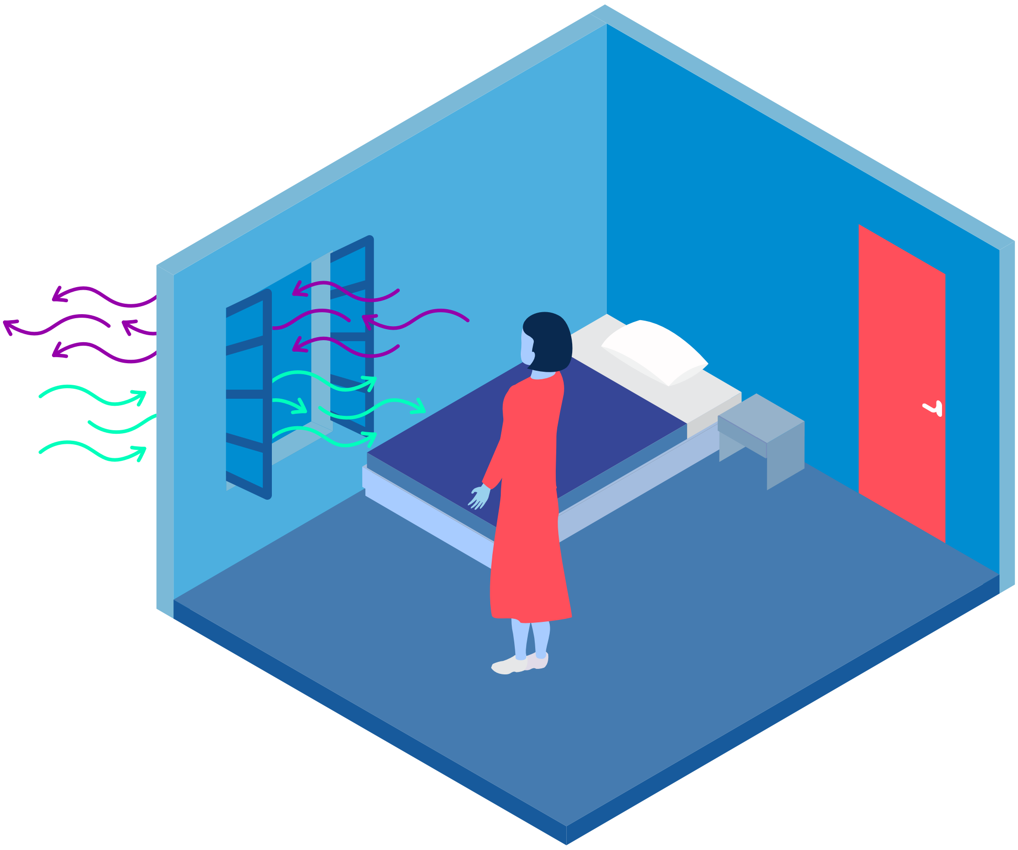
World Health Organization

Roadmap to improve and ensure good indoor ventilation in the context of COVID-19



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Contents

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Abbreviations

ACH	Air Changes per Hour
AGP	Aerosol-Generating Procedures
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CADR	Clean Air Delivery Rate
ECAP	Environment and Engineering Control Expert Advisory Panel
HCW	Health Care Worker
HEPA	High-Efficiency Particulate Air
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IPC	Infection Prevention and Control
MERV	Minimum Efficiency Reporting Value
PM	Particulate Matter
REHVA	Federation of European Heating, Ventilation and Air Conditioning Associations
WHO	World Health Organization

Glossary

Aerosol-generating procedures (AGP): Defined as any medical procedures that can induce the production of aerosols of various sizes (e.g. tracheal intubation, non-invasive ventilation, tracheostomy, cardiopulmonary resuscitation, manual ventilation before intubation, bronchoscopy, dental procedures) *(1)*.

Age of air, local: The time it takes for supply air to reach a certain indoor point *(2)*.

Air changes per hour (ACH): Ventilation airflow rate (m^3/hr) divided by room volume. It indicates how many times, during 1 hour, the air volume of a space is fully replaced with outdoor air *(2)*.

Air cleaner: Device used for removal of airborne particulates and/or gases from the air. Air cleaners may be added to heating, ventilation and air-conditioning systems (HVAC) systems or stand-alone room units *(2)*. Single-space air cleaners with high-efficiency particulate air (HEPA) filters (either ceiling mounted or portable) can be effective in reducing/lowering concentrations of infectious aerosols in a single space. The effectiveness of portable HEPA filters will depend on the airflow capacity of the unit, the configuration of the room including furniture and persons in the room, the position of the HEPA filter unit relative to the layout of the room, and the location of the supply registers or grilles *(3)*. Note that air cleaners do not replace normal ventilation as they are only able to remove a particular part of the indoor air contamination.

Air conditioning: Form of air treatment in which temperature is controlled, possibly in combination with the control of ventilation, humidity and air cleanliness *(2)*. Note that air-conditioning units in the case of, for example, split units often have no ventilation component. Therefore, ventilation requirements are to be put in place in addition to the use of air conditioning.

Air diffusion, mixing: Air diffusion where the mixing of supply air and room air is intended *(2)*.

Air, exhaust: Air removed from a space and discharged to the atmosphere by means of mechanical or natural ventilation systems *(2)*.

Air extract, mechanical: The process of extracting air with the aid of powered air movement components, usually fans *(2)*.

Air extract, natural: The process of extracting air by means of wind forces or density differences or a combination of the two *(2)*.

Air, indoor: Air in the treated room or zone *(2)*.
Air, mixed: The mixture of outdoor air and recirculated air *(2)*.

Air, outdoor: Controlled air entering the system or opening from outdoors before any air treatment *(2)*.

Air, recirculation: A part of extracted air which is not exhausted from the building, but it is recirculated back into spaces *(2)*. The air can be treated before being recirculated (thermal, air quality).

Air, supply: Air delivered by mechanical or natural ventilation to a space, composed of any combination of outdoor air, recirculated air or transferred air *(2)*.

Air transportation: Transportation of a specified airflow to or from the treated space generally by means of ducts. Along the ducts, devices for the purpose of treating the air (e.g. cleaning, heating, cooling, humidifying or dehumidifying, etc.) and known as air treatment devices, may be inserted *(2)*.

Clean air delivery rate (CADR) (m^3/hr): Usually used in relation to portable air cleaner devices.
Cross ventilation: Cross ventilation occurs where there are ventilation openings on both sides of the space. Air flows in one side of the building/room and out the other side through, for example, a window or door. Cross ventilation is usually wind driven *(4)*.

Fan coil: A component of a HVAC system containing a fan and a heating or cooling coil, used to distribute heated or cooled air. Where the unit does not include a ventilation component, ventilation in the room has to be taken care of in parallel.

Filter: Device for removing particulate matter from a fluid or gas *(2)*.

Flow rate, ventilation: Volume flow rate (m^3/hr) (l/s) (ACH) at which ventilation air is supplied or removed from a room or a building through the ventilation system or infiltration through the building envelope *(2)*.

Heat exchanger: A device in which heat is transferred between two mediums which do not come in contact *(2)*.

Heat exchanger, air-to-air plate: Heat exchanger designed to transfer thermal energy from one air stream to another without moving parts. Heat transfer surfaces are in the form of plates. This exchanger may have a parallel flow, cross flow or counter flow construction or a combination of these *(2)*.

Heat exchanger, rotary: A device incorporating a rotating cylinder or wheel for the purpose of transferring energy from one air stream to the other. It incorporates heat transfer material, a drive mechanism, a casing or frame, and includes any seals which are provided to retard the bypassing and leakage of air from one air stream to the other *(2)*.

Heat exchanger, twin coil: Heat exchanger designed to transfer thermal energy from one air stream to another without moving parts. Heat transfer surfaces are in the form of tubes. This exchanger may have a parallel flow, cross flow or counter flow construction or a combination of these *(2)*.

Heat recovery: Heat utilized from a heating system, which would otherwise be wasted *(2)*.

High-efficiency particulate air (HEPA): HEPA air filter classes E10 to H14 according EN 1822 *(2)*. Facilities that choose to use HEPA filters should follow the manufacturer's instructions, including on recommended cleaning and maintenance procedures for HEPA filters. Otherwise, portable air cleaners with HEPA filters can lead to a false sense of security as their performance decreases due to filter loading *(3)*.

Minimum efficiency reporting value (MERV): Minimum reported efficiency in specified particle size ranges during the test *(2)*.

Pressure difference: Difference between pressures measured at two points or levels in fluids or gases *(2)*.

Pressure, negative: Condition that exists when less air is supplied to a space than is exhausted from it, so the air pressure within that space is less than that in the surrounding areas. Under this condition, if an opening exists, air will flow from the surrounding areas into the negatively pressurized space *(2)*.

Pressure, positive: Condition that exists when more air is supplied to a space than is exhausted from it, so the air pressure within that space is greater than that in the surrounding areas. Under this condition, if an opening exists, air will flow from the positively pressurized space outward to the surrounding areas *(2)*.

Single-sided ventilation: Single-sided ventilation relies on opening(s) on one side only of the ventilated enclosure. It is possible to get buoyancy-driven exchanges through a single opening if the opening is reasonably large in the vertical dimension *(4)*.

Source control: A preventive strategy for reducing airborne contaminant levels in the air through removal of the material or activity generating the pollutants *(2)* or through removing the pollutant at source by means of localized exhausted strategy.

Split system: A two-component heating and cooling or cooling only system. The condensing unit is installed outside, the air handling unit is installed inside. Refrigerant lines and wiring connect them together *(2)*. Generally, this system has no ventilation component and recirculates conditioned air.

Stack effect: Pressure difference caused by the difference in density between indoor and outdoor air due to indoor/outdoor buoyancy forces *(2)*.

Ventilation: Ventilation is the process of supplying outdoor air to and removing indoor air from a space, for the purpose of controlling air contaminant levels, potentially accompanied by humidity and/or temperature, by natural or mechanical means *(5)*.

Ventilation, mechanical: The active process of supplying air to or removing air from an indoor space by powered air movement components *(2)*.

Ventilation, natural: Ventilation occurring as a result of only natural forces, such as wind pressure or differences in air density, through doors, windows or other intentional openings in the building *(2)*.

Ventilation system: A combination of appliances designed to supply interior spaces with outdoor air and/or to extract polluted indoor air *(2)*.

Whirlybird: A wind-driven turbine located on a roof to improve extraction of air from a building.

Executive summary

Context

The risk of getting COVID-19 is higher in crowded and inadequately ventilated spaces where infected people spend long periods of time together in close proximity. These environments are where the virus appears to spread by respiratory droplets or aerosols more efficiently, so taking precautions is even more important.

Understanding and controlling building ventilation can improve the quality of the air we breathe and reduce the risk of indoor health concerns including prevent the virus that causes COVID-19 from spreading indoors.

Methods

The roadmap was developed after conducting a scoping review of the available literature and an assessment of the available guidance documents from the major internationally recognized authorities on building ventilation. The available evidence and guidance were retrieved, collated and assessed for any discrepancies by international expert members of the World Health Organization (WHO) Environment and Engineering Control Expert Advisory Panel (ECAP) for COVID-19. The roadmap development process included two expert consultation sessions via virtual meetings, and two rounds of written submissions, to gather technical contributions and to ensure consensus building for the adaptation of recommendations. This process considered infection prevention and control (IPC) objectives, resource implications, values and preferences, ethics, and research gaps within the roadmap development.

Outcomes

This process resulted in a roadmap on how to improve ventilation in indoor spaces. The roadmap is divided into three settings – health care, non-residential and residential spaces – and takes into account different ventilation systems (mechanical or natural). The roadmap is aimed at health care facility managers, building managers, as well as those members of the general public who are providing home care or home quarantine.

1. Introduction

Knowledge about transmission of the SARS-CoV-2 virus is continuously evolving as new evidence accumulates. According to available evidence, SARS-CoV-2 mainly spreads between people when an infected person is in close contact with another person. Transmissibility of the virus depends on the amount of viable virus being shed and expelled by a person, the type of contact they have with others, the setting and what IPC measures are in place. The virus can spread from an infected person's mouth or nose in small liquid particles when the person coughs, sneezes, sings, breathes heavily or talks. These liquid particles are different sizes, ranging from larger "respiratory droplets" to smaller "aerosols". Close-range contact (typically within 1 m) can result in inhalation of, or inoculation with, the virus through the mouth, nose or eyes *(6–11)*.

Aerosol transmission can occur in specific situations in which procedures that generate aerosols are performed. The scientific community has been actively researching whether the SARS-CoV-2 virus might also spread through aerosol transmission in the absence of aerosol-generating procedures (AGP) *(12, 13)*. Some studies that performed air sampling in clinical settings where AGP were not performed found virus RNA, but others did not *(14)*. The presence of viral RNA is not the same as replication and infection-competent (viable) virus that could be transmissible and capable of initiating invasive infection. A limited number of studies have isolated viable SARS-CoV-2 from air samples in the vicinity of COVID-19 patients *(15, 16)*. Outside of medical facilities, in addition to droplet and fomite transmission, aerosol transmission can occur in specific settings and circumstances, particularly in indoor, crowded and inadequately ventilated spaces, where infected persons spend long periods of time with others *(10)*. High-quality research is required to address the knowledge gaps related to modes of transmission, infectious dose and settings in which transmission can be amplified. Currently, studies are under way to better understand the conditions in which aerosol transmission or superspreading events may occur.

1.1 Public health and social measures

WHO has published numerous recommendations for measures *(17–21)* to prevent spread of COVID-19, among which is ensuring good ventilation in indoor settings, including health care facilities, public spaces and residential areas. A well-designed, maintained and operated system can reduce the risk of COVID-19 spread in indoor spaces by diluting the concentration of potentially infectious aerosols through ventilation with outside air and filtration and disinfection of recirculated air. Proper use of natural ventilation can provide the same benefits. The decision whether to use mechanical or natural ventilation should be based on needs, resource availability and the cost of systems to provide the best control to counteract the risks.

This document accompanies the published recommendations cited above. It elaborates and expands on recommended actions targeting ventilation as listed in the above cited documents and provides health care facility managers, building managers (including long-term care, non-residential and residential facilities) as well as for the general public when implementing home care and home quarantine, with an operational tool to enhance indoor ventilation as an environmental and engineering control for the COVID-19 pandemic and beyond. It is neither prescriptive nor exhaustive and should be adapted to national regulatory frameworks and local social, cultural and economic contexts. The roadmap is not intended to replace other guidance and plans, but rather to complement them by helping facility managers ensure that key considerations are addressed.

1.2 Scope of the document

SARS-CoV-2 transmission is particularly effective in crowded, confined indoor spaces where there is poor or no ventilation *(22)*. Therefore, ensuring adequate ventilation may reduce the risk of COVID-19 infection *(23)*. This roadmap aims to define the key questions users should consider to assess indoor ventilation and the major steps needed to reach recommended ventilation levels or simply improve indoor air quality (IAQ) in order to reduce the risk of spread of COVID-19. It also includes recommendations on how to assess and measure the different parameters, specifically in health care, non-residential and residential settings. It is meant to be a technical document helping users to analyse building HVAC systems in order to implement, if required, the different strategies proposed to improve HVAC's ability to mitigate and reduce the risk of COVID-19 transmission.

Note: Indoor ventilation is part of a comprehensive package of prevention and control measures that can limit the spread of certain respiratory viral diseases, including COVID-19. However, ventilation alone, even when correctly implemented, is insufficient to provide an adequate level of protection. Correct use of masks, hand hygiene, physical distancing, respiratory etiquette, testing, contact tracing, quarantine, isolation and other IPC measures are critical to prevent transmission of SARS-CoV-2.

The roadmap provides guidance for health care facility managers, building managers (including long-term care, non-residential and residential facilities) as well as for the general public when home care and home quarantine are required.

2. Methodology

The methods used to develop the roadmap included two stages. First, a scoping rapid review on building ventilation and transmission of SARS-CoV-2 was undertaken. A search (see Annex 1 for the search strategy) of the WHO COVID-19 database and existing COVID-19 rapid review collections up to 2 December 2020 identified 1174 citations, 99 of which were reviewed at the full-text level. Six articles met broad inclusion criteria on ventilation systems and transmission of SARS-CoV-2 (three peer-reviewed articles and three preprint articles – see Annex 1 for details). Of the peer-reviewed studies, one was a validation study of an isolation space created by modifying a HVAC system in a hospital in Pennsylvania, United States of America. A second study evaluated transmission between patients and health care workers (HCW) in negative pressure isolation rooms in Daegu, Republic of Korea. The third study was an outbreak investigation in an air-conditioned restaurant in Guangzhou, China. Of the included preprint studies, two were studies of SARS-CoV-2 transmission on the Diamond Princess cruise ship. A third preprint study evaluated the role of HVAC systems in transmission in an academic medical centre in Oregon, United States of America.

In addition, a review and adaptation of all relevant technical guidance published by the globally recognized leading international and regional heating, refrigerating and air-conditioning associations and federations, namely the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA), and review and adaptation of the available guidance on HVAC systems in the context of COVID-19 published by the US Centers for Disease Control and Prevention and the European Centre for Disease Prevention and Control was undertaken. Links to the technical documents and guidelines considered are available in Annex 2.

Key findings from the identified studies and the relevant recommendations from the existing guidance were extracted and collated. Discrepancies in the extracted findings and recommendations were then reviewed in consultation with national and international expert members of the ECAP for COVID-19.

The ECAP constitutes an ad-hoc advisory panel supporting the WHO's World Health Emergencies preparedness, readiness and response to COVID-19 and includes, amongst other, members of the Global Infection Prevention and Control Network, engineers and architects from relevant professional engineering and architecture networks, organizations and institutions specialized in health care settings, technical experts from ministries of health and similar institutions (see Acknowledgements); and WHO staff and consultants from different departments including Environment, Climate Change and Health, Infection Prevention and Control, and Operations Support and Logistic.

The roadmap development process included two expert consultation sessions, via virtual meetings, to gather technical contributions and consensus building for the adaptation of recommendations taking IPC objectives, resource implications, values and preferences, ethics and research gaps into account. In addition to the virtual meetings, two rounds of written input by contributors were used to finalize the roadmap.

All authors contributing to this document and members of the external and internal review panels signed conflict of interest statements. No conflicts of interest were declared.

3. Key information

Ventilation is the intentional introduction of clean air into a space while the stale air is removed. Ventilation moves outdoor air into a building or a room and distributes it within the building or room. If local outdoor conditions require, e.g. high particulate matter (PM) concentration, treatment of the outdoor may be needed before introducing it into the building.

The general purpose of ventilation in buildings is to ensure that air in the building is healthy for breathing. At present this is achieved mainly by diluting pollutants originating in the building

with clean air, and by providing an airflow rate to change this air at a given rate thus removing the pollutants. Ventilation is also used for odour control, containment control and often combined with climatic control (temperature and relative humidity).
Building ventilation has three basic elements:

- ventilation rate (m^3/hr, l/s or ACH) – the volume of outdoor air that is provided into the space;
- airflow direction – the overall airflow direction in a building and spaces, which should be from clean zones to dirty zones; and
- air distribution or airflow pattern – the external air should be delivered to each part of the space in an effective and efficient manner and the airborne pollutants generated in each part of the space should also be removed in an effective and efficient manner.

There are three methods that may be used to ventilate a building: natural, mechanical and hybrid (mixed mode) ventilation. This roadmap only considers mechanical and natural ventilation as all key questions and strategies described can also be adopted for hybrid ventilation.

4. Settings

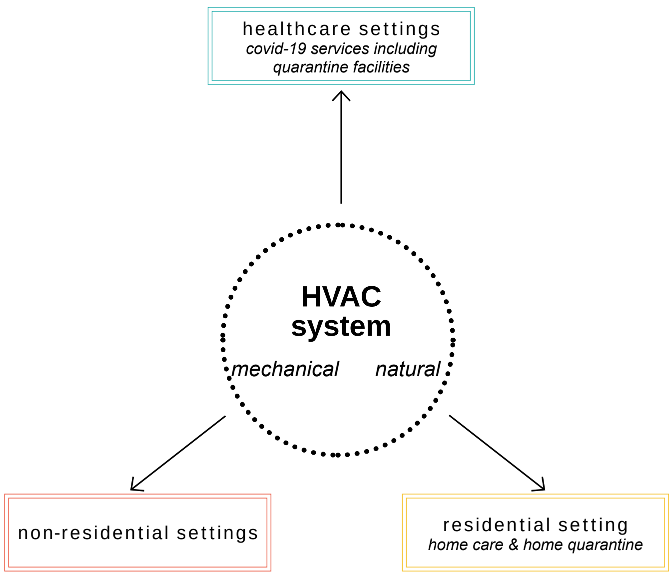
To provide maximum utility of a ventilation system and provide greater general dilution of air contaminants throughout the space, mechanical and natural systems can be used independently of the settings. However, each setting has specific ventilation requirements defined by national and international regulatory bodies which differ according to the ventilation objectives. For instance, ventilation systems in medical facilities are in place as an environment and engineering control for infection prevention *(24)* while, for residential buildings, they are mainly to create a thermally comfortable indoor environment with acceptable indoor air quality *(25).*
The roadmap focuses on three different settings according to specific IPC objectives. Each setting is described below to facilitate understanding and knowledge of implementation strategies in all contexts.

4.1 Health care settings

Adequate ventilation in all patient care areas plays a key role to help prevent and reduce infections. Nevertheless, this document specifically targets COVID-19 structures such as COVID-19 treatment centres and wards including quarantine, community facilities and long-term care facilities. Some risk factors, such as the presence of confirmed and suspected cases, the proximity required to provide medical care, AGP potentially performed, and visitor influx, make these settings particularly vulnerable. For the above reasons, together with other IPC measures described in their specific guidance, these settings require strict ventilation requirements to enable a safe working environment and reduce the risk of health care associated infections amongst HCWs, patients and visitors.

4.2 Non-residential setting

For this document “non-residential setting'' refers to public and private indoor spaces characterized by a heterogeneous occupancy rate with people not belonging to the same household, such as workplaces *(26)*, schools *(19)* and universities, accommodation sector buildings *(27)*, and religious and commercial spaces. The load of air pollution or infectious aerosol potentially released in a building depends on the activities performed inside, the number of occupants and whether or not the occupants are wearing masks.
National, regional or international requirements are available for each setting and several interim guidance documents have been developed. However, in order to strengthen proposed IPC measures, simplify the COVID-19 risk assessment and facilitate the implementation of corresponding countermeasures, a minimum ventilation rate per person is proposed. This figure, directly linked to space occupancy, will allow the assessment and improvement of ventilation and, if not possible, the adjustment of maximum building occupancy. Note that buildings repurposed in community and quarantine facilities are included in the chapter “4.1 Health care settings”.



4.3 Residential settings

In the context of the current COVID-19 outbreak, WHO recommends the rapid identification of COVID-19 cases and their isolation and management either in a medical facility or an alternative setting, such as the home. Additionally, in many contexts, health services are delivered at community level and in the home by community health workers, traditional medicine practitioners, social care workers, or a variety of formal and informal community-based providers. Specific guidance for safe home care *(20)* and home quarantine *(28)* are already available and provide recommendations on IPC measures including how to assess a potential isolation area space in residential settings. This roadmap aims to strengthen the use of ventilation as an environment and engineering control measure to reduce the risk of COVID-19 transmission amongst household members whenever a person is under home care or home quarantine and should be considered as a complementary part for the already existing IPC guidance.

5. Important considerations

5.1 Vector-borne diseases

Vector-borne diseases are human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors; the commonest one being mosquitoes, the vector for malaria, dengue, and yellow fever. Other flying vectors also contribute to human illness such as human African trypanosomiasis and leishmaniasis. Every year more than 700 000 deaths result from these diseases. The burden of these diseases is highest in tropical and subtropical areas, and they disproportionately affect the poorest populations *(29).*

One of the most used, affordable and sustainable measures to prevent and reduce the incidence for some vector-borne diseases is the installation of mosquito screening on windows, doors and other entry points. Unfortunately, simple mosquito screening on windows may reduce the natural ventilation rate significantly and this should be taken into account when calculating air changes. For the above reasons, especially where vector-borne diseases are endemic, it is essential to consider strengthening vector control activities while improving indoor ventilation.

5.2 Outdoor air pollution

Outdoor air pollution is a major environmental health problem affecting all countries. Ambient (outdoor) air pollution in both cities and rural areas is estimated to cause about 4 million *(30)* premature deaths worldwide per year. People living in low- and middle-income countries disproportionately experience the burden of outdoor air pollution.

Avoiding air pollution through staying indoors may be beneficial but the effect largely depends on the level of indoor risks (e.g. indoor and household air pollution, presence of sick persons). Also, there is uncertainty about the reduction in exposure of populations, and the health benefits of staying indoors are not clear or may be reversed, depending on various circumstances, and the potential benefits and harms depend from specific local factors. As shown in a recent report, efficacy of portable indoor air filters (or portable indoor air cleaners) in real-world situations (i.e. not laboratory or occupational settings) showed that they are efficient to reduce indoor particulate matter (PM2.5) concentration by 40–82% but that little improvement of health effects were demonstrated *(31)* (mainly for healthy adults). It would, however, be premature to recommend the use of portable air filters as a public health measure to protect from air pollution for many reasons. Thus, the use of portable indoor air filters might be proposed for people with pre-existing conditions, such as chronic obstructive pulmonary disease, heart failure or lung transplants, who should stay at home and be protected from exposure to air pollution. Yet, given the current COVID-19 pandemic, indoor air filtration and recirculation should be carefully considered, taking into account the COVID-19 mitigation measures. If appropriate, consider outdoor air pollution levels while assessing and improving indoor ventilation by using natural ventilation and outdoor air filtration. For example, in areas constantly experiencing high levels of outdoor air pollution or at times/episodes of air pollution, (outdoor) air filtration may be more appropriate than increasing ventilation rates.

6. How to use the roadmap

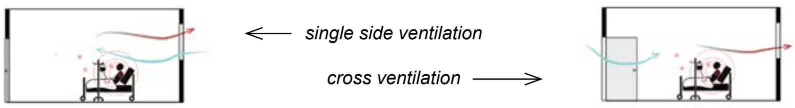
Owners and building managers should consider evaluating their building systems to check that they are operating in proper order (per design or current operational strategies), are capable of being modified to align with HVAC mitigation strategies, and to identify deficiencies that should be repaired. Several recommendations should be considered in consultation with HVAC professionals.

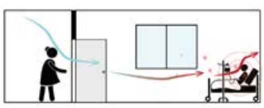
The finalized roadmap is divided into three settings: health care, non-residential and residential spaces such as private houses. For each category there is a further stratification according to the ventilation system – mechanical or natural ventilation. After identifying the correct setting and ventilation system, the reader should start from the top, beginning with the central column labelled “step – key questions”. On the left side, the minimum requirements and standards are proposed for each key question, while on the right side, the different strategies to improve the specific matter. Strategies are listed in order of preference from the most effective to the least effective, i.e. if more than one strategy can be implemented, the first one, the one on top, should be preferred. However, it is worth highlighting that neither the cost nor the time required for implementation were considered. As a rule of thumb, the strategies at the top of the list, while being the most effective, can be the most expensive and take the longest to implement. When implementing the roadmap, building owners and managers should consider, amongst other factors, weather conditions and outdoor air pollution. For a few specific cases, it is preferable to implement two or more strategies simultaneously. Those cases are marked with a plus (+) symbol in between the strategies to be combined.

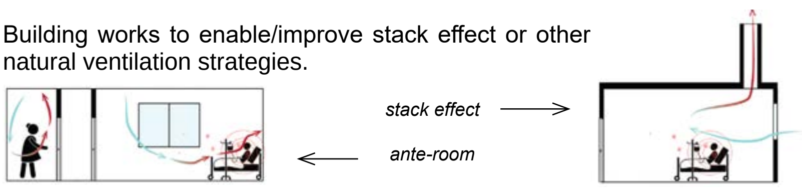
6.1 Health care settings including quarantine facilities

natural ventilation

Minimum requirements	Steps – key questions		Strategies
Ventilation rate minimum requirements *(32)*: • 160 L/s/patient or 12 ACH where AGP are performed • 60 L/s/patient or 6 ACH other	Does the ventilation rate meet WHO minimum requirements? To estimate the ventilation rate consult point 2.	NO	+ Assess the opening locations and opening surfaces considering potential new openings (add/modify window or door dimensions). + Consider enabling cross ventilation rather than single-sided ventilation. Note: Cross ventilation should not be implemented in these specific cases: • within a room or ward for COVID-19 suspected cases where AGP may take place and when the exhaust air is not properly managed; • when the airflow is moving from a less clean to a clean area. If the system does not allow increasing ventilation to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/patient standard. + If no other (short-term) strategy can be adopted, consider using a stand-alone air cleaner with HEPA filters. Pay attention to the airflow direction (from clean to less clean areas) when positioning. The air cleaner should be positioned in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Stand-alone air cleaners should be operated continuously and air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate. Note: Consider that stand-alone air cleaners do not replace ventilation in any circumstance.
	YES ↓		
The airflow direction should be from clean to less clean area *(32)*	Does the airflow move from clean to less clean area? To evaluate the airflow consult point 3.	NO	+ Consider modifying the functional distribution regarding airflow directions to minimize exposure of HCWs, i.e. changing patient and staff areas in order to have natural negative pressure (i.e. due to stack effect) close to patient rooms, if a clear airflow direction is identified. + Installation of wall or window air extractors or whirlybirds *(33)*. + The use of a pedestal fan placed close to an open window could enable ventilation. A pedestal fan facing towards the window (i.e. facing outside) serves to pull the room and exhaust air to the outside; a fan facing towards the interior of the room (i.e. facing inside) serves to pull in the outdoor air and push it inside the room. The orientation of the pedestal fan should be chosen according to the desired airflow direction. + Building works to enable/improve stack effect or other natural ventilation strategies. + In rooms, where AGP are performed: add ante-rooms in order to have strict control on airflow direction. Double doors in ante-rooms should not be open at the same time in order to clearly separate the air between patient room and corridor (clean area). Note: In most cases, this strategy cannot be combined with cross ventilation, therefore the minimum ventilation rate should be attained with other strategies. A cost-effective solution is the use of a plastic door zipper as a partition to create an ante-room.
	YES ↓		







Air should be exhausted directly to the outside away from air intake vents *(34)*

Is the exhausted air correctly managed?

NO →

Use of fences to avoid passage of people close to openings (windows and doors), keeping people or animals at a distance at least of 4 m.
No action is needed if the air is exhausted from the roof or 2 m higher than people (i.e. due to stack effect, whirlybirds).

YES ↓

Heating and air conditioning with recirculating units should be used carefully and after assessment

Air conditioning and heating are performed by non-ducted (with indoor air recirculation) convectors such as split or fan coil units.

YES →

Use of split system and fan coil units is discouraged because they are difficult to maintain, provide poor filtration and contribute to turbulence, potentially increasing the risk of infection *(35)*.
Avoid use of split system and fan coil units for COVID-19 patients *(36)*, especially where AGP are performed and consider using alternative heating and cooling systems and local exhaust systems.
Split systems can be used only in single room (suspected or confirmed cases) and in shared room hosting cohorted confirmed inpatients.
Note: Non-ducted recirculating units do not replace ventilation in any circumstance.

Whenever in-room recirculating units with poor filtration are used, consider creating a negative pressure relative to the corridor to reduce the potential for aerosols to escape from the room. Negative pressure can be created by increasing the airflow of extracted air from the room by installing extractor fans or devices. Units should be cleaned carefully in between patients *(36)*.

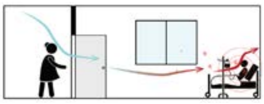
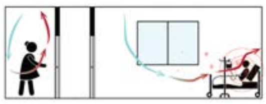
\+ If alternative air conditioning and heating are not available/feasible, consider running the air-conditioning and heating units at minimum velocity to reduce turbulence where AGP are performed. Where thermal conditioning (high temperatures) is needed, ensure that direct airflows between individuals are avoided.
Except for single room (suspected or confirmed cases) and shared room hosting cohorted confirmed inpatients.
Note: Consider non-ducted recirculating units do not replace ventilation in any circumstance

\+ Considering modifying the position of the heating/cooling unit to direct the airflow to the less clean zone or install an extractor to control the airflow where AGP are performed.

NO ↓

END

mechanical ventilation

Minimum requirements	Steps – key questions		Strategies
Ventilation rate minimum requirements *(32)*: • 160 L/s/patient or 12 ACH where AGP are performed • 60 L/s/patient or 6 ACH other	Does the ventilation rate meet WHO minimum requirements? To assess the ventilation rate consult point 1.	NO	→ In consultation with a HVAC professional assess the opportunity to increase the ventilation rate according to system capabilities. Disable demand-control ventilation controls that reduce air supply based on temperature or occupancy (CO_2 concentration). → If the ventilation rate cannot be increased mechanically, consider maximizing ventilation by using natural ventilation through opening windows *(37)* (see natural ventilation section for more strategies). → If the system does not allow increasing the ventilation to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/patient standard. → If no other (short-term) strategy can be adopted, consider using a stand-alone air cleaner with HEPA filter. Pay attention to the airflow direction (from clean to less clean areas) when positioning. The air cleaner should be positioned in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Stand-alone air cleaners should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.
	YES ↓		
The airflow direction should be from clean to less clean area *(32)*	Does the airflow move from clean to less clean area? To evaluate the airflow consult point 3. 	NO	→ Consider modifying the functional distribution regarding airflow directions to minimize exposure of HCWs, i.e. swapping patient and health care staff areas, if a clear airflow direction is identified. → In consultation with a HVAC professional, assess the opportunity to modify airflow direction, i.e. modifying the location of supply and exhaust (return) air devices. + → In rooms where AGP are performed: add ante-rooms in order to have more strict control of airflow direction. Doors in ante-rooms should not be open at the same time in order to clearly separate the air between the patient room and the corridor (cleaner area). A cost-effective solution is the use of a plastic door zipper as a partition to create an ante-room. 
	YES ↓		
Air should be exhausted directly to the outside and away from air-intake vents, people and animals *(34)*	Is the exhausted air correctly managed?	NO	→ Consider fencing the area near the exhaust outlet keeping people or animals at a distance at least of 4 m. The air intake should be at least 2 m if the air outlet is above and 4 m if air outlet is below (EN 16798-4) from the exhaust. → If fencing the area is not feasible, in consultation with a HVAC professional, assess the opportunity to install HEPA filters according to system capability.
	YES ↓		

Air recirculation should be carefully evaluated

Does the HVAC system work with recirculation mode?

YES

- Increase the percentage of outdoor air supply using economizer modes of HVAC operations, potentially up to 100%. Before increasing outdoor air percentage, verify compatibility with HVAC system capabilities *(38)*.
- In consultation with a HVAC professional, assess the opportunity to install HEPA filters on air return duct according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If no other strategy can be adopted, consider using a stand-alone air cleaner with HEPA filter. Pay attention to the airflow direction (from clean to less clean areas) when positioning. Stand-alone air cleaners should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate.
  Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. Furthermore, it is important to apply good maintenance.
- If the recirculation mode cannot be improved or modified, consider maximizing ventilation by using natural ventilation through opening windows (see natural ventilation section for more strategies).

NO

Verify heat recovery unit

Is the HVAC system equipped with heat recovery?

YES

- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin-coil "run around loop" heat exchanger that guarantees air separation between the return and supply side *(40)*.
- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with cross-flow air-to-air heat exchangers, if the heat exchanger is not compromised.
- For rotary heat exchangers, fitted with purging sectors and properly maintained seals, leakage rates are very low, and cross contamination is a minimal risk.
- If critical leaks (>3%) are detected in the heat recovery sections in consultation with a HVAC professional, assess the opportunity to install HEPA filter according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If critical leaks (>3%) are detected in the heat recovery sections and the system does not allow HEPA filter installation, pressure adjustment *(37)* (higher pressure on supply air side than exhaust air side), deactivation or by-pass of the heat exchanger could be adopted *(41)*.

NO

HVAC system should be operated continuously when people are in the building and should be regularly inspected, maintained and cleaned.

Is the HVAC system regularly inspected, maintained, cleaned and operated? Including HEPA filter replacement?

NO

- + HVAC systems should be regularly inspected, maintained and cleaned according to the manufacturer's recommendations. Contact a HVAC professional, manufacturer or a specialized company to verify that the system complies with the manufacturer's maintenance requirements.
- + Replace HEPA filter according to the manufacturer's recommendations.

YES

Heading and air conditioning with recirculating units should be used carefully and after assessment.

Air conditioning and heating are performed by non-ducted (with indoor air recirculation) convectors such as split system or fan coil units at room level.

YES

→ Use of split system and fan coil units is discouraged because they are difficult to maintain, provide poor filtration and contribute to turbulence, potentially increasing the risk of infection *(35)*.
Avoid the use of split system and fan coil units for COVID-19 patients *(36)*, especially where AGP are performed and consider using alternative heating and cooling systems.
Split systems can be used only in single room (suspected or confirmed cases) and in shared room hosting cohorted confirmed inpatients
Note: Non-ducted recirculating units (at room level) do not replace ventilation in any circumstance.

→ Whenever in-room recirculating units with poor filtration must be used, consider creating a negative pressure relative to the corridor to reduce the potential for aerosols to escape from the room. Negative pressure can be created by increasing the airflow of extracted air from the room using an extractor fan or similar. Units should be cleaned carefully in between patients *(36)*.

+→ If alternative conditioning and heating systems are not available/feasible, consider running the air-conditioning and heating units at the minimum velocity allowed, in order to reduce turbulence when AGP are performed. If for thermal conditioning (high temperatures) is needed, at least ensure that direct airflows between persons are avoided.
Except for single room (suspected or confirmed cases) and shared room hosting cohorted confirmed inpatients.Note: Consider non-ducted recirculating units do not replace ventilation in any circumstance.

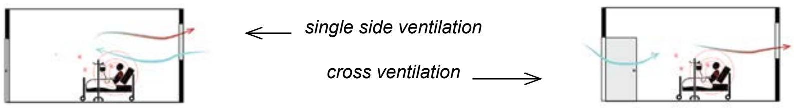
+→ Consider modifying the position of the heating/cooling unit to direct airflow to the less clean zone or install an extractor to control the airflow when AGP are performed.

