IMPROVEMENT OF INDOOR AIR QUALITY BY THE ELECTRICAL & MECHANICAL SERVICES DEPARTMENT IN HONG KONG, CHINA

L.T. Lee, Assistant Director
K.K. Lam, Chief Engineer
W.K. Kwan, Senior Engineer
Energy Efficiency Office, Electrical & Mechanical Services Department,
The Government of the Hong Kong Special Administrative Region, China

ABSTRACT

Before the 1990s, there was limited concern on indoor air quality (IAQ) in the Hong Kong Special Administrative Region, China (HKSAR) and designers specified simple fresh air rate requirements based mainly on international standard. In 1995, the Electrical and Mechanical Services Department (EMSD) of the HKSAR Government pioneered in the formation of an IAQ survey team to measure 4 parameters (carbon dioxide, radon, respirable suspended particulates and total viable count) for all government venues with HVAC installation. In 1999, EMSD strengthened the IAQ survey team to cater for activities associated with the IAQ Management Programme developed by the HKSAR Government, which includes a trial scheme to survey all government venues. EMSD will analyse progressively the data collected with a view to establishing priority programmes for improvement work on existing government buildings. Meanwhile, EMSD will explore the feasibility of setting up guidelines on IAQ for carparks in buildings, which are not covered by the existing IAQ Management Programme.

The paper highlights the EMSD experience and outlines the ways forward aiming at improving the IAQ in the HKSAR.

INTRODUCTION

On average, we spend more than 70% of our time at homes, in offices and other indoor environment. Good IAQ safeguards our health and contributes to our comfort. It can also improve productivity at the workplace. On the other hand, poor IAQ may lead to discomfort, ill health and, in workplace, absenteeism and low productivity.

In the HKSAR, indoor air pollution has received little attention in the past compared with air pollution in the outdoor environment. It has now become a matter of increasing public concern, prompted partly by the attention given to the issue in recent years in overseas countries and partly from the increasing demand for better quality of life by the community. As a result of growth in the service sector in the HKSAR, majority of our workforce is now working in indoor environment. IAQ is also considered to be part of the broader concept of "healthy living".

To demonstrate the Government's commitment in promoting the IAQ management programme, EMSD have collaborated with other government departments to take the

lead to carry out a trial scheme to survey the IAQ in all government buildings served by HVAC systems in year 2000-2003.

This programme does not cover underground or multi-storey carparks and a few others, EMSD is exploring the feasibility of establishing guidelines on IAQ for carparks.

FACTORS AFFECTING INDOOR AIR QUALITY

The overall quality of indoor air is influenced by thermal acceptability and air contaminants, which are:-

Thermal acceptability

Temperature

Air temperature has the most direct effect on thermal comfort. The temperature level at which people feel comfortable varies for individual and depends on seasonal temperatures, activity level, age and natural body temperature.

Humidity

High humidity affects human comfort and also encourages the growth of mildew and other fungi on building fabric and furnishings. Low relative humidity causes eyes, noses and throats to dry which may lead to discomfort, irritation and increased susceptibility to infection. Extremely low humidity can cause static electricity which is uncomfortable for occupants and can affect the operation of computers.

Air Movement

A certain amount of air movement round the human body is essential for thermal comfort. It is also important in dispersing air pollutants.

Air Contaminants

Carbon Dioxide

Carbon dioxide is mainly a product of human respiration in indoor environment. The levels of CO_2 concentration encountered in non-industrial environments are usually far below the prescribed health and safety standards and do not present a health risk. Carbon dioxide concentrations is commonly adopted as a surrogate in measuring air freshness.

Carbon Monoxide

Carbon monoxide can cause cardiovascular diseases and symptoms such as headaches, concentration problems, flu symptoms, nausea, fatigue, rapid breathing, chest tightness and impaired judgement. High concentration of carbon monoxide is usually due to the fresh air intake being too near roads of heavy traffic, industrial

exhaust or carpark.

