Real–Time Monitoring with Integrated Control of Air Quality in Buildings

Ir KF Lau and Ir KW Chan
Architectural Services Department

Summary
The levels of air quality parameters of a building are always changing with time. Air quality level signals from real-time monitoring instruments can be used to control the functioning of an air-conditioning system to respond to the real-time levels of air quality parameters. This enables us to control the air-conditioning to the levels of our pre-set targets to avoid wastage of energy due to over provision. In comparison real-time control with periodic sampling of air quality parameters, real-time control can respond to the actual air quality so as to ensure achievement of the pre-set targets.

A proposal is made to classify the air quality parameters into three categories. The Primary Parameters shall comprise temperature, relative humidity, carbon dioxide, carbon monoxide, nitrogen dioxide and ventilation with positive air pressure. The Secondary Parameters shall comprise ozone, total volatile organic compound, formaldehyde, and respirable suspended particles. The Tertiary Parameters shall comprise radon, air velocity and airborne bacteria.

Continuous monitoring of the profiles on the Primary Parameters can be integrated in the automatic control of HVAC systems and also be effectively used in routine building management. The need for continuous monitoring of the Secondary Parameters is at discretion of the building management. Measurement of the Tertiary Parameters shall only be done under expert advice and supervision.

The importance of categorising the indoor air quality parameters, the methodology of real-time measurements of air quality parameters and the application of real-time air condition control are discussed.

Keywords: real-time air quality parameters control monitor

Introduction

All modern office buildings and shopping centres are air-conditioned. Good air-conditioning systems should take care of human comfort, energy conservation, cost effectiveness and health of the occupants inside the building. In order to ensure the preset targets of air quality are met but not over-provided or under-provided, we could use the signals from real-time monitors to control the air-conditioning and ventilation systems.

Air quality profile by real-time monitoring

The levels of air quality parameters of a building are always changing with the passage of time, and that periodic sampling and measurement of air quality parameters is inadequate to safeguard good air-conditioning without paying due attention and recognition to the dynamics of the changing concentrations of these parameters over time. With the help of the Air Quality Profile [1] identified through the use of by real-time monitoring which depicts changes of air quality over a time period, we are able to observe the visually exact timing and degree of deterioration or improvement of air quality. Based on the Air Quality Profiles and utilising real-time monitors, an integrated control system can be developed for controlling air-conditioning and ventilating a building to enable proper management of air quality in the built environment.

The air quality parameters

We have found it prohibitively costly and time-consuming to monitor and assess the levels of all air quality parameters with reproducible, reliable and conclusive results. This is particularly true for monitoring smaller indoor environments such as an office or a school assembly hall of under 500 sq m in floor area. Such small spaces constitute the majority of air-conditioned premises in Hong Kong. Taking an active approach in solving the problem, we recommend to sub-divide the air quality parameters into Primary, Secondary and Tertiary Parameters as follows.

Primary Parameters

The Primary Parameters shall include temperature, relative humidity (RH), carbon dioxide (CO_2), carbon monoxide (CO) and nitrogen dioxide (NO_2). These are the most prevalent and essential air quality parameters that affect the comfort and work efficiency of the occupants as well as their immediate and long-term health. These are our recommended air quality parameters for routine air condition monitoring.

They are the basic indicators of the state of health of the air quality in a building. All of these Primary Parameters can be monitored by real-time monitoring with alarm signals integrated with the control of the central air-conditioning system.

We further recommend ventilation with positive air pressure to be considered as a Primary Parameter, taking into consideration the necessity to prevent ingress of contaminants from outside.

Secondary Parameters

The Secondary Parameters shall include ozone (O3), formaldehyde (HCHO), total volatile organic compounds (TVOC) and respiratory suspended particles (RSP).

Relative to the Primary Parameters, these are less commonly known to be associated with sick building syndrome, although all of them, if present at high enough concentrations, are potential health hazards. These pollutants are usually generated by a source in the indoor environment, such as a photocopier, new furniture, carpet, tobacco smoke, etc.