NO

END

6.2 Non-residential settings

natural ventilation

Minimum requirements	**Steps – key questions**		**Strategies**
Minimum recommended ventilation rate: •10 L/s/person (EN 16798-1) *(42, 43)*	Does the ventilation rate meet the minimum requirement? To estimate the ventilation rate consult point 2.	NO	+ Assess the opening location and opening surface considering potential new openings (add/modify window or door dimensions).
			+ Enable cross ventilation, if not yet present, instead of single-sided ventilation. Keep the doors open to allow air movement. 
			+ The use of a pedestal fan placed close to an open window could enable ventilation. 
			+ Installation of air extractors or whirlybirds *(33)*; building works to improve stack effect of other natural ventilation strategies. 
			+ If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter *(44)*. The air cleaner should be positioned in the areas used by people and close to people. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 
	YES ↓		
As a contaminant dilution strategy the indoor air should be changed as uniformly as possible	Is the air within the space well mixed?	NO	The use of fans and/or fan coil or split units for cooling and heating as well as ceiling fans increase the air mixing within the room or the space *(44)*. This strategy should be implemented only if the minimum ventilation rate has been met.  *1) pedestal fan* *2) ceiling fan* *3) split*
	YES ↓		
Occupancy and ventilation	Does the facility have periods of non-occupancy?	YES	Open the windows to allow proper ventilation before and after occupied times. Windows should be opened for approximately 15 minutes when entering the room (especially when the room was occupied by others beforehand) *(37)*.
	NO ↓		
Heating and air conditioning with recirculating units should be assessed, maintained and cleaned	Are air conditioning and heating performed by non-ducted (with indoor air recirculation) convectors such as split system or fan coil units?	YES	In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14 / ISO ePM1 70-80% or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters. Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
			+ Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed. Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
	NO ↓		
	END		

mechanical ventilation

Minimum requirements	Steps – key questions	Strategies
Minimum recommended ventilation rate: • 10 L/s/person (EN 16798-1) *(42, 43)*	Does the ventilation rate meet the minimum requirement? To assess the ventilation rate consult point 1. **NO** → see strategies; **YES** → next step	→ In consultation with a HVAC professional, assess the opportunity to increase the ventilation rate according to system capabilities. Disable demand-control ventilation controls that reduce air supply based on temperature or occupancy. → If the ventilation rate cannot be increased mechanically, consider maximizing ventilation by using natural ventilation through opening windows *(37)* (see natural ventilation section for more strategies). → If the system does not allow increasing the ventilation up to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/person standard. + → If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter. The air cleaner should be positioned in the areas used by people and close to people. Stand-alone air cleaners should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate *(44)* – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 
As a contaminant dilution strategy, the indoor air should be changed as uniformly as possible.	Is the air within the space well mixed? **NO** → see strategies; **YES** → next step	→ The use of fans and/or fan coil units or split system units for cooling and heating increase the air mixing within the room or the space *(44)*. This strategy should be implemented only if the minimum ventilation rate has been met.  *1) pedestal fan 2) ceiling fan 3) split*
Occupancy and ventilation	Does the facility have periods of non-occupancy? **YES** → see strategies; **NO** → next step	→ Operate the HVAC system with maximum outside airflow for 2 hours *(37)* at normal speed before and after occupied times.
Verify air recirculation	Does the HVAC system work with recirculation mode? **YES** → see strategies; **NO** → next step	→ Increase the percentage of outdoor air as air supply, using economizer modes of HVAC operations, potentially up to 100%. Before increasing outdoor air percentage, verify compatibility with HVAC system capabilities *(38)*. → In consultation with a HVAC professional, assess the opportunity to install MERV 14 / ISO ePM1 70-80% filter on air return duct according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter *(45)*. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*. → If no other strategies can be adopted, consider using stand-alone air cleaners (often called air purifiers) with particle filters. These should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate. Use high-efficiency media filters (such as MERV 14 / ISO ePM1 70-80% or higher) *(44)*. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 

Verify heat recovery unit

Is the HVAC system designed with heat recovery?

YES

- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin-coil "run around loop" heat exchanger that guarantees air separation between the return and supply side *(40)*.

  Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with cross-flow air-to-air heat exchangers, if the heat exchanger is not compromised.
- For rotary heat exchangers, fitted with purging sectors and properly maintained seals, leakage rates are very low, and cross contamination is a minimal risk.
- If critical leaks (>3%) are detected in the heat recovery device, in consultation with a HVAC professional, assess the opportunity to install MERV 14 / ISO ePM1 70-80% filter according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If critical leaks (>3%) are detected in the heat recovery sections and the system does not allow MERV 14 / ISO ePM1 70-80% filter installation or the highest compatible with the filter rack, pressure adjustment *(37)* (higher pressure on supply air side than exhaust air side), deactivation or by-pass of the heat exchanger could be adopted *(41)*.

NO

HVAC system should be operated continuously when people are in the building and should be regularly inspected, maintained and cleaned

Is the HVAC system regularly inspected, maintained, cleaned and operated, including filter cleaning and replacement?

NO

- HVAC systems should be regularly inspected, maintained and cleaned according to the manufacturer's recommendations. Contact a HVAC professional, manufacturer or a specialized company to verify that the system complies with the manufacturer's maintenance requirements.
- Clean or replace the air filter according to the manufacturer's recommendations.

YES

Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Conditioning and heating is performed by non-ducted (with indoor air recirculation) convectors such as split or fan coil units.

YES

- In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14 / ISO ePM1 70-80% filter or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
  Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
- Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
  Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

NO

Air should be exhausted directly to the outside away from air-intake vents, people and animals *(34)*

Is the exhausted air correctly managed?

NO

- If the system does not allow air filter installation, consider fencing the area nearby the exhausted outlet, keeping people or animals at a distance at least of 4 m. The air intake should be at least at 2 m if air outlet is above and 4 m if air outlet is below (EN 16798) from the exhaust.
- In consultation with a HVAC professional, assess the opportunity to install MERV 14 / ISO ePM1 70-80% filter according to system capability.

YES

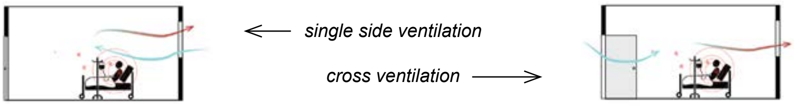
END

6.3 Residential settings including homes and self-quarantine at home

This section refers specifically to the isolation area, space or room previously identified for home care or self-quarantine according to the available guidance. The recommendations proposed are based on the assumption that the house and the identified isolation area can be considered as separated spaces. Hence, the following strategies should not be considered for the whole residential area but for the isolation space only. Note: Long-term care facilities are not included.

natural ventilation

Minimum requirements	**Steps – key questions**		**Strategies**
Minimum recommended ventilation rate: • 10 L/s/person *(42)* (EN 16798-1) within the isolation area	Does the ventilation rate meet the minimum requirement? To estimate the ventilation rate, consult point 2.	NO	+ Assess the opening location and opening surface considering potential new openings (add modify window or door dimensions). If available, exhaust fans in bathrooms, toilets and kitchen should be operated continuously within the isolation area *(44).* + Ensure cross ventilation, if not yet present, instead of single-sided ventilation. Keep doors open to allow air movement. Note: Consider step below prior to implementing cross ventilation. Window-installable products are available to provide exhaust ventilation *(44)*. The use of a pedestal fan placed close to an open window could enable ventilation. A fan facing towards the window (i.e. facing outside) serves to pull the room and exhaust air to the outside. + If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter *(44)*. The air cleaner should be positioned in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.
	YES ↓		
Separate the isolation area from the rest of the house *(44)*	The isolation area has a separate ventilation from the other rooms.	NO	If available, choose a room with a private toilet with an air extractor. That air extractor should run continuously at high speed. + Consider using stand-alone air cleaners with MERV 14 / ISO ePM1 70-80% filter. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate. The air cleaner should be positioned in areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.
	YES ↓		



As a contaminant dilution strategy, the indoor air (within the isolation area) should be changed as uniformly as possible.

Is the air within the isolation area well mixed?

NO → The use of fans and/or fan coil or split system units for cooling and heating increases air mixing within the room or space. This strategy should be implemented only if the minimum ventilation rate has been met.

1) pedestal fan
2) ceiling fan
3) split

YES ↓

Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Air conditioning and heating are performed by non-ducted (with indoor air recirculation) convectors such as split system or fan coil units.

YES →

+ Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

→ In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14 / ISO ePM1 70-80% filter or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

→ Create negative pressure relative to the corridor (outside the room) by increasing general or toilet exhaust airflow. Carefully perform room unit cleaning and disinfection.

NO ↓

END

mechanical ventilation

Minimum requirements	Steps – key questions	Strategies
Minimum recommended ventilation rate: • 10 L/s/person *(42)* (EN 16798-1) within the isolation area	Does the ventilation rate meet the minimum requirement? To assess the ventilation rate, consult point 1. **NO** → Strategies **YES** ↓	+ If the ventilation rate cannot be increased mechanically, consider maximizing ventilation by using natural ventilation through opening windows *(37)* (see natural ventilation section for more strategies). → Forced air systems should be run as much as possible, such as by using "FAN ON" settings *(44)*. → In consultation with a HVAC professional, assess the opportunity to increase the ventilation rate according to system capabilities. Disable demand-control ventilation controls that reduce air supply based on temperature or occupancy. → If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter *(44)*. The air cleaner should be positioned in areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 
Separate the isolation area from the rest of the house *(44)*	The isolation area has a separate ventilation from the other rooms. **NO** → Strategies **YES** ↓	+ If there is a forced air system that would mix the air between the household and the isolation space, return grilles or supply grilles within the isolation area should be sealed *(44)*. Therefore, the isolation area should switch the ventilation mode to natural (refer to the natural ventilation section for more strategies). + Portable room heaters or room air conditioners could be used in the isolation space *(44)* instead of heating and cooling based on air provided by the HVAC central system. Clean and disinfect the device once isolation is over. + Consider using stand-alone air cleaners (often called air purifiers) with particle filters. They should be operated continuously. Use high-efficiency media filters (such as MERV 14 / ISO ePM1 70-80% filter or higher) *(44)*. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 
As a contaminant dilution strategy the indoor air (within the isolation area) should be changed as uniformly as possible	Is the air within the space well mixed? **NO** → Strategies **YES** ↓	The use of fans and/or fan coil or split system units for cooling and heating increases the air mixing within the room or space. This strategy should be implemented only if the minimum ventilation rate has been met. Note: Air mixing should be enhanced within areas but considering the isolation area and the rest of the house separately.  1) pedestal fan 2) ceiling fan 3) split

Verify air recirculation

Does the HVAC system work with centralized recirculation mode?

YES →

- Increase the percentage of outdoor air as air supply, using economizer modes of HVAC operations, potentially up to 100%. Before increasing the outdoor air percentage, verify compatibility with HVAC system capabilities *(38)*.
- If there is a forced air system that would mix the air between the household and the isolation space, return grilles or supply grilles within the isolation area should be sealed. Therefore, the isolation area switches the ventilation mode to natural (refer to the natural ventilation section for more strategies).
- Update or replace existing air filters with MERV 14 / ISO ePM1 70-80% or the highest compatible with the filter rack on the air return duct. Make sure the HVAC system can overcome the additional pressure drop of the new filters.
- If no other strategy can be adopted, consider using stand-alone air cleaners with MERV 14 / ISO ePM1 70-80% filter *(44)*. The air cleaner should be positioned in areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Pay attention to the airflow direction (from clean to less clean areas) when positioning.
  Note: Consider that filtered recirculated air does not replace ventilation in any case.

NO ↓

Verify heat recovery unit

Is the HVAC system designed with heat recovery?

YES →

- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin-coil "run around loop" heat exchanger that guarantees air separation between the return and supply side *(40)*.
- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with cross-flow air-to-air heat exchangers, if the heat exchanger is not compromised.
- For rotary heat exchangers, fitted with purging sectors and properly maintained seals, leakage rates are very low, and cross contamination is a minimal risk.
- If critical leaks (>3%) are detected in the heat recovery sections, in consultation with a HVAC professional, assess the opportunity to install MERV 14 / ISO ePM1 70-80% or higher filter according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If critical leaks (>3%) are detected in the heat recovery sections and the system does not allow MERV 14 / ISO ePM1 70-80% filter installation or the highest compatible with the filter rack, pressure adjustment *(37)* (higher pressure on supply air side than in exhaust air side), deactivation or by-pass of the heat exchanger could be adopted *(41)*.

NO ↓

HVAC system should be regularly inspected, maintained, cleaned and operated continuously

Is the HVAC system regularly inspected, maintained, cleaned and operated, including filter cleaning and replacement?

NO →

- HVAC systems should be regularly inspected, maintained and cleaned according to the manufacturer's recommendations. Contact a HVAC professional, manufacturer or a specialized company to verify that the system complies with the manufacturer's maintenance requirements.
- Clean or replace filter according to the manufacturer's recommendations.

YES ↓

Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Conditioning and heating is performed by non-ducted (with indoor air recirculation) convectors such as split or fan coil units.

YES →

- Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
  Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
- In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14 / ISO ePM1 70-80% filter or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
  Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
- Create negative pressure relative to the corridor (outside the room) by increasing general or toilet exhaust airflow. Carefully perform cleaning and disinfection of room units.

NO ↓

END

7. Evaluating ventilation

Ventilation rate and airflow direction are key elements to be assessed and evaluated before undertaking any action on the ventilation system. This first evaluation will provide the baseline and allow the user to better understand the gap between the ventilation system functionality and the proposed requirements. A second evaluation should be carried out once improvement strategies have been implemented. Comparing the second evaluation with the initial baseline will provide an overview of the effectiveness of the implemented improvement strategies and a clear understanding of the new ventilation rate and flow.
Mechanical and natural ventilation systems require different methods to evaluate the ventilation airflow rate.

Point 1) Minimum ventilation rate – mechanical ventilation system. How to assess it?

Each mechanical ventilation system is designed for specific airflow rates. Consult the technical manual to verify the system capacity.

Point 2) Minimum ventilation rate – natural ventilation system. How to estimate it?

As a rule of thumb, wind-driven natural ventilation rate through a room can be calculated as follows *(20)*:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

k = 0.05 in the case of single-sided ventilation
k = 0.65 in the case of cross ventilation
in the case of mosquito net presence = ventilation rate x 0.5
wind speed: the wind speed refers to the value at the building height at a site sufficiently away from the building without any obstructions (e.g. at an airport) *(32)*

Point 3) Airflow direction. How to evaluate it?

The airflow direction is usually assessed through a gas tracer. However, other cost-effective solutions can be used, such as incense sticks or other smoke generators – a smoke test can be used to highlight the direction of the airflow.

Annex 1:Search strategy and included studies

Search strategy

Concept	Search strategy	Results (2 December 2020)
Ventilation, filtration	hvac OR "air conditioning" OR "forced air" OR "air flow"~3 OR (enclosed AND (space* OR area*)) OR "forced ventilation" OR window* OR fans OR (air AND (recirculation OR recirculated OR ducted OR duct OR ducts OR filterat* OR purif* OR cleaner*)) OR "air exchange"~5 OR HEPA OR mh:("Air Microbiology" OR "Ventilation" OR "Air Filters" OR "Air Conditioning" OR "Filtration" OR "Air Pollution, Indoor" OR "Heating" OR "Air Movements" OR "Air Pollutants") OR MERV	1174

Included studies

Author	Title	Journal and date	Key findings
PUBLISHED LITERATURE			
SL Miller, et al.	Implementing a negative pressure isolation space within a skilled nursing facility to control SARS-CoV-2 transmission	Am J Infect Control 2 October 2020	Validation study of an isolation space at a skilled nursing facility in Pennsylvania, USA. Goal: minimize disease transmission between residents and staff. Isolation space was created by modifying an existing HVAC system; performed computational fluid dynamics and Lagrangian particle-based modelling to test containment and possible transmission. No transmission between residents isolated to the space occurred, nor any transmission to staff or other residents.
SY Lee, et al.	Crucial role of temporary airborne infection isolation rooms in an intensive care unit: containing the COVID-19 outbreak in South Korea	Crit Care 18 May 2020	In an academic hospital in Daegu, Republic of Korea, temporary airborne infection isolation rooms (AAIRs) were assembled. An air volume control damper was used to maintain a negative pressure gradient between pre-existing AIIRs and the ante-room (-5.0 Pa) at a level below the standard negative pressure (-2.5 Pa) recommended for these facilities. The common negative pressure isolation zone was equipped with five mobile negative-air machines that generated negative pressure (-5.0 Pa) compared with the ante-room. Airflow in isolation rooms reached 15–20 air exchanges per hour. Over a 4-week period, 7 patients were treated: 6 patients required mechanical ventilation, 2 patients were treated with extracorporeal membrane oxygenation, and continuous renal replacement therapy was provided to 1 patient. The COVID-19 team included 5 physicians and 40 nurses. All HCWs in the newly remodelled ICU were screened for COVID-19 after the first 2 weeks on duty; no tests were reported as positive.
J Lu, et al.	COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020	Emerg Infect Dis 2 April 2020	Epidemiological investigation in Guangzhou, China. During 26 January to 10 February 2020, an outbreak of COVID-19 occurred in an air-conditioned restaurant, involving 3 family clusters. From an examination of the potential routes of transmission, authors concluded that the most likely cause of the outbreak was droplet transmission prompted by air-conditioned ventilation.

PREPRINT LITERATURE			
Xu P, et al.	Transmission routes of Covid-19 virus in the Diamond Princess Cruise ship	medRxiv 14 April 2020	Diamond Princess cruise ship study. Collected the daily number of 197 symptomatic cases, and that of the 146 passenger cases in two categories (those who stayed and did not stay in the same stateroom). Infections started on 28 January and finished by 6 February for passengers except those who stayed in the same stateroom with infected individual(s). No other confirmed cases were identified among the disembarked passengers in Hong Kong, SAR, China, except an 80-year-old passenger. No confirmed cases were reported in three other stopovers between 27–31 January associated with disembarked passengers or visitors from the ship. However, two Okinawa taxi drivers became confirmed cases in association with driving the ship's passengers. Infection among passengers after 6 February was limited to those who stayed in the same stateroom with an infected passenger. Infections in crew members peaked on 7 February, suggesting significant transmission among crew members after quarantine on 5 February. Authors concluded that the central air-conditioning system did not play a role in transmission and that transmission appears to have occurred through close contact and fomites.
O Almilaji and PW Thomas	Air recirculation role in the infection with COVID-19, lessons learned from Diamond Princess cruise ship	medRxiv 9 July 2020	Diamond Princess cruise ship study. Analysis of count data published on 21 February 2020 and collected by the ship's onboard clinic. By using only passenger count data from the first prepared dataset of 115 symptomatic cases with symptom onset dates during the quarantine period of 6–17 February, analysis showed that 20% occurred in cabins with a previous case, and 80% occurred in cabins without a previous case. Results showed that symptomatic infection rate with recoded symptom onset in cabins with previously confirmed cases was not significantly higher than that in cabins without previously confirmed cases during the whole quarantine period. No evidence was found to conclude that SIRR in the cabins with previously confirmed cases was not significantly higher than that in cabins without previously confirmed cases on and after the median quarantine period day.
PF Horve, et al.	Identification of SARS-CoV-2 RNA in Healthcare Heating, Ventilation, and Air Conditioning Units	medRxiv 28 June 2020	Objective: to assess the potential role of HVAC systems in airborne viral transmission by determining the viral presence on air handling units in a setting where COVID-19 patients were treated (Oregon, USA). The presence of SARS-CoV-2 RNA was detected in 14/56 (25%) of samples taken from nine different locations in multiple air handlers. While samples were not evaluated for viral infectivity, the presence of viral RNA in air handlers raises the possibility that viral particles can enter and travel within the air handling system of a hospital, from room return air through high efficiency MERV 15 filters and into supply air ducts. No known transmission events were determined to be associated with these specimens; however, findings may suggest the potential for HVAC systems to facilitate transmission by environmental contamination via shared air volumes with locations remote from areas where infected persons reside.

Annex 2: Relevant technical guidance

Guidance developer	Reference	Hyperlink
ASHRAE	ANSI/ASHRAE/ASHE Standard 170-2017 Ventilation of health care facilities. 2017.	https://www.ashrae.org/technical-resources/standards-and-guidelines/standards-addenda/ansi-ashrae-ashe-standard-170-2017-ventilation-of-health-care-facilities
ASHRAE	HVAC design manual for hospitals and clinics (second edition). 2013.	https://www.ashrae.org/technical-resources/bookstore/hvac-design-manual-for-hospitals-and-clinics
ASHRAE	Handbook HVAC fundamentals. 2017.	https://www.ashrae.org/technical-resources/ashrae-handbook
ASHRAE	Technical resources for health care settings	https://www.ashrae.org/technical-resources/healthcare
ASHRAE	Technical resources for reopening of schools and universities	https://www.ashrae.org/technical-resources/reopening-of-schools-and-universities
ASHRAE	Technical resources for multifamily building owners/managers	https://www.ashrae.org/technical-resources/multifamily-buildings
ASHRAE	Technical resources for residential settings	https://www.ashrae.org/technical-resources/residential
ASHRAE	Technical resources for commercial settings	https://www.ashrae.org/technical-resources/commercial
ASHRAE	Filtration/Disinfection	https://www.ashrae.org/technical-resources/filtration-disinfection
US Centers for Disease Control and Prevention	COVID-19 employer information for office buildings. 4 January 2021.	https://www.cdc.gov/coronavirus/2019-ncov/community/office-buildings.html
European Centre for Disease Prevention and Control.	Heating, ventilation and air-conditioning systems in the context of COVID-19. 2020.	https://www.ecdc.europa.eu/en/publications-data/heating-ventilation-air-conditioning-systems-covid-19
REHVA	COVID-19 guidance document. 3 August 2020.	https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf
WHO	SARI treatment centers: interim guidance, 28 March 2020	https://www.who.int/publications/i/item/10665-331603
WHO	Natural Ventilation for Infection Control in Health-Care Settings: guidance 2009	https://www.who.int/water_sanitation_health/publications/natural_ventilation/en/
WHO	Considerations for quarantine of contacts of COVID-19 cases: interim guidance, 19 August 2020	https://www.who.int/publications/i/item/considerations-for-quarantine-of-individuals-in-the-context-of-containment-for-coronavirus-disease-(covid-19)
WHO	Home care for patients with COVID-19 presenting with mild symptoms and management of their contacts: interim guidance, 17 March 2020	https://apps.who.int/iris/handle/10665/331473
WHO	Infection prevention and control during health care when COVID-19 is suspected: interim guidance, 19 March 2020	https://www.who.int/publications/i/item/10665-331495
WHO	Aide-memoire: infection prevention and control (IPC) principles and procedures for COVID-19 vaccination activities, 15 January 2021	https://apps.who.int/iris/handle/10665/338715
WHO	COVID-19 management in hotels and other entities of the accommodation sector: interim guidance, 25 August 2020.	https://apps.who.int/iris/handle/10665/333992
WHO	Considerations for school-related public health measures in the context of COVID-19: Annex to Considerations in adjusting public health and social measures in the context of COVID-19,14 September 2020	https://www.who.int/publications/i/item/considerations-for-school-related-public-health-measures-in-the-context-of-covid-19
WHO	Rational use of personal protective equipment for COVID-19 and considerations during severe shortages: interim guidance, 23 December 2020.	https://apps.who.int/iris/handle/10665/338033
WHO	Laboratory biosafety guidance related to coronavirus disease (COVID-19): interim guidance, 28 January 2021.	https://apps.who.int/iris/handle/10665/339056

WHO	Prevention, identification and management of health worker infection in the context of COVID-19: interim guidance, 30 October 2020.	https://apps.who.int/iris/handle/10665/336265
WHO	Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19: interim guidance, 29 July 2020.	https://apps.who.int/iris/handle/10665/333560.
WHO	Infection prevention and control guidance for long-term care facilities in the context of COVID-19: interim guidance, 8 January 2021.	https://apps.who.int/iris/handle/10665/338481.
WHO	Mask use in the context of COVID-19: interim guidance, 1 December 2020.	https://apps.who.int/iris/handle/10665/337199
WHO	Transmission of SARS-CoV-2: implications for infection prevention precautions: scientific brief, 09 July 2020.	https://apps.who.int/iris/handle/10665/333114.

Note: Links accessed 12 February 2021.

Annex 3: Air filter category

Composite Average Particle Size Efficiency % in Size Range µm (ASHRAE standard 52.2-2012)			ASHRAE Standard (52.2-2012)
Range E1	**Range E2**	**Range E3**	**Minimum Efficiency Reporting Value**
0.3 - 1.0 µm	**1.0 - 3.0 µm**	**3.0 - 10.0 µm**	**MERV**
50% ≤ E1	85% ≤ E2	90% ≤ E3	MERV13
75% ≤ E1	90% ≤ E2	95% ≤ E3	MERV14
85% ≤ E1	90% ≤ E2	95% ≤ E3	MERV15
95% ≤ E1	95% ≤ E2	95% ≤ E3	MERV16

International and European Standard (EN ISO 16890)		
ePM1 classification	**ePM2,5 classification**	**ePM10 classification**
0.3 µm ≤ x ≤ 1 µm	**0.3 µm ≤ x ≤ 2.5 µm**	**0.3 µm ≤ x ≤ 10 µm**
ePM1 (95)	ePM2.5 (95)	ePM10 (95)
ePM1 (90)	ePM2.5 (90)	ePM10 (90)
ePM1 (85)	ePM2.5 (85)	ePM10 (85)
ePM1 (80)	ePM2.5 (80)	ePM10 (80)
ePM1 (75)	ePM2.5 (75)	ePM10 (75)
ePM1 (70)	ePM2.5 (70)	ePM10 (70)
ePM1 (65)	ePM2.5 (65)	ePM10 (65)
ePM1 (60)	ePM2.5 (60)	ePM10 (60)
ePM1 (55)	ePM2.5 (55)	ePM10 (55)
ePM1 (50)	ePM2.5 (50)	ePM10 (50)

International standard (ISO 29463) European Standard (EN 1822)		
Filter class (ISO 29463)	**Filter class (EN 1822)**	**Efficiency at MPPS**
-	**-**	**%**
	E10	>85
ISO 15E - ISO 20E	E11	>95
ISO 25E - ISO 30E	E12	>99.5
ISO 35H - ISO 40H	HEPA - H13	>99.95
ISO 45H - ISO 50U	HEPA - H14	>99.995

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Records 2 to 7 are not released in accordance with sections 43(1)(d) and 45(a) of the

Freedom of Information Act 2016.

Flint, Katrina

From: Yapp, Phillip
Sent: Friday, 21 January 2022 4:07 PM
To: Mitchell, BethL; Flint, Katrina
Subject: RC-Reporter: CO2 Report
Attachments: Indoor Air Quality (IAQ) Report - Major Sites Overview.pdf

Have spent this Branch catchup putting together an overview report of maximum and average CO2s, repetitive work setting up points and the graphs. Obviously a couple of faulty CO2s, one at Hawker College definitely which will be DLP.

Sites where we have a lot in RC-Reporter, still have another 4-5 to add in but the computer being really slow now!

Happy Friday and hope you have a good weekend 😊

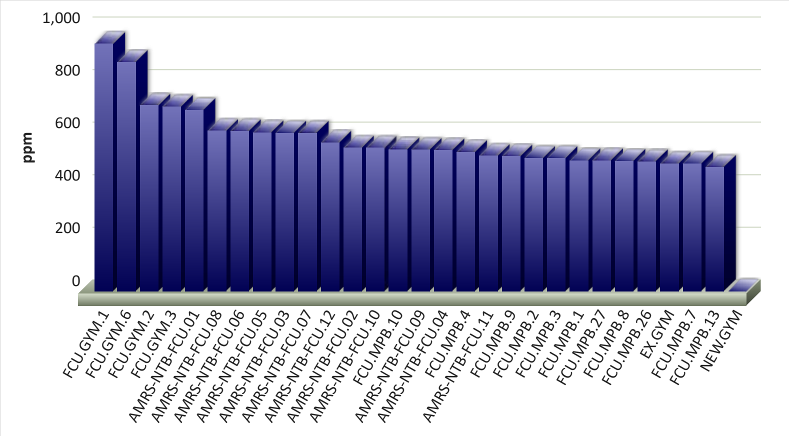
Indoor Air Quality (IAQ) Report - "School Name"

Record 8

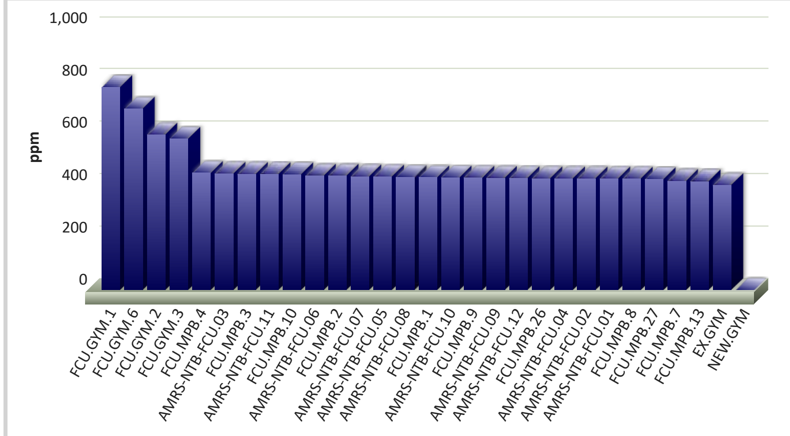
This Indoor Air Quality report provides a summary of the school's Heang , Venla on and Air Condioning (HV AC) system performance through analysing data from the HVAC's Building Management System (BMS). The BMS is a computerised control system that manages the school's air condioning s ystems, including the venla on br ought into classrooms. The report provides a useful tool to monitor the effecv eness of the mechanical venla on s trategies and idenf y any areas that may need further control measures implemented.

The World Health Organisaon (WHO) and Aus tralian Instut e of Refrigeraon Air -condioning and Hea ng (AIRAH) r ecommend a range of measures for minimising risk of COVID-19 in a school environment, including introducing addional fr esh air and maintaining levels of CO2 in condioned ar eas to <800ppm. CO2 levels are an effecv e proxy for venla on r ates, as occupants breathe out, the levels of CO2 increase and the HVAC systems adjust venla on based on the in ternal CO2 levels from the space.

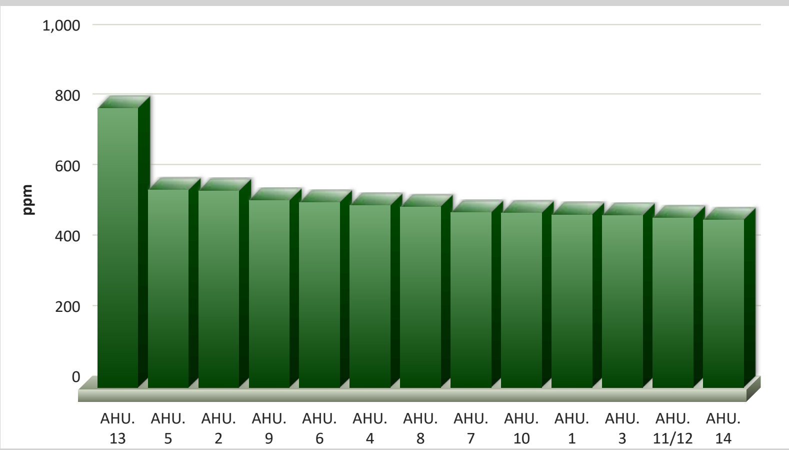
Amaroo School - Max CO2



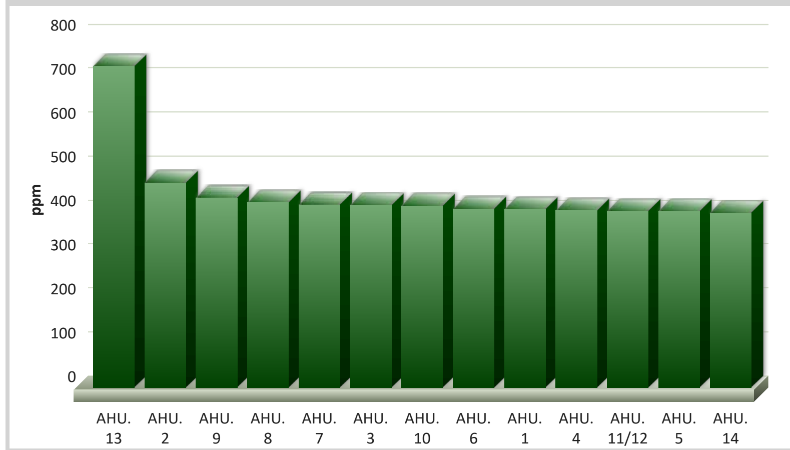
Amaroo School - Average CO2



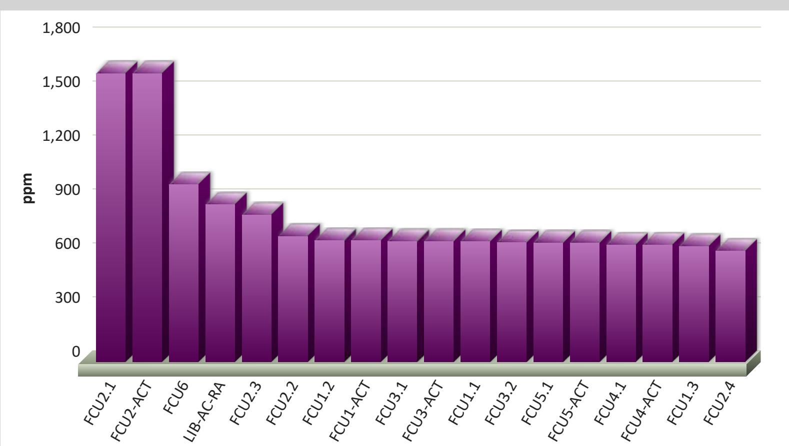
Canberra College - Max CO2



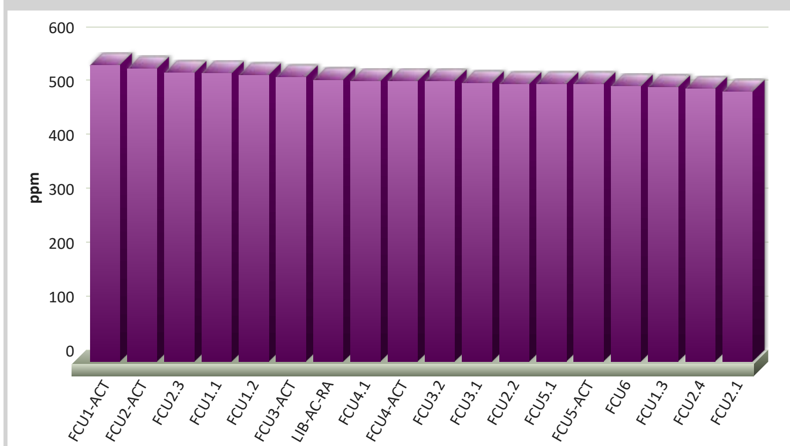
Canberra College - Average CO2

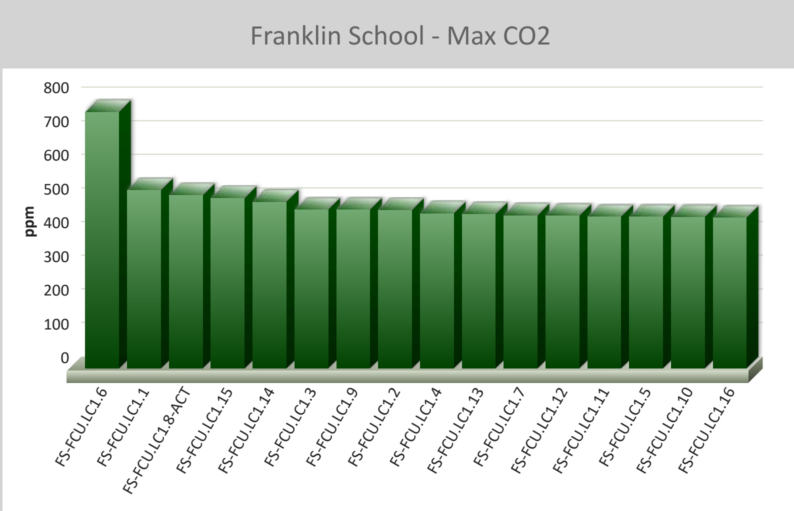


Caroline Chisholm School - Max CO2



Caroline Chisholm School - Average CO2




Franklin School - Max CO2
800
700
600
500
400
300
200
100
0
ppm
FS-FCU.LC1.6
FS-FCU.LC1.1
FS-FCU.LC1.8-ACT
FS-FCU.LC1.15
FS-FCU.LC1.14
FS-FCU.LC1.3
FS-FCU.LC1.9
FS-FCU.LC1.2
FS-FCU.LC1.4
FS-FCU.LC1.13
FS-FCU.LC1.7
FS-FCU.LC1.12
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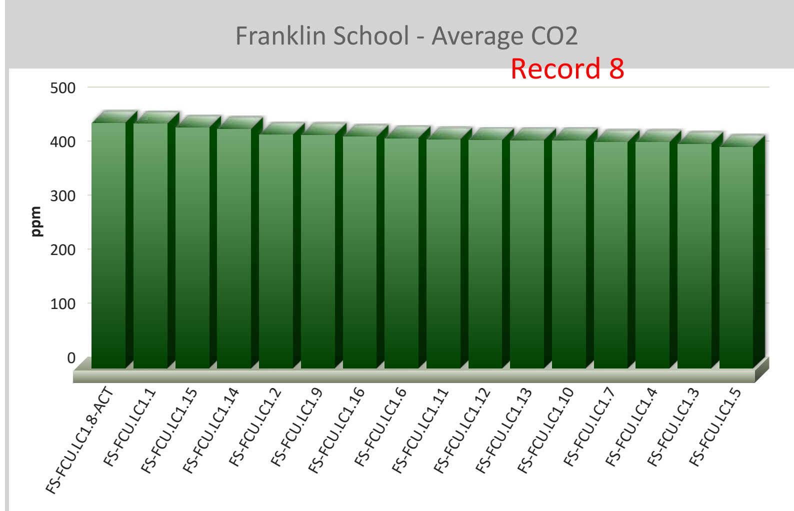
FS-FCU.LC1.16