Respirable Suspended Particulates

Respirable suspended particulates are defined as suspended airborne particles with a nominal aerodynamic diameter less than 10 μm. The size, shape, density and chemical reactivity of the particles will give rise to various health hazard such as respiratory irritation and infection, lung cancer and mesothelioma, itching and irritation to the skin and eye.

Nitrogen Dioxide

Nitrogen dioxide comes mainly from vehicle exhaust from outdoors. Inhalation of excessive dosage of nitrogen dioxide can cause symptoms relating to potent eyes and respiration system.

Ozone

Ozone mainly comes from office equipment under normal situation and is highly reactive and could cause serious damage to the lung if inhaled in high concentrations. It also irritates the eyes and respiratory tract.

Formaldehyde

The most common sources of formaldehyde emissions in buildings are plywood, particleboard, carpets and urea-formaldehyde foam insulation. Unusually high concentrations of formaldehyde are known to cause eye, nose and respiratory irritation and sensitisation. Formaldehyde is also a suspected human carcinogen.

Total Volatile Organic Compounds

Volatile Organic Compounds (VOCs) may enter from the outdoor environment, or be emitted from building materials, cleaning agents, cosmetics, and office equipment. Exposure to VOCs at high levels in the industrial environment has been shown to have toxicological effects on the central nervous systems, liver, kidney and blood of the human body. Some studies have linked exposure of VOCs commonly found in office buildings to symptoms of sick building syndrome, such as eye and throat irritation, respiratory problems, headaches, poor concentration, dizziness, tiredness, irritability.

Radon

Radon is formed when radium found in soils and rocks, especially granite, disintegrates radioactively. As radon further decays, a series of tiny radioactive particles are formed. When either the gas or these particles are inhaled, some will be deposited in the lung and will continue to emit radiation. The lung tissue will be affected by the associated radiation emission.

Airborne Bacteria

In air-conditioned buildings, water or condensation in ventilation system can act as breeding grounds for harmful bacteria, which are then dispersed through the ventilation, process. As bacteria cannot be measured on real time basis, cultivation of bacteria on agar medium is adopted to determine the viable bacteria in the environment. Bacterial counts are not meant to be a direct indicator of health risk but serve as screening tests for further investigation.

INDOOR AIR QUALITY OBJECTIVES

A 2-level IAQ Objectives is established to act as the benchmark for evaluating and assessing indoor air quality. These objectives are comparable to the international health-based air quality standards and can encourage building owners to aim at the best IAQ. Level 1 of the Objectives represents very good indoor air quality that a high-class and comfort-able building should have, whilst Level 2 represents indoor air quality that provides protection to the public at large including the very young and the aged.

If all the parameters for "Level 1" or "Level 2" are met, the likelihood of indoor air pollution leading to health problems or discomfort in the building is remote. Building owners and employers therefore should endeavour to achieve at least Level 2 of the IAQ Objectives, as far as practicable. A summary of the Level 1 and 2 objectives is indicated below:

Table 1

Parameter	**Unit**	**8-hr average** *(under review)*	
		Level 1	**Level 2**
Carbon Dioxide (CO_2)	ppm	< 800	< 1,000
Carbon Monoxide (CO)	$\mu g/m^3$	< 2,000	< 10,000
Respirable Suspended Particulates (RSP)	$\mu g/m^3$	< 20	< 180
Nitrogen Dioxide (NO_2)	$\mu g/m^3$	< 40	< 150
Ozone (O_3)	$\mu g/m^3$	< 50	< 120
Formaldehyde (HCHO)	$\mu g/m^3$	< 30	< 100
Total Volatile Organic Compounds (TVOC)	$\mu g/m^3$	< 200	< 600
Radon (Rn)	Bq/m^3	< 150	< 200
Airborne Bacteria	Cfu/m^3	< 500	< 1,000
Room Temperature	°C	20 – 25.5	< 25.5
Relative Humidity	%	40 – 70	< 70
Air movement	m/s	< 0.2	< 0.3

The IAQ Objectives will not be applicable to any part of a building where there is no air-conditioning but is totally enclosed and served by mechanical ventilation system such as store rooms, plant rooms, switch rooms, etc.