Both ozone and formaldehyde have distinct recognisable odours and can cause irritation to mucous membrane of the eyes, nose and throat. Ozone, being highly active and short-living, does not travel far before it is totally destroyed in the atmosphere.

Formaldehyde, being more stable then ozone, tends to accumulate in an environment with stagnant air. TVOC and RSP are common contaminants in premises with new interior decoration. The levels of all Secondary Parameters can be controlled either by removal of the sources of pollutants or by improved ventilation, and in particular conditions by isolation and decontamination.

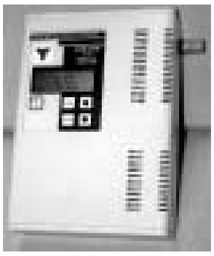
Tertiary Parameters

The Tertiary Parameters shall include radon (Rn), airborne bacteria and air movement. Radon is an inherent pollutant generated by uranium-bearing construction material. Its presence in our indoor atmosphere is of such low levels that it can only be detected on the μ radiation of its atomic decay. Being a noble gas eight times heavier than air, and having very short half-life, radon gas is never evenly distributed in air which renders all short-term or grab sampling measurements meaningless.

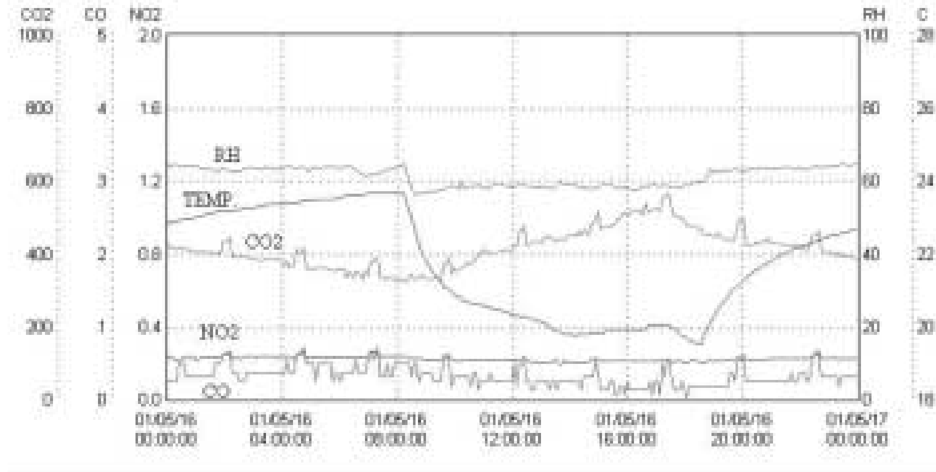
Airborne bacteria cannot be monitored by real-time instruments, and their counts cannot be correlated to public health and human comfort. Airborne aerobic bacteria are usually non-pathogenic micro-organisms. Anaerobic bacteria are pathogenic but most of them are easily killed by exposure to air. Viruses, fungal spores, mites, etc are not classified as airborne bacteria, although they can cause disease. As the human body, not the air, usually is the main carrier of pathogenic diseases, bacteria counts are often related to density of occupancy.

Air Movement is totally inconsistent from one testing point to another. For controlling of air-conditioning systems, it is more appropriate to replace ‘Air Velocity’ with the Primary Parameter of ‘Ventilation with positive indoor pressure’ as the latter is more homogeneous in an indoor space and can be more easily monitored by strategically positioned sensors.