Franklin School - Average CO2
500
400
300
200
100
0
ppm
FS-FCU.LC1.8-ACT
FS-FCU.LC1.1
FS-FCU.LC1.15
FS-FCU.LC1.14
FS-FCU.LC1.2
FS-FCU.LC1.9
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FS-FCU.LC1.11
FS-FCU.LC1.12
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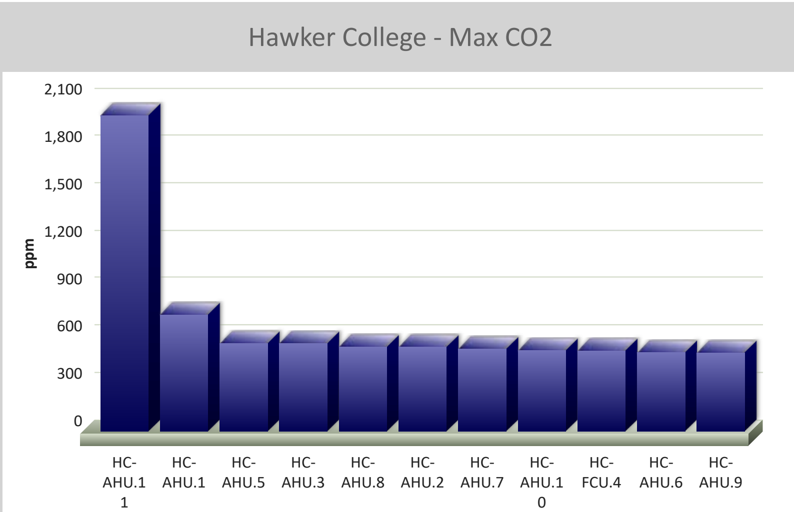
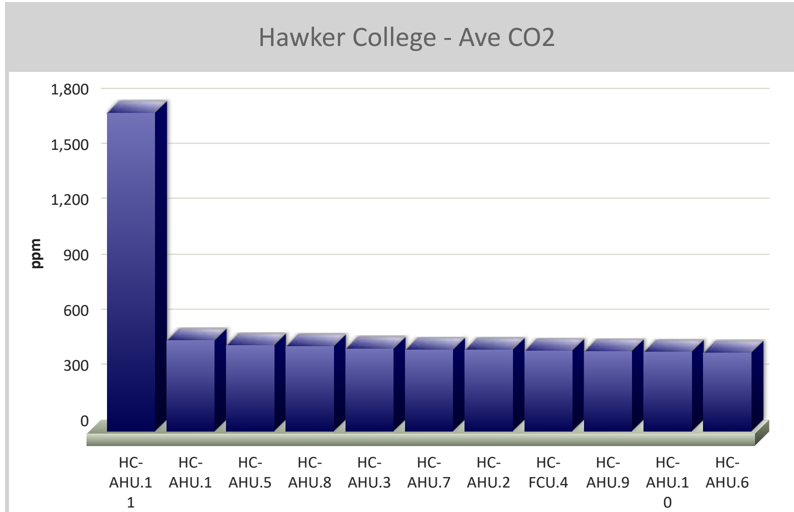
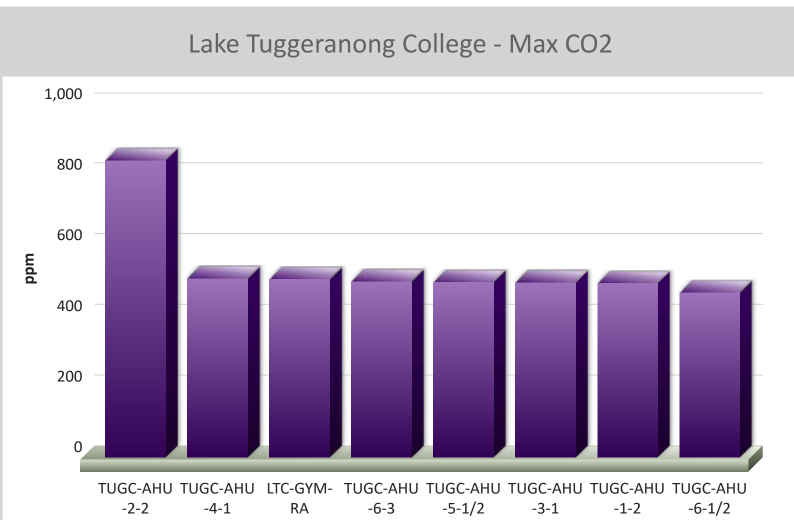
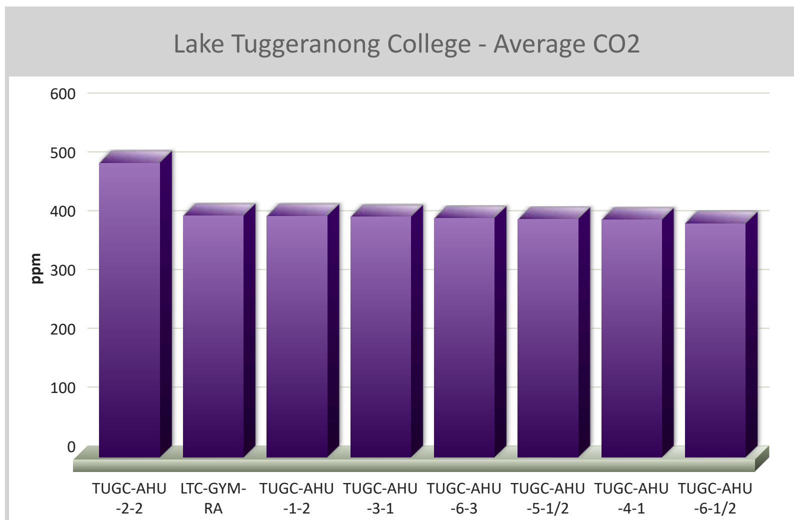
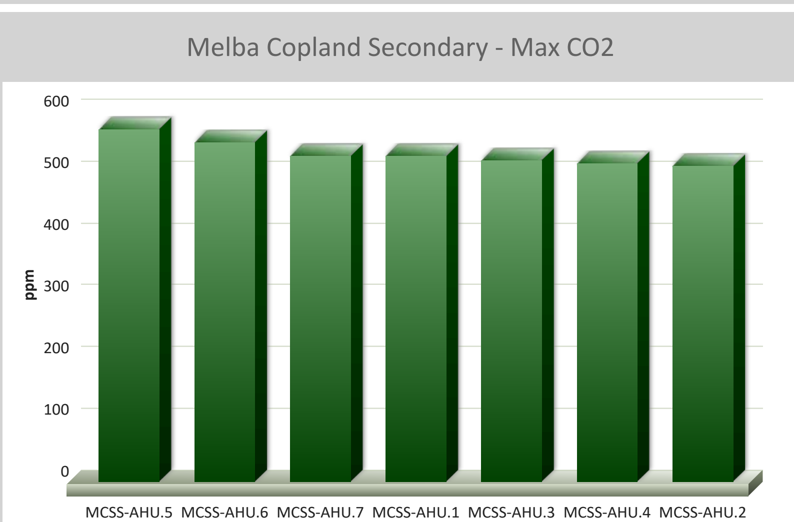
Record 8

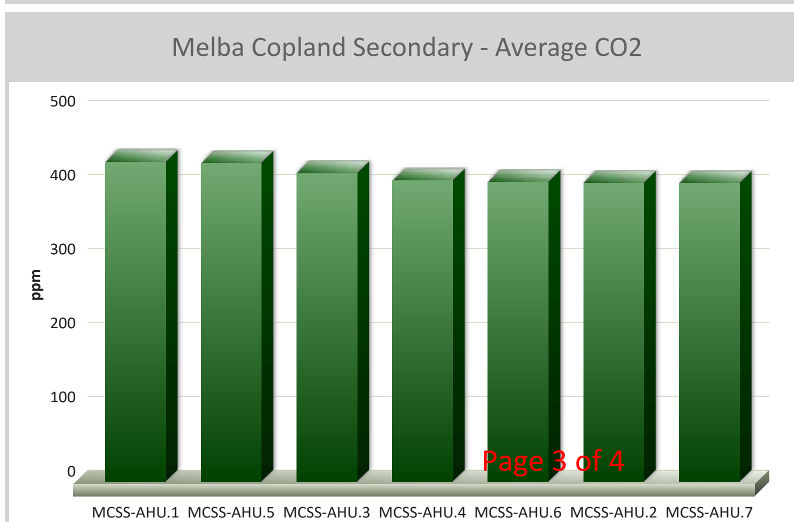

Hawker College - Max CO2
2,100
1,800
1,500
1,200
900
600
300
0
ppm
HC-AHU.11
HC-AHU.1
HC-AHU.5
HC-AHU.3
HC-AHU.8
HC-AHU.2
HC-AHU.7
HC-AHU.10
HC-FCU.4
HC-AHU.6
HC-AHU.9

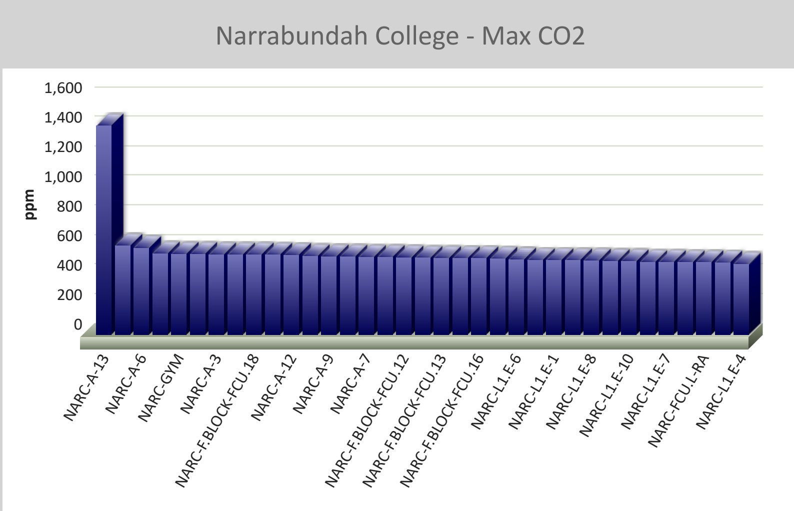

Hawker College - Ave CO2
1,800
1,500
1,200
900
600
300
0
ppm
HC-AHU.11
HC-AHU.1
HC-AHU.5
HC-AHU.8
HC-AHU.3
HC-AHU.7
HC-AHU.2
HC-FCU.4
HC-AHU.9
HC-AHU.10
HC-AHU.6


Lake Tuggeranong College - Max CO2
1,000
800
600
400
200
0
ppm
TUGC-AHU-2-2
TUGC-AHU-4-1
LTC-GYM-RA
TUGC-AHU-6-3
TUGC-AHU-5-1/2
TUGC-AHU-3-1
TUGC-AHU-1-2
TUGC-AHU-6-1/2

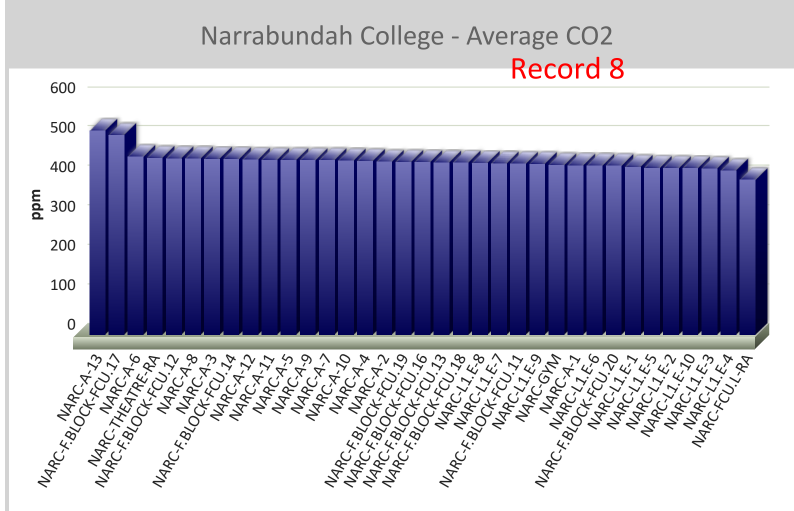

Lake Tuggeranong College - Average CO2
600
500
400
300
200
100
0
ppm
TUGC-AHU-2-2
LTC-GYM-RA
TUGC-AHU-1-2
TUGC-AHU-3-1
TUGC-AHU-6-3
TUGC-AHU-5-1/2
TUGC-AHU-4-1
TUGC-AHU-6-1/2


Melba Copland Secondary - Max CO2
600
500
400
300
200
100
0
ppm
MCSS-AHU.5
MCSS-AHU.6
MCSS-AHU.7
MCSS-AHU.1
MCSS-AHU.3
MCSS-AHU.4
MCSS-AHU.2


Melba Copland Secondary - Average CO2
500
400
300
200
100
0
ppm
MCSS-AHU.1
MCSS-AHU.5
MCSS-AHU.3
MCSS-AHU.4
MCSS-AHU.6
MCSS-AHU.2
MCSS-AHU.7


Narrabundah College - Max CO2
ppm
1,600
1,400
1,200
1,000
800
600
400
200
0
NARC-A-13
NARC-A-6
NARC-GYM
NARC-A-3
NARC-F.BLOCK-FCU.18
NARC-A-12
NARC-A-9
NARC-A-7
NARC-F.BLOCK-FCU.12
NARC-F.BLOCK-FCU.13
NARC-F.BLOCK-FCU.16
NARC-L1.E-6
NARC-L1.E-1
NARC-L1.E-8
NARC-L1.E-10
NARC-L1.E-7
NARC-FCU.L-RA
NARC-L1.E-4

Record 8


Narrabundah College - Average CO2
ppm
600
500
400
300
200
100
0
NARC-A-13
NARC-F.BLOCK-FCU.17
NARC-A-6
NARC-THEATRE-RA
NARC-F.BLOCK-FCU.12
NARC-A-8
NARC-A-3
NARC-F.BLOCK-FCU.14
NARC-A-12
NARC-A-11
NARC-A-5
NARC-A-9
NARC-A-7
NARC-A-10
NARC-A-4
NARC-A-2
NARC-F.BLOCK-FCU.19
NARC-F.BLOCK-FCU.16
NARC-F.BLOCK-FCU.13
NARC-F.BLOCK-FCU.18
NARC-L1.E-8
NARC-L1.E-7
NARC-F.BLOCK-FCU.11
NARC-L1.E-9
NARC-GYM
NARC-A-1
NARC-L1.E-6
NARC-F.BLOCK-FCU.20
NARC-L1.E-1
NARC-L1.E-5
NARC-L1.E-2
NARC-L1.E-10
NARC-L1.E-3
NARC-L1.E-4
NARC-FCU.L-RA

Records 9 to 11 are not released in accordance with sections 43(1)(d) and 45(a) of the *Freedom of Information Act 2016.*

Flint, Katrina

From: Parkinson, Andrew
Sent: Wednesday, 4 May 2022 9:02 AM
To: Ryan, JohnW; Yapp, Phillip
Subject: Re: IAQ Winter Plans - Documentation for review
Attachments: FACTSHEET - IAQ Winter Ventilation.docx

OFFICIAL

Hi there

Jane has approved the attached natural ventilation FAQ

Andrew Parkinson | Executive Branch Manager
Infrastructure & Capital Works | Education Directorate | **ACT Government**
Phone 02 6205 4593 | **Mobile 0478 301 085**
220 London Circuit, Civic | www.act.gov.au

Dhawura nguna, dhawura Ngunnawal

From: Parkinson, Andrew <Andrew.Parkinson@act.gov.au>
Sent: Tuesday, 3 May 2022 14:59
To: Ryan, JohnW <JohnW.Ryan@act.gov.au>; Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: Re: IAQ Winter Plans - Documentation for review

Likewise - I'm happy with these changes

Andrew Parkinson | Executive Branch Manager
Infrastructure & Capital Works | Education Directorate | **ACT Government**
Phone 02 6205 4593 | **Mobile 0478 301 085**
220 London Circuit, Civic | www.act.gov.au

Dhawura nguna, dhawura Ngunnawal

From: Ryan, JohnW <JohnW.Ryan@act.gov.au>
Sent: Tuesday, 3 May 2022 13:20
To: Yapp, Phillip <Phillip.Yapp@act.gov.au>; Parkinson, Andrew <Andrew.Parkinson@act.gov.au>
Subject: RE: IAQ Winter Plans - Documentation for review

OFFICIAL

Hi Phil,

The changes look good to me. All my questions are now resolved.

Cheers

John

John Ryan |Senior Director
Asset Strategies
Phone: +61 2 62051874 |Email: johnw.ryan@act.gov.au
Infrastructure and Capital Works | Education | ACT Government
Level 4, 220 London Circuit | GPO Box 158 Canberra ACT 2601
www.education.act.gov.au | Facebook | Twitter | Instagram | LinkedIn | Google+

From: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Sent: Tuesday, 3 May 2022 12:28 PM
To: Parkinson, Andrew <Andrew.Parkinson@act.gov.au>; Ryan, JohnW <JohnW.Ryan@act.gov.au>
Subject: FW: IAQ Winter Plans - Documentation for review

Hi Andrew and John

For approval, updated Winter Action Plan dot-points, and the updated UVC wording for the legend. Once these are approved we can finalise the maps that have UVC, and start on the IAQ Plans.

Cheers
Phil

Phil Yapp | Assistant Director – Asset Strategies, Sustainability and Environment

Phone: +61 2 6207 9190 | M: 0435 655 176 | Email: phillip.yapp@act.gov.au
Infrastructure and Capital Works | Education | ACT Government
Level 4 220 London Circuit | GPO Box 158 Canberra ACT 2601 | www.det.act.gov.au

---

From: Ryan, JohnW <JohnW.Ryan@act.gov.au>
Sent: Monday, 2 May 2022 4:11 PM
To: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: FW: IAQ Winter Plans - Documentation for review

OFFICIAL

Hi Phil,

Some draft words for the rooms with UV-C.

Happy to discuss.

John

From: Parkinson, Andrew <Andrew.Parkinson@act.gov.au>
Sent: Thursday, 28 April 2022 10:28 AM
To: Ryan, JohnW <JohnW.Ryan@act.gov.au>; Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: Re: IAQ Winter Plans - Documentation for review

Hi all

I've had a look at the IAQ actions and made a couple of comments.

Generally we just need to make sure the rooms name/descriptions match the map and plans.

Andrew Parkinson | Executive Branch Manager
Infrastructure & Capital Works | Education Directorate | **ACT Government**
Phone 02 6205 4593 | **Mobile 0478 301 085**
220 London Circuit, Civic | www.act.gov.au

Dhawura nguna, dhawura Ngunnawal

From: Parkinson, Andrew <Andrew.Parkinson@act.gov.au>
Sent: Tuesday, 19 April 2022 09:05
To: Ryan, JohnW <JohnW.Ryan@act.gov.au>; Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: Re: IAQ Winter Plans - Documentation for review

Hi all

i've made some edits to the fact sheet. I spoken to the DDG about it on Wednesday and shared a copy with her. I haven't had any feedback from her yet about it. I also had a session with the AEU late on thursday and described our approach and they seemed comfortable. We've undertaken to share the document with them later this week.

I noted John's comment about the map category for UVC fans. We need to decide it they still count as naturally ventilated (ie open and shut windows in the space) or if we treat them as mechanically ventilated (just make sure they are turned on). I'm not sure which way I'm leaning (lets discuss further) but happy for them to have their own colour on the map

I'm still looking at the IAQP standard actions. I'll have comment back on those later today.

Regards

Andrew Parkinson | Executive Branch Manager
Infrastructure & Capital Works | Education Directorate | **ACT Government**
Phone 02 6205 4593 | **Mobile 0478 301 085**
220 London Circuit, Civic | www.act.gov.au

Dhawura nguna, dhawura Ngunnawal

From: Ryan, JohnW <JohnW.Ryan@act.gov.au>
Sent: Wednesday, 13 April 2022 08:57
To: Yapp, Phillip <Phillip.Yapp@act.gov.au>; Parkinson, Andrew <Andrew.Parkinson@act.gov.au>
Subject: RE: IAQ Winter Plans - Documentation for review

Hi Phil and Andrew,

Attached are my comments in tracked changes. They mostly refer to the adoption of common terminology for mechanical ventilation systems and it is not clear to me if rooms with UVC lights are ok for full time use.

Cheers

John

From: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Sent: Tuesday, 12 April 2022 4:33 PM
To: Parkinson, Andrew <Andrew.Parkinson@act.gov.au>; Ryan, JohnW <JohnW.Ryan@act.gov.au>
Subject: IAQ Winter Plans - Documentation for review

Hi John/Andrew, having trouble finishing off the Fact Sheet/guidance this afternoon as my brain has ceased functioning today. I'll try and give it another go first thing tomorrow morning. The recommended categories moving into winter and action points are ready for approval/comment though. If categories can be approved, we can start on updating the maps..

Cheers
Phil

Phil Yapp | Assistant Director – Asset Strategies, Sustainability and Environment

Phone: +61 2 6207 9190 | M: 0435 655 176 | Email: phillip.yapp@act.gov.au
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Level 4 220 London Circuit | GPO Box 158 Canberra ACT 2601 | www.det.act.gov.au

Keep CBR safe & strong

Ventilation and air quality Frequently Asked Questions for staff

Q: Why do we need to ventilate learning spaces?

ACT Health has advised schools to optimise fresh air circulation to reduce the risk of COVID-19 transmission. The risk of transmission is higher in crowded and poorly ventilated spaces where people spend long periods of time together in close proximity. Good ventilation is one part of a suite of controls to minimise transmission in schools, like vaccination, physical distancing, student cohorting, good hygiene, cleaning and mask use.

Q: What's the evidence that it reduces risk?

The Chief Health Officer, the *Australian Health Protection Principal Committee*, *World Health Organisation* and *Safe Work Australia* all recommend good indoor air quality to reduce the chance of COVID-19 transmission.

Q: How can my school optimise fresh air circulation?

We know there are easy and quick changes we can make to improve ventilation and fresh air circulation. The simplest of these is opening windows in classrooms and turning on the exhaust fans in rooms that have them. Other actions include opening windows that had previously been either mechanically fixed or painted shut - where it's safe to do so.

We've also been undertaking detailed investigations of all schools including early childhood schools and preschools including technical assessment of HVAC systems and our ability to control fresh air. As a result, the Education Directorate knows that fresh air flow can be adjusted in ALL public schools to improve ventilation.

Q: What's the Indoor Air Quality framework and how is that different from the Indoor Air Quality Plan?

The Directorate has developed an Indoor Air Quality (IAQ) framework to assess the IAQ of all 3,500 public school learning spaces. It includes a checklist, which has been completed by schools.

Every school has its own IAQ Plan. This includes a list of actions already undertaken by the Directorate (e.g., HVAC systems change) and actions for schools to undertake. The Plan includes a map that identifies the type of ventilation in each learning and teaching space that have ventilation provided by either natural or mechanical means. Natural ventilation is provided either by operable windows or louvres, while mechanical ventilation is provided by the school's HVAC systems.

Q: Who's going to be adjusting ventilation in schools?

Many actions in your school's IAQ are carried out by non-teaching staff like your Building Service Officers or external HVAC contractors. Some action will need to be carried out by the room occupants.

Date of Publication: 5 May 2022

VENTILATION AND AIR QUALITY

Keep CBR safe & strong

Q: Won't rooms be less comfortable for students and staff?

In naturally ventilated spaces, thermal comfort and ventilation will need to be balanced to provide safe learning environments. The "Indoor Air Quality – Winter Ventilation" factsheet provides guidance on how to achieve this balance.

Q: Is there an estimation of what will happen to energy bills?

Higher energy bills are anticipated to result from the increase in fresh air as a greater volume of air needs to be heated or cooled.

Q: What about CO2 sensors?

Many of our schools have Building Management Systems with CO2 sensors which provide a proxy for ventilation in a room. CO2 monitoring commenced in those schools when students and staff returned on-site in Term 4, 2021.

Q: My school doesn't have CO2 sensors. Will it be receiving them?

Longer term, the Directorate will look to introduce additional mechanical ventilation in spaces that require it. This may include installation of new building management systems with CO2 sensors that can remotely control HVAC systems and windows.

The Directorate is monitoring air quality in learning spaces to further refine the strategy to provide the best ventilation for ACT public schools.

Portable CO2 monitors are available to schools with naturally ventilated spaces to help balance thermal comfort and ventilation.

Date of Publication: 5 May 2022

Flint, Katrina

From: Graham, Cathy
Sent: Sunday, 8 May 2022 6:45 PM
To: CMTEDD ACTPG HVAC Services
Cc: Flint, Katrina; Yapp, Phillip
Subject: IAQ 21-22/357 - Telopea Park School Library Co2 sensors

OFFICIAL

Hi Team,

Please raise the below job for Telopea Park School.

IAQ 21-22/357	Telopea Park School	08/05/2022	HVAC	CO2	Please install CO2 sensors to each Library AHU zone, connect to BMS and adjust ventilation to maintain CO2 levels <800ppm, update RC WebView and connect to RC-Archive/Reporter

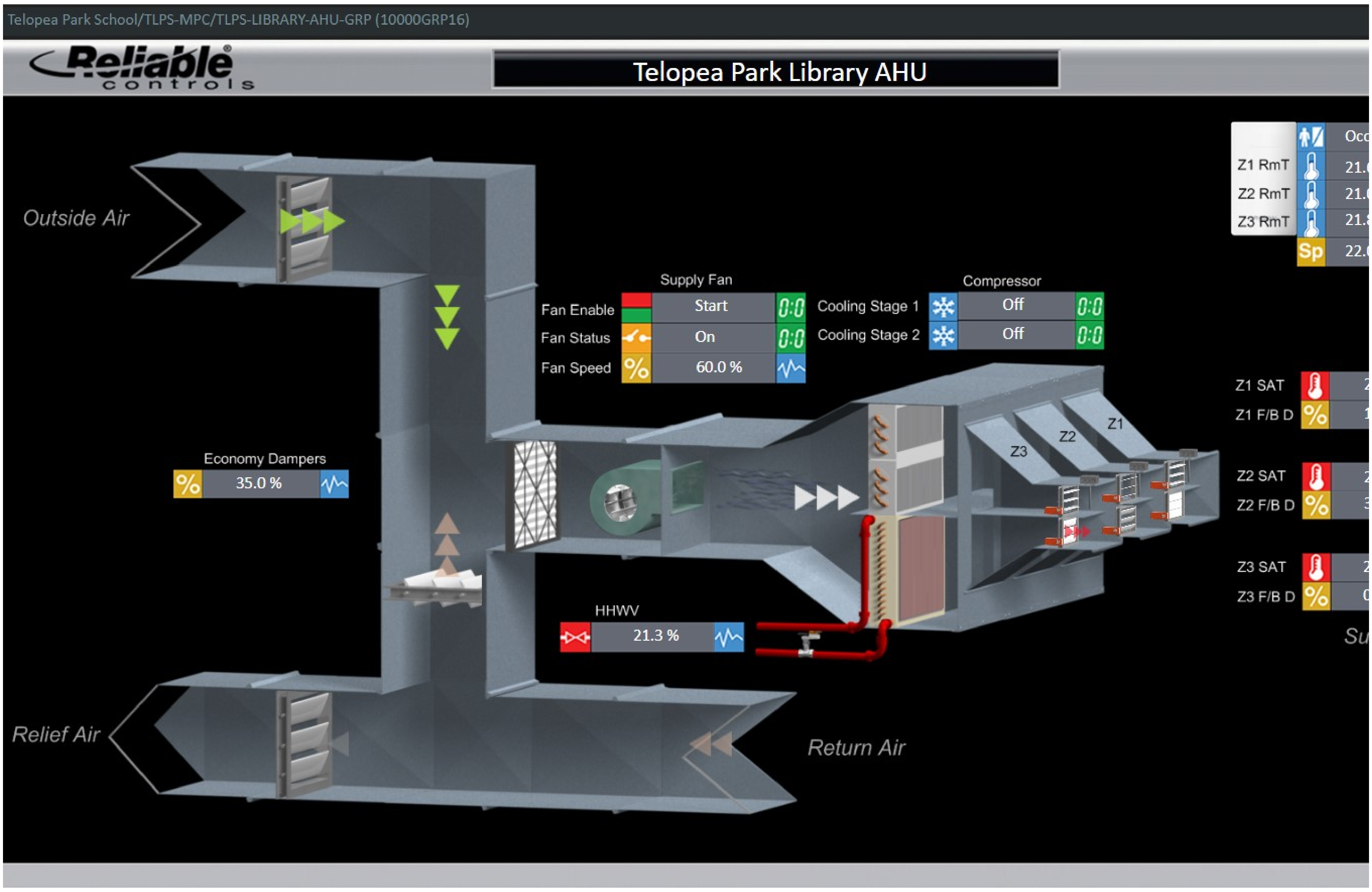
Thanks,
Cathy

From: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Sent: Friday, 6 May 2022 2:29 PM
To: Graham, Cathy <Cathy.Graham@act.gov.au>
Cc: Flint, Katrina <Katrina.Flint@act.gov.au>
Subject: IAQ - Telopea Park School Library Co2 sensors

Hi Cathy

Can you please raise a job to ACTPG for Telopea Park School to install CO2 sensors to each Library AHU zone, connect to BMS and adjust ventilation to maintain CO2 levels <800ppm, update RC WebView and connect to RC-Archive/Reporter?

Cheers



Phil Yapp | Assistant Director – Asset Strategies, Sustainability and Environment

Phone: +61 2 6207 9190 | M: 0435 655 176 | Email: phillip.yapp@act.gov.au

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Level 4 220 London Circuit | GPO Box 158 Canberra ACT 2601 | www.det.act.gov.au

Record 15 is not released in accordance with sections 43(1)(d) and 45(a) of the

Freedom of Information Act 2016.

ACT Government
Education

CO_2 MONITOR OPERATION

COVID Safety: CO_2 Monitor

In order to optimise COVID-19 safety in ACT schools and help maintain a high level of indoor air quality, this classroom contains a CO_2 monitor to indicate the level of ventilation in the room (pictured above). Natural ventilation via manually opening windows or louvres is required to reduce the risk of COVID transmission so this fact sheet should be used a guide to operate the monitor and help maintain a safe and thermally comfortable learning space.

Installation

This portable CO_2 monitor should be placed at desk height in a visible location away from fresh air inlets (e.g. open windows) and not within 1m of a student or teacher. As the batteries in these monitors need to be recharged, wall mounting is not recommended.

Operation

The monitors are supplied with a USB-C cable, which is similar to the cables used to charge most mobile phones. Monitors should be plugged in regularly to ensure the battery is charged.

To turn on the monitor press the power button for three seconds. Once the monitor is on it will constantly display the CO_2 concentration in the air.

What do the readings mean?

• Less than 800ppm: **Low Relative Risk** - A CO_2 concentration of <800ppm is considered an indicator of good indoor air quality.
• 800-1500ppm: **Moderate Relative Risk** – At this level of concentration windows should be at least partially opened to increase ventilation
• Higher than 1500ppm: **High Relative Risk** - windows should be fully opened to increase ventilation

Once levels have reduced below 800ppm, windows can be closed or left slightly open to restore thermal comfort.

Contact for further information

For further information about the CO_2 monitors or to report a fault, please contact the Business Manager or Principal at your school.

ACT Government Education

CO_2 MONITOR OPERATION

Recalibration Procedure

This portable CO2 monitor does not generally require recalibration as the monitor uses a self-calibrating function to automatically maintain correct CO2 levels over a typical 10-year life span.

However, rough transport or being dropped may cause the CO2 cell to be jarred out of calibration beyond the auto calibration capabilities, in which case a manual recalibration will be required.

To check calibration, place module in a protected outside fresh air environment - within 1 hour module should display a typical fresh air CO2 value of between 400 to 450ppm, if high, perform a manual reset of the module by the following procedure.

1. Remove external power supply for this procedure.
2. Momentary push the power button twice and "HHHH" will be displayed. After approximately 1 minute the display will change to read "0000".
3. Wait 10 seconds, then turn module power off by pressing & holding power button for 3 seconds.
4. After 30 seconds turn power back on by pressing power button for 3 seconds ...unit should now display a more accurate reading & over 1/2 hour settle down to a correct calibration tolerance.

[redacted]

From: CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Sent: Friday, 29 July 2022 12:43 PM
To: Graham, Cathy <Cathy.Graham@act.gov.au>; CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Cc: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: RE: IAQ 21-22/357 - Telopea Park School Library Co2 sensors

OFFICIAL

HI Cathy,

No these works have not been carried as we are still waiting on a quotation from IES.

Kind Regards,

John Hull

Property Workplan & Building report Coordinator – HVAC
ACT PROPERTY GROUP | PROPERTY UPGRADES | CHIEF MINISTERS, TREASURY & ECONOMIC DEVELOPMENT DIRECTORATE ACT GOVERNMENT | www.act.gov.au
PH: M: 0466 503 475 E: john.hull@act.gov.au or ACTPG HVAC Team ACTPGHVAC@act.gov.au
COVID-19: there are currently travel restrictions in place for people travelling to the ACT from specified locations around Australia. These restrictions apply to contractors and suppliers of ACT Property Group unless an exemption has been granted.

ACT Property Group requires all contractors and suppliers to comply with any restrictions that are in force which are applicable to them. If permitted to travel to the ACT please follow COVID-safe practices and use the Check In CBR App at venues to support contact tracing. Updates can be found at: https://www.covid19.act.gov.au/travel/entering-the-act. Please contact ACT Property Group on 6213 0700, or where applicable the project officer, to discuss any impact this may have on delivery of services to ACT Property Group. 255 Canberra Avenue, Fyshwick, ACT 2609, PO Box 777 Fyshwick ACT 2609 *If you have any feedback for the ACT Property Group, please email actpgfeedback@act.gov.au*

"ACTPG is engaged by the Education Directorate to ensure the management of all contractors, past and present HVAC works are providing a turn-key solution".

From: Graham, Cathy <Cathy.Graham@act.gov.au>
Sent: Friday, 29 July 2022 12:13 PM
To: CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Cc: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: RE: IAQ 21-22/357 - Telopea Park School Library Co2 sensors

OFFICIAL

Thanks John,

Can you confirm that works haven't been completed as if hats the case I can take this site out of he FOI we are working on.

Cathy

From: CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Sent: Friday, 29 July 2022 12:02 PM
To: Graham, Cathy <Cathy.Graham@act.gov.au>; CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Cc: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: RE: IAQ 21-22/357 - Telopea Park School Library Co2 sensors

OFFICIAL

Hi Cathy,

I have followed this up again today with IES.

Kind Regards,

John Hull

Property Workplan & Building report Coordinator – HVAC
ACT PROPERTY GROUP | PROPERTY UPGRADES | CHIEF MINISTERS, TREASURY & ECONOMIC DEVELOPMENT DIRECTORATE ACT GOVERNMENT | www.act.gov.au
PH: M: 0466 503 475 E: john.hull@act.gov.au or ACTPG HVAC Team ACTPGHVAC@act.gov.au
COVID-19: there are currently travel restrictions in place for people travelling to the ACT from specified locations around Australia. These restrictions apply to contractors and suppliers of ACT Property Group unless an exemption has been granted.

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"ACTPG is engaged by the Education Directorate to ensure the management of all contractors, past and present HVAC works are providing a turn-key solution".

From: Graham, Cathy <Cathy.Graham@act.gov.au>
Sent: Friday, 29 July 2022 11:16 AM
To: CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Cc: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: FW: IAQ 21-22/357 - Telopea Park School Library Co2 sensors

OFFICIAL

Hi John,

As at 24/5/22 you were awaiting a quote.
Has this come through and did it get approved?

Thanks,
Cathy

From: Graham, Cathy
Sent: Sunday, 8 May 2022 6:45 PM
To: CMTEDD ACTPG HVAC Services <ACTPGHVAC@act.gov.au>
Cc: Flint, Katrina <Katrina.Flint@act.gov.au>; Yapp, Phillip <Phillip.Yapp@act.gov.au>
Subject: IAQ 21-22/357 - Telopea Park School Library Co2 sensors

OFFICIAL

Hi Team,

Please raise the below job for Telopea Park School.

IAQ 21-22/357	Telopea Park School	08/05/2022	HVAC	CO2	Please in Library A BMS and maintain update R to RC-Ar

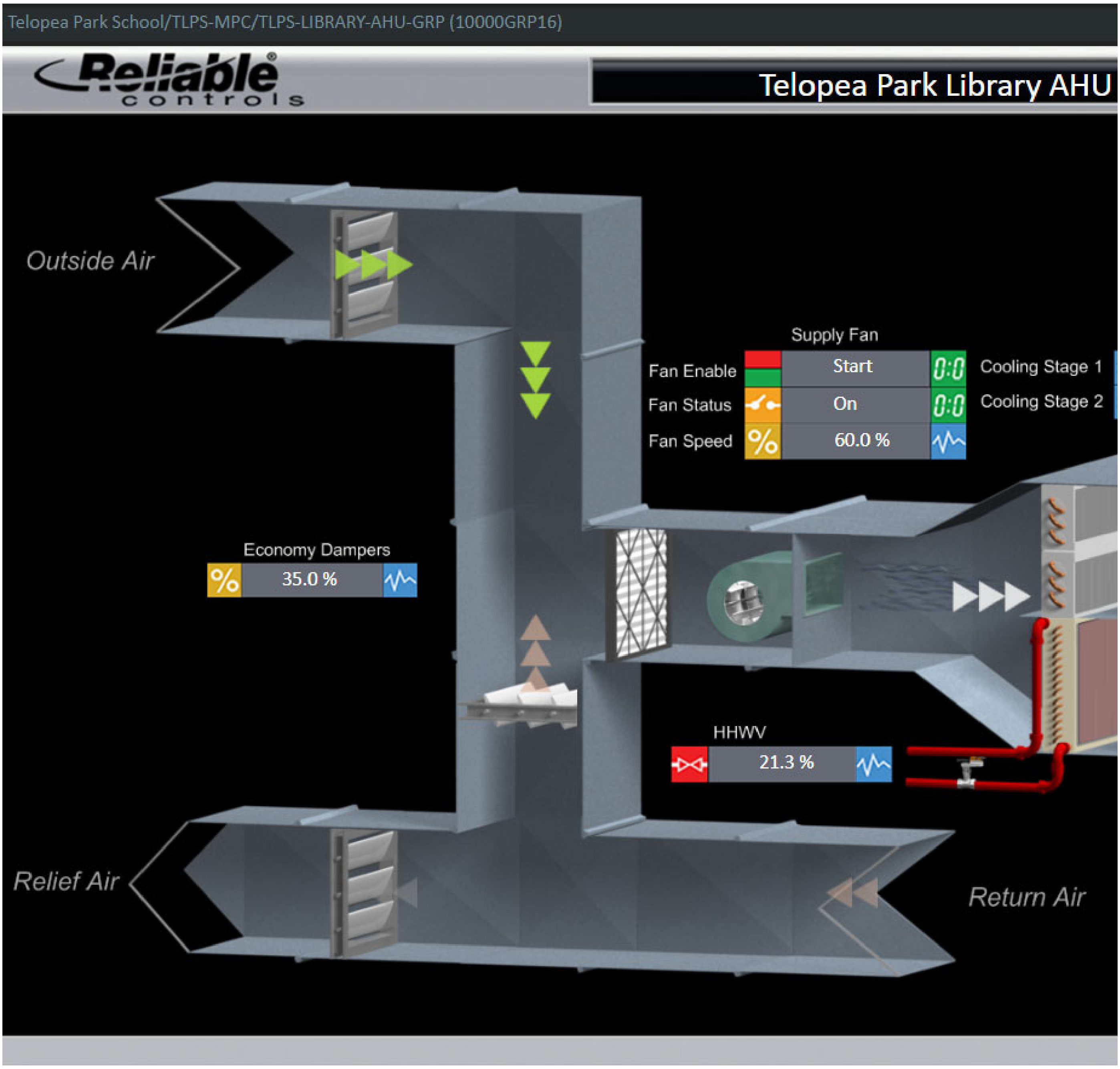
Thanks,
Cathy

From: Yapp, Phillip <Phillip.Yapp@act.gov.au>
Sent: Friday, 6 May 2022 2:29 PM
To: Graham, Cathy <Cathy.Graham@act.gov.au>
Cc: Flint, Katrina <Katrina.Flint@act.gov.au>
Subject: IAQ - Telopea Park School Library Co2 sensors

Hi Cathy

Can you please raise a job to ACTPG for Telopea Park School to install CO2 sensors to each Library AHU zone, connect to BMS and adjust ventilation to maintain CO2 levels <800ppm, update RC WebView and connect to RC-Archive/Reporter?

