GV)	annual		WHO, 2000
Chlorobenzene	500 (TC)	1 year		WHO, 1999
Ethylbenzene	22,000 (GV)	1 year		WHO, 1999
m/p-xylene	870 (GV)	1 year		WHO, 1999
Styrene	260 (GV)	1 week		WHO, 2000
2-butoxyethanol	13,100 (TC)	1 week		WHO, 1999
1,1,2,2tetrachloroethane			$(0.6\text{-}3.0) \times 10^{-6}$	WHO, 1999
1,2,4-trichlorobenzene	50 (TC)	1 year		WHO, 1999

[a] Cancer risk estimates for lifetime exposure to a concentration of 1 µg m^{-3}

Table 3: Environmental categories for mixed populations of fungi and bacteria in internal environments (after Wanner *et al.*, 1993).

Category	Domestic indoor environments	Non-industrial indoor environments	Domestic indoor environments	Non-industrial indoor environments
	Fungi* (cfu m^{-3})**		Bacteria* (cfu m^{-3})	
very low	<50	<25	<100	<50
low	<200	<100	<500	<100
intermediate	<1,000	<500	<2,500	<500
high	<10,000	<2,000	<10,000	<2,000
very high	>10,000	>2,000	>10,000	>2,000

Table 4: Environmental categories for dust mites in the internal environment (Platts-Mills TAE and Werk A (1988)

Risk level	Mites g^{-1} dust
Low	<100
Moderate	<500
High	>500

Table 5: CIBSE Guide A on temperature and RH

Building	Temperature limit (ºC)	RH range (%)
Educational buildings	19–21 (winter) 21–23 (summer)	40–75%
Classrooms	18	