Fig. 1 Multi-gas Real-time Monitor



Air Quality (5P, 24H) Profile on 5 Primary Parameters of an executive office



Levels of CO_2, CO and NO_2 are measured in ppm

Fig. 2 Formaldehyde™ Real-time Monitor

Air Quality (1P, 8H) Profiles on formaldehyde and profile statistics of a room with new furniture by two units of Formaldemeter 400 operating in parallel

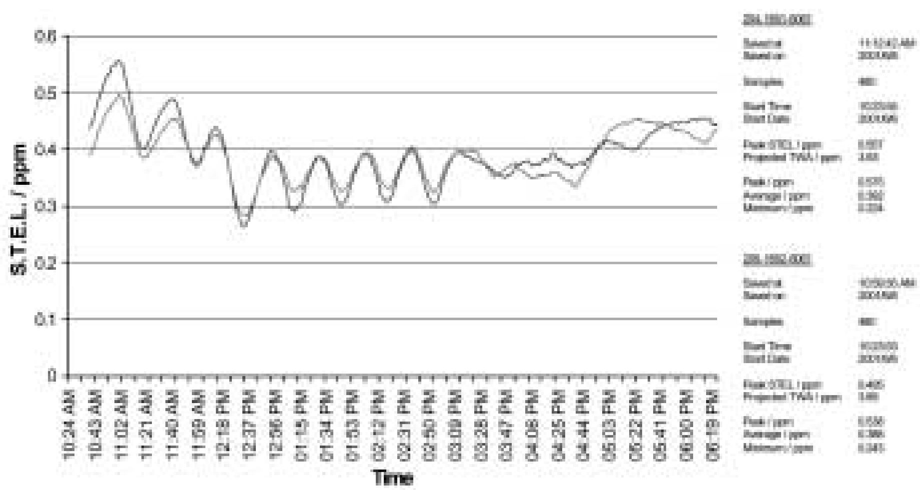


Fig. 3 TVOC Real- time Monitor

Air Quality (1P, 5H) Profile on TVOC of a 35 square metre room using split type room cooler

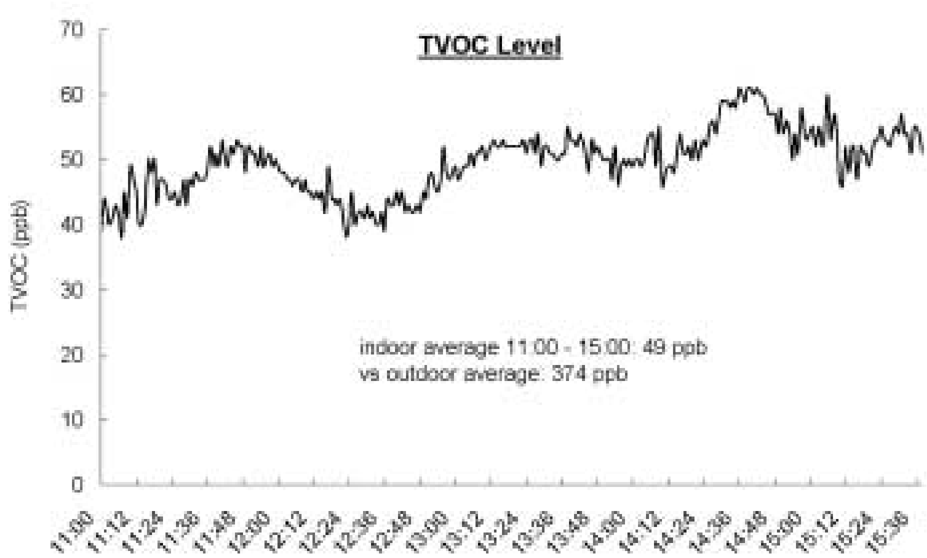
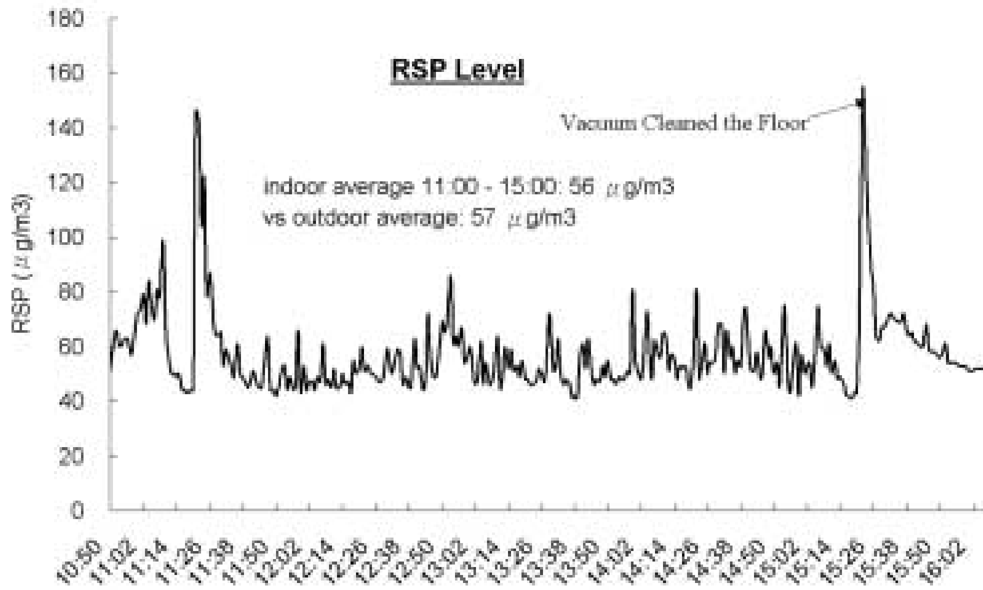