Cheers



Phil Yapp | Assistant Director – Asset Strategies, Sustainability and Environment

Phone: +61 2 6207 9190 | M: 0435 655 176 | Email: phillip.yapp@act.gov.au

Infrastructure and Capital Works | Education | ACT Government
Level 4 220 London Circuit | GPO Box 158 Canberra ACT 2601 | www.det.act.gov.au

Breadcrumb

Home » Improving ventilation in indoor workplaces: COVID-19

Improving ventilation in indoor workplaces: COVID-19

Page last updated: 18 Nov 2021

On this page:

Summary

The Australian Health Protection Principal Committee (AHPPC) advises that improved ventilation may limit the spread of certain respiratory diseases, such as COVID-19 in indoor environments. Understanding and controlling building ventilation can help improve indoor air quality. In combination with other reasonably practicable control measures, improving indoor ventilation can be used to minimise the *risks* of COVID-19.

Why indoor ventilation is important

Airborne transmission of COVID-19 can occur through dispersal of large respiratory droplets or smaller aerosols containing the virus. The COVID-19 virus can be transmitted in poorly ventilated indoor settings. Good ventilation is important to minimise build-up and stagnation of infectious aerosols indoors, including those containing the COVID-19 virus. Information on assessing the quality of indoor ventilation and practical ways to improve indoor ventilation is outlined below and in the resource on heating, ventilation and air conditioning (HVAC) systems.

It is important to ensure adequate air flow indoors and that HVAC systems are well-maintained and operating properly to manage the risk of virus transmission in indoor workplaces. This includes any risks associated with the HVAC system being restarted after a period of shutdown, including potential risks caused by Legionella bacteria.

Ventilation as part of a combination of control measures

As an employer, you have a duty under the model Work Health and Safety (WHS) laws to eliminate, or if that is not reasonably practicable, minimise the risks of COVID-19 in the workplace, so far as is reasonably practicable. You also have a duty to consult workers regarding COVID-19 risks and how these risks are to be managed.

To minimise risks of COVID-19 in the workplace, you must:

- undertake a risk assessment for the business (more information is available on the risk assessment page). Note in some jurisdictions, workplaces are required to develop COVID-19 safety plans under public health orders or directions
- consider the effectiveness of available control measures and how they will help manage the risks of COVID-19, including ventilation
- consult with workers and health and safety representatives about COVID-19 and relevant control measures (more information on consultation obligations is available on the consultation page)
- consult, co-operate and co-ordinate, so far as is reasonably practicable, with any other duty holders
- determine what control measures are reasonably practicable to implement in the workplace (more information on the meaning of reasonably practicable is available on the risk assessment page), and
- continue to implement all reasonably practicable control measures to minimise the risks of COVID-19.

It is important to note that, under the hierarchy of controls, improving indoor ventilation is an engineering control and, on its own, will not eliminate or minimise the risks of COVID-19 at the workplace.

As an employer, you must also continue to implement all reasonably practicable control measures to minimise the risks of COVID-19 in your workplace, such as:

- encouraging or ensuring vaccination, where applicable
- ensuring your workers do not come to work when unwell
- practising physical distancing and adhering to density limits (check occupancy limits for the type of building and building standards)
- relocating work tasks to different areas of the workplace, off-site or supporting workers to work from home
- practising good hygiene
- increasing cleaning and maintenance
- staggering your workers' start, finish and break times
- reducing the number of situations where workers come into close contact, for example in lunchrooms and other shared spaces, and
- wearing face masks.

Some workplaces may already have adequate indoor ventilation or further improvements may be unable to be made. It is still important to consider ventilation in your risk assessment, monitor indoor air quality and regularly review the effectiveness of all control measures.

When determining whether a *control measure* is reasonably practicable under the *model WHS laws*, consideration must be given to several factors:

- likelihood of risk occurring
- degree of harm that might result
- what person should reasonably have known
- availability of and suitability of ways to minimise risk, and
- after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the costs associated, including whether the cost of implementing a control measure is grossly disproportionate to the risk.

Further information is available on the risk assessment page.

The COVID-19 situation is evolving and you must continue to assess the risks and review the control measures to ensure they continue to be effective.

For information on applying the hierarchy of controls in healthcare and quarantine settings please refer to the Commonwealth Department of Health's document Minimising the risk of infectious respiratory disease transmission in the context of COVID-19: The hierarchy of controls .

For information on ventilation in hotel quarantine facilities please refer to the:

- Australian Health Protection Principal Committee (AHPPC) statement on National Principles for Infection Prevention and Control in Quarantine
- AHPPC statement on national principles for managed quarantine.

Important considerations

Consultation, cooperation and coordination

As an employer, the *model WHS Act* requires you to consult, cooperate and coordinate activities with all other persons who have a work health or safety duty in relation to the same matter, so far as is reasonably practicable.

For example, in a large office building with multiple floors, with a complex HVAC system that is shared by several businesses (tenant organisations), the building owner and/or facilities manager may obtain advice from a ventilation engineer or an occupational hygienist about monitoring and improving the indoor ventilation in the building. The building owner and/or facilities manager, and the tenant organisations should share information and work together in a cooperative and coordinated way so that risks associated with indoor air quality are eliminated or minimised, so far as is reasonably practicable.

Other hazards

Poor quality indoor and outdoor air can contain other hazards that can be harmful to your health. Work processes can release dusts, gases, fumes, vapours, mists and microorganisms into the air. Environmental pollutants, such as bush fire smoke, may also be present in outdoor air. You should consider both indoor and outdoor air quality and other potential hazards when you propose any changes to indoor ventilation.

Further information:

- model Code of Practice: Managing the work environment and facilities
- Safe Work Australia's Clean Air. Clear Lungs. resources
- Working safely when there is bushfire smoke infographic .

COVID-19 public health orders and directions

Some business operations are restricted under state or territory government public health orders and directions. For information about what COVID-19 public health orders and directions apply in your state or territory, go to your government website (links are available via the Fair Work Ombudsman website) .

Assessing the quality of indoor ventilation

General information on assessing the quality of indoor ventilation and minimum ventilation rates in the context of COVID-19, can be found in the World Health Organization Roadmap to improve and ensure good indoor ventilation in the context of COVID-19 (the *WHO* Roadmap). The WHO Roadmap defines the key questions to consider when assessing whether indoor ventilation is adequate. It outlines steps to reach recommended ventilation rates through both natural and mechanical ventilation to reduce the risks of COVID-19. Section 6.2 of the WHO Roadmap provides a helpful flow chart outlining these steps and strategies. The British Occupational Hygiene Society has also published a ventilation tool with helpful guidance for workplaces.

Many businesses have complex indoor spaces and/or complex ventilation systems which may make assessment of indoor ventilation and airflow difficult. In these cases, building owners and/or facilities managers or other businesses should consult with a mechanical or ventilation engineer and an occupational hygienist to assess the quality of indoor ventilation and get advice on maintaining or improving ventilation to minimise the risks of COVID-19. These experts may also advise on minimum ventilation rates per person and maximum building occupancy.

Monitoring the quality of indoor ventilation

Although carbon dioxide (CO2) levels are not a direct measure of possible exposure to the COVID-19 virus, checking levels using a CO2 monitor may help identify poorly ventilated areas. However, CO2 levels will depend on the occupancy density and do not measure the effectiveness of other infection prevention and control measures put in place.

According to the UK Health and Safety Executive , a consistent indoor air concentration of less than 800 parts per million (ppm) CO2 is likely to indicate that a space is well ventilated.

When CO2 concentration measurements average between 800-1500ppm over the occupied period this is an indicator to take action to improve indoor ventilation. An average of 1500ppm CO2 concentration over the occupied period in a space is likely an indicator of poor ventilation. You should particularly take action to improve ventilation where CO2 readings are consistently higher than 1500ppm. However, where there is continuous talking or singing, or high levels of physical activity (such as dancing, playing sport or exercising), a higher level of ventilation may be required to keep CO2 levels below 800ppm, given the higher risks of transmission.

Measurements of CO2 should be taken at different times with different occupancies to get a better indication of how the ventilation system is working under different conditions. There are some situations where CO2 monitors may be less informative, such as areas that rely on air cleaning units, or large, open spaces with high ceilings (e.g. warehouses), or areas with very limited occupation density (e.g. large office areas with one or two occupants). There are many different types of CO2 monitors available and you should consult a ventilation engineer or occupational hygienist about whether CO2 monitoring is required, and which type is best for your circumstances.

Measures to improve indoor ventilation

This section provides general information about improving indoor ventilation through natural and mechanical ventilation. Improving ventilation using a combination of natural and mechanical ventilation is also possible, using the strategies outlined below. Further information can be found in the WHO Roadmap. You may need to consult with a mechanical or ventilation engineer, your building owner and/or facilities manager to adjust your systems to help minimise the risks of COVID-19.

Natural ventilation (passive air flow)

Many buildings do not have mechanical ventilation systems. In these cases, improving ventilation will require you to consider passive air flow. You can consider ways to improve natural ventilation in your workplace such as opening windows, doors (but not fire doors), air vents and roof turrets/whirlybirds, where possible. Do not open windows and doors if doing so poses a security risk, safety risk (such as a risk of falling), or other health risk, such as triggering asthma or other respiratory diseases when pollen counts are high or bush fire smoke is present outside (refer to guidance on Managing the risks from air pollution: Advice for PCBUs for more information about air pollutants). If improvement to indoor air quality is needed in these situations, consider alternatives such as filtration (outlined in Table 2 in the section on Mechanical Ventilation below).

You should also consider whether objects such as furniture, pillars and screens prevent the flow of air and cause stale air to accumulate in parts of the workplace, noting that screens may be useful to protect workers. As mentioned above, using a CO2 monitor may help assess whether there is a need to improve air quality.

Where possible, you can open windows on opposite sides of the room to increase airflow through cross ventilation (air entering through one window, crossing the room and exiting via another window). When the room is occupied, the thermal comfort (heat and cold) of workers needs to be taken into consideration.

You should consider still days and areas where airflow improvement is difficult (such as stairwells or elevators). Ceiling and portable fans can also be used to improve natural ventilation, but you should take care to ensure the air is not directly blowing from one person to another and that fresh air is available. Refer to Table 2 for more information about using mechanical ventilation options such as exhaust fans and air cleaners to improve indoor air quality.

Where possible, you should continue to leave doors and windows open even when the room is unoccupied to air the room.

Table 1 lists some ways you can improve natural ventilation in the workplace.

Table 1: Measures to improve natural ventilation (adapted from the United States Centers for Disease Control and Prevention Ventilation in Buildings).

Increase the introduction of outdoor air	Opening windows and doors, where possible and when weather conditions allow, to increase outdoor air flow. Do not open windows and doors if doing so poses a safety or health risk (e.g., risk of falling, triggering asthma or hay fever symptoms, exposure to extreme temperatures or bushfire smoke and outdoor noise pollution) to occupants in the building.
Use portable fans to increase the effectiveness of open windows	To achieve this, fan placement is important and will vary based on room configuration. Avoid placing fans in a way that could potentially cause contaminated air to flow directly from one person to another. This is particularly important in indoor environments where people are exercising and breathing heavily, such as in gyms.

Mechanical ventilation

Mechanical ventilation is the active process of supplying air to or removing air from an indoor space by powered air movement components.

Ventilation can be improved by adjusting mechanical ventilation systems such as HVAC systems. Building mechanical ventilation systems can be complex and adjustments should be made by people familiar with the operation of your building's systems. You may need to consult with a mechanical or ventilation engineer, your building owner and/or facilities manager to adjust your systems to help minimise the risks of COVID-19.

For HVAC systems, it is preferable to maximise fresh air supply and not recirculate air. If you have exhaust fans in restrooms, kitchens and other facilities, check they are functional and operating continuously and at full capacity. Operating them when the space is not occupied will also improve overall ventilation.

Kitchen exhausts in many fast-food shops and restaurants often deliver good ventilation outcomes providing there is a source of fresh air. To prevent contaminated air moving outside bathrooms, keep exhaust fans running in toilets provided the fan motors are suitable to be operated continuously. A mechanical engineer or electrician can check the fan motor's capacity to operate continuously, or you may be able to download the fan specification. Do not operate fans continuously if they are not rated for this.

Exhausted air should be directed outdoors and away from windows and air intake systems of your building and that of any surrounding buildings. Your building owner and/or facilities manager can assist you with checking and adjusting air flow at your workplace.

Air purifiers or cleaners such as those fitted with high-efficiency particulate air (HEPA) filters can lower the concentration of airborne contaminants (including viruses) in the air and are useful additions in areas with poor ventilation. It is important to consider the filtration capacity required and to place in a location that does not interfere with existing HVAC airflow. Air purifiers or cleaners should be operated and maintained in accordance with the manufacturer's instructions. Businesses should consider consulting an occupational hygienist to assist in determining appropriate placement of these devices within the room to ensure maximum benefit is achieved.

HVAC systems must always be maintained by a qualified mechanical or ventilation engineer in accordance with the manufacturer's instructions to ensure ongoing compliance with building regulations, including during the COVID-19 pandemic.

If you do not directly control or manage the HVAC unit or system, you will need to liaise with the building owner and/or facilities manager to ensure the system is regularly inspected and maintained. Before you allow your workers to resume work after a period of shutdown, you should confirm with the building owner and/or facilities manager that the correct start-up procedures and control settings have been followed.

It is important that you do not open windows or doors to improve air quality in buildings with mechanical ventilation systems unless checked by a mechanical engineer. You should not operate fans outside their designed operation to avoid the risk of overheating fan motors.

See our webpage on HVAC Systems for more details on maintenance.

Table 2 lists some ways you can improve mechanical ventilation in the workplace.

Table 2: Measures to improve mechanical ventilation (adapted from the United States Centers for Disease Control and Prevention Ventilation in Buildings).

HVAC systems	Consider opening outdoor air dampers beyond minimum settings to reduce or eliminate HVAC air recirculation and increase the introduction of outdoor air. In mild weather, this will not affect thermal comfort or humidity. However, this may be difficult to do in cold, hot, or humid weather, and as systems differ may require consultation with a mechanical or ventilation engineer regarding your individual HVAC system. Rebalance or adjust HVAC systems to increase total airflow to occupied spaces, where possible. Consider running the HVAC system at maximum outside airflow for 2 hours before and after the building is occupied. You may need to consult a ventilation engineer regarding your individual HVAC system. Turn off any demand-controlled ventilation (DCV) controls that reduce air supply based on occupancy or temperature during occupied hours. In buildings where the HVAC fan operation can be controlled at the thermostat, set the fan to the "on" position instead of "auto," which will operate the fan continuously, even when heating or air-conditioning is not required.
Improve central air filtration	HVAC filters that only filter outdoor air do not need to be upgraded. Increase indoor air filtration to as high as possible without significantly reducing design airflow. Increased filtration efficiency (the fraction of particles removed from air passing through the filter) is especially helpful when enhanced outdoor air delivery options are limited. Inspect filter housing and racks to ensure appropriate filter fit and minimise air that flows around, instead of through, the filter. Make sure air filters are maintained in accordance with the manufacturer's instructions and replaced at the end of their service life.

Use and maintain window, restroom and kitchen exhaust fans	Use a window exhaust fan, placed safely and securely in a window, to exhaust room air to the outdoors. This will help draw outdoor air into the room via other open windows and doors without generating strong room air currents. Similar results can be achieved in larger facilities using other fan systems, such as gable fans and roof ventilators. Ensure restroom exhaust fans are functional and operating at full capacity. Operating them even when the specific space is not occupied will increase overall ventilation. Inspect and maintain exhaust ventilation systems in areas such as kitchens, cooking areas. Operate these systems any time these spaces are occupied. Operating them for a few hours even when the specific space is not occupied will increase overall ventilation. However, it is important to ensure that fans are not operated outside of their designed cycle time to avoid the risk of overheating the fan motors.
Air purifiers or cleaners with HEPA filters	Use of air purifiers or cleaners with HEPA filters can reduce the concentration of COVID-19 virus in the air, if it is present. Use only HEPA filters. Air cleaners that use other types of filters are less efficient than those with HEPA filters at reducing the concentration of COVID-19 virus in the air. Choose an air purifier or cleaner that is appropriate for the size of the room it is placed in. Placement of air cleaners or purifiers is important to improve airflow and quality and businesses may want to consult an occupational hygienist. Air cleaners and purifiers should be maintained as per manufacturer's instructions.

To ensure this information is as accessible and easy to understand as possible, we refer to 'employers' and their responsibilities.

However, under the model WHS laws, duties apply to any person conducting a business or undertaking (PCBU) which includes employers, but also others who engage workers. For more information about who is a PCBU see our Interpretive Guideline – model Work Health and Safety Act – the meaning of 'person conducting a business or undertaking'.

The model WHS laws have been implemented in all jurisdictions except Victoria.

Safe Work Australia does not regulate or enforce WHS laws or the recently introduced COVID-19 restrictions on business operations. If you want to know how WHS laws apply to you or need help with what to do at your workplace, contact the WHS regulator in your jurisdiction. If you want to know what restrictions on business operations apply to you or your workplace, go to your relevant state and territory government website for information.

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Employer
Small Business
Worker

Flint, Katrina

From:	Nakkan, John
Sent:	Tuesday, 30 August 2022 8:33 AM
To:	Matthews, David; McMahon, Kate
Cc:	Hunter, Stuart; Gumley, Clair; ICW EBM Office; EDU, Safe at School; EDU, EGMBSG; Ryan, JohnW; Anderson, Damien; Steele, Peter
Subject:	RE: Dickson College air quality report
Attachments:	454001_CO2_Dickson_20220829.pdf

Dear all,

The final report into air quality at Dickson College is attached for your information. The only substantive change is the addition of the following sentence in the second paragraph of Section 7.2 – Analysis of Results.

'While carbon dioxide concentrations varied greatly between rooms, all school-hours average carbon dioxide concentrations were below 1 500 ppm. A study by Luther and Atkinson (2012) found carbon dioxide concentrations exceeding 2 700 ppm in Australian classrooms during winter, which suggests that these results are not higher than the norm in a school environment.'

Regards,

John Nakkan | Acting Executive Branch Manager
Phone: +61 2 6205 1289 | Mobile: 0466 015 922 | Email: john.nakkan@act.gov.au
Infrastructure and Capital Works | Education | ACT Government
Level 4, 220 London Circuit | GPO Box 158 Canberra ACT 2601
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From: Nakkan, John
Sent: Friday, 26 August 2022 5:47 PM
To: Matthews, David <David.Matthews@act.gov.au>; McMahon, Kate <Kate.McMahon@act.gov.au>
Cc: Hunter, Stuart <Stuart.Hunter@act.gov.au>; Gumley, Clair <Clair.Gumley@act.gov.au>; ICW EBM Office <ICWEBMOffice@act.gov.au>; EDU, Safe at School <safeatschool@act.gov.au>; EDU, EGMBSG <EGMBSG.EDU@act.gov.au>; Ryan, JohnW <JohnW.Ryan@act.gov.au>; Anderson, Damien <Damien.Anderson@act.gov.au>
Subject: Dickson College air quality report

Dear all,

Please see the draft report into air quality at Dickson College attached. [redacted] are undertaking a final quality assessment over the weekend and will issue a final version on Monday afternoon.

I have had a quick scan of the report and as forecast, notes that our control measures are not sustainable due to the reliance on human intervention.

Importantly, through an examination of available literature, it provides advice that monitoring CO_2 levels are not a reliable indicator of the risk of transmission for COVID-19, but are useful for managing the level of fresh air in a space, provided the devices are calibrated and the readings are understood.

There are no easy or simple solutions to improve the ventilation in a number of areas in the college.

I will continue to review over the weekend and provide and further observations on Monday.

Regards,

John Nakkan | Acting Executive Branch Manager
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Carbon Dioxide and Air Flow Assessment

Dickson College

August, 2022

Certificate of approval for issue of documents

Document Name	Carbon Dioxide and Air Flow Assessment – Dickson College	**Date of Issue**	29 August 2022
Job Number	454001	**Client**	ACT Property Group

Site Sampling		
[redacted] BSc Hazmat Consultant [redacted]	[redacted] BSc. Graduate Scientist [redacted]	[redacted] BSc. For. Sc., BNatSc. Env. Mgt. Graduate Scientist [redacted]

Site Sampling and Report Preparation	**Reviewed & Approved**
[redacted] BSc. MSc Occ. Hyg. Senior Occupational Hygienist [redacted]	[redacted] BSc (Hons) MSc Occ. Hyg. Occupational Hygiene Manager [redacted]

Table of Contents

1 Executive summary

On 8 July 2022, an Improvement Notice was issued by WorkSafe ACT, for Dickson College. In response to this Improvement Notice, [redacted] was engaged by ACT Property Group to undertake assessment of indoor air quality (IAQ) focusing on carbon dioxide concentrations and air flow across multiple locations.

Assessment of air quality was undertaken via:

- measurement of carbon dioxide in 135 agreed locations for at least 48 hours in each location;
- measurement of air velocity to assess ventilation rates in all classrooms, offices and corridors, whilst the HVAC system is operational; and
- Advice on rectification and remediation, if required.

1.1 Assessment criteria and the use of carbon dioxide monitoring

Since the start of the COVID-19 pandemic in early 2020 there has been great interest in using this measurement as an indicator for the risk of transmission of the COVID-19 virus and for assessment of other aspects of indoor air quality.

Carbon dioxide is exhaled by people, so measurement can be used to indicate whether ventilation is adequate to remove human-produced bioeffluents for the number of people in a given area. According to ASHRAE (2022), indoor air carbon dioxide concentrations can only be reliably used as an indicator of acceptable ventilation of body odour (ASHRAE, 2022).

There is little evidence that carbon dioxide levels reliably or accurately predict the risk of COVID-19 transmission (SAGE, 2020; PHAC, 2021; CDC, 2021; VICDH, 2022; ASHRAE, 2022). The Victorian Department of Health (2022) advise that:

> Carbon dioxide monitors can be utilised as an indicator metric for poor ventilation and air quality in occupied indoor spaces, but may have limited benefit to predicting COVID-19 transmission risk.

There is no scientific basis for selection of criteria levels for carbon dioxide for assessment of ventilation (except for body odour/bioeffluents). Assessment against any selected criteria will only provide indication of adequacy of ventilation, and will not indicate any exposure risk (including, but not only, for COVID-19 virus transmission).

As there are no clear 'acceptable' levels of carbon dioxide, [redacted] have used a conservative approached based on all the current available research for using carbon dioxide as an indicator of ventilation rate. For this assessment the following levels have been set as an indication of ventilation adequacy (not exposure risk):

- Levels below 850ppm area considered best practice for ventilation related to occupancy;
- Levels between 850ppm and 1000ppm indicate somewhat inadequate ventilation relative to occupancy; and
- Levels above 1000ppm indicate likely inadequate ventilation relative to occupancy.

1.2 Assessment findings

Overall, average school-hours carbon dioxide concentrations varied greatly, probably mostly due to room occupancy. Most rooms in Block A, the ground floor of Block B, most of Block C, the First Floor of Block D and Blocks G, H & R and Arts and Crafts and the Library maintained adequate ventilation throughout the assessment period, with some outliers above 850 ppm or 1000 ppm. The First Floor of Block B and the Ground Floor of Block D had a much greater number of rooms with poor ventilation, with many rooms exceeding 850 or 1000 ppm.

Some areas at Dickson College have ducted HVAC systems but the existence of these systems did not preclude high carbon dioxide measurements. Areas without HVAC systems mostly rely on natural ventilation (openable windows). As this assessment was conducted in winter, nearly all the windows were closed and no fans were in operations. As such, there is essentially no ventilation (mechanical or natural) in many of the rooms assessed. Air velocity measurements reflect this. This is unlikely to be a situation unique to Dickson College.

Measured carbon dioxide levels returned to background levels fairly quickly after periods of peak occupancy, suggesting that rooms identified as having poor ventilation probably had high occupancy relative to their size, given that carbon dioxide concentrations rise and fall rapidly. Unsurprisingly, rooms with natural ventilation generally had higher average carbon dioxide concentrations than rooms with mechanical ventilation.

1.3 Recommendations

Elevated average carbon dioxide concentration is a very general indicator of inadequate ventilation for the rooms' occupancy, but there is little evidence that carbon dioxide levels reliably or accurately predict the risk of pathogen transmission, and a relationship between carbon dioxide concentrations and the concentration of other non-human bioeffluent contaminants probably does not exist.

Action should probably be taken to improve ventilation in areas where carbon dioxide readings are consistently elevated (see Section 7.5 for control options), but given that:

> Existing evidence for direct impacts of carbon dioxide on health, well-being, learning outcomes and work performance at commonly observed indoor concentrations is inconsistent, and therefore does not currently justify changes to ventilation and IAQ standards, regulations or guidelines (ASHRAE, 2022).

cost benefit analysis for any action is strongly recommended.

If carbon dioxide monitors are to be continued to be used (See Section 7.4), they should be used only as indicators of poor ventilation that may trigger controls to be implemented, such as opening windows or doors. This should be reflected in any COVID-19 control documentation.

2 Introduction

On 8 July 2022, an Improvement Notice was issued by WorkSafe ACT (N-0000004598, attached at Appendix 1) , for Dickson College, following a visit by two inspectors on 15 June 2022, who performed an indicative assessment of the use of carbon dioxide monitors by Dickson College to test accuracy and suitability as a control listed in the *Dickson College Winter Indoor Air Quality Plan* (available online) to mitigate the risk of COVID-19 transmission, and issued an Improvement Notice, requiring:

- *An occupational hygienist to arrange assessment of Dickson College and prepare a report documenting the ventilation (flow rate of air movement, humidity levels of respiratory by-products) throughout the College.*
- *This testing must occur during normal school hours to ensure an accurate reflection of work conditions.*

In response to this Improvement Notice, [redacted] was engaged by ACT Property Group to undertake assessment of indoor air quality (IAQ) focusing on carbon dioxide concentrations and air flow across multiple locations, determined in consultation with ACT WorkSafe, at Dickson College, on behalf of ACT Property Group.

2.1 Objective

The purpose of this assessment was to undertake indoor air quality, focusing on carbon dioxide and air flow as set out under Improvement Notice N-0000004598 issued by WorkSafe ACT on 8 July 2022, across Dickson College.

2.2 Scope

Assessment of air quality was undertaken via:

- measurement of carbon dioxide in 135 locations for at least 48 hours in each location;
- measurement of air velocity to assess ventilation rates in all classrooms, offices and corridors, whilst the HVAC system is operational; and
- Advice on rectification and remediation, if required.

After consultation with WorkSafe ACT and ACT Property Group the testing locations given in Table 1 were agreed upon for the monitoring program.

Table 1: Agreed upon sampling locations with WorkSafe ACT

Block	Ground Floor		First Floor		Requested percentage of rooms
	Samples	Locations	Samples	Locations	
A	10	5 classrooms 3 offices 2 toilets	N/A		50%
B	13	7 classrooms 1 office 1 toilet 4 stores	9	6 classrooms 2 offices 1 toilet	50%
C	5	3 offices 1 toilet 1 sick room	5	2 classrooms 2 offices 1 toilet	50%

Block	Ground Floor		First Floor		Requested percentage of rooms
	Samples	Locations	Samples	Locations	
D	23	9 classrooms 12 offices 2 toilets	19	13 classrooms 5 offices 1 toilet	100%
G	7	2 gym 2 offices 2 change rooms 1 plant room	N/A		50%
H	5	2 auditorium 2 work areas 1 toilet	N/A		100%
R	6	3 classrooms 2 stores 1 toilet	N/A		50%
Arts	8	3 classrooms 3 offices 2 toilets	3	2 classrooms 1 office	75%
Library	12	4 classrooms 2 library 3 offices 1 store 2 toilets	7	4 classrooms 1 open learning space 1 office 1 store	100%
Theatre	3	3 theatre	N/A		100%
Subtotal	**92**		**43**		
Total	**135**				

3 Background

3.1 The use of carbon dioxide monitors as a proxy for ventilation

Since the start of the COVID-19 pandemic in early 2020 there has been growing awareness of the importance of ventilation for both management of risk of COVID-19 virus transmission, and for maintaining the quality of indoor air more generally. One challenge in assessing indoor air quality is the wide range of factors influencing air quality, and the difficulties in meaningfully assessing air quality with regard to the impact on building occupants.

One option for assessment which has gained widespread interest has been the use of carbon dioxide monitoring as a tool for assessing air quality. Carbon dioxide is exhaled by people, so measurement can be used to indicate whether ventilation is adequate to remove human-produced bioeffluents for the number of people in a given area. Since the start of the pandemic there has been great interest in using this measurement as an indicator for the risk of transmission of the COVID-19 virus and also for assessment of other aspects of indoor air quality.

The ability to use carbon dioxide levels as an absolute indicator of infection risk, or for assessment of non-human bioeffluent contaminants is contentious with widely varying opinions. A brief literature review was undertaken to provide a basis for informed, evidence-based evaluation of the role of dioxide monitors for these purposes.

3.1.1 Review method

Relevant studies were identified through online literature searches, primarily of academic sources (via Google Scholar), but also considering published documents from regulatory and industry bodies where relevant. The search was conducted using relevant keywords, reviewing abstracts and identifying relationships between articles based on cross-referencing.

Studies were included within this review where they provided data or findings to answer the objectives of the review and met a subjective minimum quality standard (for example: sufficiently recent to be suitable to address the risk of the recent strains, published by a recognised peer-reviewed journal, government or industry body; containing sufficient information on methods as to be reproducible; containing sufficient information to allow for comparison to other studies, etc.).

3.1.2 Findings

Carbon dioxide monitors can be useful as a measure of the effectiveness of ventilation, but the US Centers for Disease Control and Prevention (CDC) do not generally recommend air quality monitoring in mechanically ventilated buildings. They only suggest should be considered in buildings with natural only, hybrid or no ventilation system. There is little evidence linking carbon dioxide concentrations to a risk of COVID-19 transmission (CDC, 2021).

The Victorian Department of Health (2022) state that 'Based on the current available evidence, there is limited benefit in using carbon dioxide monitors to predict the risk of COVID-19 infection transmission or acquisition in community and workplace settings.' and note that 'carbon dioxide monitors are not designed with the intention of preventing infection transmission, there are some limitations when using these for IPC (Infection Prevention Control) purposes.'

The UK Scientific Advisory Group for Emergencies (SAGE, 2020) published a paper on the role of ventilation in controlling COVID-19 transmission. In this paper they considered the use of carbon dioxide monitoring as a control measure for the transmission of COVID-19. They stated:

> Measurements of elevated carbon dioxide levels in indoor air are an effective method of identifying poor ventilation in multi-occupant spaces. In low occupancy or large volume spaces a low level of carbon dioxide cannot necessarily be used as an indicator that ventilation is sufficient to mitigate transmission risks (medium confidence).

The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) released a position paper in 2022 that clarified the relationship of indoor carbon dioxide concentrations to indoor air quality (IAQ) and ventilation. This paper reported that 'While carbon dioxide concentrations are related to the perception of human bioeffluents and the level of acceptance of their odour, they are not a good overall metric of IAQ'.

In this paper, ASHRAE considered carbon dioxide as an indicator of airborne infections risk transmission and noted that recommendations have been made to use indoor carbon dioxide levels as a risk indicator and that some organisations have set limits for carbon dioxide levels. ASHRAE states that these levels are generally derived from ventilation standards and, unless in a medical setting, have the aim of providing acceptable IAQ with regard to human bioeffluents and the level of acceptance of their odour, not the control of airborne disease transmission.

ASHRAE recommend that carbon dioxide concentrations are used as a qualitative indicator rather than as a quantitative measure of risk as carbon dioxide concentrations 'may not be highly accurate predictors of risk'.

Public Health Agency of Canada's National Collaborating Centre for Environmental Health's 2021 advice on whether carbon dioxide monitors can be used to assess COVID-19 transmission warns that while the value of carbon dioxide can be used to assess ventilation as a factor in transmission risk, the establishment of a carbon dioxide level that can reliably signal elevated COVID-19 risk is more complex.

They also note that:

> although carbon dioxide levels are useful to indicate whether enough outside air is being brought into the space, carbon dioxide levels should not be relied upon to determine whether a space is ventilated enough to mitigate transmission risk.

Studies have quantified the risk of indoor airborne transmission of COVID-19 using carbon dioxide monitoring, however the methodology relies on mathematical modelling with significant caveats that make the use of the models impractical in the real world (e.g., Bazant, et. al., 2021).

Some sources found during the literature review recommended how carbon dioxide monitors should be used (if at all); these recommendations are detailed in Table 2.

Table 2: Recommendations for the use of indoor air quality monitoring to indicate risk of COVID-19 transmission and general indoor air quality

Source	Recommendation
ASHRAE 2022	Existing evidence for direct impacts of carbon dioxide on health, well-being, learning outcomes and work performance at commonly observed indoor concentrations is inconsistent, and therefore does not currently justify changes to ventilation and IAQ standards, regulations or guidelines. The use of indoor carbon dioxide measurements to assess and control the risk of airborne disease transmission must account for the definition of acceptable risk, the type of space and its occupancy, and differences in carbon dioxide and infections aerosol emissions and their subsequent fate and transport. Sensory accuracy, location, and calibration are all critical for drawing meaningful inferences from measured indoor carbon dioxide monitors. Indoor air carbon dioxide concentrations can only be reliably used as an indicator of acceptable ventilation of body odour.
CIBSE 2021 & 2020	Regularly used multi-occupant spaces with poor ventilation (below 5 L/s/person or above 1500 ppm carbon dioxide for prolonged periods) should be identified and prioritised for improvement. If carbon dioxide monitors are used provide information to occupants on what monitors show and what interventions to the ventilation strategy they can use.
REHVA 2021	If a building has natural only, hybrid or no ventilation system, carbon dioxide sensor should be occupied to warn of underventilation, with the following carbon dioxide settings: • Alarm at > 1000ppm • Warning at > 800 ppm
VICDH 2022	Carbon dioxide monitors can be utilised as an indicator metric for poor ventilation and air quality in occupied indoor spaces but may have limited benefit to predicting COVID-19 transmission risk.

3.2 Role of ventilation in COVID-19 infections

In their 24 February 2021 *Indoor Ventilation Factsheet* Safe Work Australia (SWA, 2021) recommend ‘ensuring heating, ventilation and air conditioning (HVAC) systems are well maintained and operating properly’ to manage the risk of COVID-19 virus transmission.

Whilst theoretically possible (Witts & Coleman, 2021), there is currently no evidence of human infection with the COVID-19 virus caused by the movement of infectious aerosols through HVAC systems (SWA 2021; REHVA, 2021), but indoors, ‘transmission can occur in specific settings and circumstances, particularly in indoor, crowded and inadequately ventilated spaces, where infected persons spend long periods of time with others’ (WHO, 2021). Indoor aerosol transmission occurs from exposure to contaminated air moving within inhabited areas of a building (i.e., exposure to virus particles produced by an infectious person within the same room) not from transmission of virus particles moving through the ventilation system itself.

COVID-19 viral particles spread between people more readily indoors than outdoors (CDC, 2021), but ‘in buildings with excellent ventilation with high air changes per hour (e.g., 12), aerosol transmission is mostly eliminated’ (REHVA, 2021).

Poorly ventilated areas and areas that are occupied for long periods of time present the greatest risk of airborne transmission (CIBSE, 2021). In such areas, there is insufficient outside air supply or exhaust ventilation to meet the principle ‘to dilute and remove airborne pathogens as much as possible, extracting them to the outside and reducing the chance that they deposit on indoor surfaces or are inhaled by room users.’ (CIBSE, 2021).

3.3 Carbon dioxide levels in schools

Most standards for indoor environment conditions have been developed based on studies conducted with healthy and fit adults, and often in a workplace or office settings. School populations are much denser than populations in offices, often up to four times as many occupants per square metre as a typical office building (Chatzidiakou et al., 2012).

Children spend extended periods of time in schools and are considered a more vulnerable group due to their developing immune system (Csobod et al., 2014; Taptiklis and Phipps, 2017). Studies have shown classrooms around the world to have carbon dioxide concentration levels exceeding 1 000 ppm (Shendell et al., 2004; Luther & Atkinson, 2012). Mendell and Heath (2005) have identified that students’ attention and performance are linked to ventilation rates. According to Daisey et al., (2003) poor ventilation has direct impacts on health and students’ performance, yet IAQ and ventilation rates are rarely measured in schools.