IMPROVEMENT INITIATIVES

Good IAQ can be achieved by looking after the fundamental elements, namely, control of contaminant source, adequate ventilation, humidity control, air filtration and purification, as detailed below:-

Control of contaminant source

Housekeeping

Housekeeping is important in reducing IAQ concerns as it keeps dust levels down and removes dirt that could otherwise becomes sources of contamination. The cleaning schedule should be arranged with reference to occupancy patterns and activity levels. Cleaning agents emitting vapours with strong odours should be avoided, or only used after normal occupied hours. Building managers should make sure that smells from cleaning products have disappeared before air handling systems switch to their 'unoccupied' cycles. No smoking is also essential.

Outdoor air intake position

Some contaminants such as O_3 & NO_2 are heavier than air and tend to stay close to the ground. As outdoor air quality improves with altitude, selection of outdoor air intake as high above ground as possible is essential. Also, the wind direction, traffic condition and other conditions may affect the outdoor air quality.

Building pressure control

Outdoor air pollutants can be brought in the indoor environment through infiltration and fresh air intake. Air treatment on fresh air intake can be easily carried out in the air handling units. However, pollutants from infiltration are difficult to be identified and controlled, the building should be properly sealed and pressurised so as to eliminate or reduce the pollutants from uncertain paths. Normally, building pressurization can be achieved by adjusting the difference between exhaust and supply airflow rates. During night time, HVAC systems are usually switched off and indoor air pollutants either generated inside the occupied areas or entering from outside environment will be accumulated. Therefore, purging systems for pressurization and removal of accumulated pollutants are necessary to be provided and operated after office hour.

Adequate ventilation

Dilution by outdoor air

The Ventilation Rate Procedure in ASHRAE 62-1999 is commonly used to achieve IAQ objectives as it is simple and effective. The minimum requirement of fresh air supply per person is determined based on the assumption that outdoor air quality is far more superior to the indoor one. Concentration of carbon dioxide in outdoor rises gradually during the past years, which reflects that outdoor air quality has been deteriorating. Therefore, the minimum requirements, which were adopted with confidence previously, should be reviewed from time to time based on local outdoor conditions. Additional outdoor air treatment may also be provided.

CO_2-based demand-controlled ventilation

Instead of supplying a constant amount of outdoor air supply to conditioned space regardless the degree of occupancy, demand control ventilation can be a useful method to achieve required indoor air quality and to reduce energy consumption, especially for an intermittent or fluctuated occupancy pattern in which contaminant levels result primarily from people. Carbon dioxide sensors can be installed at the return air stream to determine the state of occupancy, and hence, the fresh air supply is controlled to suit the actual demand. Alternatively, occupancy sensors can be installed to switch on or off the air-conditioning system.

Air duct cleaning

Air duct cleaning can remove the dust particles that are not trapped and removed by filters and accumulated inside the duct surfaces and will contaminate the air flowing through. The UK Heating & Ventilation Contractors' Association has a "Guide to Good Practice – Cleanliness of Ventilation Systems" which provide good reference on how to establish whether or not it would be appropriate to clean a mechanical ventilation system. The US National Airduct Cleaners Association has also developed a standard to measure the results of duct cleaning.

Humidity control

Hong Kong is an area with humid climate, air conditioning systems should ensure that relative humidity is low compare with the outdoor relative humidity to minimise the problem of microbial growth. Another problem in humid climates is the infiltration of moist outside air that condenses on interior surfaces. Dehumidification can also be achieved by, other than ordinary cooling coils, desiccant which works either by adsorption or hygroscopic liquid technology.

Air filtration and purification

Particulates filtration

Particulate filters are the most commonly used air cleaning devices in modern buildings. Filters are classified according to the size of the particles that they catch and the energy required to send air through them. One or a combination of filters should be selected depending on the physical characteristics and levels of the dust to be controlled, the capacity of the system to overcome the associated pressure drop across the filter, and the degree of indoor air cleanliness required.