Fig. 4 Particle Real-time Monitor

Air Quality (1P, 5H) Profile on RSP of a 35 square metre room with near roadside



Real-time air quality monitors

Real-time monitors are available for most of the air quality parameters. However, for integrated control of air quality, monitors with accuracy, sensitivity and reliability are of paramount importance because their signals are used to control the operation of the air-conditioning system to maintain good air quality and to save energy, as well as sound the alarm in case of system failures. Real-time monitors should have microprocessor control with digital data logging functions, and should have demonstrated reliability for continuous operation to provide sampling data and Air Profiles for annual surveillance.

An example of each type of real-time air quality monitor is given in the following:

• The YES205 Air Quality Monitor (Figure 1) is a highly compact instrument for continuous and simultaneous monitoring of five Primary IAQ Parameters with data logging capacity of 15 days based on 5-minute sampling intervals, on all five parameters. The instrument has a precision calibrated NTC thermister for temperature sensing, a capacitive polymer sensor for the measurement of RH, a dual beam absorption infrared sensor for the measurement of CO_2, and electro-chemical sensors for the measurement of CO and NO_2. These intelligent sensors, coupled with a micro-processor and proprietary software, provide reliable, reproducible and accurate data for evaluation, assessment and control of air quality parameters. The instrument is equipped with high level CO_2 alarm signal for integral air condition control.

• The Formademeter™ 400 (Figure 2) is an ultra-compact instrument with microprocessor control, electrochemical formaldehyde sensor, sampling pump and digital LCD display. Linking up with a monitor station, it is a continuous monitor with full data logging and alarm capabilities. The instrument is designed to accurately monitor formaldehyde at levels below 400 ppb, and has a built-in programme to read and compute parameters such as peak concentration, short-term average exposure (STEL) and eight-hour time weighed average (TWA) offering complete automation from sampling to presentation of air quality statistics.