While each state in Australia has its guidelines for indoor air quality in schools, school classroom ventilation typically relies upon natural and manual airing, which is not always possible. Often, windows are closed to avoid discomfort caused by external noise from people, traffic and construction and extreme weather to prevent drafts (Knight, 2021).

4 Methods

4.1 Carbon dioxide

Monitoring of carbon dioxide was conducted from 18 July to 19 August 2022 using a combination of Telaire/SRP2 IAQ monitors and TSI Multi-function Model 7575-X-NB Meters with TSI Model 982 IAQ probes with carbon dioxide sensors attached. Data was collected at 1-minute intervals for approximately 48-hours in each location over a period of five weeks. Calibration certificates for all monitors used are attached at Appendix 2.

To allow for a minimum of 48 hours of sampling in each location, the monitors were either installed on Monday after 0800 (start of the school day) and picked up to be moved on Wednesday around 1300 and the repositioned into a new location on the Wednesday at 1300 and removed from monitoring on Friday afternoon at 1500.

4.2 Air velocity

Monitoring of air velocity was conducted using a TSI VelociCalc (serial number 9545A1007001, calibration certificate attached at Appendix 3) throughout Dickson College on Friday 5th August – 7th August, 2022. Air flow rates were measured at a height at approximately 1.5 metres from the ground. At the time of the air flow assessment, all available heating and HVAC systems were in operation (0700 – 1700).

5 Assessment criteria

5.1 Carbon dioxide

At high levels carbon dioxide can cause headaches and may cause changes in respiratory patterns. Increasing concentrations of 5 – 10% will lead to dizziness, confusion, dyspnoea, sweating, dim vision followed by vomiting, disorientation, hypertension, and ultimately loss of consciousness. The Safe Work Australia (SWA, 2019) exposure standard for the occupational environment is 5 000 parts per million (ppm) which is the 8-hour time weighted average limit for occupational exposures. Safe Work Australia standards are developed for a presumed fit, adult, working population and are generally less stringent than ambient or indoor air quality standards or guidelines (Australian Building Codes Board, 2021).

There are no specific standards for maximum carbon dioxide concentrations in indoor environments, with ASHRAE and AS 1668.2 providing a guidance level for indoor concentration to be kept below 1000 ppm in mechanically ventilated buildings for management of bioeffluents (ASHRAE, 2016; AS 1668.2-2012). Typical carbon dioxide guidance limits and recommendations for a range of purposes are indicated in Table 4.1 of the Australian Building Codes Board (ABCB, 2021) *Indoor Air Quality Verification Method Handbook,* as shown in Table 3.

Table 3: Various carbon dioxide level (from ABCB, 2021)

Source	Carbon dioxide concentration (ppm)
SWA (2019) occupational exposure limit	5 000
ASHRAE Standard 62.1-2016 recommendation (occupant comfort)	1 000
AS 1668.2:2012 recommendation (for carbon dioxide-controlled mechanical ventilation – not an exposure guidance level)	600 – 800
ABCB *Indoor Air Quality Verification Method* (2021) (as an indicator for body odour)	850
Typical outdoor air concentration range	300 – 400

Elevated carbon dioxide concentrations are an indicator that ventilation is inadequate to remove metabolic products associated with human occupancy (bioeffluents/odour management). The use of this measure for other purposes, such and for management of infection risk, is contentious, as discussed in Section 3.1, and should be done with care.

According to ASHRAE (2022), indoor air carbon dioxide concentrations can only be reliably used as an indicator of acceptable ventilation of body odour (ASHRAE, 2022). There is little evidence that carbon dioxide levels reliably or accurately predict the risk of COVID-19 transmission (SAGE, 2020; Public Health Agency of Canada, 2021; CDC, 2021; VICDH, 2022; ASHRAE, 2022).

As such, there is no scientific basis for selection of criteria levels for carbon dioxide for the assessment of ventilation (except for body odour/bioeffluents). Assessment against any selected criteria will only provide indication of adequacy of ventilation, and will not indicate any exposure risk (including, but not only, for COVID-19 virus transmission).

Despite this, the OzSAGE (2021) *Safe Indoor Air (Ventilation) Recommendations* suggest the following action limits for carbon dioxide monitoring related to COVID-19 transmission risk:

- Below 800 ppm - indicates a low relative risk of infection;
- Between 800 ppm to 1 500 ppm - indicates a moderate relative risk of infection. Improvements should be made where practicable to increase the provision of fresh air into the indoor space; and
- Above 1 500 ppm - indicates a high relative risk of infection. Immediate improvements must be made to increase the provision of fresh air into the indoor space or air filters must be operational. If this is not possible, the space should be evacuated.

The ABCB *Indoor Air Quality Verification Method* (2021) states:

> Because CO_2 is used as a measure for body odour in the IAQ Verification Methods the contaminant limit is not based on the occupational exposure health limit of 5000 ppm. The maximum contaminant limit has been set at a CO_2 level of 850 ppm over an 8-hour period which is based on a 450 ppm rise above an assumed ambient CO_2 level of 400 ppm. This represents what is considered to be an adequately ventilated building from an occupant "odour amenity" point of view.

As there are no clear 'acceptable' levels of carbon dioxide, have used a conservative approach based on all the current available research for using carbon dioxide as an indicator of ventilation rate (noting method limits as previously discussed). For this assessment the following levels have been set as an indication of ventilation adequacy (not exposure risk):

- Levels below 850ppm area considered best practice for ventilation related to occupancy;
- Levels between 850ppm and 1000ppm indicate somewhat inadequate ventilation relative to occupancy; and
- Levels above 1000ppm indicate likely inadequate ventilation relative to occupancy.

5.2 Air velocity

The SWA *Managing the Work Environment and Facilities Code of Practice* (2020) states that 'Enclosed workplaces should be supplied with comfortable rates of air movement usually between 0.1 m and 0.2 m per second' (m/s). This recommendation is not intended to manage the risk of transmission of infections agents in the workplace but is a comfort recommendation.

6 Results

6.1 Carbon dioxide

The maximum and minimum measured carbon dioxide concentrations as well as the listed room occupancy for one person per 2 m^2 are given in the following tables:

- Table 4: Block A – B6 carbon dioxide concentrations
- Table 5: Block B – Ground Floor – B1 carbon dioxide concentrations
- Table 6: Block B – First Floor – B1 F1 carbon dioxide concentrations
- Table 7: Block C – Ground Floor – B5 carbon dioxide concentrations
- Table 8: Block C – First Floor B5 F1 carbon dioxide concentrations
- Table 9: Block D – Ground Floor – B2 carbon dioxide concentrations
- Table 10: Block D – First Floor B2 F1 carbon dioxide concentrations
- Table 11: Block G – B9 carbon dioxide concentrations
- Table 12: Building H – B8 carbon dioxide concentrations
- Table 13: Building R – B7 carbon dioxide concentrations
- Table 14: Arts & Craft – Ground Floor – B4 carbon dioxide concentrations
- Table 15: Arts & Craft – First Floor – B4 carbon dioxide concentrations
- Table 16: Library – Ground Floor – B3 carbon dioxide concentrations
- Table 17: Library – First Floor – B3 F1 carbon dioxide concentrations

The average concentration shown in these tables is the average for the school hours generally occupied by the students, set as 08:50 to 15:00 during a normal school day.

Graphs of minute-by-minute recorded readings for each of the 135 sample locations are given in Appendix 4. Graphs are colour-coded based on the selected assessment criteria:

- Levels below 850pmm are shown in green;
- Levels between 850 and 1000ppm are shown in amber; and
- Levels above 1000ppm are shown in red.

It should be noted that these graphs show different levels of 'baseline' carbon dioxide concentrations, (i.e., not necessarily between 300 – 400 ppm for normal atmospheric concentrations) which just reflect different calibration levels for the monitors, as sensors which are constant exposure to an analyte (e.g. oxygen, carbon dioxide etc.) tend to have sensitivity issues.

6.1.1 Block A

The measured school hours average carbon dioxide levels in Block A were almost all below 850 ppm, indicating mostly adequate ventilation rates for occupancy during the assessment period (Table 4).

Table 4: Block A – B6 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
1 – Hallway in front of drama	Figure 1	–	1 239	301	560

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
6 – Metalwork room	Figure 2	39	531	140	345
7 – Auto Hoist Room	Figure 3	24	454	260	319
8 – Motor metals room	Figure 4	55	866	655	704
10 – Woodwork room	Figure 5	24	874	221	560
11 – Office	Figure 6	21	1 040	482	687
12 – Music classroom	Figure 7	36	1 975	473	940
13 – Music practice room	Figure 8	2	1 173	386	581
14 – Drama room	Figure 9	56	870	340	511
16 – Male toilet	Figure 10	5	2 706	422	860
17 – Staff Lounge	Figure 11	60	1 038	394	666

6.1.2 Block B

The measured school hours average carbon dioxide levels on the Ground Floor of Block B were all below 850 ppm (Table 5), except in two rooms which exceeded 850 ppm or 1000 ppm indicating inadequate ventilation in these areas during busy periods of use.

Table 5: Block B – Ground Floor – B1 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
4 – Chemistry lab	Figure 12	34	1 531	395	704
6 – Chemistry lab	Figure 13	34	1 281	464	736
8 – Physics lab	Figure 14	36	1 084	425	789
10 - Physics lab	Figure 15	34	1 574	698	1 095
14 – Lab	Figure 16	41	1 177	369	617
17- Biology Lab	Figure 17	29	757	410	579
23 – Earth Science Room	Figure 18	28	1 830	430	826
26 – Earth Science Room	Figure 19	29	1 552	363	808
27 – Staff Study	Figure 20	22	879	280	598
29 – Agricultural lab	Figure 21	24	1 395	403	966

The measured school hours average carbon dioxide levels on the First Floor of Block B varied greatly (Table 6), with some rooms remaining below 850 ppm, while others exceeded 850 or 1000 ppm, indicating inadequate ventilation in some rooms during busy periods of use.

Table 6: Block B – First Floor – B1 F1 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
2 – Store	Figure 22	5	1 021	411	770
3 - Office	Figure 23	5	1 314	472	1 007
4 – Staff Study	Figure 24	9	1 256	405	833
7 – Biology Science Room	Figure 25	48	1 048	361	757
12 – Photo Lab/Kitchenette	Figure 26	4	1 498	470	1 110
13 – Preparation room	Figure 27	10	1 053	387	814
14 – Biology Science Room	Figure 28	48	870	340	437
16 – Maths Room	Figure 29	24	2 270	455	1 254
19 – Stairwell from ground floor	Figure 30	–	3 795	524	1 170
20 – Classroom	Figure 31	25	2 483	390	1 423
22 – Tutorial Room	Figure 32	18	2 909	596	1 429
23 – Staff study/classroom	Figure 33	17	1 595	175	822
25 – Classroom	Figure 34	24	2074	146	793
26 – Classroom	Figure 35	24	1482	441	933
30 – Hallway	Figure 36	–	3123	649	1055
32 – Access ramp from Block D	Figure 37	–	1011	416	756

6.1.3 Block C

The measured school hours average carbon dioxide levels on the Ground Floor in Block C were mostly below 850 ppm, and all below 1000 ppm, indicating mostly adequate ventilation rates on this floor in this building (Table 7).

Table 7: Block C – Ground Floor – B5 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
4 – Lobby	Figure 38	47	703	335	555
4 – Lobby	Figure 39	47	954	505	724
7 – Sick Bay	Figure 40	4	818	353	539
10 – Main Office/reception	Figure 41	31	1 236	651	987
13 – Dept Principal office	Figure 42	7	832	337	592
15 – Boardroom	Figure 43	15	1 438	730	997
17 – Welcome room	Figure 44	28	2 028	384	938

The measured school hours average carbon dioxide levels on the First Floor of Block C varied greatly (Table 8), with some rooms remaining below 850 ppm, while others exceeded 850 or 1000 ppm, indicating inadequate ventilation in some rooms during busy periods of use.

Table 8: Block C – First Floor B5 F1 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
1 – Hallway	Figure 45	–	763	347	502
3 – Office	Figure 46	21	762	349	531
5 – Classroom	Figure 47	24	1 006	290	667
8 – Classroom	Figure 48	24	1 877	438	939
9 – Classroom	Figure 49	32	2 444	492	1 099
11 – Classroom	Figure 50	31	2 082	253	1 285

6.1.4 Block D

The measured school hours average carbon dioxide levels on the Ground Floor of Block D varied greatly (Table 9), with some rooms remaining below 850 ppm, while most exceeded 850 or 1000 ppm, indicating inadequate ventilation in some rooms during busy periods of use.

Table 9: Block D – Ground Floor – B2 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
3 – Lecture Theatre	Figure 51	75	609	383	505
3 – Lecture Theatre rear room	Figure 52	75	514	358	435
4 – Classroom	Figure 53	24	1 529	691	1 130
5 – Tutorial room	Figure 54	13	1 470	435	895
6 – Staff room	Figure 55	10	2 631	519	906
7 – Classroom	Figure 56	24	3 010	414	998
8 – Classroom	Figure 57	21	1 547	391	1 026
9 – Office	Figure 58	6	1 540	410	1 080
11 – Classroom	Figure 59	24	2 669	270	1 000
12 – Classroom	Figure 60	24	1 546	382	1 136
13 – Office	Figure 61	5	877	401	848
15 – Classroom	Figure 62	24	1 768	463	970
16 – Office/classroom	Figure 63	24	2 943	282	916
20 – Toilet	Figure 64	4	1 276	443	897
21 – Office	Figure 65	4	2 282	729	1 526

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
22 – Office	Figure 66	5	832	298	456
23 – Office	Figure 67	5	2 075	407	1 349
24 – Reception waiting area	Figure 68	45	1 681	381	1 139
25 – Office tea area	Figure 69	45	1 807	653	1 406
26 – Front Office	Figure 70	15	1 637	438	1 201
27 – Office	Figure 71	5	2 510	339	1 135
28 – Office	Figure 72	6	2 204	549	1 391
30 – Classroom	Figure 73	24	2 281	758	1 303
31 – Store / Kitchenette	Figure 74	6	1 961	396	956
34 – Hallway	Figure 75	–	1 430	530	909

The measured school hours average carbon dioxide levels on the First Floor of Block D were all below 850 ppm (Table 10), except in two rooms which exceeded 850 ppm or 1000 ppm indicating inadequate ventilation in these areas during busy periods of use.

Table 10: Block D – First Floor B2 F1 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
1 – Hallway	Figure 76	–	1 425	721	1 192
2 – Office	Figure 77	6	1 142	643	963
3 – Office	Figure 78	17	1 032	466	760
5 – Office	Figure 79	13	936	404	715
6 – Staff study	Figure 80	19	975	269	621
7 – Study	Figure 81	29	875	389	603
8 – Classroom	Figure 82	33	782	348	554
9 – Classroom	Figure 83	19	967	636	806
10 – Classroom	Figure 84	12	792	122	468
11 – Access Hallway to B3/B1	Figure 85	–	1 011	416	756
12 – Classroom	Figure 86	25	828	396	614
14 – English suite	Figure 87	40	580	361	458
15 – English suite	Figure 88	27	637	379	504
16 – Classroom	Figure 89	25	616	416	496
17 - Office	Figure 90	2	555	392	455

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
19 – Classroom	Figure 91	25	581	408	469
20 – Classroom	Figure 92	25	505	378	435
21 - Classroom	Figure 93	25	649	384	559
22 – Classroom	Figure 94	25	586	346	333
Tutorial - Humanities Office 2	Figure 95	13	873	359	686

6.1.5 Block G

The measured school hours average carbon dioxide levels in Block G were below 850 ppm, indicating adequate ventilation for occupancy during the assessment period (Table 11).

Table 11: Block G – B9 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
1 – Gymnasium	Figure 96	400	623	217	399
1 – Gymnasium	Figure 97	400	911	485	651
3 – Female Change Room	Figure 98	16	656	435	492
7 – Store	Figure 99	6	745	393	459
8 – Foyer	Figure 100	12	734	131	424
11 - Office	Figure 101	9	732	247	435

6.1.6 Block H

The measured school hours average carbon dioxide levels in Block H were below 850 ppm, indicating adequate ventilation for occupancy during the assessment period (Table 12).

Table 12: Building H – B8 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
2 – Toilet	Figure 102	5	655	464	508
3 – Toilet	Figure 103	5	886	637	699
4 – Auditorium	Figure 104	168	692	387	466
5 – Stage	Figure 105	168	763	427	497
6 – Gym – Weights rm 1	Figure 106	31	666	260	467
9 – Gym – Weights rm 2	Figure 107	14	584	393	507
10 – Hall Stage Storeroom	Figure 108	7	918	605	664

6.1.7 Block R

The measured school hours average carbon dioxide levels in Block R were all below 850 ppm (Table 13), except in two rooms which exceeded 850 ppm indicating inadequate ventilation in these areas during busy periods of use.

Table 13: Building R – B7 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
1 – Hallway West	Figure 109	–	825	383	583
2 – Hallway North	Figure 110	–	1 555	423	823
3 – Janitor room	Figure 111	7	611	388	493
4 – Male toilet	Figure 112	5	763	347	532
6 – Canteen	Figure 113	30	706	168	441
7/8 – Canteen Store	Figure 114	14	679	456	582
9 – BSO room	Figure 115	6	1 140	372	728
11 – Student common room	Figure 116	230	1 996	284	948
14 – Student common room booths	Figure 117	230	2 086	371	938

6.1.8 Arts & Craft

The measured school hours average carbon dioxide levels on the Ground Floor of Arts and Crafts were below 850 ppm, indicating adequate ventilation for occupancy during the assessment period (Table 14).

Table 14: Arts & Craft – Ground Floor – B4 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
2 – Home crafts	Figure 118	65	519	355	414
3 – Home economics	Figure 119	65	778	352	494
11 – Photography Lab	Figure 120	–	793	403	574
13 – Art room	Figure 121	–	749	414	480

The measured school hours average carbon dioxide levels on the First Floor of Arts & Crafts were all below 850 ppm (Table 15), except in the Open Learning Area which was slightly elevated, indicating that the rate of fresh air exchange may be slightly inadequate for busy periods of use in this area.

Table 15: Arts & Craft – First Floor – B4 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
3 – Open Learning Area	Figure 122	65	1 185	641	901
5 – Lum	Figure 123	–	820	371	588
6 – Textile classroom	Figure 124	–	1 035	288	559
8 – Store	Figure 125	–	907	179	496

6.1.9 Library

The measured school hours average carbon dioxide levels on the Ground Floor in the Library were generally below 850ppm (Table 16), with one common reading area above 1000 ppm, indicating that the rate of fresh air exchange may be slightly inadequate for busy periods of use.

Table 16: Library – Ground Floor – B3 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
4 – Library	Figure 126	256	600	393	514
4 – Library	Figure 127	256	1 642	443	1 182
6 – Audio Visual	Figure 128		904	350	699

The measured school hours average carbon dioxide levels on the First Floor of the Library were below 850 ppm, indicating adequate ventilation for occupancy during the assessment period (Table 17).

Table 17: Library – First Floor – B3 F1 carbon dioxide concentrations

Location (SPM Number)	Figure Reference	Max. Occupancy	Carbon dioxide (ppm)		
			Max.	Min.	School hours average
4 – Open learning space	Figure 129	54	892	392	594
6 – Classroom	Figure 130	15	896	383	651
8 – Tutorial/classroom	Figure 131	15	872	377	613
9 – Staff room	Figure 132	16	600	393	514

6.2 Air velocity

Measurement of air velocity was conducted in every accessible room at Dickson College, over the weekend of 6 & 7 August 2022, with no students or staff present.

The buildings' HVAC and heating systems were turned on prior to commencement and was running for the entire period of the assessment. It was noted that most of the buildings are fitted with wall radiated heating units, windows and fans.

The Library, Music room, Drama room in Block A, Block B (Ground Floor), Block C, and the Gymnasium are each fitted with HVAC systems that are either controlled centrally or in the room (Drama & Music) providing heating and cooling with a supply and return air system.

No fans were turn on for the assessment, as it was noted that during the carbon dioxide assessment that none of the fans were being used and only a few windows were opened. All fans were fitted with a winter function (reversing the direction).

Table 18 shows a summary of the measured air velocity throughout the school, and contour maps showing measured airflow in each room are attached at Appendix 6. Generally, air velocity was below the recommended minimum of 0.1m/s, showing most areas had relatively still air. This is unsurprising given most areas do not have mechanically supplied air, windows were closed and fans were not running. The detailed list of air velocity measurements for each location in each room across the school is given in Appendix 7.

Table 18: Summary of air velocity measurements

Location		Range (m/s)	Comparison to recommended range	Comments
Block A		0.00 – 2.02	Half below	The rooms that had spilt system aircons and or HVAC supply ducts were measured between 0.1 and 2.02m/s
Block B	Ground	0.00 – 0.51	Majority below	The rooms that had HVAC supply ducts were measured between 0.12 and 0.51m/s
	First	0.00 – 0.32	Majority below	
Block C	Ground	0.00 – 0.1	All bar one below	One reading at 0.1m/s
	First	0.00 – 0.158	Majority below	
Block D	Ground	0.00 – 0.31	Majority below	
	First	0.00 – 0.3	Majority below	
Block G		0.02 – 1.32	Majority above	
Block H		0.00 – 0.55	Majority below	
Block R		0.00 – 0.35	Majority below	
Arts & Crafts	Ground	0.01 – 0.12	All bar one below	One reading at 0.12m/s
	First	0.00 – 0.26	Majority below	
Library	Ground	0.00 – 0.12	Majority below	
	First	0.00 – 0.12	Majority below	

7 Discussion

7.1 Assessment limitations

Aside from the limitations of the use of carbon dioxide monitoring to assess ventilation suitability previously discussed (Section 3.1 and Section 5.1), several other limitations were identified.

While sampling in this assessment was broad, measurements were only conducted in each location for two days, so it is unlikely worse-case scenarios were captured in all (or most) locations.

Further, despite efforts, no data on room occupancy was obtained, so it is not possible to determine the relationship between measured carbon dioxide concentrations and the number of people in the assessed rooms.

7.2 Analysis of results

Overall, average school-hours carbon dioxide concentrations varied greatly, probably mostly due to room occupancy. Most rooms in Block A, the ground floor of Block B, most of Block C, the First Floor of Block D and Blocks G, H & R and Arts and Crafts and the Library maintained adequate ventilation throughout the assessment period, with some outliers. The First Floor of Block B and the Ground Floor of Block D had a much greater number of rooms with poor ventilation.

While carbon dioxide concentrations varied greatly between rooms, all school-hours average carbon dioxide concentrations were below 1 500 ppm. A study by Luther and Atkinson (2012) found carbon dioxide concentrations exceeding 2 700 ppm in Australian classrooms during winter, which suggests that these results are not higher than the norm in a school environment.

Most of the buildings are fitted with heating radiators and the occasional split system air conditioner, opening windows and fans that can operate in summer and winter modes. There are a few buildings that have ducted heating and cooling HVAC systems (Library, Music room, Drama room in Block A, Block C, the Ground Floor of Block B and the Gymnasium) but the existence of these systems did not necessarily preclude high carbon dioxide measurements.

As this assessment was conducted in winter, nearly all the windows were closed and no fans were in operation, as expected due to the temperatures at this time of year. It was rare to find any of the window open in classrooms or offices and when they were it was generally one side which will not provide cross ventilation. As such, there is essentially no ventilation (mechanical or natural) in many of the rooms assessed. This is unlikely to be a situation unique to Dickson College.

The graphed data in Appendix 4 shows measured carbon dioxide levels returned to background levels fairly quickly after periods of peak occupancy, indicated that air does turnover in rooms, just not at a rate adequate to maintain good ventilation in periods of peak occupancy. It seems likely that rooms identified as having poor ventilation probably had high occupancy relative to their size, given that carbon dioxide concentrations rise and fall rapidly.

The results from the air flow measurements also highlight that the school is predominately designed with natural ventilation as the main way to ventilate the rooms. There are exceptions to this with the Library, Music & Drama rooms, Gymnasium, Block C and the Ground Floor of Block B having their own mechanical ventilation for these spaces and when operate. Unsurprisingly, rooms with natural ventilation generally had higher average carbon dioxide concentrations than rooms with mechanical ventilation.

7.3 Review of ACT Education Directorate *Factsheet – IAQ Winter Ventilation* and *Dickson College Winter Indoor Air Quality Plan*

The ACT Education Directorate *Factsheet – IAQ Winter Ventilation* was reviewed. The recommendations are that for any 'teaching and learning spaces that rely on natural ventilation via windows or louvres, consideration will need to be given to balancing ventilation and thermal comfort during colder weather'.

This information is incorporated into the Daily actions to be undertaken by the school in the *Dickson College Winter Indoor Air Quality Plan.* The additional daily measures the school is to undertake includes opening windows/louvres and doors. Whilst this would assist with increasing the flow of fresh air into the spaces and reduce the carbon dioxide levels, it relies on the intervention of staff or students to open the windows and doors. In winter this will often result in the rooms becoming unpleasantly cold, and staff and students are unlikely to open them. This action is an administrative control, which is one of the lower level, least effective controls. As it relies on actions that make the classroom environment uncomfortable, it will always be an unreliable control.

It was clear from-onsite observation that, where controls rely on human action, they are rarely occurring. Further, it is unrealistic to expect that windows will be opened in Winter in Canberra.

7.4 Use of carbon dioxide monitors for ventilation assessment

Portable carbon dioxide monitors being used in a few locations across the school which show current levels. These units do not store the data and are reliant on the teacher, student or staff to note when the levels are above their action criteria.

[redacted] was also unable to obtain calibration certificates for these units to determine if they meet the accuracy range listed on their website and specification data sheet. Sensor accuracy, location, and calibration are all critical for drawing meaningful inferences from measured indoor carbon dioxide concentrations (ASHRAE 2022).

As discussed in Section 3.1, indoor carbon dioxide concentrations do not provide an overall indication of IAQ, but they can be a useful tool in IAQ assessments if users understand the limitations in these applications. ASHRAE (2022) states:

> that there is a misunderstanding of the significance of 1000 ppm has resulted in many confusing and erroneous conclusions about IAQ and ventilation in buildings. The use of carbon dioxide as an indicator of outdoor air ventilation must reflect the fact that outdoor air ventilation requirements depend on space type, occupant density, and occupant characteristics (e.g., age, body mass, and activity levels).
>
> Therefore, a single carbon dioxide concentration does not apply to all space types and occupancies for the purposes of assessing the ventilation rate. Also, carbon dioxide concentrations can vary significantly within a building or space based on the details of how ventilation and air distribution are implemented.

While the use of carbon dioxide monitors at Dickson College may be an appropriate part of a ventilation management strategy, it is important that the limitations of these devices are well understood. Caution must be taken when using the levels from monitors that are not calibrated, as they might not be reliable or accurate and may be measuring localised values at a single point in time.

It is also important to note that in and of itself a carbon dioxide monitor is not a control for managing risk. The results from monitoring carbon dioxide levels can be used to indicate possible deficiencies in the ventilation of a workspace. Once a monitored level reaches a pre-set level, this can be used to trigger implementation of a control to manage the risk.

7.5 Ventilation control options

The impact of ventilation as a control on airborne contaminants is mainly influenced by three parameters:

1. the amount of ventilation provided to a space, generally reported as litres/second/person or air changes per hour;
2. the filtration of the returned air, and
3. the amount of fresh or outdoor air that is mixed into the returned air which is generally reported as a percentage.

In the context of carbon dioxide concentrations and management of human-produced bioeffluents managing the number of occupants in a space relative to its size is also important.

The following control options could be used to improve the air velocity rates and minimise built-up of bioeffluents and indoor contaminants.

7.5.1 Natural ventilation

This assessment demonstrated that natural ventilation which relies on opening of windows and doors will only work if windows are doors are opened. Improvements to the design of natural ventilation (e.g. improving cross-ventilation) will only work if they are used.

Consideration should be given to the suitability of current natural ventilation systems as the primary ventilation at Dickson College in the Canberra climate.

7.5.2 Mechanical ventilation

Consideration should be given to the installation of mechanical ventilation in areas with poor ventilation (e.g. areas which rely on opening windows). Mechanical ventilation can include small-scale systems such as individual reversible energy recovery ventilators as well as large scale systems such as building-wide HVAC systems. Consultation with a ventilation or mechanical engineer is recommended.

For areas which already have mechanical ventilation, increasing the proportion of outdoor air provided into enclosed spaces may improve ventilation. Consult with an engineer to increase the total airflow being supplied to maximise the air changes per hour that the HVAC system can deliver. Ensure that mechanical ventilation systems are inspected and maintained regularly to ensure they are working as per their design.

7.5.3 Wall-mounted air-conditioning systems

Wall-mounted air-conditioning systems (split systems) without fresh-air intake will simply recirculate contaminated air. These systems need to be supplemented with an outdoor air supply. Therefore, work should be considered to bring outdoor air inside by improving natural ventilation or using a mechanical fresh air system in areas with split systems air-conditioning systems.

7.5.4 Flushing of buildings

It is widely accepted practice to flush buildings wherever possible in the periods between occupancy to reduce concentrations of airborne contaminants. Where possible, doors and windows should be left open or HVAC systems should be run out of hours to facilitate this.

7.5.5 Occupancy

The rapid rise and fall of carbon dioxide concentrations measured in this assessment suggest that rooms identified as having poor ventilation probably had high occupancy relative to their size. Reducing maximum occupancy in rooms with poor ventilation will improved air quality in these rooms.

7.5.6 Air purifying devices

If immediate ventilation improvements are impractical, small offices or areas with low airflow can be improved by using air purifying devices. At a minimum, these should have a HEPA filter and the size of the unit should be matched to the space. However, air-cleaning technologies that remove only carbon dioxide will not necessarily improve overall IAQ and can interfere with HVAC systems using carbon dioxide for ventilation control or IAQ monitoring (ASHRAE 2022).

This is not a good-quality control and should not be a primary control of indoor air quality.

8 Conclusion and recommendations

[redacted] was engaged by ACT Property Group to undertake an assessment of indoor air quality (IAQ) focusing on carbon dioxide and air flow across Dickson College, between 18 July – 19 August 2022 to determine if the air quality is appropriate for an indoor school environment, in response to an improvement noticed issued by WorkSafe ACT.

Air movement measured throughout the building was well below the recommend range. The majority of the buildings are fitted with heating radiators and the occasional split system air conditioner, along with opening windows and fans that can operate in summer and winter modes. Most of the buildings rely on natural ventilation via openable windows and fans. Few areas had mechanical HVAC ventilation.

Unsurprisingly, given this assessment was undertaken in winter, it was rare to find any of the windows open in classrooms or offices. As such, there is essentially no ventilation (mechanical or natural) in many of the rooms assessed. This is unlikely to be a situation unique to Dickson College.

Overall, average school-hours carbon dioxide concentrations varied greatly, probably mostly due to room occupancy. Most rooms in Block A, the ground floor of Block B, most of Block C, the First floor of Block D and Blocks G, H & R and Arts and Crafts and the Library maintained adequate ventilation throughout the assessment period, with some outliers. The First Floor of Block B and the Ground Floor of Block D had a much greater number of rooms with poor ventilation.

It seems likely that rooms identified as having poor ventilation probably had high occupancy relative to their size, given that carbon dioxide concentrations were found to rise and fall rapidly.

8.1 Recommendations

Elevated average carbon dioxide concentration is a very general indicator of inadequate ventilation for the rooms' occupancy, but there is little evidence that carbon dioxide levels reliably or accurately predict the risk of pathogen transmission, and a relationship between carbon dioxide concentrations and the concentration of other non-human bioeffluent contaminants probably does not exist.

Action should probably be taken to improve ventilation in areas where carbon dioxide readings are consistently elevated (see Section 7.5 for control options), but given that:

> Existing evidence for direct impacts of carbon dioxide on health, well-being, learning outcomes and work performance at commonly observed indoor concentrations is inconsistent, and therefore does not currently justify changes to ventilation and IAQ standards, regulations or guidelines (ASHRAE, 2022).

cost benefit analysis for any action is strongly recommended.

If carbon dioxide monitors are to be continued to be used (See Section 7.4), they should be used only as indicators of poor ventilation that may trigger controls to be implemented, such as opening windows or doors. This should be reflected in any COVID-19 control documentation.

9 Limitations

While [redacted] has taken all care to ensure that this report includes the most accurate information available, samples were taken at certain times on the day or days indicated within the report and [redacted] is unable to comment on conditions at other times. Any statement of expected conditions at other times should be taken as possible conditions only.

The report, including any risk assessment presented, is based on the information obtained by Robson at the time of sampling. Any variation in the environment, activities, methods, practices, products, or equipment used may change exposures to hazards, invalidating the presented risk assessment. [redacted] recommends that risks be re-assessed prior to making any changes to the aforementioned factors.

The findings contained within this report are developed from the interpretation of the results of specific sampling methods used in accordance with generally accepted practices and standards, based on the current state of knowledge. To the best of [redacted]'s knowledge, our assessment of the data represents a reasonable interpretation of the general conditions, and subsequent risk at the time of sampling. Should you have any questions or require further information please contact [redacted]

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Appendix 1 WorkSafe ACT Improvement Notice

WORKSAFE ACT SAFE + HEALTHY WORKPLACES

IMPROVEMENT NOTICE

This is an Improvement Notice issued under section 191 of the Work Health and Safety Act 2011

Information

Notice number N-0000004598

Issued By: Kurt Kuehl ID number: P53987

To whom this notice is issued

Directorate Name: Dickson College Head of Directorate: Katy Haire

Site/workplace: 184 Phillip Avenue DICKSON ACT 2602

Location within address of workplace: 184 Phillip Avenue, DICKSON ACT 2602

Served on: Katy Haire Method of service: Email Date of issue: 08/07/2022

Due date to remedy the contravention or likely contravention: 11/08/2022

Description

The inspector believes the person:

a) is contravening a provision of this Act; or

b) has contravened a provision in circumstances that make it likely that the contravention will continue to be repeated: and

The provision that the inspector believes is being or has been contravened is **WHS Regulations** Section number - **38**

Briefly, how the provision is being, or has been, contravened:

On 15 June 2022 at 1334h, WorkSafe ACT Inspectors Kurt KUEHL (myself, I) and Owen WARING attended Dickson College, 184 Phillip Avenue Dickson, in response to complaints regarding work environment ventilation, temperature, hygiene, and worker consultation.

During the visit, I was advised by workers that CO2 monitors had been supplied by Dickson College for the purpose of testing ventilation and rate of air exchange. This is a control listed in the Dickson College Winter Indoor Air Quality Plan to mitigate the risk of COVID-19 transmission.

I performed an indicative measurement to test the hypothesis that the devices supplied by Dickson College were inaccurate. Method: two monitoring devices, one supplied personally by a worker (Device A) and one supplied by Dickson College (Device B), were placed side by side in a 4.5m x 3m office with four occupants, window open by approximately 15cm. I note that the supplied monitors are unbranded.

I recorded the following results:

Time - Device A - Device B:

1406h - 646ppm - 406ppm

1408h - 682ppm - 406ppm

1410h - 724ppm - 406ppm

From my observations I have formed the reasonable belief that the monitors supplied by the ACT Education Directorate are not an effective control and, unless a review into the control is undertaken, the Directorate has breached section 19 of Work Health and Safety Act 2011 (Primary duty of care) and section 38 of Work Health and Safety Regulation 2011 (Review of control measures):

(1) A duty holder must review and, as necessary, revise control measures implemented under this regulation so as to maintain, so far as is reasonably practicable, a work environment that is without risks to health or safety.

(2) Without limiting subsection (1), the duty holder must review and, as necessary, revise a control measure in the following circumstances:

(a) the control measure does not control the risk it was implemented to control so far as is reasonably practicable;

Examples:

1 the results of monitoring show that the control measure does not control the risk

2 a notifiable incident occurs because of the risk

(b) before a change at the workplace that is likely to give rise to a new or different risk to health or safety that the measure may not effectively control;

(c) a new relevant hazard or risk is identified;

(d) the results of consultation by the duty holder under the Act or this regulation indicate that a review is necessary;

(e) a health and safety representative requests a review under subsection (4).

(3) Without limiting subsection (2) (b), a change at the workplace includes—

(a) a change to the workplace itself or any aspect of the work environment; or

(b) a change to a system of work, a process or a procedure.

(4) A health and safety representative for workers at a workplace may request a review of a control measure if the representative reasonably believes that—

(a) a circumstance mentioned in subsection (2) (a), (b), (c) or (d) affects or may affect the health and safety of a member of the work group represented by the health and safety representative; and

(b) the duty holder has not adequately reviewed the control measure in response to the circumstance.

This Notice may include directions concerning the measures to be taken to remedy the contravention or prevent the likely contravention, or matters or activities causing the contravention or likely contravention to which this notices relates.

The inspector directs you to:

1. Display this Notice in a prominent location and supply evidence of display to the issuing inspector to determine compliance.

2. Contact an occupational hygienist to arrange assessment of Dickson College and prepare a report documenting the ventilation (rate and volume of air movement, humidity, levels of respiratory by-products) throughout the College. This testing must occur during normal school hours to ensure an accurate reflection of work conditions.

3. Arrange for the completion of any corrective actions recommended by the report.

When the Directions have been completed contact the issuing inspector. The inspector will determine compliance with the Directions.

The inspector recommends that you:

In complying with the Directions you may consider further guidance available:

Work Health and Safety (How to Manage Work Health and Safety Risks) Code of Practice Approval 2020

Work Health and Safety (Managing the Work Environment and Facilities Code of Practice) Approval 2020

See over for important information on your rights and responsibilities.

MAIL
PO Box 158 Canberra ACT 2601
EMAIL
worksafe@act.gov.au
PHONE
02 6207 3000

Improvement Notice issued under section 191 of the Work Health and Safety Act 2011 - further information

If you have any questions you may contact the inspector who issued this notice.

Display of Notices

A person to whom a notice is issued must, as soon as possible, display a copy of the notice in a prominent place at or near the workplace, or part of the workplace, at which work is being carried out that is affected by the notice (s 210(1)). A person must not intentionally remove, destroy, damage or deface a notice displayed under s 210(1) while the notice is in force (s 210(2)). The maximum penalty for failing to comply with these provisions is $5,000 for an individual or $25,000 for a corporation.

Compliance with direction or notice

The person to whom an improvement notice is issued must comply with the notice within the period specified in the notice.