Electrostatic precipitators

Electrostatic precipitators are the most common type of electronic air cleaners. Dust particles are electronically charged by one set of electrodes and then collected by another set of electrodes with the opposite charge. The absence of any filtering media means that this type of cleaner has minimal effect on airflow and can be installed in air distribution systems without having to modify the system significantly. Electrostatic precipitators offer relatively high efficiencies of up to 95% dust spot

values. However the efficiency rate may be substantially reduced if air is very moist or if the collecting plates inside the precipitator become clogged with dust. The latter is a particular problem when buildings are not regularly cleaned and maintained.

Gaseous filtration

Gas filters are design to remove contaminating gases from the air. This can be done through absorption and catalytic conversion, but adsorption is the most common method. Solid sorbents including activated carbons, molecular sieves, silica gel and activated alumina, each of which has a different adsorbing characteristic, are used to remove the various contaminant gases. Activated carbons can adsorb most of the common volatile organic compounds in indoor air. Other reactive gases such as formaldehyde can be removed by oxidation using activated alumina impregnated with potassium permanganate. Gas filters can be installed either in-duct or as independent devices. Despite the potential usefulness of gas filters, there are currently no widely accepted performance standards. There are also considerable difficulties in determining the breakthrough time of these gas filters in real life usage situations. Gas filters should therefore only be used with good technical support and maintenance.

Germicidal ultraviolet sterilizer

Germicidal, or short-wave ultraviolet is wavelength band between 200nm and 300nm. Germicidal ultraviolet is primarily intended for the destruction of bacteria and other micro-organisms, like mould and spores in the air or on exposed surfaces.

INDOOR AIR QUALITY FOR CARPARKS IN BUILDINGS

The HKSAR Government have issued a Practice Notes on the control of air pollution in carparks. The Notes stipulates the monitoring and control of CO and NO_2 as the measurement parameter on human health.

With the introduction of the IAQ Management Programme, it now becomes worthwhile to investigate on the feasibility of establishing guidelines on IAQ for carparks in buildings.

Some trial measurement was conducted by EMSD. The results indicated that the majority of the IAQ objectives (at level 2) could be met, with the exception of temperature and relative humidity as all indoor carparks in HKSAR are not air-conditioned. Due to the limited measurement taken, attempts would be made to obtain more measurement and data with a view to determining details to be included in the ultimate guidelines for IAQ for carparks in buildings.

SUMMARY AND CONCLUSION

IAQ is becoming one of major concerns for citizens of Hong Kong. Good IAQ is much more than providing a fixed amount of outdoor fresh air for each occupant. There is no single rule of thumb for achieving good IAQ, which are a combination of adequate

HVAC design, operation and maintenance, as well as a good selection of building material and a good house keeping. To improve IAQ in existing buildings is a multi-discipline teamwork for all parties involved in the proper operation of a building. Only with the assistance of all parties involved, good IAQ can be achieved. Also, the IAQ management programme does not cover some areas in a building and this need to be addressed at a later stage.

REFERENCES

1. Indoor Air Quality Management Group, Managing Indoor Air Quality A Consultation Paper, The Government of the Hong Kong Special Administration Region

2. Indoor Air Quality Management Group, Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places, The Government of the Hong Kong Special Administration Region

3. American Society of Heating, Refrigerating and Air-conditioning Engineers, ASHRAE Standard 62-1999 – Ventilation for Acceptable Indoor Air Quality, 1999

4. UK Heating and Ventilating Contractors' Association, Guide to Good Practice Cleanliness of Ventilation Systems

5. US National Air Duct Cleaners Association (NADCA), (1992), "Mechanical Cleaning of Non-Porous Air Conveyance System Components (Standard 1992-01)"

6. Environmental Protection Department, HKSAR Government, "Practice Note For Professional Persons – Control of Air Pollution in Carparks"