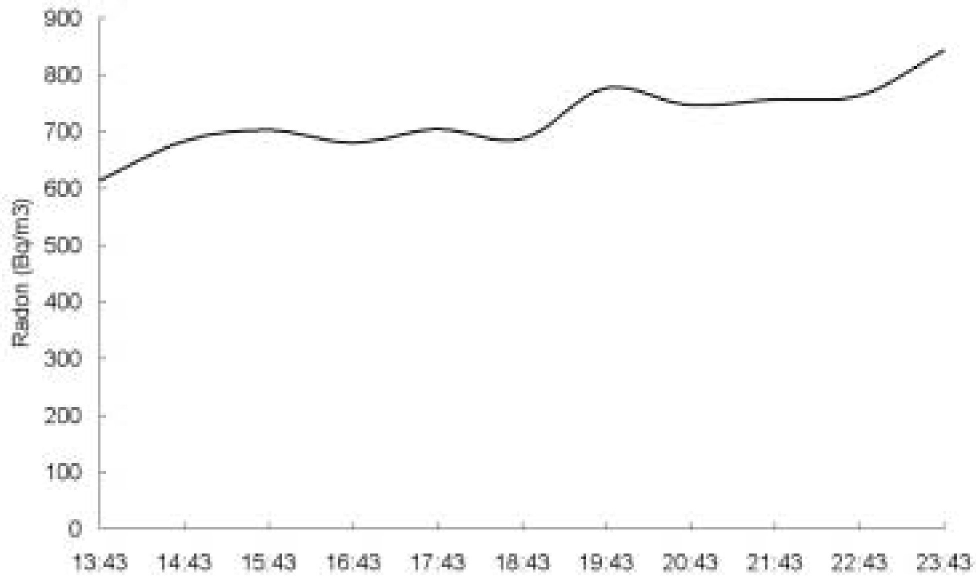
• ppbRAE TVOC Monitor (Figure 3) is a compact instrument with microprocessor control using a photo-ionization detector to detect a wide range of organic vapours. Organic vapours passing through a UV lamp are photo-ionized and the ejected electrons are detected as current. The default calibration gas is Isobutylene.

• TSI Dust Trak RSP Monitor (Figure 4) is a compact laser particle counter. Use the data logging features to make unattended measurements and to pinpoint hard-to-locate time-of-day. By attaching proper filters, the counter can select ranges of particle sizes for measurement, e.g. PM10 particles.