Maximum penalty:

(a) in the case of an individual—$50 000; or

(b) in the case of a body corporate—$250 000

Contents of Notice

This Notice may state one or more of the following: (a) a workplace, or part of a workplace, at which the activity is not to be carried out; (b) anything that is not to be used in connection with the activity; (c) any procedure that is not to be followed in connection with the activity (s196(3)).

Directions and recommendations

A direction may refer to a code of practice and may offer the person a choice of ways in which to remedy the contravention (s 204). A Improvement notice may include recommendations. It is not an offence to fail to comply with recommendations in a notice (s205).

Changes to notice by inspector

An inspector may make minor changes to a notice for clarification, to correct errors or references, or to reflect changes of address or other circumstances (s206).

Privacy statement

WorkSafe ACT may obtain personal information about you in connection with this notice. The information may be collected and stored using the powers, and to carry out functions or activities, under the *Work Health and Safety Act 2011* and related work safety laws. Under that Act, the information can be disclosed to other ACT Government agencies or non-government organisations, and other Australian work safety enforcement agencies. WorkSafe ACT is obliged to handle your information openly, transparently and in accordance with the Territory Privacy Principles set out in the *Information Privacy Act 2014*. For more information about how WorkSafe ACT will collect, use, share, and store your personal information and how you can access and correct the information, please see the Privacy Statement at www.act.gov.au/privacy.

Review of this *Work Health and Safety Act* notice

If you have any questions or need more information you may contact the inspector who issued this notice, or email worksafe@act.gov.au.

You, or another person whose interests are affected by the decision, may apply for an internal review of the decision to issue this notice.

A review may be sought within 14 days, or in the case of an improvement notice within the compliance date period specified in the notice, whichever is lesser. You may also make an application for the reviewer to stay the operation of the Improvement notice.

Please ensure you include the notice number in your application for a review, together with the applicant's name and address, and the reason you are seeking the review.

An application for a review can be made in writing to: The Work Health and Safety Commissioner WorkSafe ACT, GPO Box 158 Canberra City ACT 2601 or by email: worksafe@act.gov.au

You may then seek a review of an internal reviewer's decision in the ACT Civil and Administrative Tribunal (ACAT). Information about that process can be found at www.acat.act.gov.au.

The decision to issue this notice is also reviewable under the *Administrative Decisions (Judicial Review) Act 1989* on application to the ACT Supreme Court. Further, a person may make a complaint to the ACT Ombudsman about the issue of this notice.

WorkSafe ACT contact details

PO Box 158, Canberra ACT 2601

Email: Worksafe @act.gov.au

Phone: (02) 6207 3000

Fax:(02) 6205 0336.

Translating and Interpreting Service

Phone: 131 450

WORKSAFE.ACT.GOV.AU

MAIL PO Box 158 Canberra ACT 2601 **EMAIL** worksafe@act.gov.au **PHONE** 02 6207 3000

[redacted]

Appendix 2 Calibration Certificates – Carbon Dioxide Monitors

[redacted]

Page 1 of 2

Customer	[redacted]
Address	
Contact	
Equipment	TSI Indoor Air Quality Meter
Model	7575 with 982 Probe
Serial Number	7575X1230008 / P08260003
Calibration Date	20/06/2022
Condition as Received	*As Left*

ENVIRONMENTAL CONDITIONS	
Ambient Temp	23.6°C
Humidity	44.0%RH
Barometric Pressure	1007.4hPa

Uncertainty of Measurement

The uncertainty of Measurement values stated in this report are at a confidence level of 95% with coverage factor of K = 2

[redacted] **ertifies That :-**

The above described instrument has been calibrated using standards with accuracies traceable to the standards held by the National Measurement Institute of Australia.

Procedures Followed:	LABP 2, 5 & 6 [redacted]
Approved Signatory:	
Date:	20/06/2022

[redacted]

REFERENCE EQUIPMENT			
Instrument	Model	Serial No.	Calibration Due
Fluke Digital Thermometer	1523	3500137	Aug-22
Thunder Scientific	2500	1104842	Aug-22

CALIBRATION RESULTS					
Reference Bath Temp. (Deg C)	Before Adjustment (Deg C)	After Adjustment (Deg C)	Correction (Deg C)	Uncertainty	
0.00	-0.3	-0.1	0.10	+/-0.2	
60.00	59.9	60.1	-0.10	+/-0.2	
Humidity Reference (%RH)	Before Adjustment (%RH)	Humidity Reference (%RH)	After Adjustment (%RH)	Correction ppm to be added (%RH)	Uncertainty
20.0	20.9	20.0	20.2	-0.2	2.6% of Reading
50.0	52.4	50.0	50.9	-0.9	
80.0	82.1	80.0	79.8	0.2	
Air Liquide Lab Report No.	CO2 ppm per Reference	Reading ppm Before Adjustment	Reading ppm After Adjustment	Correction ppm to be added	Uncertainty
19054	405	422	415	-10	+/- 10
16526	1000	1023	1006	-6	+/- 24
16530	2502	2518	2488	14	+/- 60
16529	5004	5065	5025	-21	+/- 140
Air Liquide Lab Report No.	CO ppm per Reference	Reading ppm Before Adjustment	Reading ppm After Adjustment	Correction ppm to be added	Uncertainty
16527	20.1	18.6	20.3	-0.2	+/- 1.3
16528	106.0	97.4	105.9	0.1	+/- 2.0
17275	203.0	191.5	209.1	-6.1	+/-6.0

Barometric Pressure		
Standard	As Found	After Calibration
1007.4 hPa	1007.2 hPa	1007.4 hPa

***NOTE** Copy of reference gas certificates of conformance to be attached to this certificate, if requested.*

[redacted]

Customer	[redacted]
Address	
Contact	
Equipment	TSI Indoor Air Quality Meter
Model	7575-982
Serial Number	7575X1913008-P12300033
Calibration Date	26-10-2021
Condition as Received	*As Left*

ENVIRONMENTAL CONDITIONS	
Ambient Temp	22.2°C
Humidity	35.1%RH
Barometric Pressure	1005hPa

Uncertainty of Measurement

The uncertainty of Measurement values stated in this report are at a confidence level of 95% with coverage factor of K = 2

[redacted] **Certifies That :-**

The above described instrument has been calibrated using standards with accuracies traceable to the standards held by the National Measurement Institute of Australia.

Procedures Followed:	LABP 2, 5 & 6
Approved Signatory:	[redacted]
Date:	26-10-2021

[redacted]

[redacted]

REFERENCE EQUIPMENT			
Instrument	Model	Serial No.	Calibration Due
Fluke Digital Thermometer	1523	3600137	Aug-22
Thunder Scientific	2500	1104842	Aug-22

CALIBRATION RESULTS

Reference Bath Temp. (Deg C)	Before Adjustment (Deg C)	After Adjustment (Deg C)	Correction (Deg C)	Uncertainty
0.00	0.0	0.0	0.00	+/-0.2
60.00	59.9	59.9	0.10	+/-0.2

Humidity Reference (%RH)	Before Adjustment (%RH)	Humidity Reference (%RH)	After Adjustment (%RH)	Correction ppm to be added (%RH)	Uncertainty
20.0	19.8	20.0	20.8	-0.8	2.6% of Reading
50.0	49.9	50.0	50.8	-0.8	
80.0	78.7	80.0	79.3	0.7	

Air Liquide Lab Report No.	CO2 ppm per Reference	Reading ppm Before Adjustment	Reading ppm After Adjustment	Correction ppm to be added	Uncertainty
16012	399	398	403	-4	+/- 10
16526	1000	1022	1009	-9	+/- 24
16530	2502	2508	2503	-1	+/- 60
16529	5004	5019	5020	-16	+/- 140

Air Liquide Lab Report No.	CO ppm per Reference	Reading ppm Before Adjustment	Reading ppm After Adjustment	Correction ppm to be added	Uncertainty
16527	20.1	19.3	20.2	-0.1	+/- 1.3
16528	106.0	99.0	105.9	0.1	+/- 2.0
17276	203.0	190.8	205.3	-2.3	+/-6.0

Barometric Pressure		
Standard	As Found	After Calibration
1005.0hPa	1004.3hPa	1004.9hPa

***NOTE** Copy of reference gas certificates of conformance to be attached to this certificate, if requested.*

[redacted]

CERTIFICATE OF CALIBRATION AND TESTING

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 1-800-874-2811 1-651-490-2811 Fax: 1-651-490-3824 http://www.tsi.com

ENVIRONMENT CONDITIONS		
TEMPERATURE	75.7 (24.3)	°F (°C)
RELATIVE HUMIDITY	14	%RH
BAROMETRIC PRESSURE	29.72 (1006.4)	inHg (hPa)

MODEL	7575-X-NB
SERIAL NUMBER	7575X2204020

☒ AS LEFT ☒ IN TOLERANCE
☐ AS FOUND ☐ OUT OF TOLERANCE

– CALIBRATION VERIFICATION RESULTS –

THERMO COUPLE — SYSTEM PRESSURE01-01 — *Unit: °F (°C)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	73.2 (22.9)	73.4 (23.0)	71.2~75.2 (21.8~24.0)				

BAROMETRIC PRESSURE — SYSTEM PRESSURE01-01 — *Unit: inHg (hPa)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	29.76 (1007.8)	29.76 (1007.8)	29.16~30.36 (987.5~1028.1)				

TSI does hereby certify that the above described instrument conforms to the original manufacturer's specification (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the United States National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. TSI's calibration system is registered to ISO-9001:2015.

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E010540	12-09-20	06-30-22
Temperature	E002827	07-21-21	03-31-22
Pressure	E010853	01-19-22	07-31-22

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E003300	12-09-20	06-30-22
Pressure	E003302	08-31-21	02-28-22

CALIBRATED

January 20, 2022
DATE

Doc. ID: CERT_GEN_WCC

TSI P/N 2300157

CERTIFICATE OF CALIBRATION AND TESTING

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 1-800-874-2811 1-651-490-2811 Fax: 1-651-490-3824 http://www.tsi.com

ENVIRONMENT CONDITIONS		
TEMPERATURE	75.8 (24.3)	°F (°C)
RELATIVE HUMIDITY	20	%RH
BAROMETRIC PRESSURE	29.69 (1005.4)	inHg (hPa)

MODEL	7575-X-NB
SERIAL NUMBER	7575X2206002

☒ AS LEFT ☐ AS FOUND
☒ IN TOLERANCE ☐ OUT OF TOLERANCE

– CALIBRATION VERIFICATION RESULTS –

THERMO COUPLE — SYSTEM PRESSURE01-01 — *Unit: °F (°C)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	74.5 (23.6)	74.5 (23.6)	72.5~76.5 (22.5~24.7)				

BAROMETRIC PRESSURE — SYSTEM PRESSURE01-01 — *Unit: inHg (hPa)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	29.72 (1006.4)	29.72 (1006.4)	29.13~30.31 (986.5~1026.4)				

TSI does hereby certify that the above described instrument conforms to the original manufacturer's specification (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the United States National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. TSI's calibration system is registered to ISO-9001:2015.

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E010540	12-09-20	06-30-22
Temperature	E002827	07-21-21	03-31-22
Pressure	E010853	01-19-22	07-31-22

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E003300	12-09-20	06-30-22
Pressure	E003302	08-31-21	02-28-22

[redacted]
CALIBRATED

February 3, 2022
DATE

DOC. ID: CERT_GEN_WCC

TSI P/N 2300157

TSI P/N 2900157

Certificate of Calibration and Testing

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 1-800-874-2811 1-651-490-2811 Fax: 1-651-490-3824 http://www.tsi.com

Environment Conditions		
Temperature	74.6 (23.7)	°F (°C)
Relative Humidity	21	%RH
Barometric Pressure	28.89 (978.3)	inHg (hPa)

Model	982
Serial Number	P22060003

☒ As Left
☐ As Found

☒ In Tolerance
☐ Out of Tolerance

– Calibration Verification Results –

Temperature Verification — System T-100 — *Unit: °F (°C)*

#	Standard	Measured	Allowable Range	#	Standard	Measured	Allowable Range
1	32.0 (0.0)	32.0 (0.0)	31.0~33.0 (-0.6~0.6)	2	140.0 (60.0)	140.1 (60.1)	139.0~141.0 (59.4~60.6)

Humidity Verification — System H-100 — *Unit: %RH*

#	Standard	Measured	Allowable Range	#	Standard	Measured	Allowable Range
1	9.9	10.3	7.7~12.1	4	69.9	69.8	67.7~72.1
2	29.9	30.1	27.7~32.1	5	89.9	89.6	87.7~92.1
3	49.9	49.8	47.7~52.1				

CO_2 Gas Verification — System G-100 — *Unit: ppm*

#	Standard	Measured	Allowable Range	#	Standard	Measured	Allowable Range
1	0	0	0~50	4	3000	3020	2910~3090
2	500	499	450~550	5	4972	4987	4823~5121
3	1000	1019	950~1050				

CO Gas Verification — System G-100 — *Unit: ppm*

#	Standard	Measured	Allowable Range	#	Standard	Measured	Allowable Range
1	35	38	32~38	2	100	101	97~103

TSI does hereby certify that the above described instrument conforms to the original manufacturer's specification (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the United States National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. TSI's calibration system is registered to ISO-9001:2015.

Measurement Variable	System ID	Last Cal.	Cal. Due	Measurement Variable	System ID	Last Cal.	Cal. Due
Temperature	E003617	01-14-22	07-31-22	Temperature	E003305	01-14-22	07-31-22
Humidity	E003296	08-12-21	08-31-22	Flow	E011122	07-24-21	07-31-22
Flow	E003525	04-14-21	04-30-22	5000 CO2	HP695429	08-04-21	08-04-29
200 CO	201302140	08-05-21	08-05-29	N2	T1118	12-13-21	12-13-29
Air	CT307612	11-12-20	11-12-28	Flow	E003980	06-16-21	06-30-22
Flow	E011127	08-13-21	08-31-22	20 C4H8	CC716221	02-22-21	02-22-29

Calibrated

February 2, 2022
Date

Doc. ID: CERT_GEN_WCC

[redacted]

TSI P/N 2300157

CERTIFICATE OF CALIBRATION AND TESTING

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 1-800-874-2811 1-651-490-2811 Fax: 1-651-490-3824 http://www.tsi.com

ENVIRONMENT CONDITIONS		
TEMPERATURE	75.8 (24.3)	°F (°C)
RELATIVE HUMIDITY	17	%RH
BAROMETRIC PRESSURE	29.55 (1000.7)	inHg (hPa)

MODEL	7575-X-NB
SERIAL NUMBER	7575X2206007

☒ AS LEFT
☐ AS FOUND

☒ IN TOLERANCE
☐ OUT OF TOLERANCE

– CALIBRATION VERIFICATION RESULTS –

THERMO COUPLE — SYSTEM PRESSURE01-01 — *Unit: °F (°C)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	73.4 (23.0)	73.5 (23.1)	71.4~75.4 (21.9~24.1)				

BAROMETRIC PRESSURE — SYSTEM PRESSURE01-01 — *Unit: inHg (hPa)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	29.58 (1001.7)	29.58 (1001.7)	28.99~30.17 (981.7~1021.7)				

TSI does hereby certify that the above described instrument conforms to the original manufacturer's specification (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the United States National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. TSI's calibration system is registered to ISO-9001:2015.

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E010540	12-09-20	06-30-22
Temperature	E002827	07-21-21	03-31-22
Pressure	E010853	01-19-22	07-31-22
DC Voltage	E003300	12-09-20	06-30-22
Pressure	E003302	08-31-21	02-28-22

[redacted]
CALIBRATED

February 2, 2022
DATE

DOC ID: CERT_GEN_WCC

CERTIFICATE OF CALIBRATION AND TESTING

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 1-800-874-2811 1-651-490-2811 Fax: 1-651-490-3824 http://www.tsi.com

ENVIRONMENT CONDITIONS		
TEMPERATURE	73.25 (22.9)	°F (°C)
RELATIVE HUMIDITY	27.9	%RH
BAROMETRIC PRESSURE	28.89 (978.3)	inHg (hPa)

MODEL	982
SERIAL NUMBER	P22060004

☒ AS LEFT ☒ IN TOLERANCE
☐ AS FOUND ☐ OUT OF TOLERANCE

– CALIBRATION VERIFICATION RESULTS –

TEMPERATURE VERIFICATION — SYSTEM T-101 — *Unit: °F (°C)*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	32.1 (0.0)	32.0 (0.0)	31.1~33.1 (-0.5-0.6)	2	139.8 (59.9)	140.0 (60.0)	138.8~140.8 (59.4~60.5)

HUMIDITY VERIFICATION — SYSTEM H-120 — *Unit: %RH*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	10.0	9.7	7.8~12.2	4	70.0	69.7	67.8~72.2
2	30.0	29.9	27.8~32.2	5	90.0	89.7	87.8~92.2
3	50.0	49.9	47.8~52.2				

CO_2 GAS VERIFICATION — SYSTEM G-101 — *Unit: ppm*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	0	0	0~50	4	3005	2992	2915~3095
2	510	495	460~560	5	5051	5039	4899~5203
3	1009	1008	959~1059				

CO GAS VERIFICATION — SYSTEM G-101 — *Unit: ppm*

#	STANDARD	MEASURED	ALLOWABLE RANGE	#	STANDARD	MEASURED	ALLOWABLE RANGE
1	35	36	32~38	2	100	99	97~103

TSI does hereby certify that the above described instrument conforms to the original manufacturer's specification (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the United States National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. TSI's calibration system is registered to ISO-9001:2015.

Measurement Variable	System ID	Last Cal.	Cal. Due	Measurement Variable	System ID	Last Cal.	Cal. Due
Temperature	E010657	02-28-22	02-28-23	Temperature	E010658	02-28-22	02-28-23
Temperature	E010656	02-10-22	02-28-23	Humidity	E002008	02-18-22	08-31-22
5000 CO2	18k175016	07-15-20	07-15-25	200 CO	149834	03-22-22	03-22-30
N2	T-0220	03-15-22	03-15-30	Air	T763591	08-02-21	08-02-29
Flow	E005600	11-05-21	11-30-22	Flow	E003502	06-16-21	06-30-22
Flow	E003981	12-28-21	12-31-22	Flow	E003298	04-21-21	04-30-22
2000 C4H8	CC716226	02-09-21	02-09-29	100 C4H8	CC507330	04-14-20	04-14-28

CALIBRATED

April 5, 2022
DATE

Doc. ID: CERT_GEN_WCC

TSI P/N 2300157

Appendix 3 Calibration Certificate – Air Flow Meter

CALIBRATION CERTIFICATE

REPORT NO: 139826-1

CLIENT:	CLIENT ADDRESS:
[redacted]	[redacted]

INSTRUMENT DATA

A	EQUIPMENT TYPE	HOT WIRE ANEMOMETER
B	MAKE	TSI
C	MODEL	9545A
D	EQUIPMENT SERIAL NUMBER	9545A1007001
E	EQUIPMENT ASSET NUMBER	NOT FOUND
F	DESCRIPTION OF TYPE	DIGITAL DISPLAY
G	RANGE	VARIOUS
H	RATED ACCURACY / TOLERANCE OF U.U.T. (±)	AS FOUND

CALIBRATION DATE

I	DATE OF CALIBRATION	19/05/2022
J	RECOMMENDED DUE DATE	19/05/2023

CALIBRATION RESULT

The results of the tests, calibrations, and /or measurements included in this document are traceable to Australian/national standards.

K	READING OF U.U.T.	SEE PAGE 2
L	READING OF MASTER INSTRUMENT	SEE PAGE 2
M	ADJUSTMENT	NIL
N	REPAIR	NIL
O	SERVICEABILITY/FUNCTIONALITY	ACCEPTABLE
P	TECHNICIAN COMMENT	THIS INSTRUMENT WAS FOUND TO BE FUNCTIONING AS INDICATED BY OUR FINDINGS WITHIN THIS REPORT.

The applicable measurement uncertainties are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement, with confidence level of 95% using a coverage factor k=2.

CALIBRATION PROCEDURE AND TRACEABILITY

Q	LOCATION OF EQUIPMENT	TEST AND MEASUREMENT LAB
R	CALIBRATED BY	SYD TEC
S	CALIBRATION ENVIRONMENT	TEMPERATURE: 23.0 ± 2°C AVERAGE HUMIDITY: 45% ± 10% RH
T	CALIBRATION PROCEDURE	HKC SOP 11-05-V3
U	REFERENCE CALIBRATION STANDARD USED:- HKCT'S PRECISION INSTRUMENT TRACEABLE TO AUSTRALIAN NATIONAL STANDARDS VIA A NATA CERTIFIED CALIBRATION CERTIFICATE:-	*ANEMOMETER* *MAKE : LUTRON* *MODEL: AM-4203HA* *SR.NO: Q844004* *ASSET NO: HKC 203* *NATA REPORT NO: 023937*

[redacted]	[redacted]	19/05/2022
AUTHORIZED SIGNATORY	TECHNICIAN SIGNATURE	DATE OF ISSUE

Report No.: 139826-1
Calibration Date: 19 MAY 2022

Equipment S/No.: T9545A1007001

FUNCTION 1: VELOCITY

MASTER READING m/s	READING OF U.U.T m/s	ERROR
3.20	3.23	0.03
5.14	5.19	0.05
10.27	10.32	0.05

FUNCTION 2: TEMPERATURE

MASTER READING °C	READING OF U.U.T °C	ERROR
23.1	22.9	-0.2

PAGE 2 OF 2

Appendix 4 Carbon Dioxide Graphs for each Sample Location

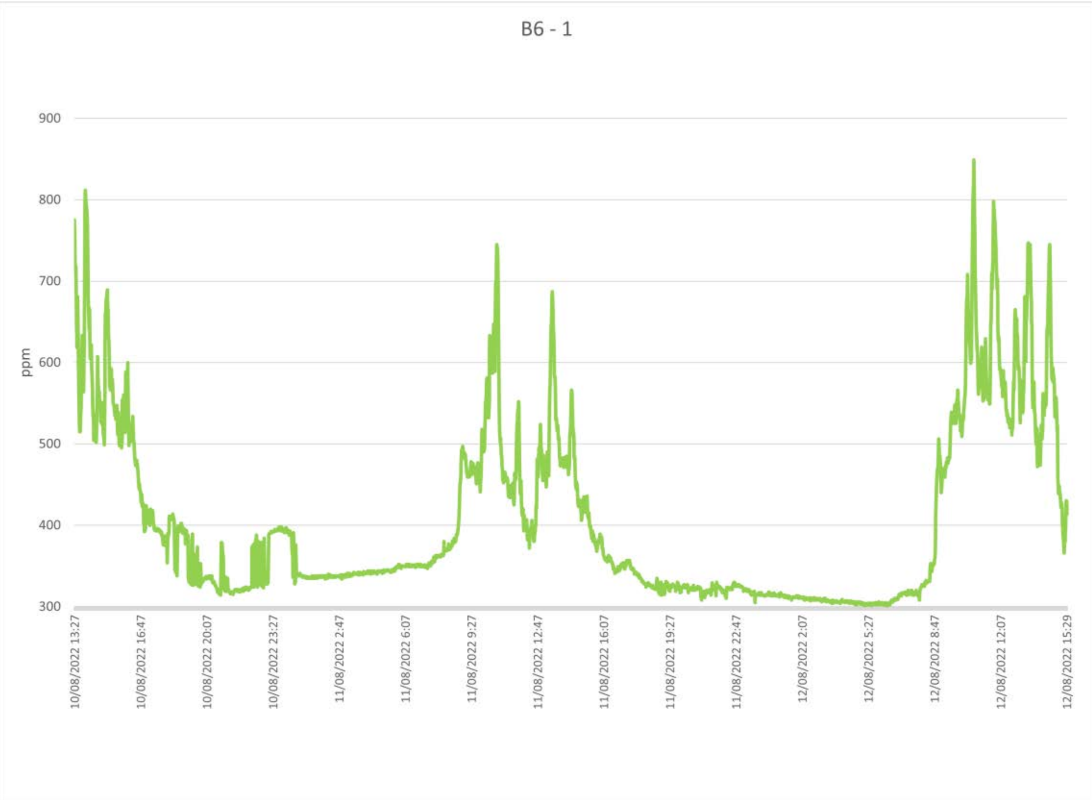

Figure 1: Location B6-1

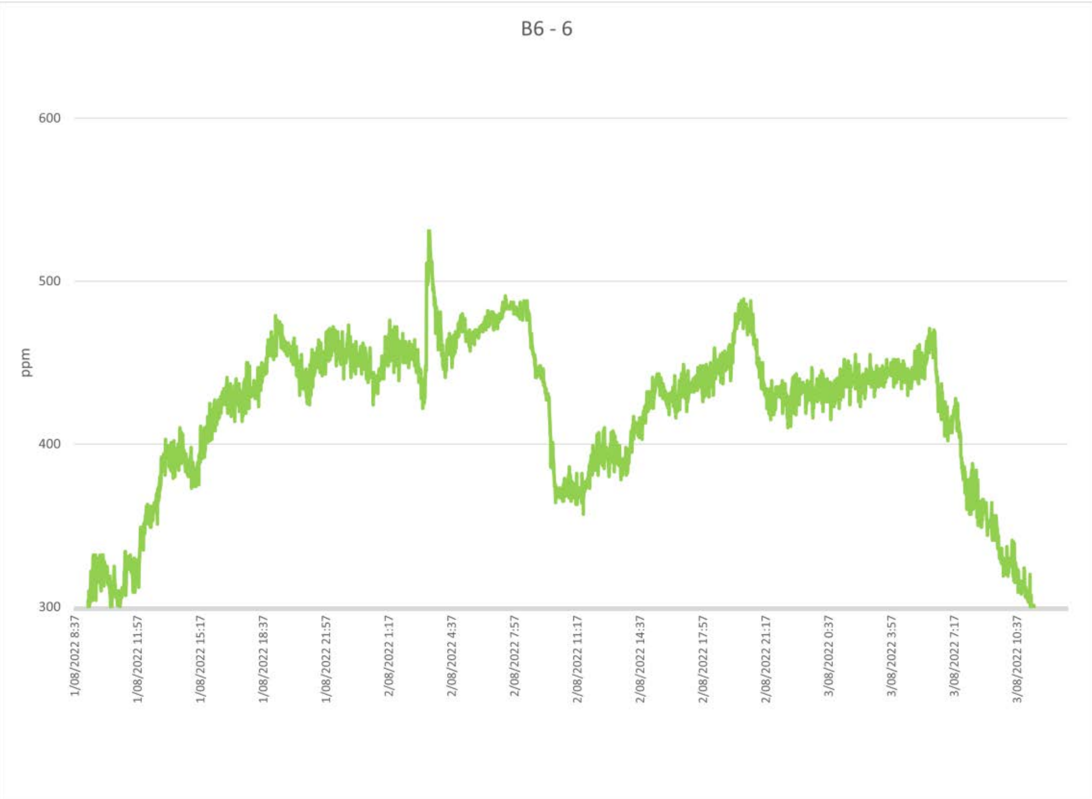

Figure 2: Location B6-6

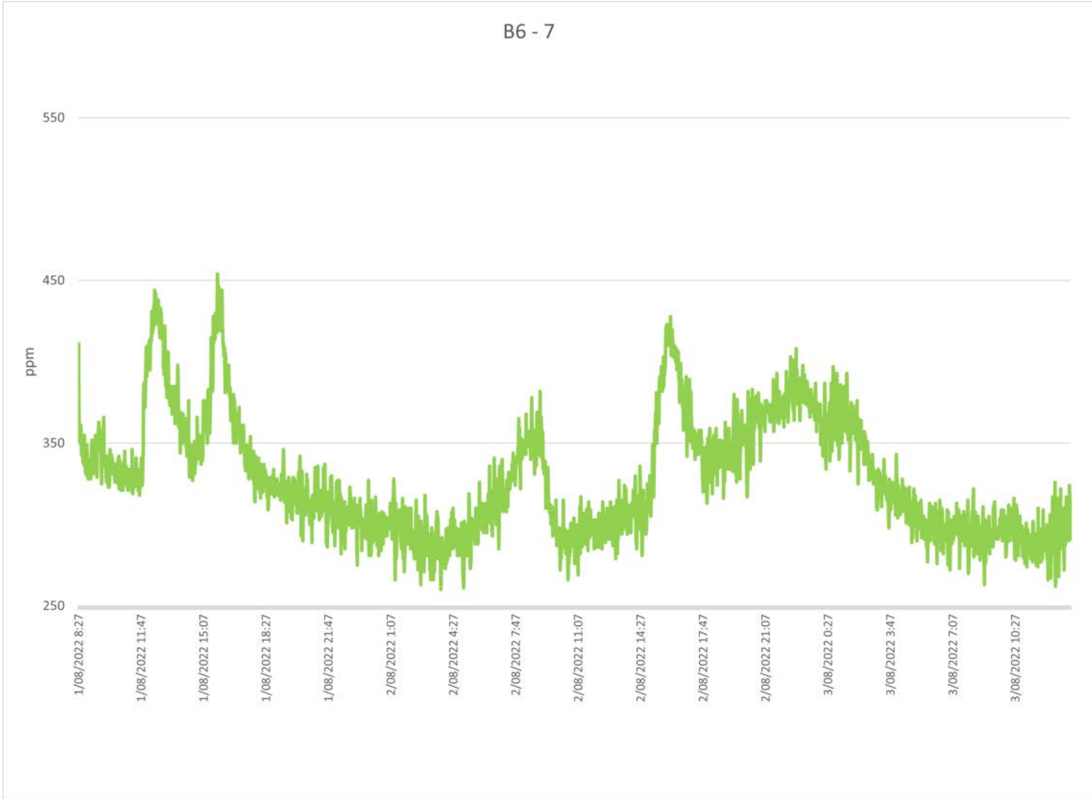

Figure 3: Location B6-7

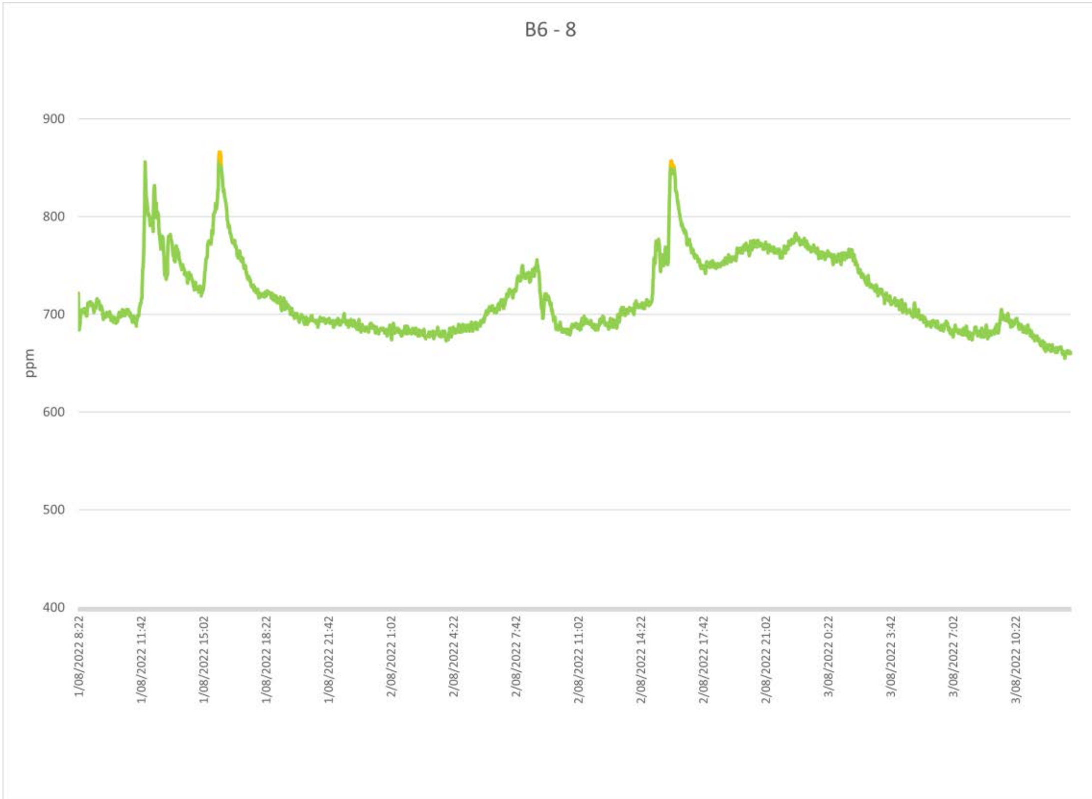

Figure 4: Location B6-8

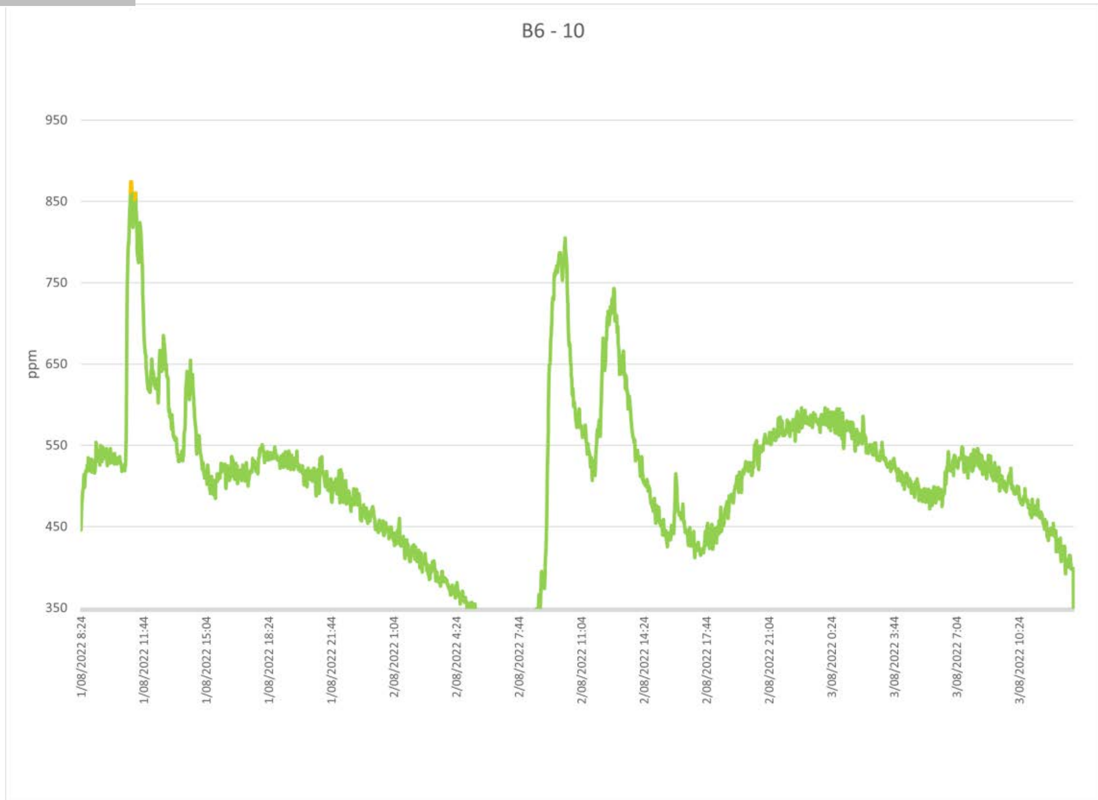

Figure 5: Location B6-10

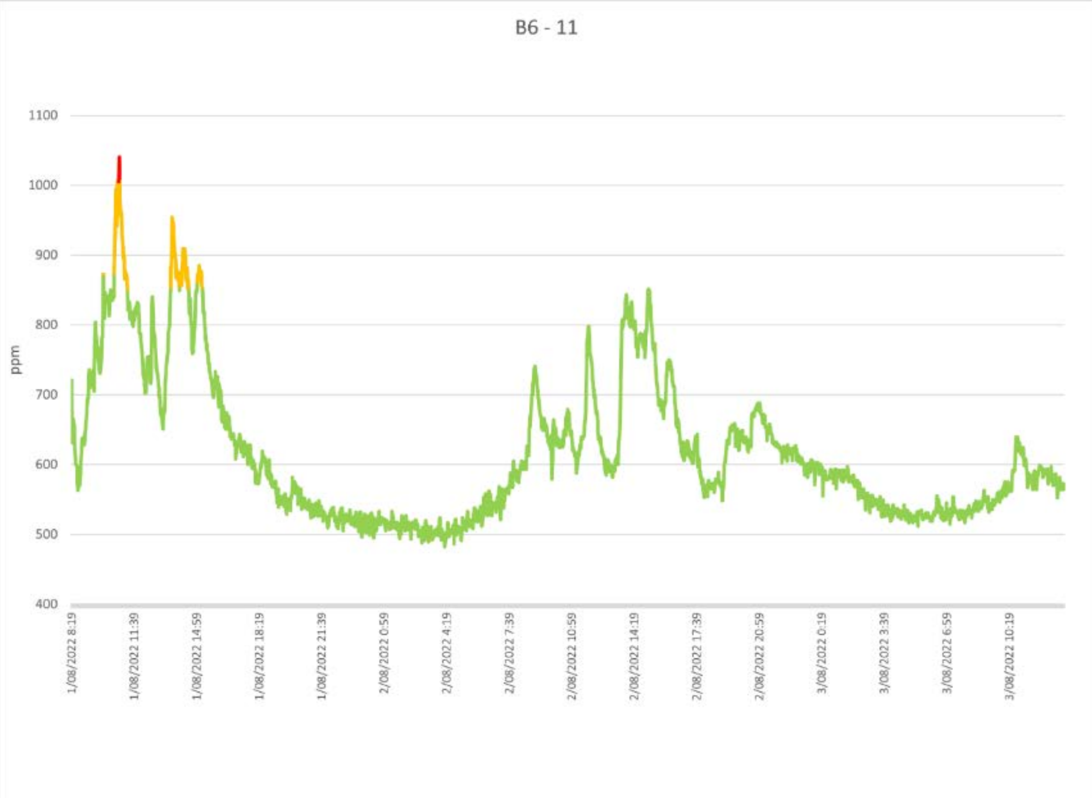

Figure 6: Location B6-11

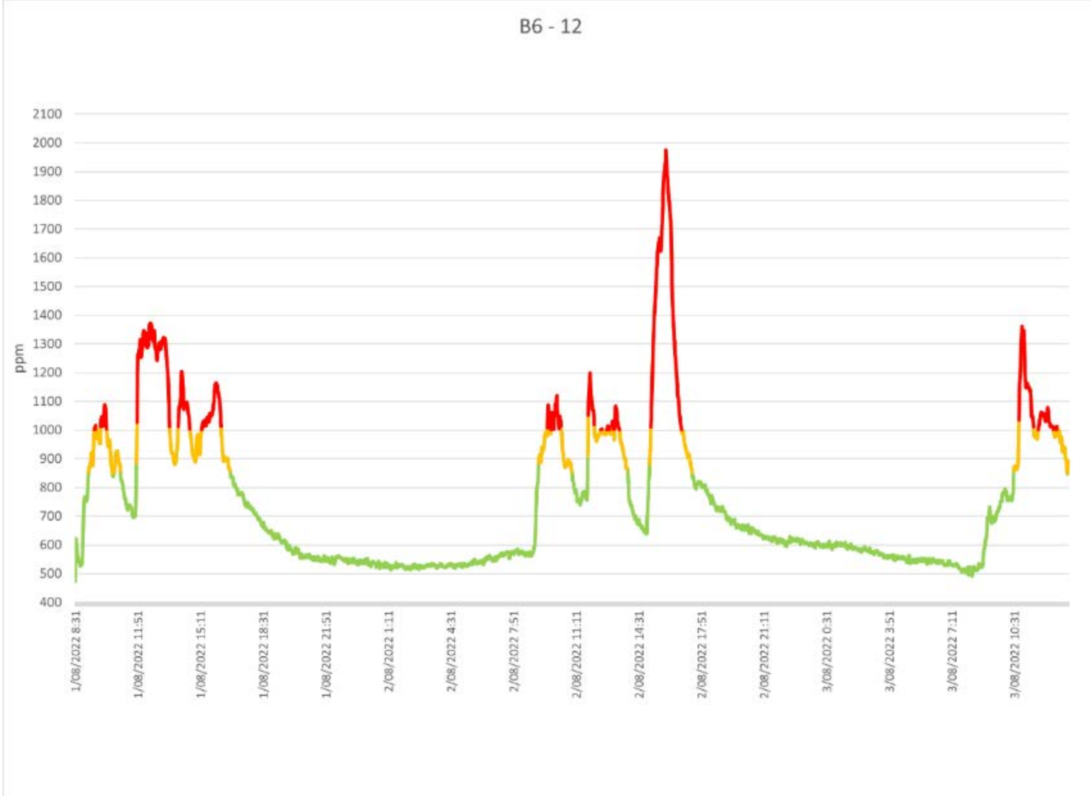

Figure 7: Location B6-12

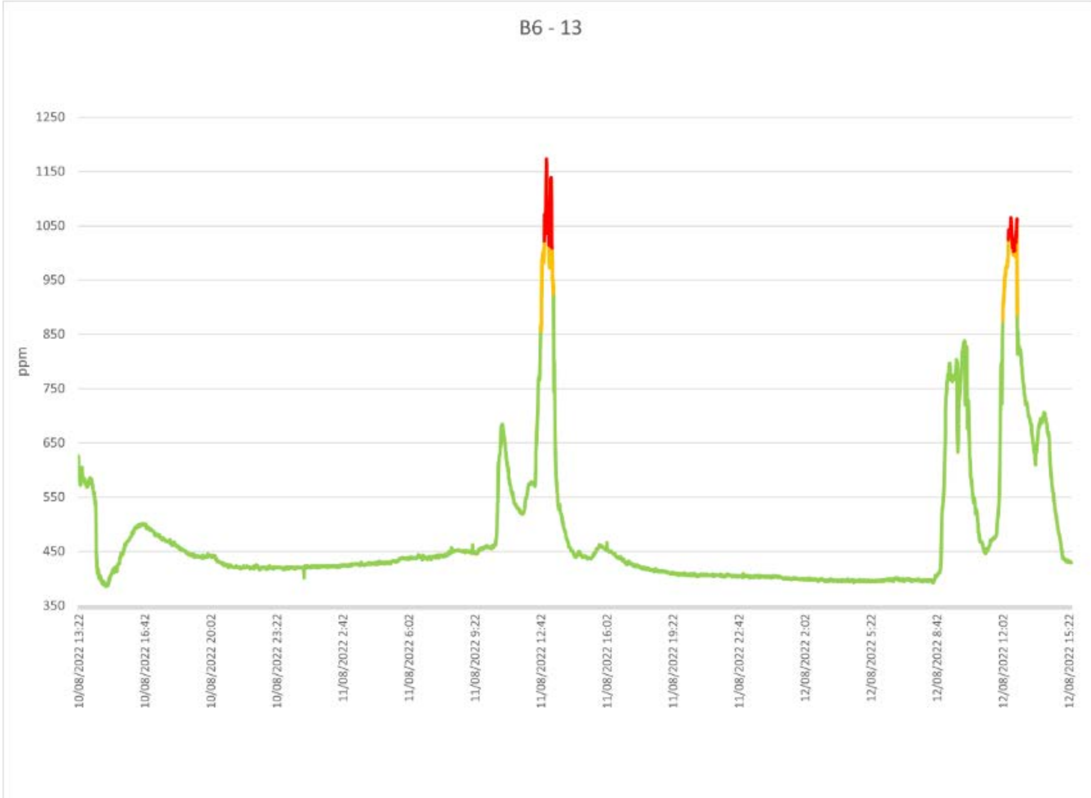

Figure 8: Location B6-13

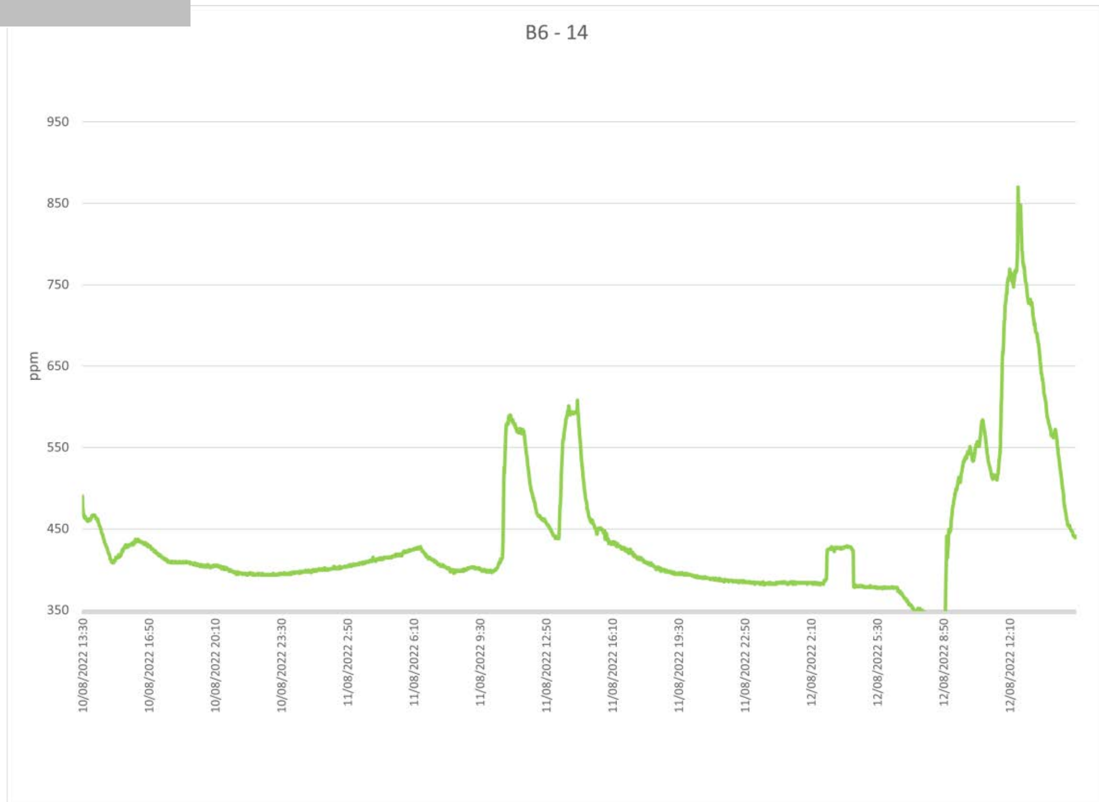

Figure 9: Location B6-14

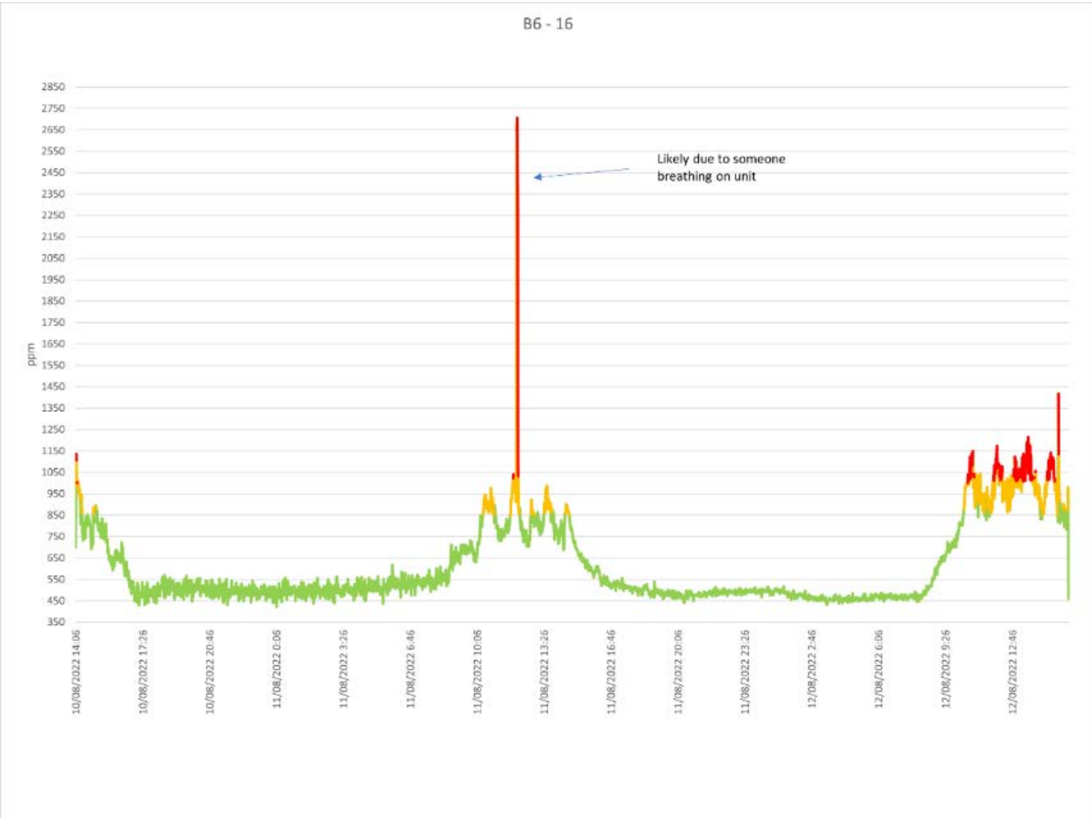

Figure 10: Location B6-16

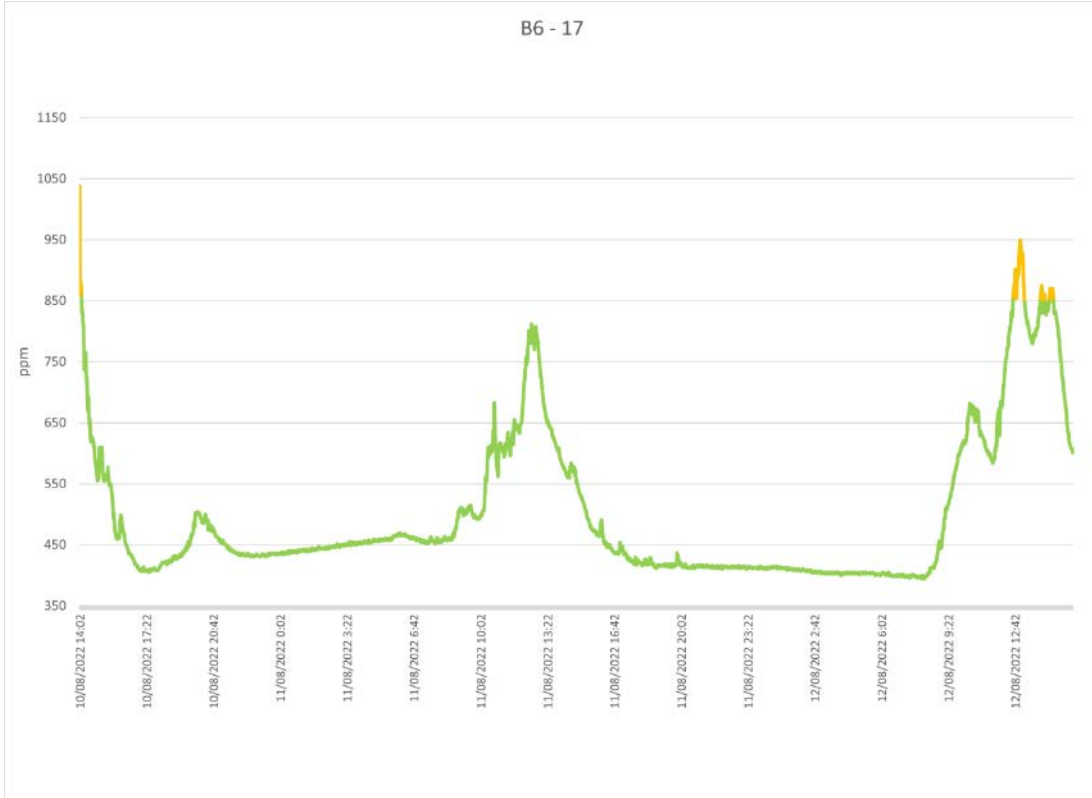

Figure 11: Location B6-17

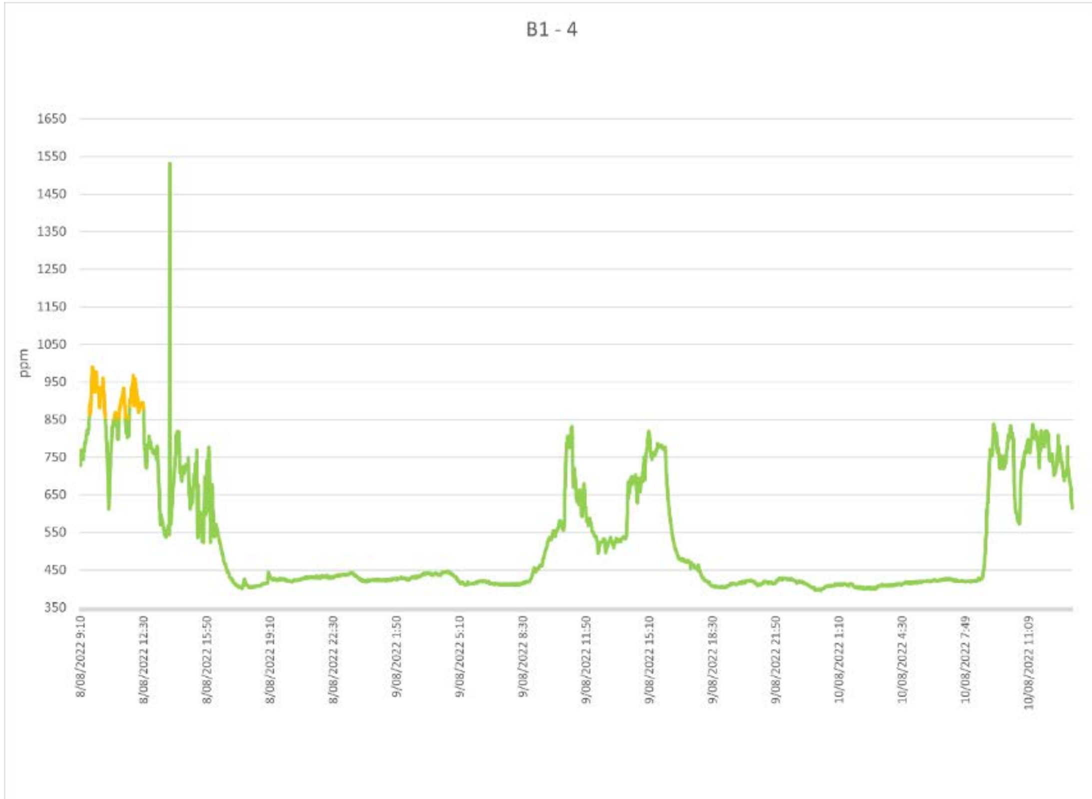

Figure 12: Location B1-4

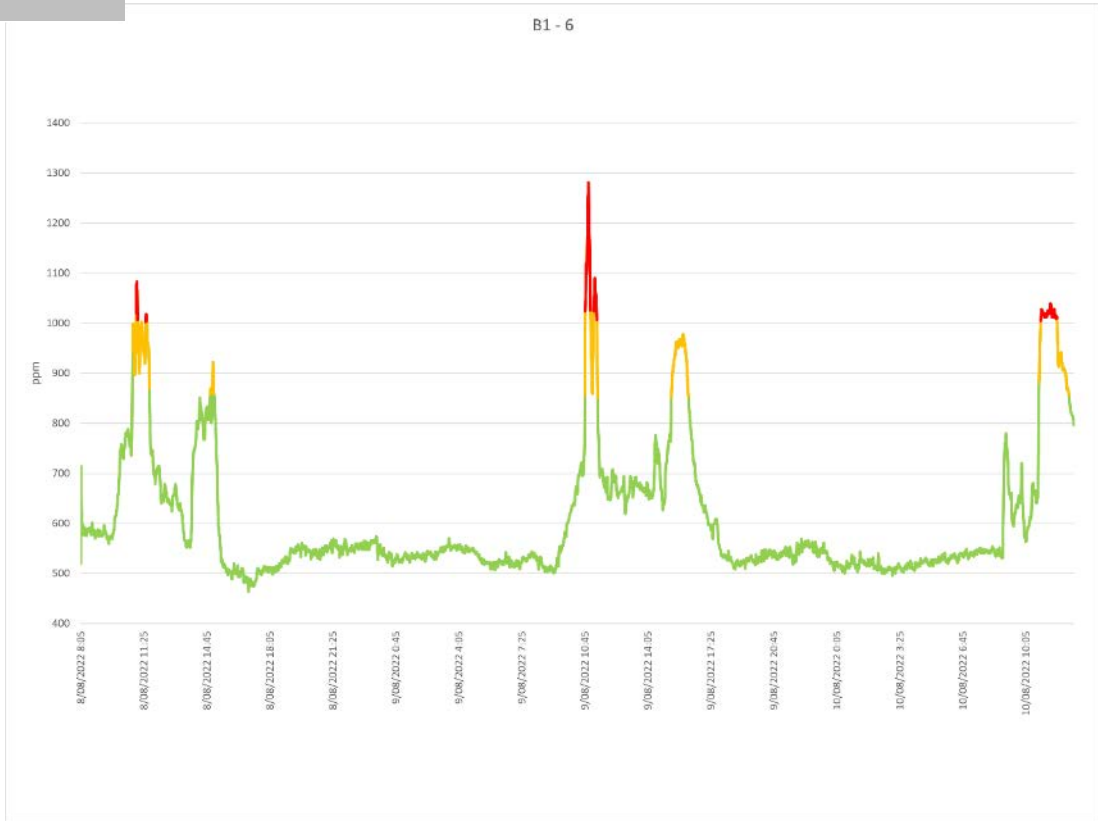

Figure 13: Location B1-6

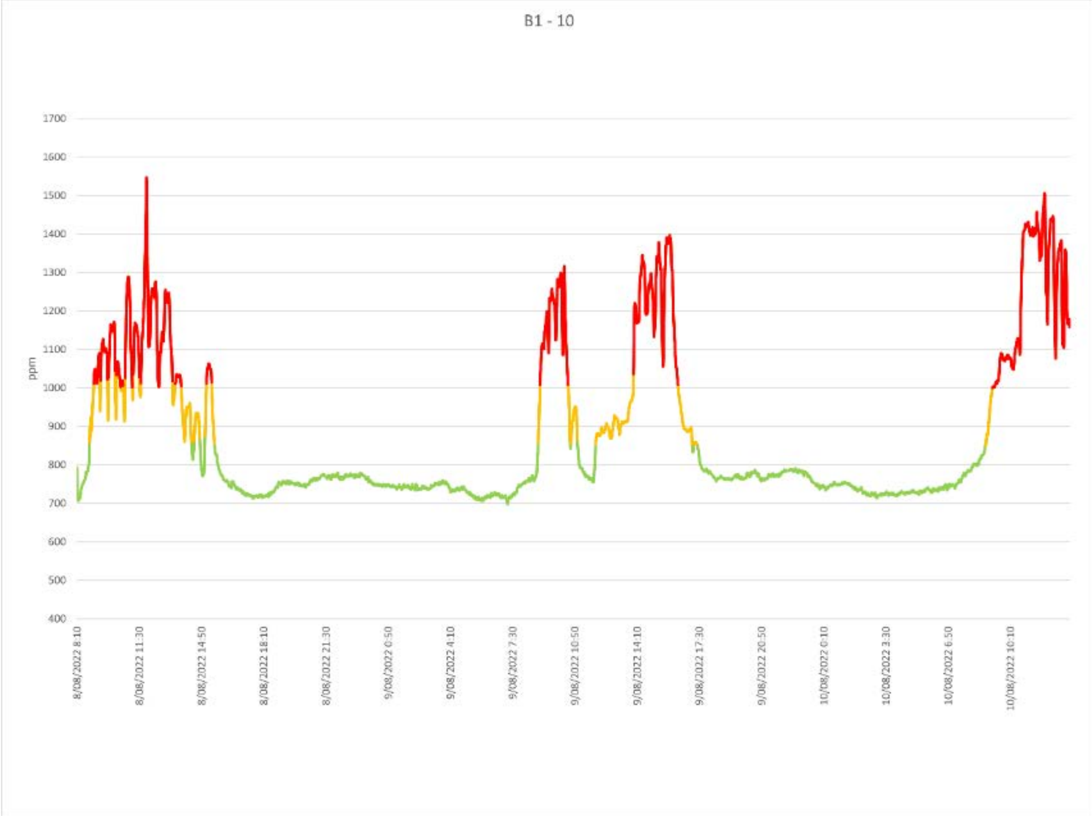

Figure 15: Location B1-10

Figure 14: Location B1-8

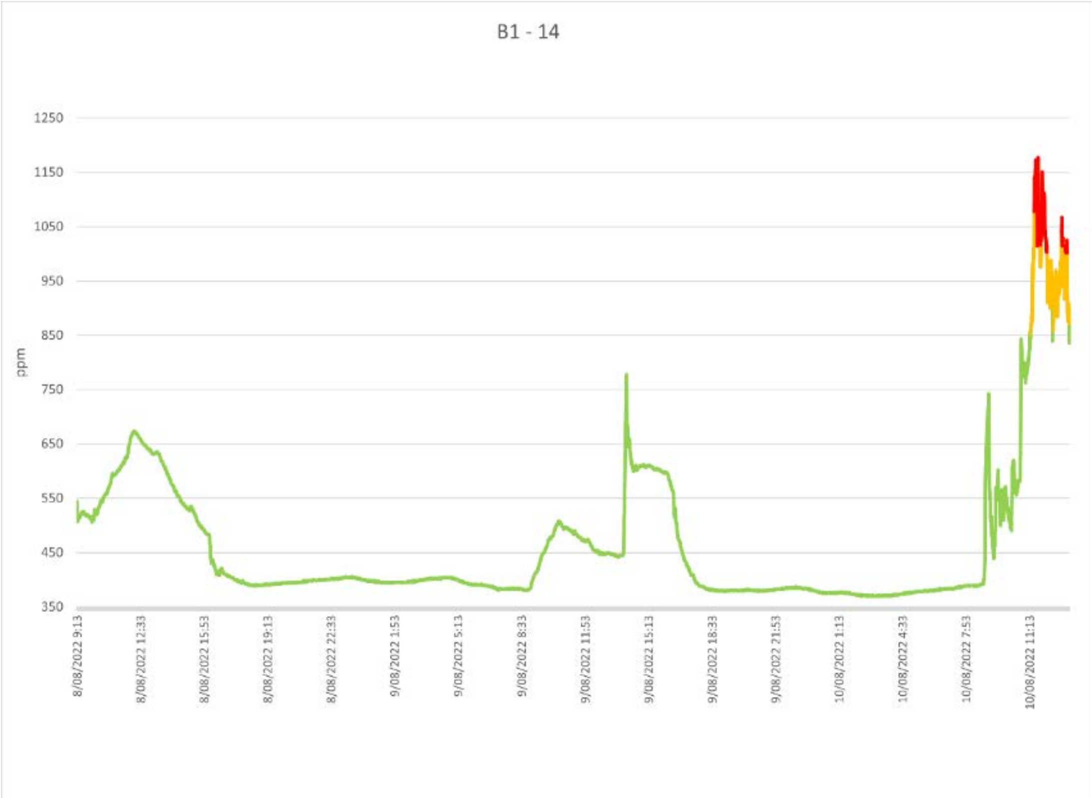