• RAD 7 Radon Monitor (Figure 5) is a portable monitor adopting the measurement

Fig. 5 Radon Real-time Monitor

Air Quality (1P, 10H) Profile on Radon of a store room deprived of ventilation

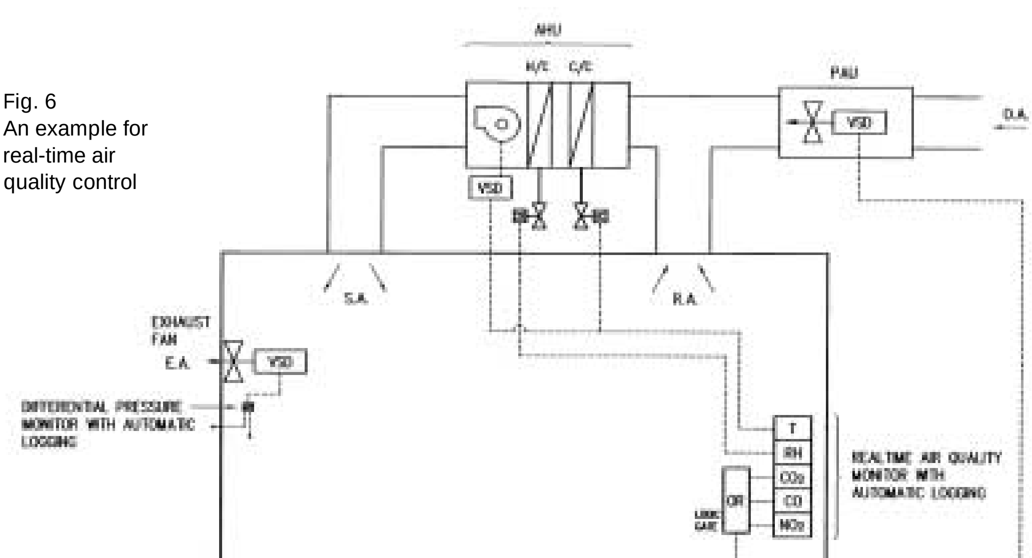


principle of 'electrostatic collection of alpha-emitters with spectral analysis'. After the initial decay from Radon to Polonium-218, there is a chain of further radioactive decays, all of which occur inside the instrument. A series of different elements are formed. Each has a different half-life and each emits either an alpha, beta or gamma particle/ray when it decays. Polonium-218 has a half-life of three minutes, and emits an alpha particle when it decays to Lead-214. Later on there are a couple of beta particles and then another alpha particle from the decay of Polonium-214, typically around 45 mins later. The Lead-210 that forms has a half-life of 22 years, so it builds up continuously. The Lead-210 contributes a steadily increasing count to the background, and this can severely degrade the Lower Limit of Detection of electronic radon detectors. Overlapping of the different decays can obscure radon monitoring. The monitor measures the energy of every alpha particle detected. In SNIFF MODE it looks at the 6 MeV alpha particles from the Polonium-218 decay and ignores all the rest. Thus there is a 95 per cent recovery from high readings in 15 minutes.

Air treatment methods for air quality control

In real-time air quality control, selected air quality parameters are monitored and the

Fig. 6
An example for real-time air quality control



Air quality parameter	Possible air treatment methods
1. Temperature	Regulate coil temperature and air flow of the AHU
2. RH	Regulate coil temperature of the AHU and air-reheat
3. CO_2	Increase ventilation by controlling of fresh air intake and air exhaust
4. CO	Remove source of pollutant, increase ventilation
5. NO_2	Remove source of pollutant, remove pollutant by passing through wet coils of the AHU
6. TVOC	Remove source of pollutant, increase ventilation
7. Radon	Remove source of pollutant, increase ventilation
8. Formaldehyde	Remove source of pollutant, increase ventilation, detoxification
9. Ozone	Remove source of pollutant, isolation, detoxification
10. RSP	Air filtering
11. Airborne Bacteria	Low temperature and low RH controls
12. Air Movement	Adjust direction of air flow
13. Ventilation with positive indoor air pressure	Regulate the air quality difference between the air intake and exhaust air

Table 1

signals from the real-time monitors are used to control functioning of the corresponding air-treatment components of the air-conditioning and ventilation systems. Some common air treatment methods being used for improvement of air quality are listed in Table 1.

The above table shows that real-time monitoring with integrated control of air quality can be effectively applied to control the levels of different air quality parameters as follows:

1. To control temperature by regulating coil temperature and air flow of the AHU.
2. To regulate RH by controlling coil temperature and reheating indoor air by heat reclaim.
3. To reduce the levels of CO_2, TVOC, radon and formaldehyde by increasing ventilation with variable speed ventilation fans.
4. Control functioning of ventilation fans to maintain positive indoor pressure.
5. To initiate alarms when the levels of CO and/or formaldehyde have exceeded a preset limit.

An example of real-time air quality control

The schematic drawing of a system of air quality control of the Primary Parameters is depicted in Figure 6. This example shows the following arrangement:

1. The temperature signal is used to control the chilled water inlet modulating valve and air flow of the AHU chilled water coil.
2. The RH signal is used to control the modulating valve of the hot water coil for air-reheat.
3. The CO_2, CO and NO_2 signals are fed into an OR gate for controlling the amount of outdoor air in response to the highest demand amongst the three parameters.
4. The differential pressure signal is used to control the amount of exhaust air.

Conclusion

Real-time monitors are used to depict Air Quality Profiles. This enables the changing concentration levels of various air quality parameters over a time period in an indoor environment to be seen in graphic form and to allow them to be accurately measured.

Through the use of these real-time monitors, it is now possible to make accurate control of temperature and ventilation of the indoor environment by real-time monitoring with integrated control of the air-conditioning and ventilation systems. For efficient monitoring of air quality, air quality parameters are sub-divided into three classes as Primary, Secondary and Tertiary parameters. The functions and reliability of real-time air quality monitors are reviewed. A design drawing is shown to illustrate how Primary Parameters can be used for continuous monitoring and control of an air-conditioning system.

Reference

[1] Wai, K.N., IAQ Profile, paper submitted for the Symposium 2001 on "Towards Environmental Sustainability" 20 Nov. 2001.