Figure 16: Location B1-14

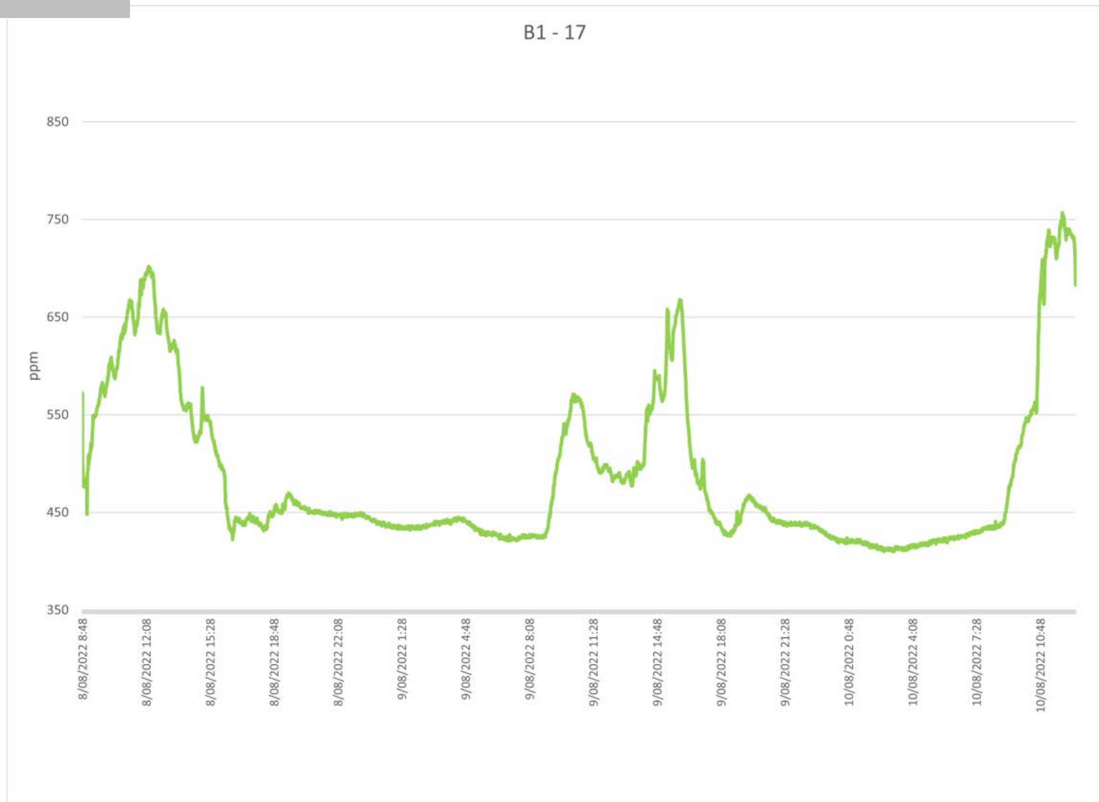

Figure 17: Location B1-17

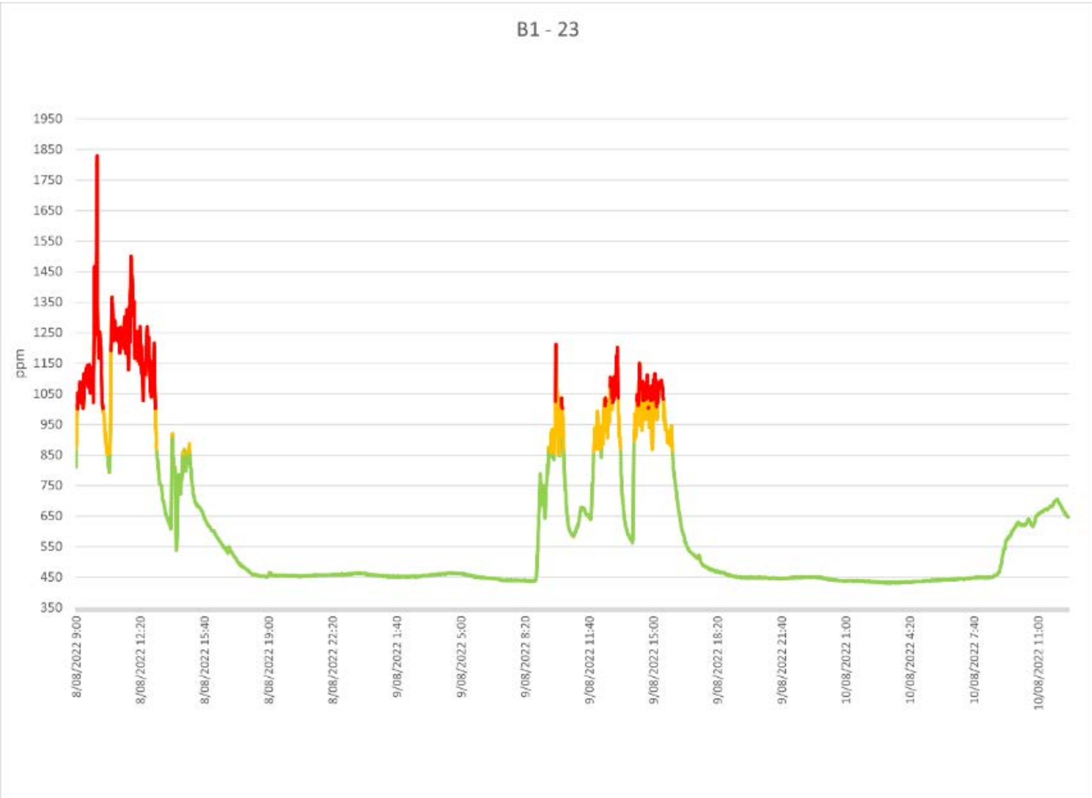

Figure 18: Location B1-23

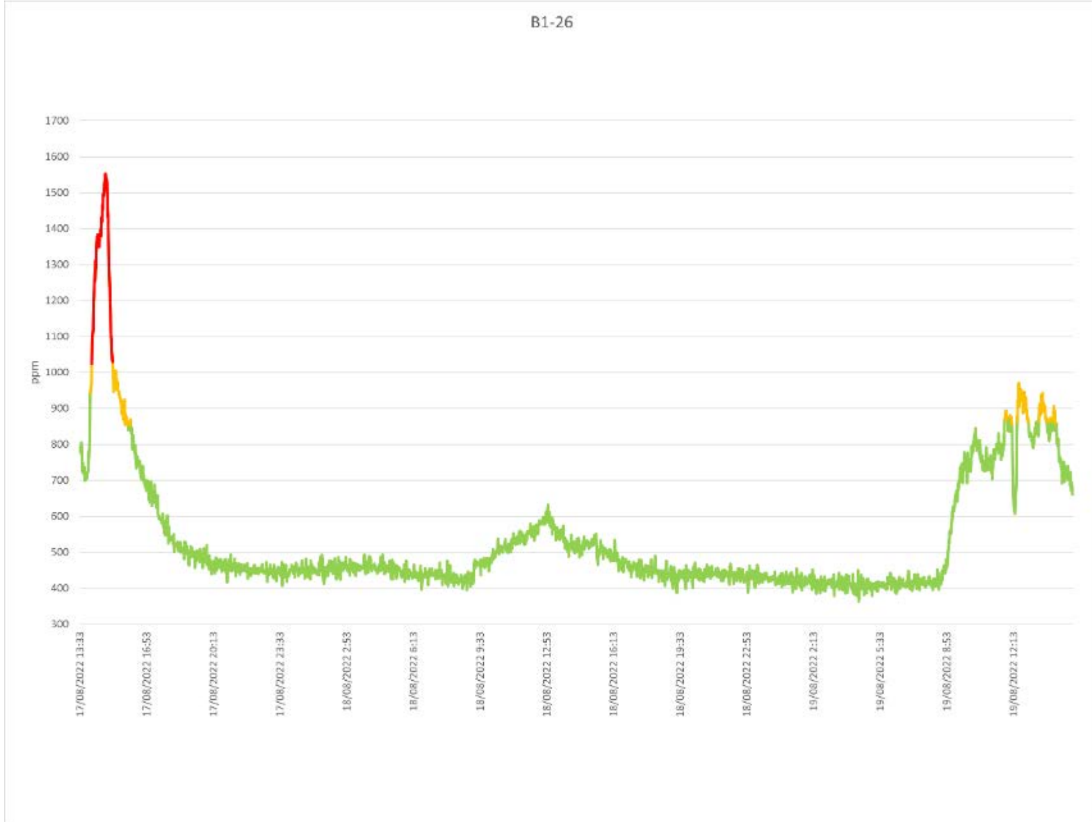

Figure 19: Location B1-26

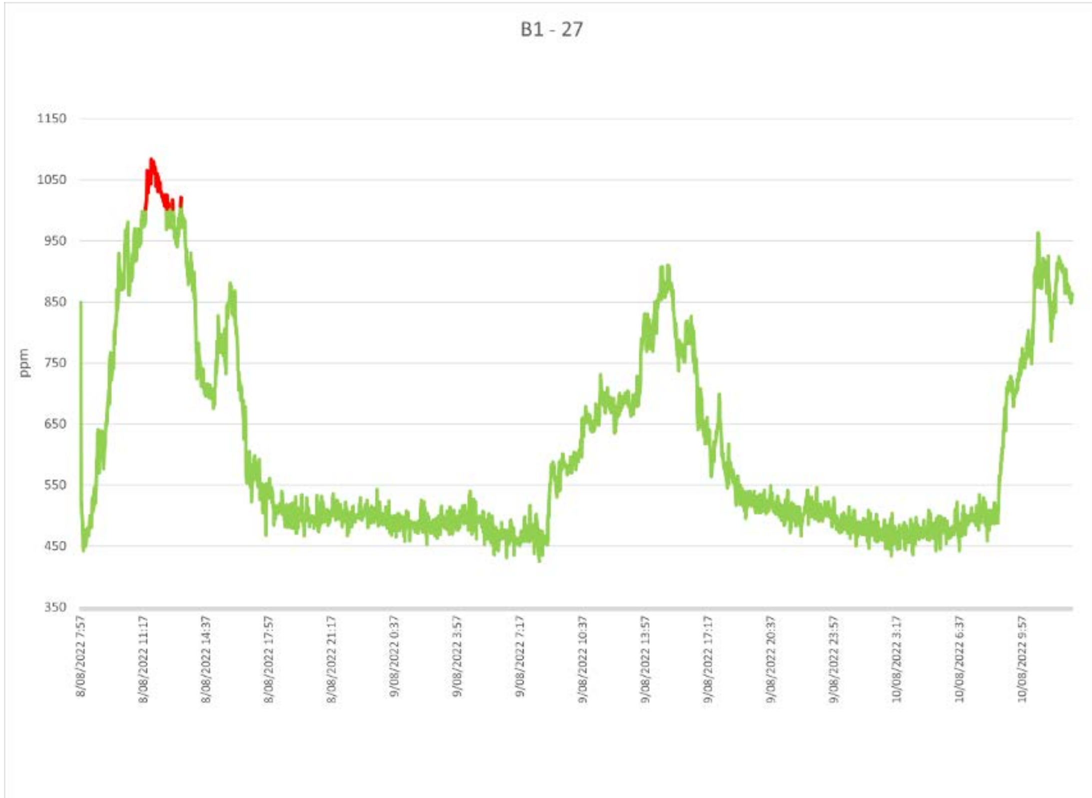

Figure 20: Location B1-27

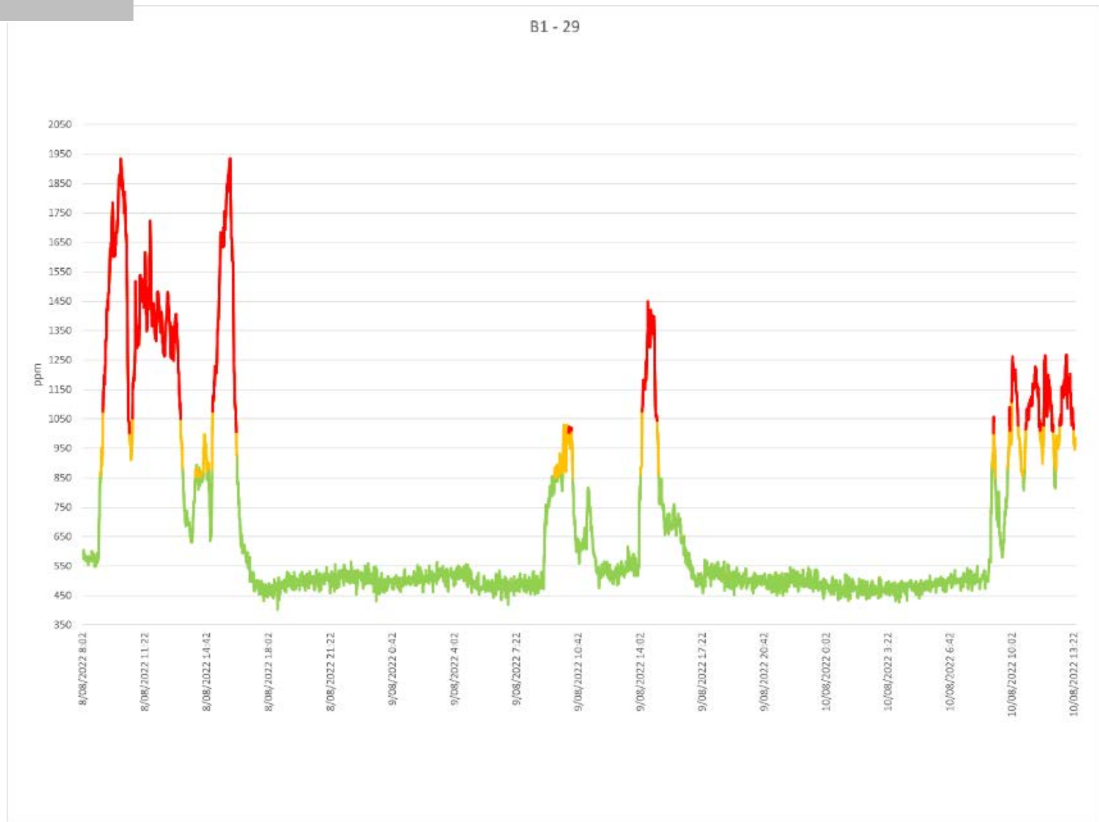

Figure 21: Location B1-29

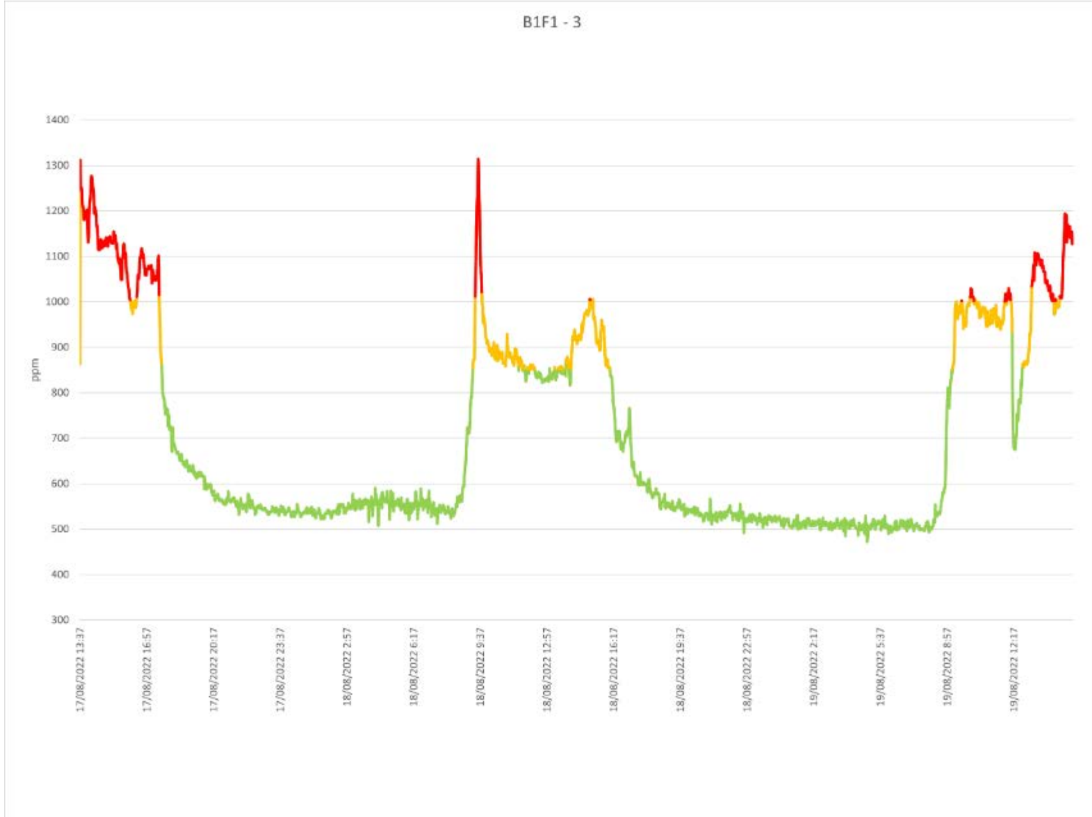

Figure 23: Location B1F1-3

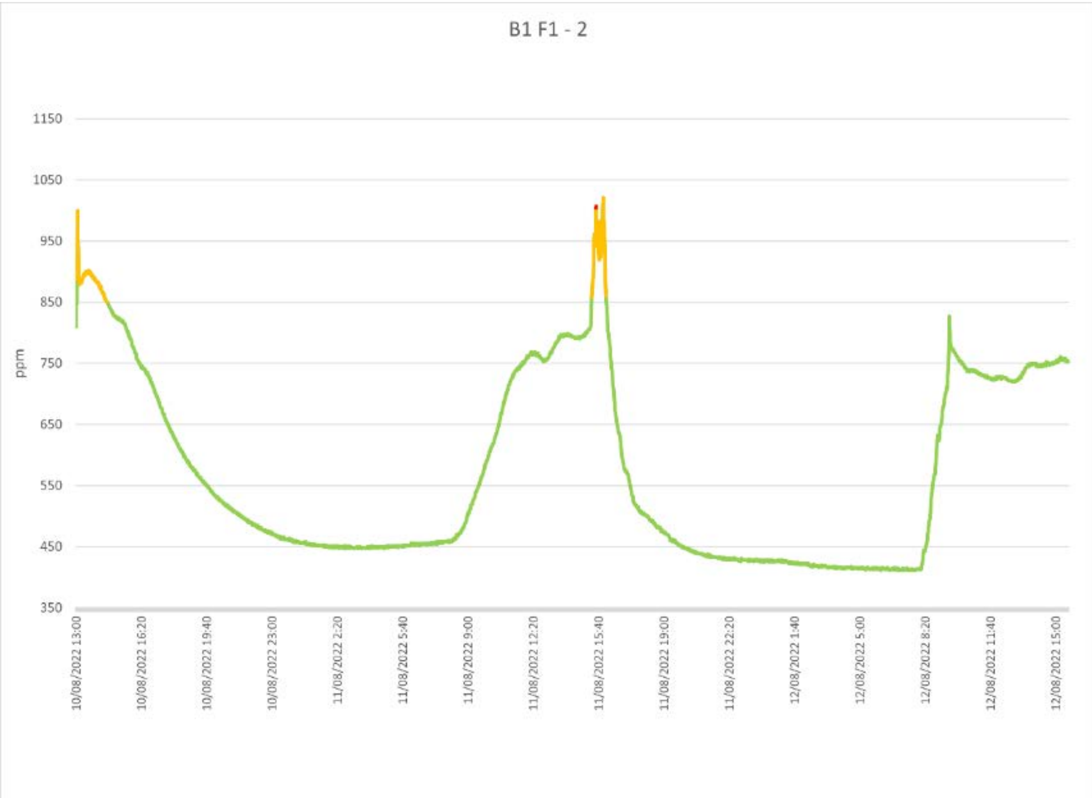

Figure 22: Location B1F1-2

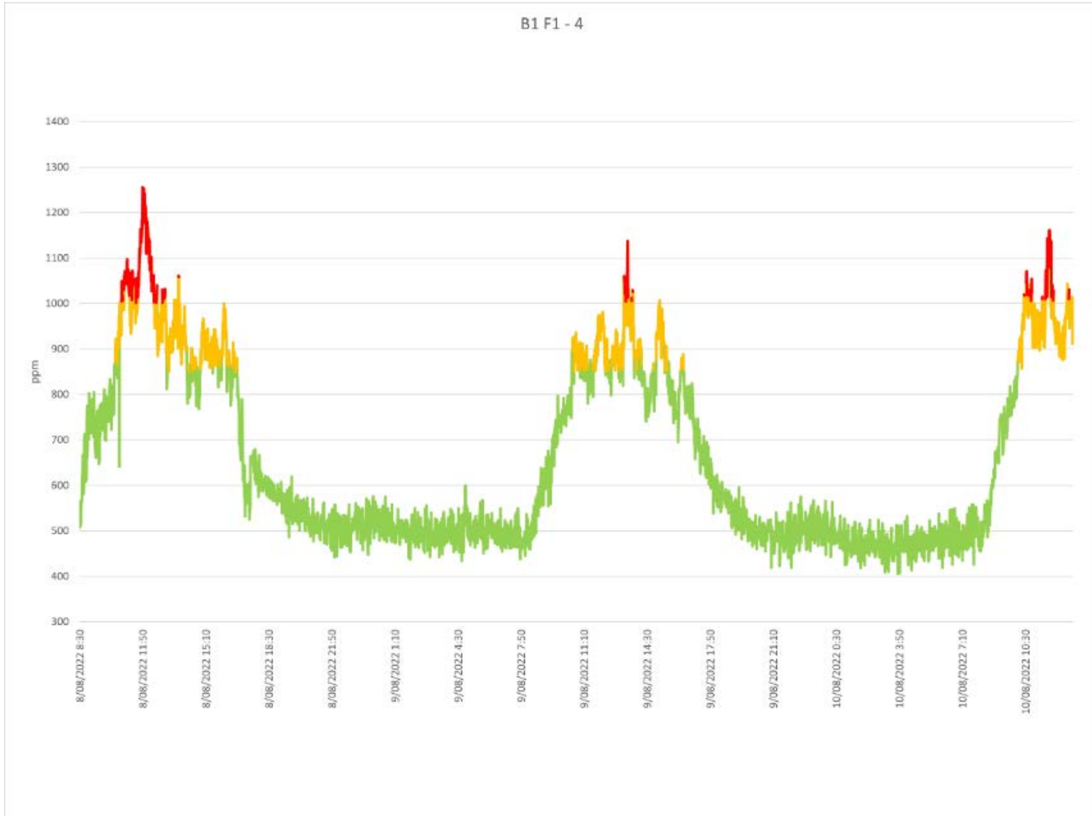

Figure 24: Location B1F1-4

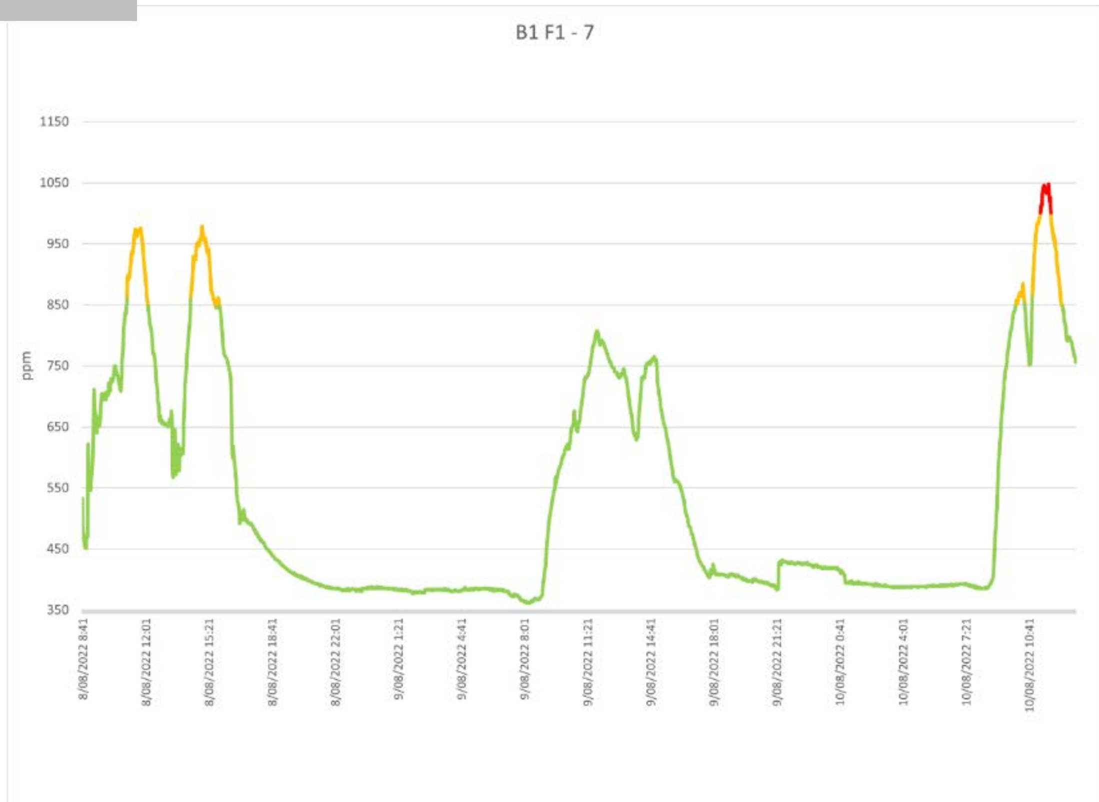

Figure 25: Location B1F1-7

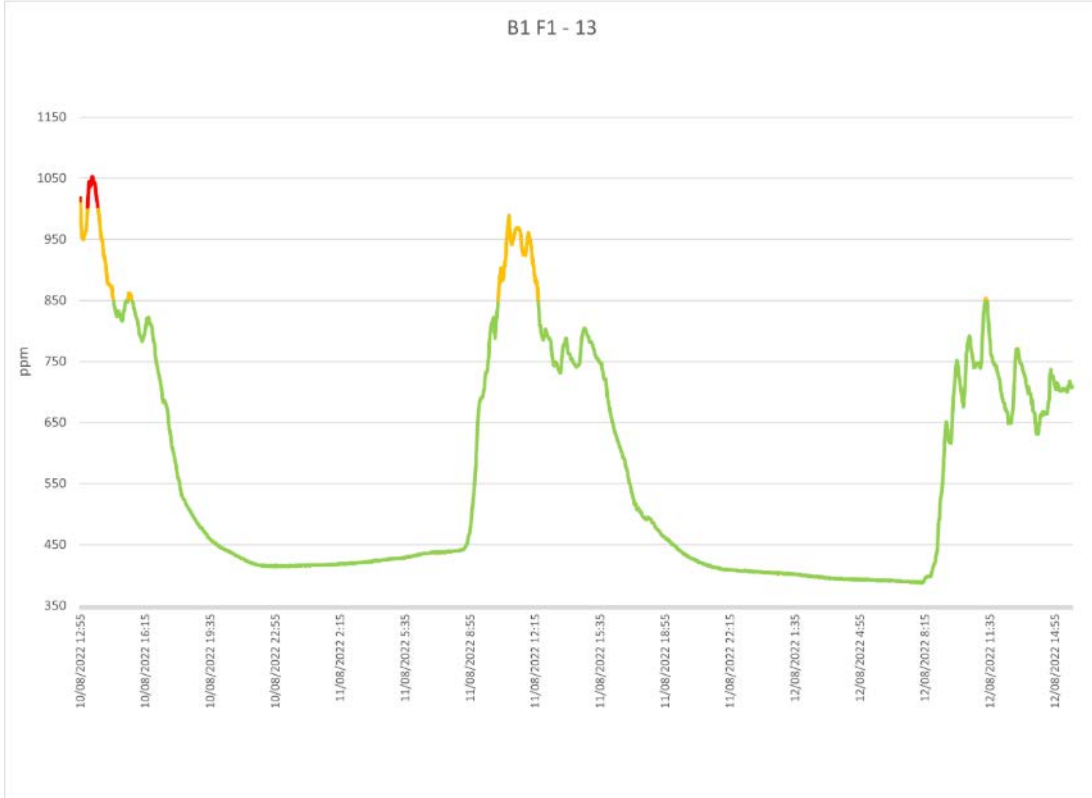

Figure 27: Location B1F1-13

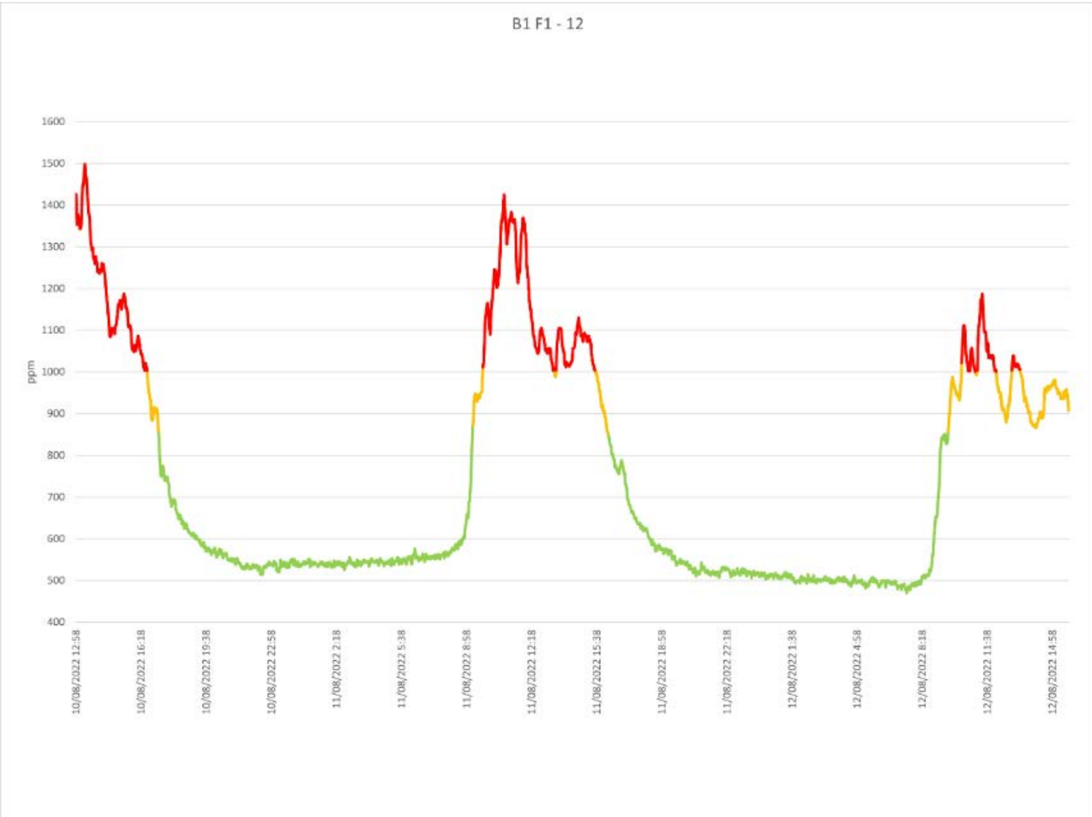

Figure 26: Location B1F1-12

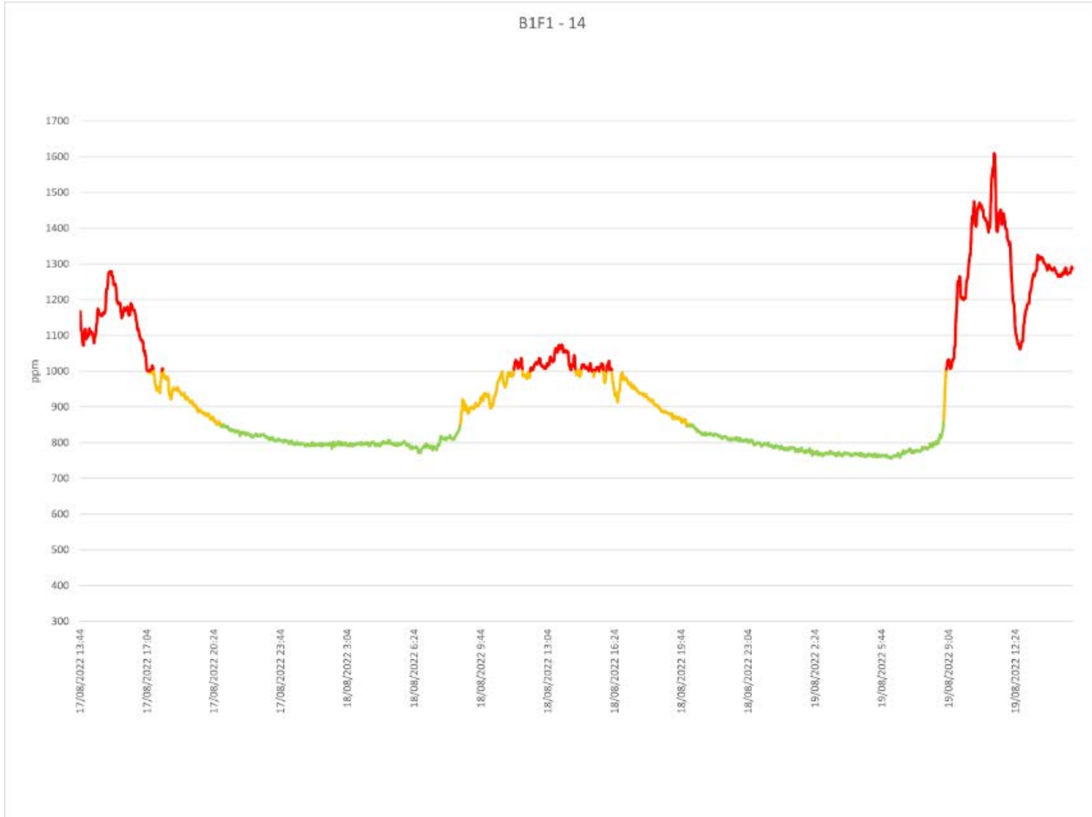

Figure 28: Location B1F1-14

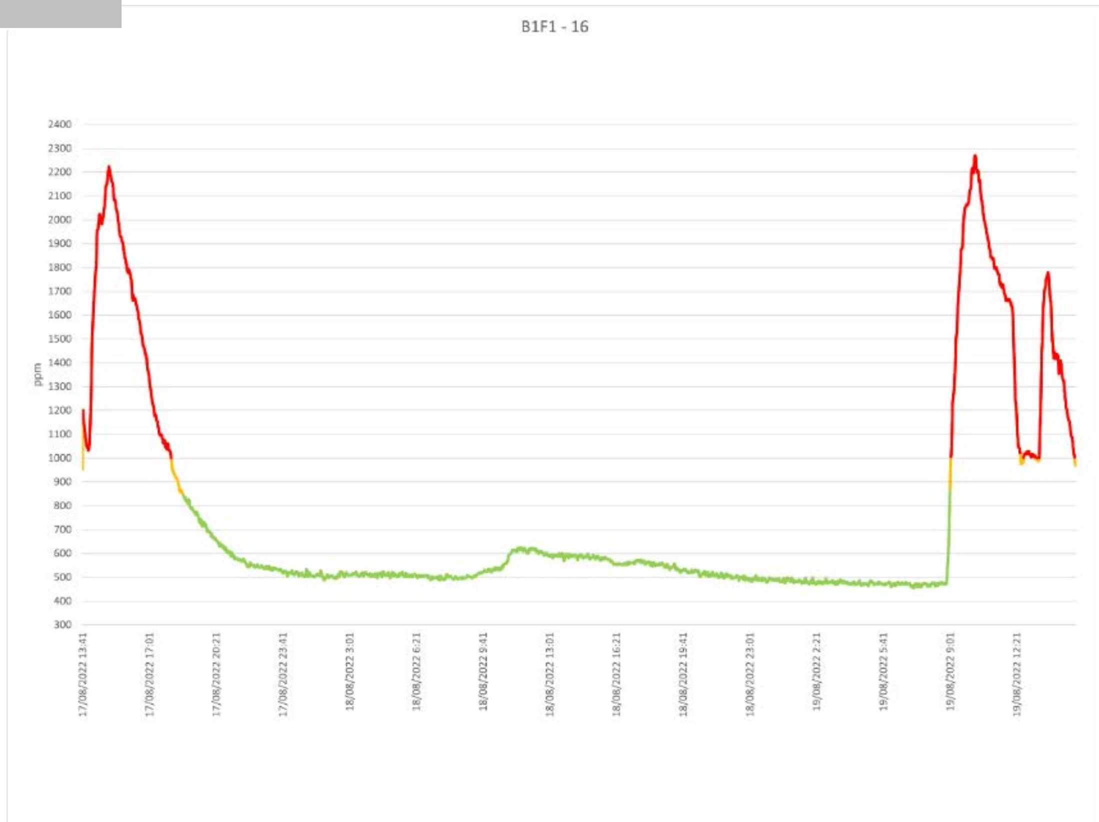

Figure 29: Location B1F1-16

Figure 30: Location B1F1-19

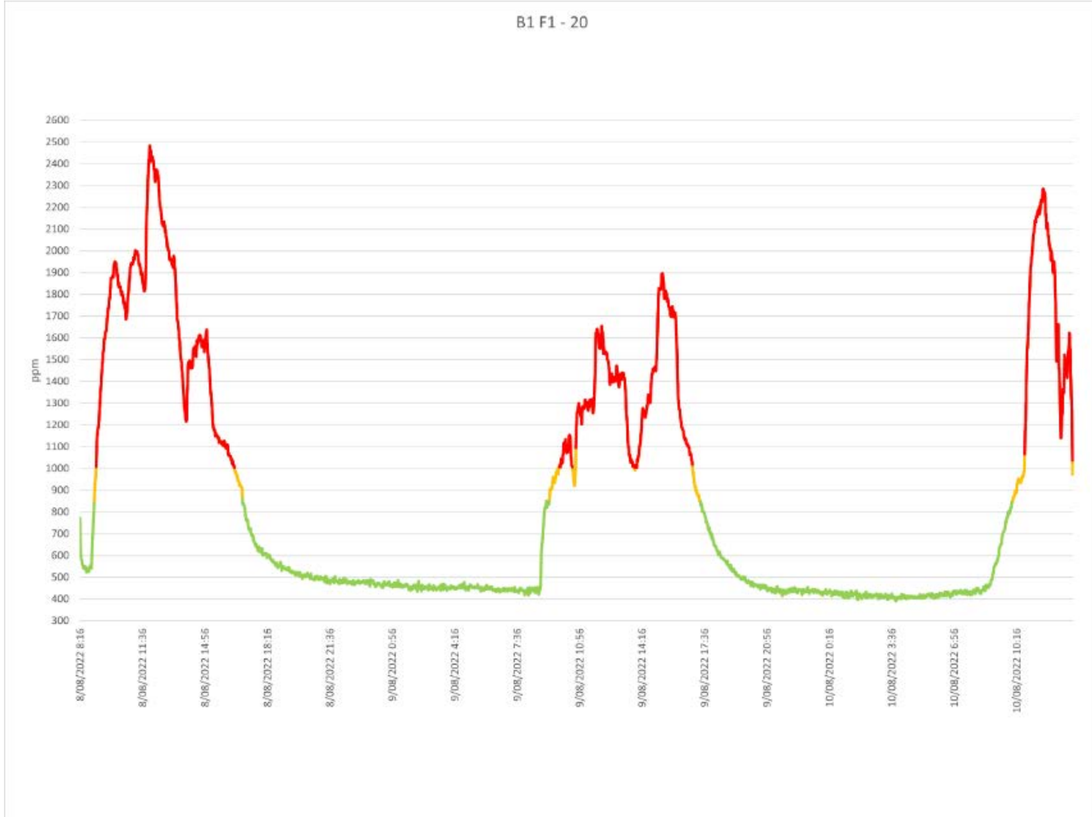

Figure 31: Location B1F1-20

Figure 32: Location B1F1-22

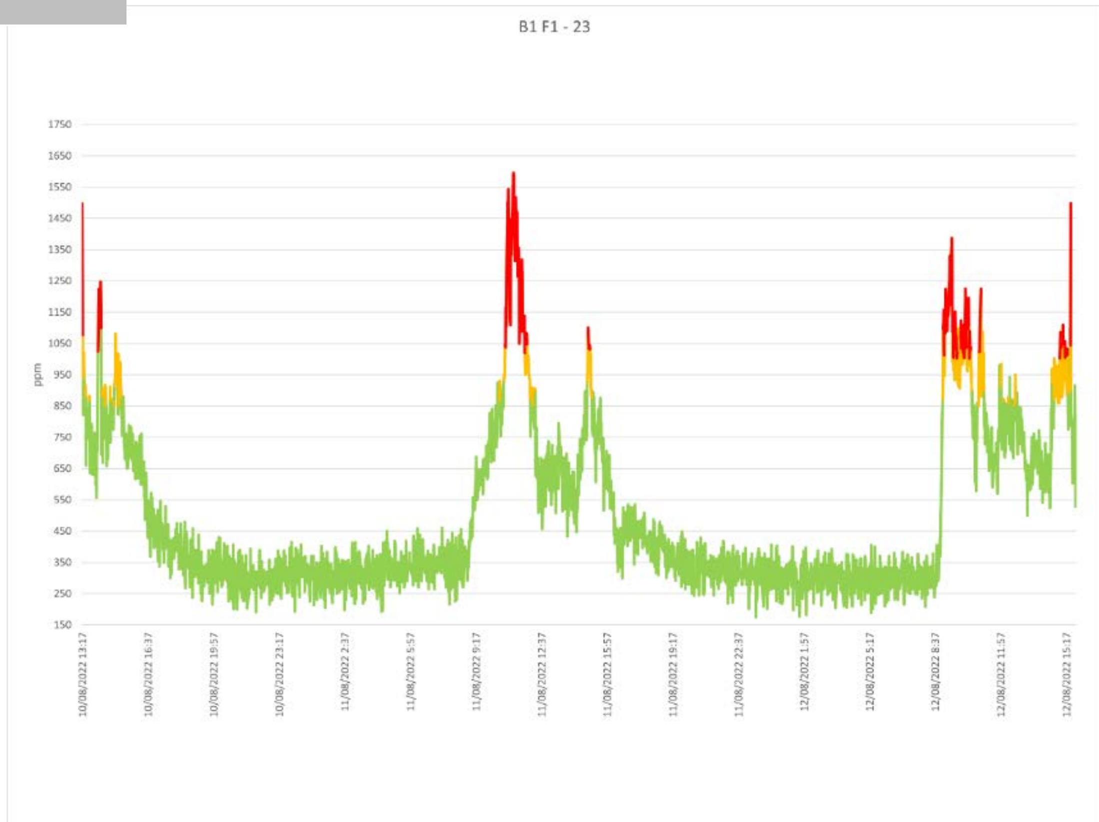

Figure 33: Location B1F1-23

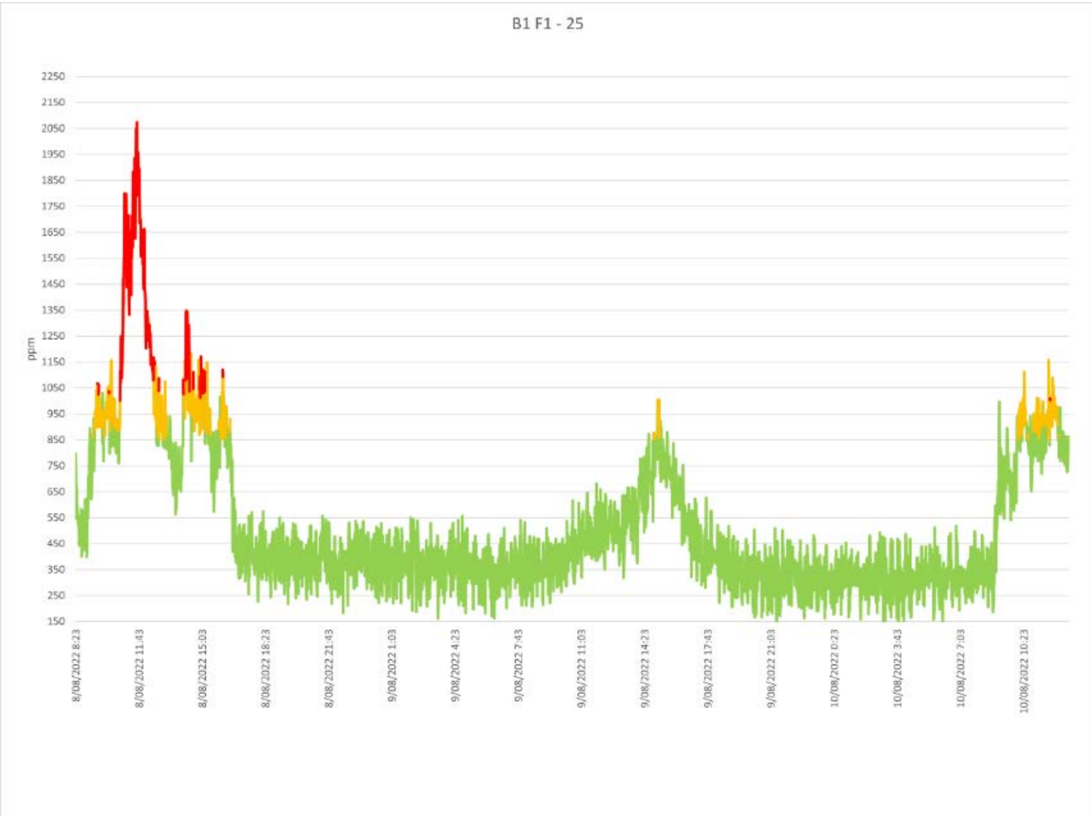

Figure 34: Location B1F1-25

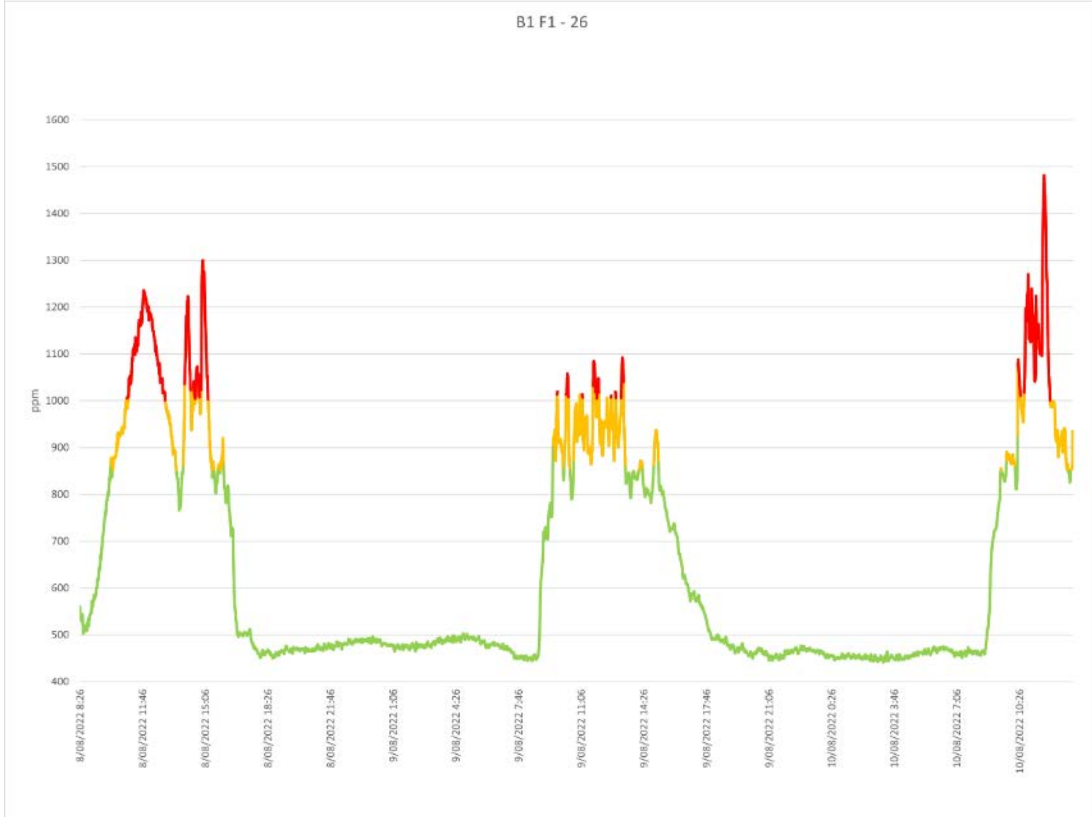

Figure 35: Location B1F1-26

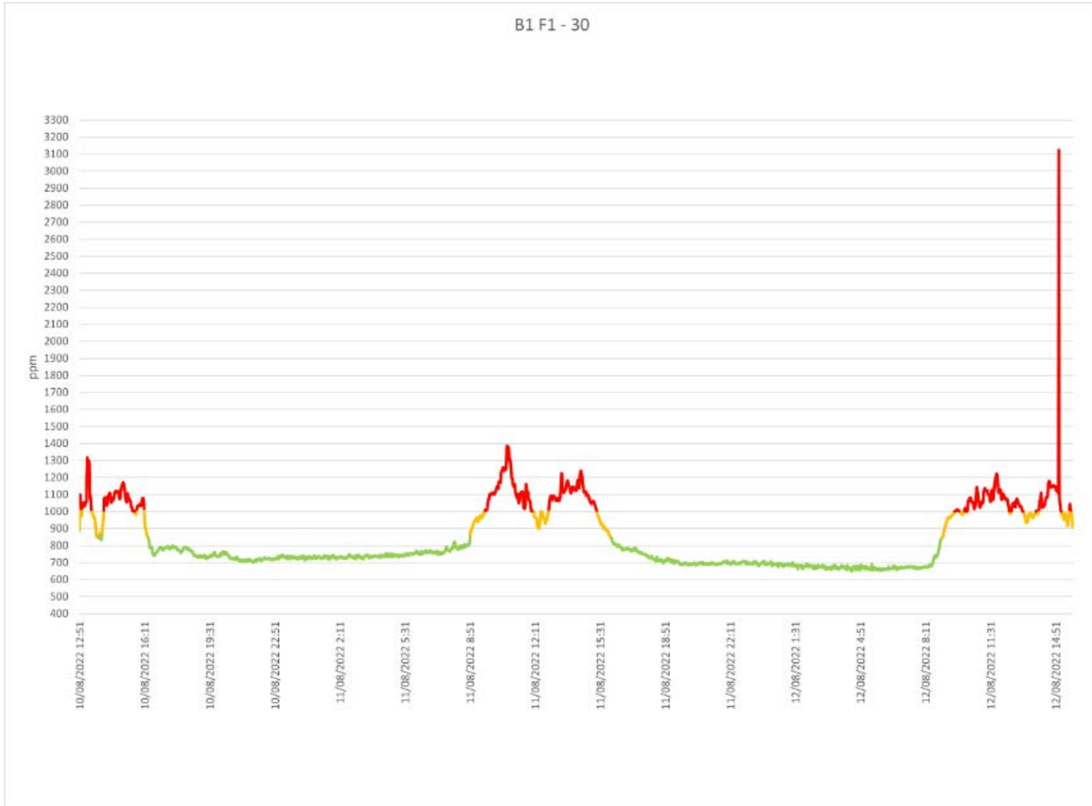

Figure 36: Location B1F1-30